Power Electronics

Dr.Mhmd Haj-Ahmad

By: Anoud Al-Hallaq

POWERUNIT-JU.COM

PU
2018

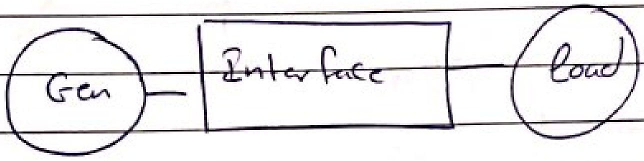
POWER EIECTRONIC

30/1 Tue

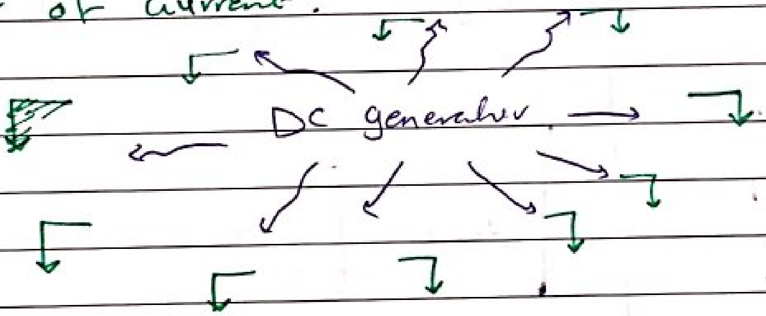
* Power electronics :- is about to convert and monitor electric power from one shape to another.

* 4 - types of conversion :-

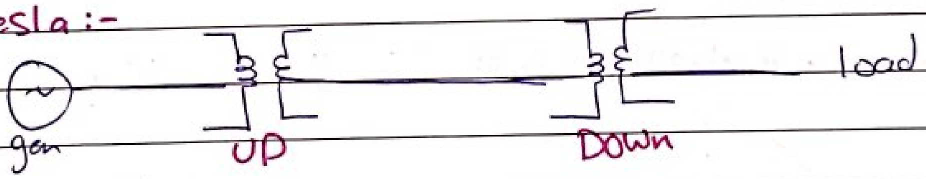
1- DC to DC conversion
2- DC to AC . Inversion
3- AC to DC Rectification.
4- AC to AC control.



⇒ war of current.



Tesla :-



* Microgrid → DC microgrid
→ AC ״

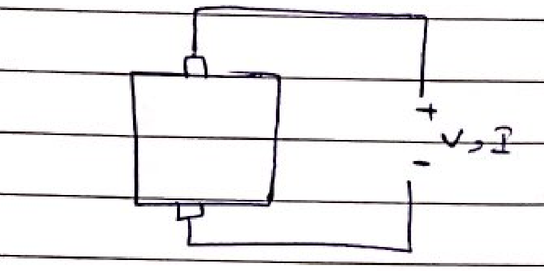
* Applications 8⊲

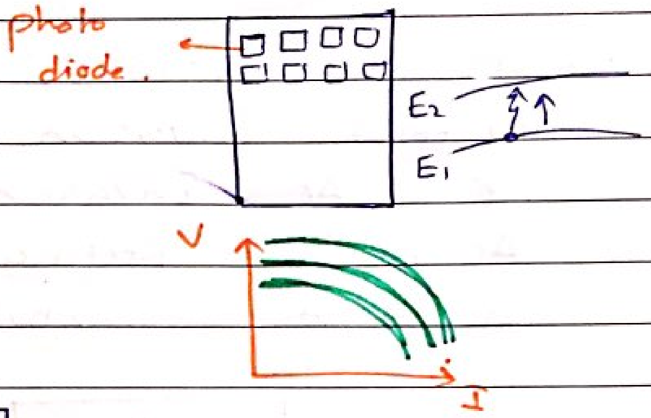
$\boxed{1}$ Renewables → solar system
→ wind energy

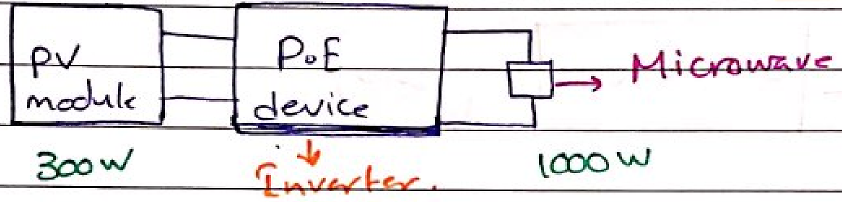
Solar system → PV system
→ CSP system.

⇒ PV system :-

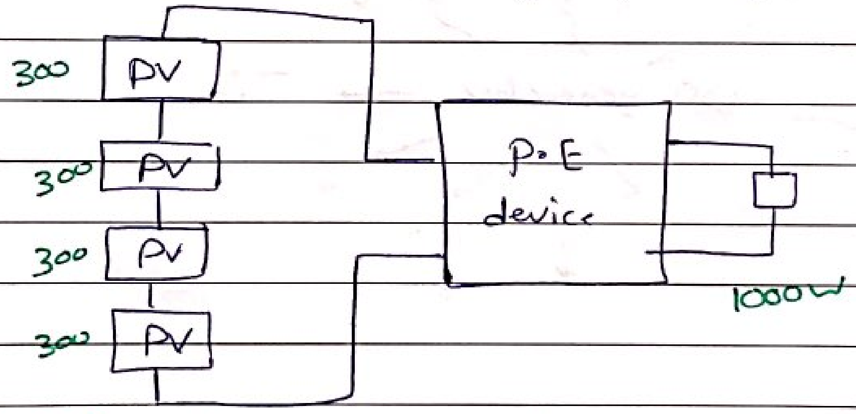
* PV module / 300 W



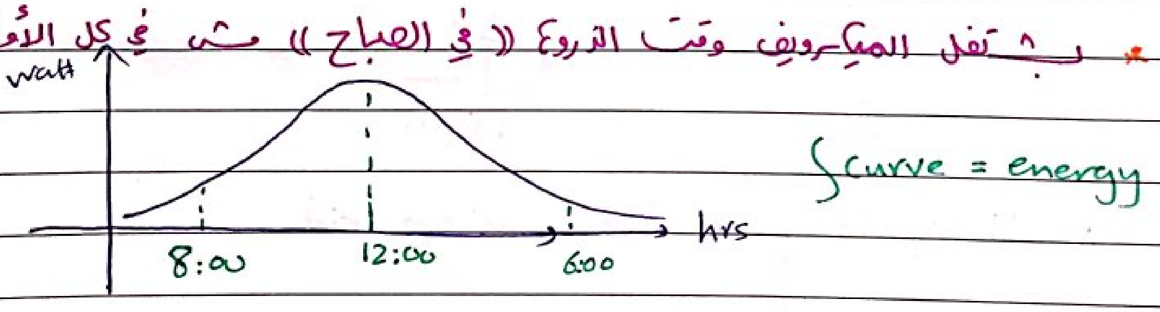




* في هاي الحالة الميكروويف ما بيشتغل.



* بشتغل الميكروويف وقت الذروع ((في الصباح)) مش في كل الأوقات.

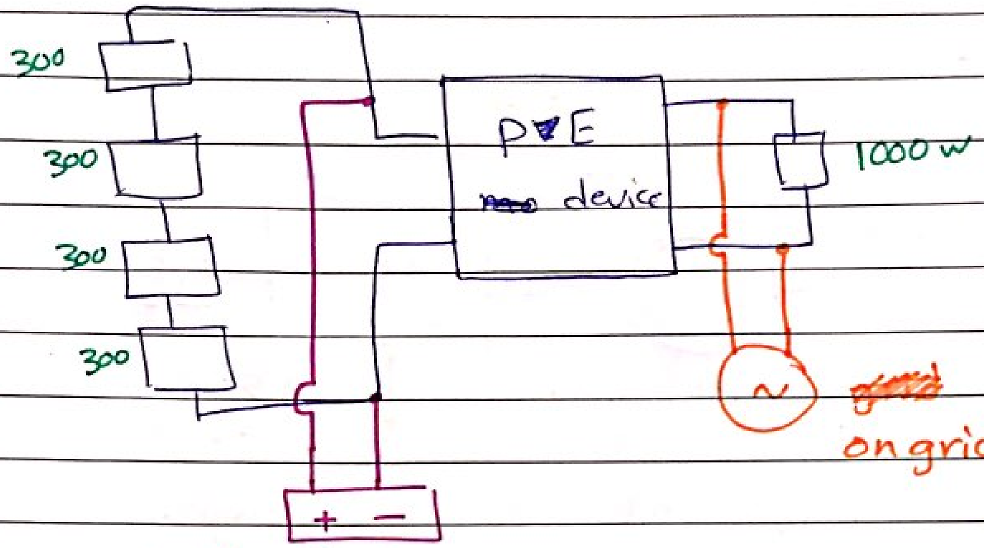


* عشان نستغل كل مساحة الـ PV بنحطها بزاوية 45° جنوباً.

* 7 دونم ⇒ 1 M watt

* في عنا حلين لهي المشكلة ← الحل الاول ← اشتري بطاريه.
↳ الحل الثاني ← اني اضيف ongrid عن load
system.

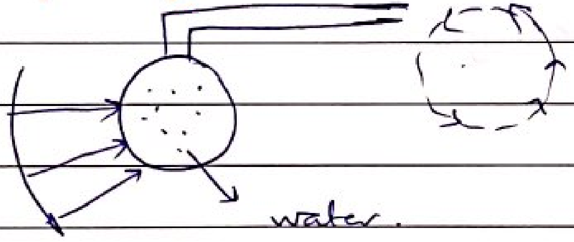
2

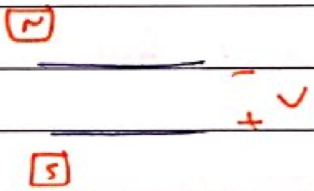


ongrid system ← sol2
لـ المستخدم

sol 1 → بطارية
1KWH

* CSP system:-

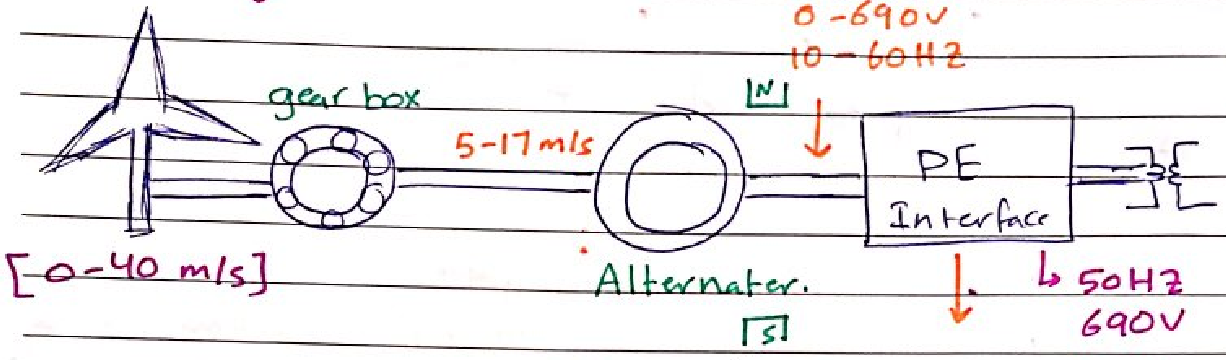




* لما تزيد درجة حرارة ← ماء بتبخر ← بتبرد

1/8 Thur

Wind generators :-



وظيفته عشان يطلع volt ثابت.

Alternater :-

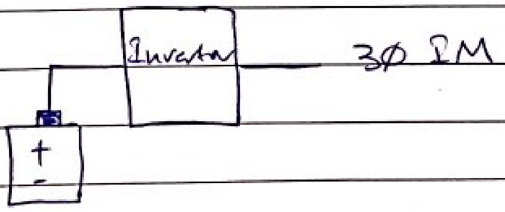
1. SG = synchronous generator.
2. IG = Induction Generator.
3. DFIG = doubly fit Induction generator.
4. FCG = full converter gen.

application ⇒

2. Electronic devices.

3. Trans portation :-
   (electric cars and trains]

↳ 3ϕ Induction motor.



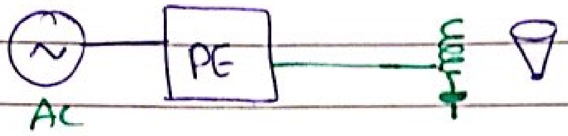
ex ⇒ Tesla cars are 3phase Induction motor

4 Efficiency Improvment

* transformer mean there is alosses.

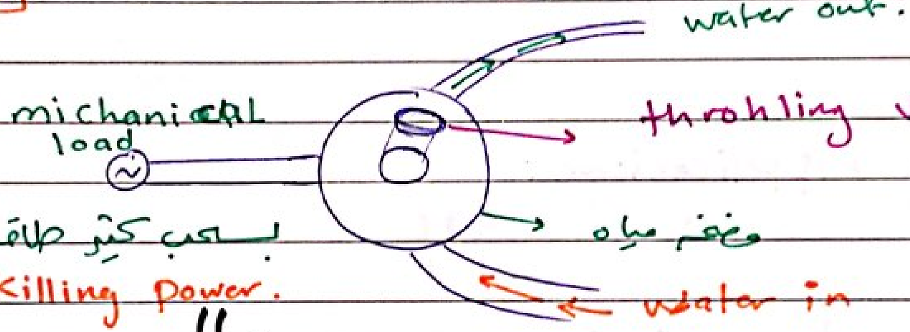
A LED, CFL

CFL = compact flurecah.



Efficacy "candela/w" better than effecincy.

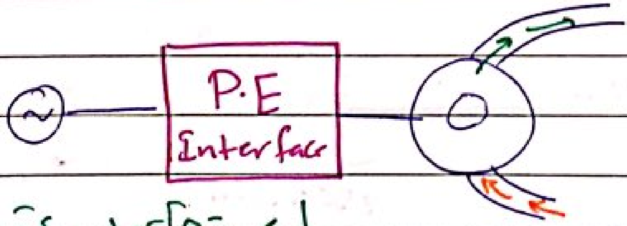
B



بيسحب كتير طاقة

↳ Killing power.

⇓

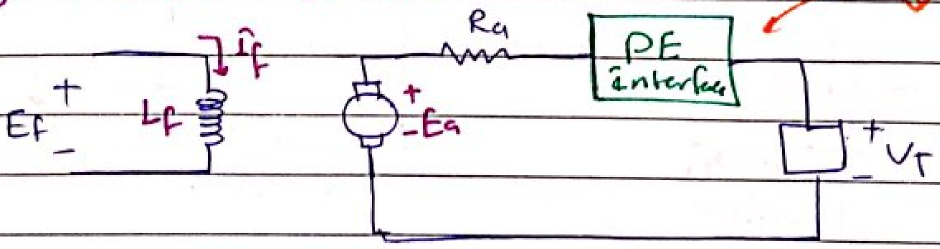


← بتحكم بـ سرعة دوران المضخة

volt ↑ للمضخة ← ماء ↑ اكثر.

5 Motor Drive :-

"بتحكم بـ V_T ↑↓"



$$I_a = \frac{E_a - V_T}{R_a}$$

$$E_a = K\phi\omega$$

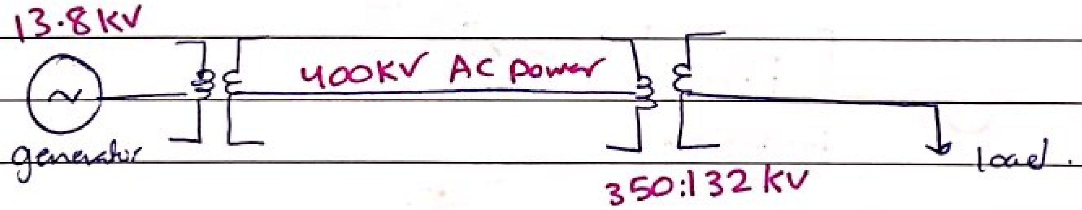
$$\rightarrow I_a = \frac{K\omega\phi - V_T}{R_a}$$

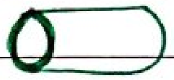
$$\boxed{\omega = \frac{I_a R_a + V_T}{K\phi}}$$

6 Utility Applications:-

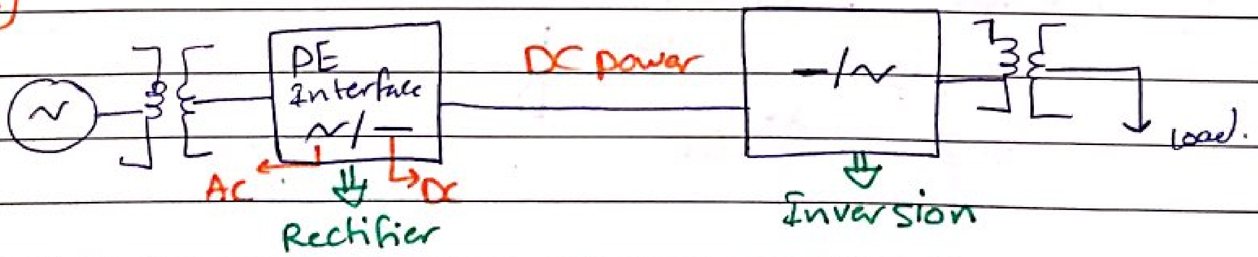
A HVDC transmission systems:-

I

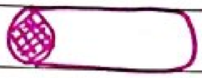


((بس على الاطراف)) Rac  loss in AC is more than in DC

II



* لما تكون ال volt عالي والمسافات طويلة بتكون ال effe. في DC power اعلى من AC

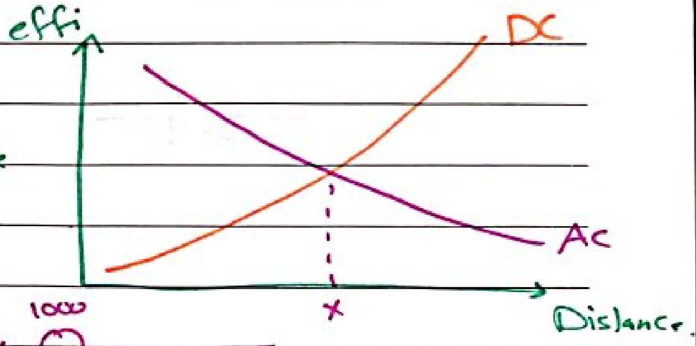
RDC 

$$\delta = \frac{1}{\sqrt{\mu \sigma \pi f}}$$

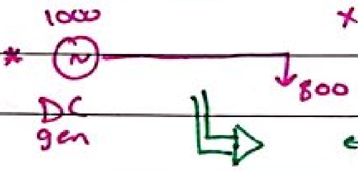
$R_{AC} > R_{DC}$

* losses AC > losses DC because of skin effect.

* f↑ → بتقل المساحة إلي بجري فيها تيار

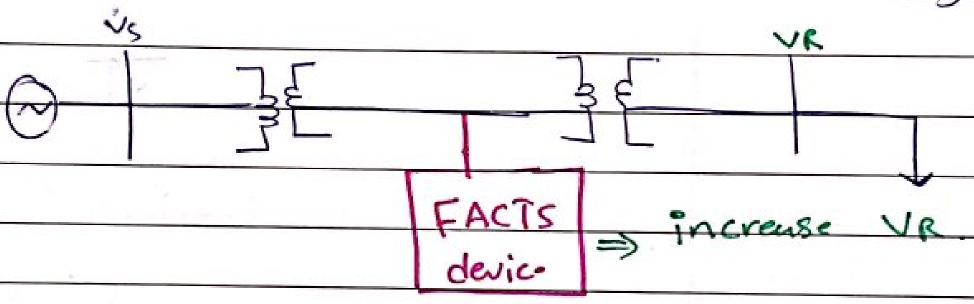


B FACTS :-

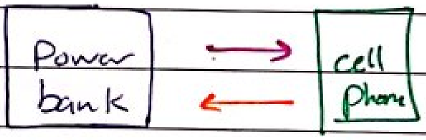


مسافة عالية ← more voltage drop

FACTS = flexible AC transmission System.



⇒ increase VR.



3% 80%

3-4% 76%

* انتقال الطاقة من الاقوى source ← الاضعف source

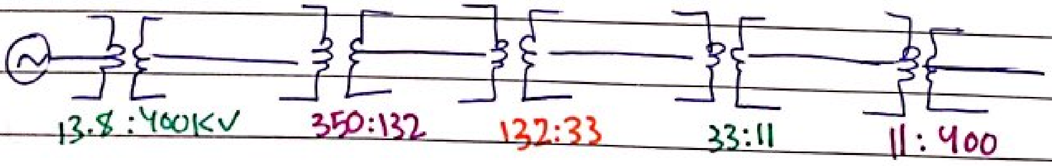
⇒ Essence of Power electronics :⇒ switching

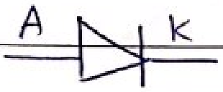
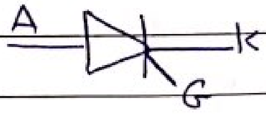
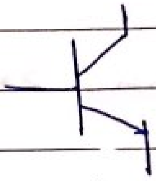
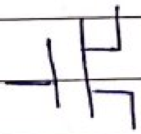
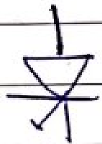
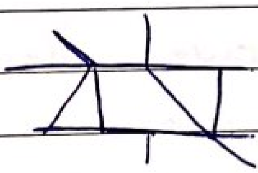
transistor , mosFET , diodes

\# Switching device categorization :-

↳ controllability and Direction.

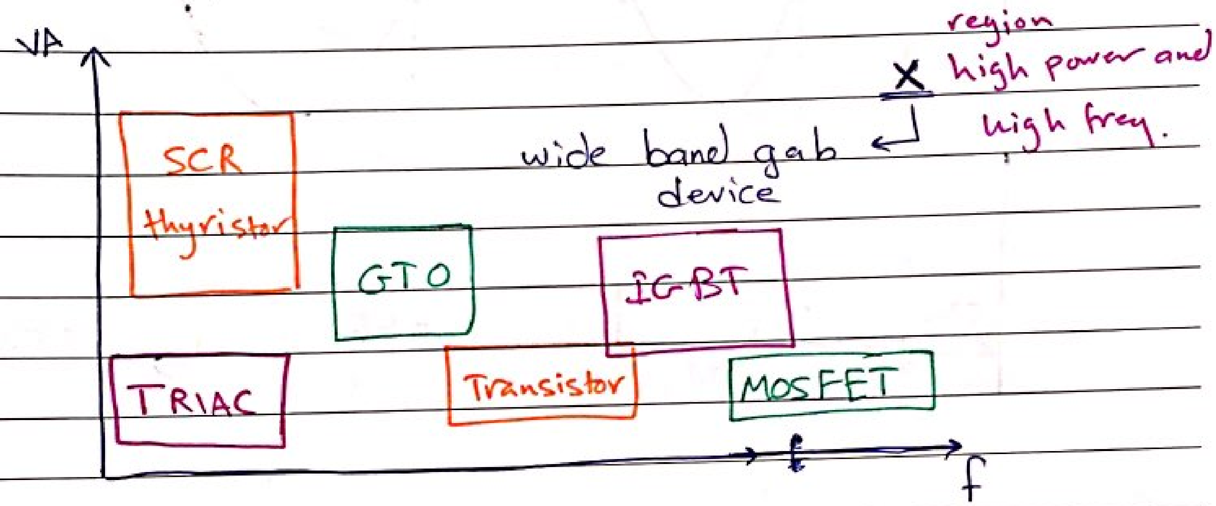
* AC in Aqaba



	UNcontrollable	Controllable ON	fully Controlled
UNI - direction	 diode	 G = gain Thyristor (SCR) OFF ← ON كولس	 transistor.  MOSFET  Gate turn OFF Thyristor (GTO)  insolated gate Bipolar transistor (IGBT) OFF ⇆ ON كولس.
BI - direction.	—	 Traic	

Power electronics Switches categores :-

Power and frequency

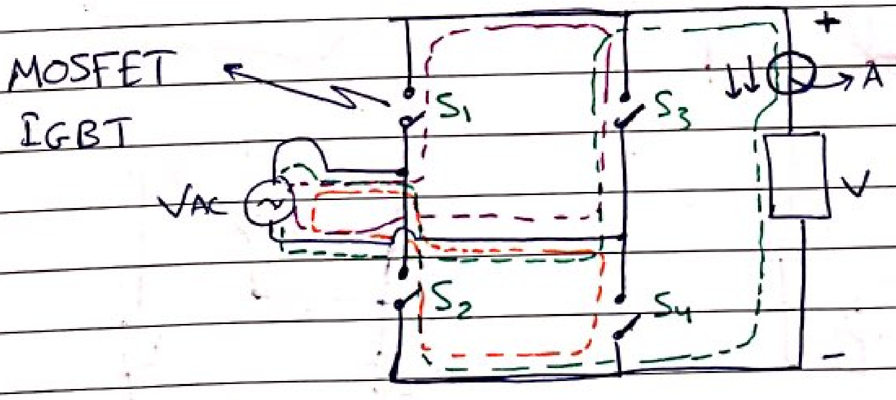


* SCR thyristor ⇒ Power system في دوائر الـ

* بدي احول من DC لـ AC عشان اربط بين الالواح [illegible]

#1 Principle of Ac - Dc conversion :-

[Rectification]

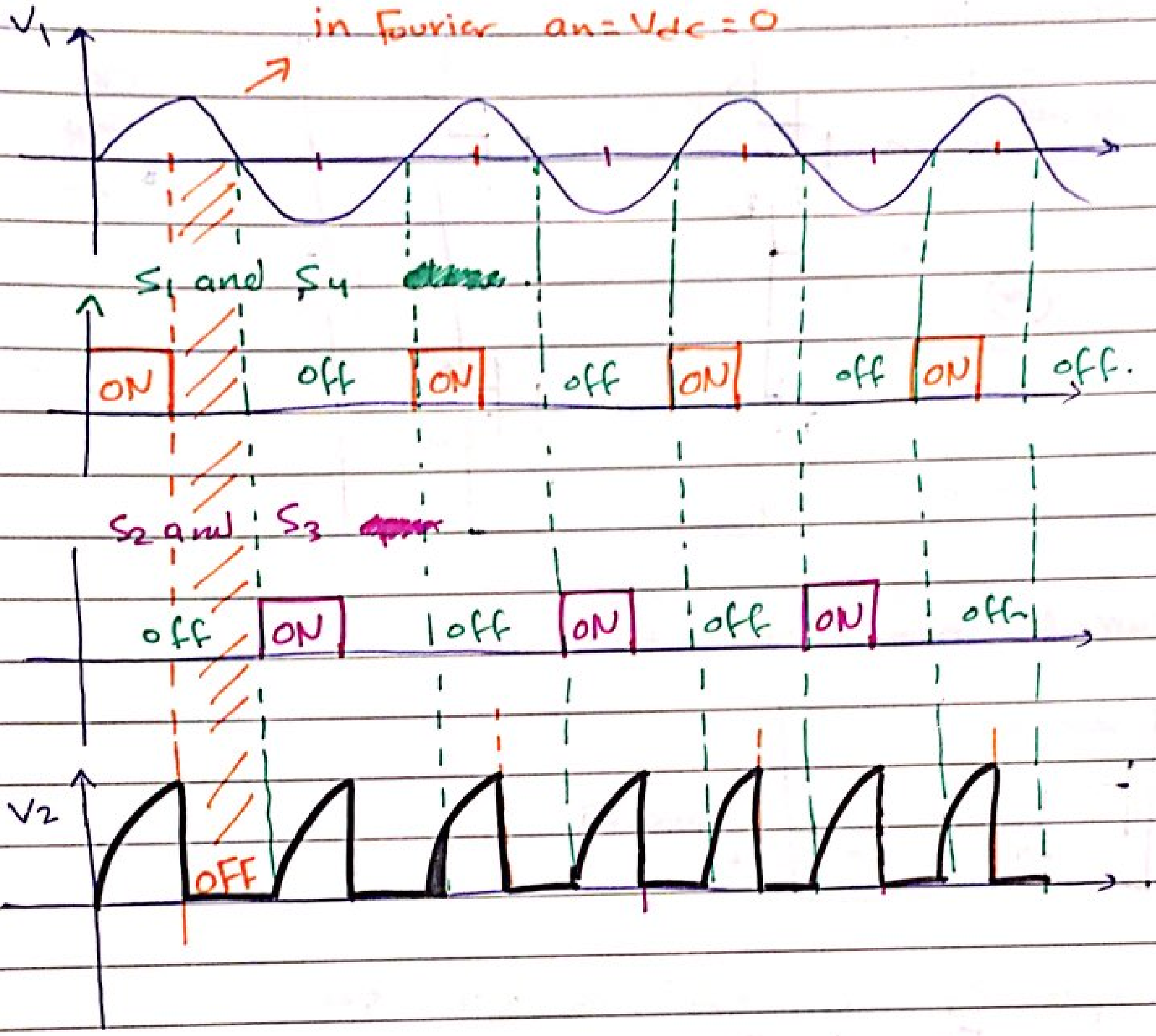


* S_1 and S_3 close → S.C
* S_2 and S_4 close → S.C

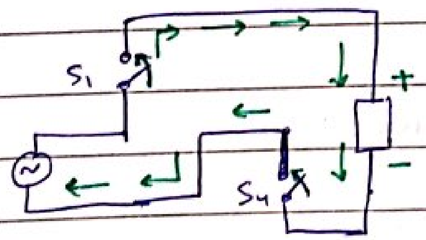
S_3 ON S_4 off

switching function

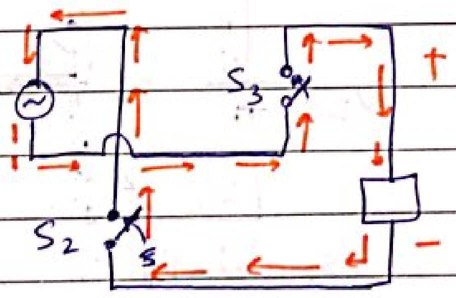
$$V_2 = (\underset{\substack{1\\0}}{S_1} - \underset{\substack{1\\0}}{S_3}) V_1 = (S_4 - S_2) V_1$$



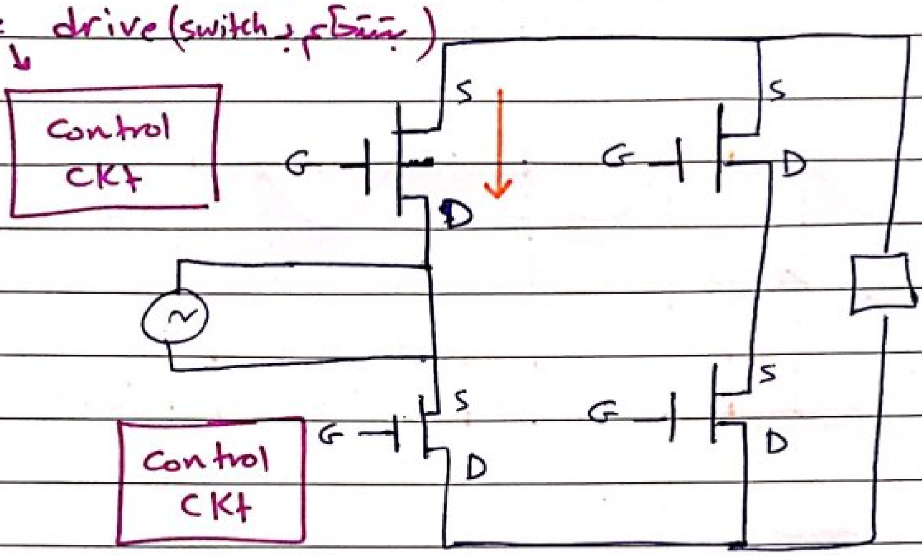
* S_1 and S_4 close.



S_3 and S_2 closed.

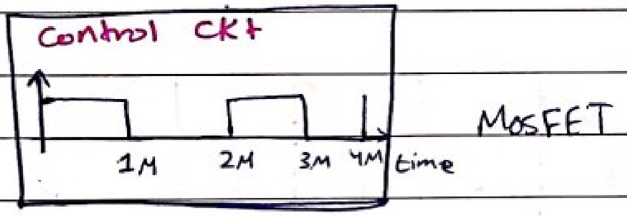


gate drive (switch بيتحكم)



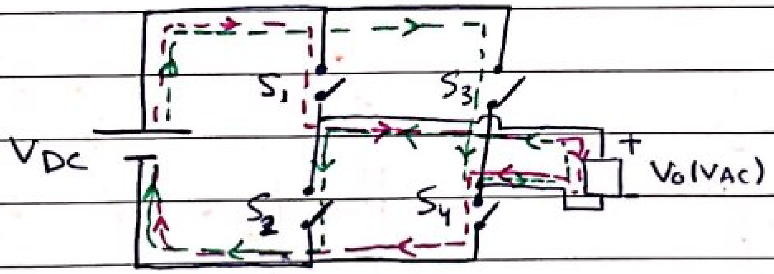
CKt
نفس
غلط *

↓ current from source to drain



Principle of DC-AC converter :Δ

[Inverter] using in solar system.



case 1: (S_1 and S_4 ON)

$-V_{DC} + V_o = 0 \Rightarrow \boxed{V_o = +V_{DC}}$

case 2: (S_3 and S_2) ON

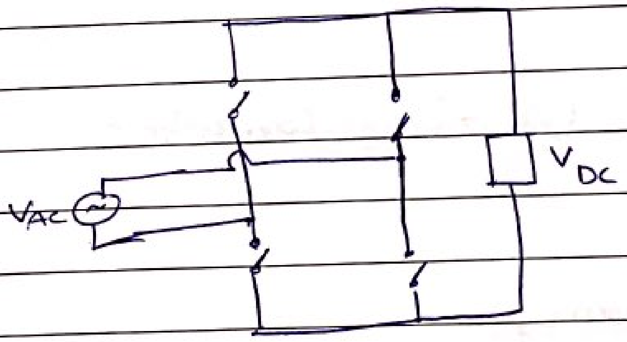
$-V_{DC} + -V_o = 0 \Rightarrow \boxed{V_o = -V_{DC}}$

$a_n = 0$ $b_n = 0$ $a_0 = V_{DC}$

$a_n \neq 0$ $b_n = 0$

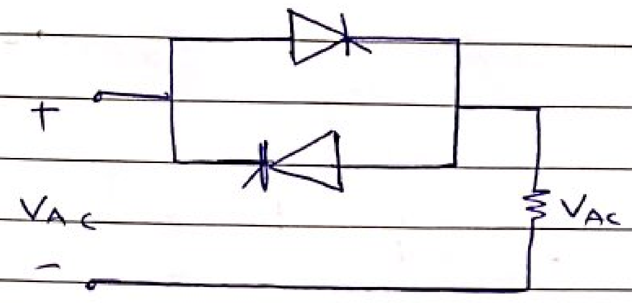
$a_0 = 0$

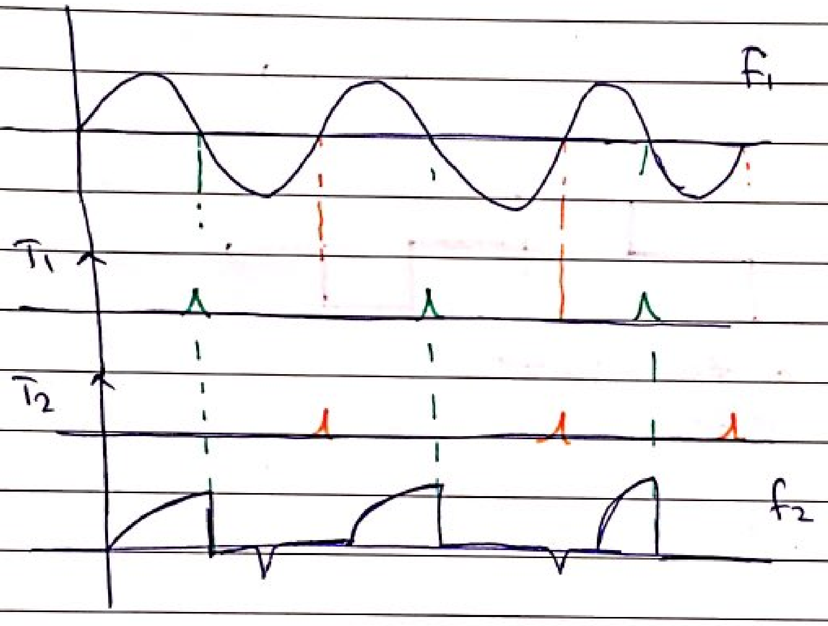
$$V_{AC} = (S_1 - S_2)\,V_{DC}$$



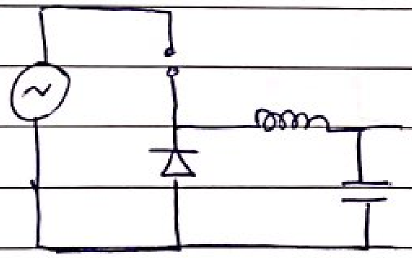
6/2 TUE

Principle of AC-AC conversion [Controllers] :-

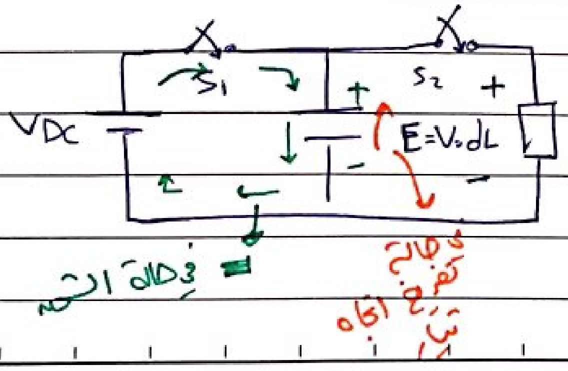




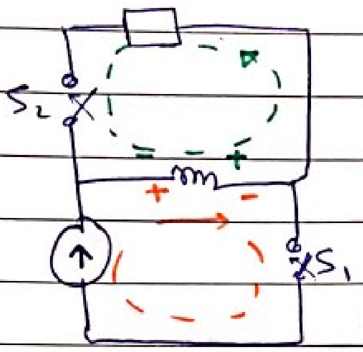
Principle of DC-DC converter.



$$i_c = C\frac{dv}{dt}$$

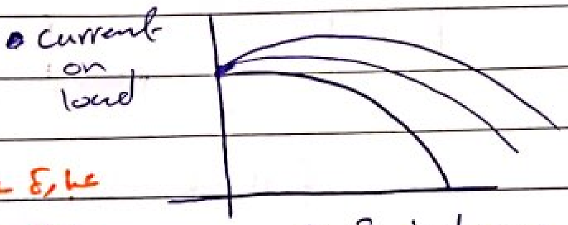


- * close S_1 → Cap charge.
  → open S_1 → close S_2
  output on load.
- * ↑▼ Cap → يعمل voltage source.
  تغير



close S_1 → شحن → open S_1
conductor

→ close S_2 → conduct يفرغ



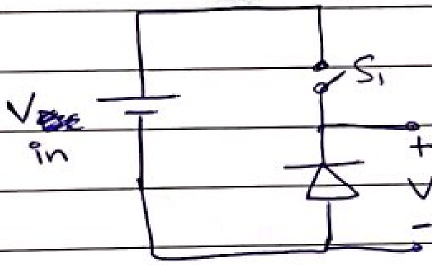
Inductor current → عبارة عن مجال مغناطيسي بلف باتجاه (↻) غاجر،
اغير اتجاهه

↑ Inductor → تصير current source.

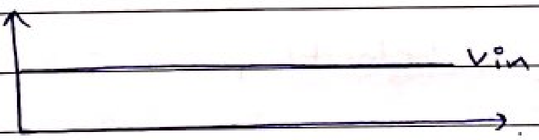
$$V_L = L\frac{di}{dt}$$

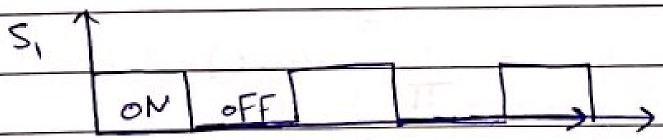
- * Capacitor بعاكس تيار وما بعاكس volt.
- * inductor بعاكس volt وما بعاكس تيار .

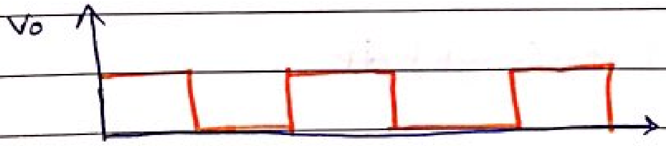
* DC - DC converter.



Ideal

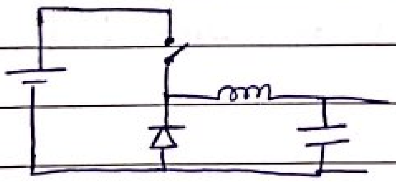






$\boxed{V_0 = V_{in}}$

* official ~~BB~~ DC - DC converter ⇒ capacitor ~~or~~, inductor بس *

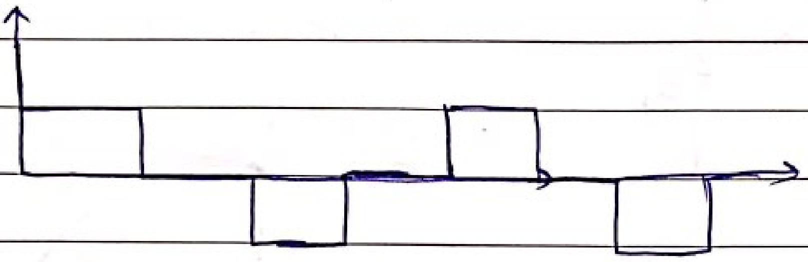


cap ← بثبت ال voltage)

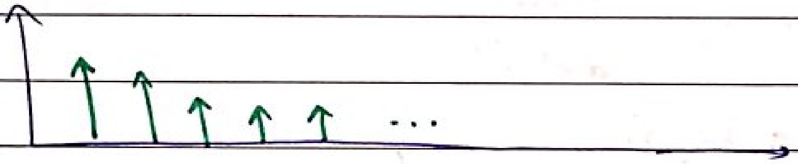
Ind ← وبثبت التيار

* Problems :-

1 Harmonics and ripple :-



full of harmonics



طلع إلي بعملها not pure مكلف احط Filter ...

2 NO over load capabilities

Fouriers Series :-

$$v(t) = \frac{a_0}{2} + \sum_{n=1}^{\infty} a_n \cos(n\omega t) + b_n \sin(n\omega t)$$

$$a_0 = \frac{2}{T}\int_0^T v(t)\, dt = \frac{1}{\pi}\int_0^{2\pi} v(\omega t)\, d\omega t$$

$$a_n = \frac{2}{T}\int_0^T v(t)\cos(n\omega t)\, dt$$

$$= \frac{1}{\pi}\int_0^{2\pi} v(\omega t)\cos(n\omega t)\, d\omega t$$

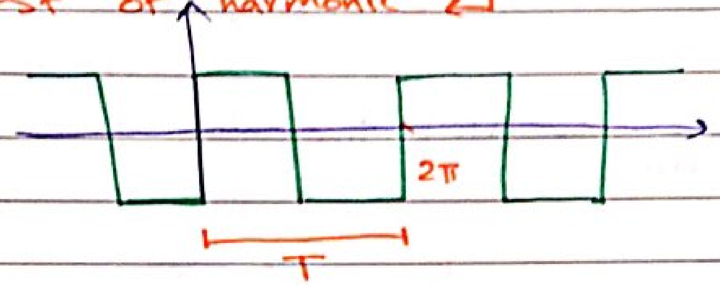
$$b_n = \frac{2}{T}\int_0^T v(t)\sin(n\omega t)\,dt = \frac{1}{\pi}\int_0^{2\pi} v(\omega t)\sin(n\omega t)\,d\omega t$$

$\boxed{\text{Ex}}$ Find the 1^{st} and 3^{rd} Harmonic For:

Rest of harmonic

* بقدر اوديها ع اصلها ؟!

← لا لانو بدي AC signal.



$$\Rightarrow a_0 = \frac{1}{\pi}\int_0^{2\pi} v(\omega t)\,d\omega t.$$

$$a_0 = \frac{1}{\pi}\left[\int_0^{\pi} 1\,d\omega t + \int_{\pi}^{2\pi} -1\,d\omega t\right.$$

$$= 0$$

$\boxed{\text{pure DC signal.}}$

$$\Rightarrow a_n = \frac{1}{\pi}\int_0^{2\pi} v(\omega t)\cos(n\omega t)\,d\omega t$$

$\boxed{a_n = 0 \rightarrow \text{odd signal}}$

$$= \frac{1}{\pi}\int_0^{\pi} \cos n\omega t\,d\omega t + \frac{1}{\pi}\int_{\pi}^{2\pi} -\cos n\omega t\,d\omega t$$

$$= \frac{1}{n\pi}\sin n\omega t\Big]_0^{\pi} - \frac{1}{n\pi}\sin n\omega t\Big]_{\pi}^{2\pi} = 0$$

$$b_n = \frac{1}{\pi}\int_0^{\pi}\sin n\omega t\,d\omega t + \frac{1}{\pi}\int_{\pi}^{2\pi} -\sin n\omega t\,d\omega t.$$

$$= \frac{-1}{\pi n}\cos(n\omega t)\Big]_0^{\pi} + \frac{1}{\pi n}\cos(n\omega t)\Big]_{\pi}^{2\pi}$$

$$b_n = \frac{2}{n\pi} - \frac{2}{n\pi}\cos n\pi$$

First harmonic $n=1$ $\Rightarrow \boxed{b_1 = \frac{4}{\pi}}$ $\Rightarrow$ Fundemental.

$$v(t) = \sum_{n=1}^{\infty}\left(\frac{2}{n\pi} - \frac{2}{n\pi}\cos n\pi\right)\sin n\omega t.$$

2^{nd} harmonic $n=2$ $\Rightarrow \boxed{b_2 = 0}$

3^{rd} 〃 $n=3$ $\Rightarrow \boxed{b_3 = \frac{4}{3\pi}}$

$b_4 = 0$

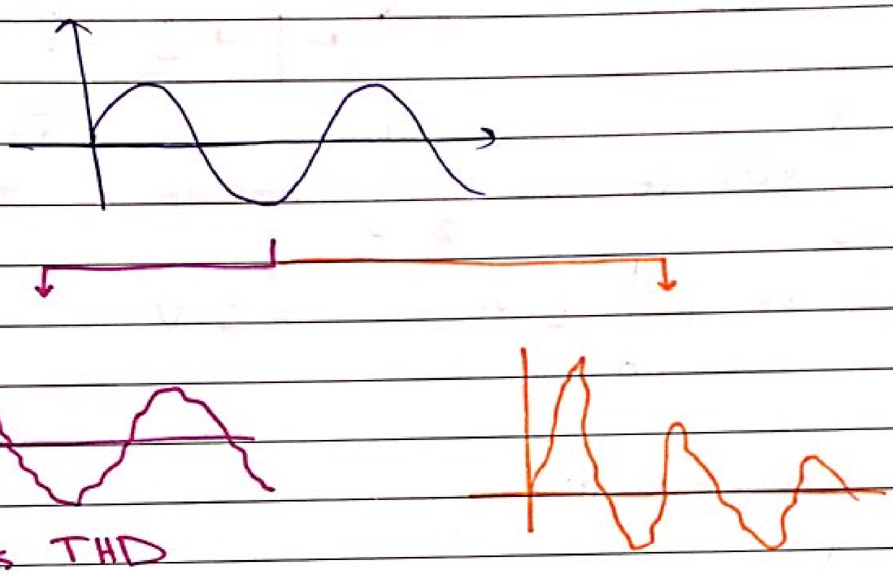
$b_5 = \frac{4}{5\pi}$

* 1st har هي أهم وحدة لأنها بتعطيني ال Power و Energy وباقي ~~الهارمونيك~~ harmo-nic

ال harmonic بدي أتخلص منهم.

* Total Harmonic Distortion :-

THD : is a measure of the closeness in shape btween a waveform and its fundemental component :-



$$\boxed{THD_I = \frac{\sqrt{\sum_{n=2}^{\infty} I_n^2}}{|I_1|}}$$

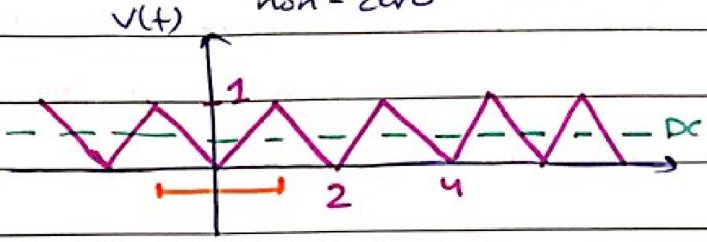
$$\boxed{THD_V = \frac{\sqrt{\sum_{n=2}^{\infty} V_n^2}}{|V_1|}}$$

For DC - Signal : $\frac{a_0}{2}$ → value of intersect

$\hookrightarrow a_n, b_n = 0$

Ex Find the total Harmonic distortion for the signal [consider the first $\overset{\downarrow}{}$ 5 Harmonic] !?
non-zero

$$v(t) = \begin{cases} -t & -1<t<0 \\ t & 0<t<1 \end{cases}$$



Sol:- $T=2$

$\Rightarrow a_0 = \frac{2}{T}\int_0^T v(t)\,dt = \frac{2}{2}\int_{-1}^{1} v(t)\,dt.$ $T = \frac{1}{f} = \frac{2\pi}{\omega}$

$= \int_{-1}^{0} -t\,dt + \int_0^1 t\,dt. = 1\,V$ $\boxed{\pi = \omega}$

$\Rightarrow b_n = 0$ [even function]

$\Rightarrow a_n = \frac{2}{T}\int_0^T v(t)\cos(nwt)\,dt$

$= \frac{2}{T}\int_{-1}^{1} v(t)\cos(nwt)\,dt$

$= 2\int_0^1 v(t)\cos(nwt)\,dt$

$u = t$ $dv = \cos nwt\,dt.$

$du = dt$ $v = \frac{1}{nw}\sin nwt.$

$= 2\left(\left[\frac{t}{nw}\sin \overset{0}{wnt}\right]_0^1\right) - \int_0^1 \frac{1}{nw}\sin wt\,dt.$

$\boxed{w = \pi}$

$= \frac{2}{n^2w^2}\cos nwt\Big]_0^1 = \frac{2}{n^2\pi^2}\left[\cos n\pi - 1\right]$

$$a_n = \begin{cases} 0 & n \text{ is even} \\ \dfrac{-4}{n^2\pi^2} & n \text{ is odd} \end{cases}$$

Fundemental at $n=1 \longrightarrow \dfrac{-4}{\pi^2}$

$n=2,\ n=4,\ n=5,\ n=6,\ n=8,\ \cdots = 0$

3rd $n=3 \longrightarrow a_3 = \dfrac{-4}{9\pi^2}$

$n=5 \longrightarrow a_5 = \dfrac{-4}{25\pi^2}$

$n=7 \longrightarrow a_7 = \dfrac{-4}{49\pi^2}$

$n=9 \longrightarrow a_9 = \dfrac{-4}{81\pi^2}$

$$THD = \frac{\sqrt{\sum_{n=2}^{9} V_n^2}}{|V_1|}$$

$$THD = \frac{\sqrt{\left(\frac{4}{9\pi^2}\right)^2 + \left(\frac{4}{25\pi^2}\right)^2 + \left(\frac{4}{49\pi^2}\right)^2 + \left(\frac{4}{81\pi^2}\right)^2}}{4/\pi^2} = 12\%$$

if $b_n = \dfrac{2\pi}{3n} \Rightarrow C_n = \sqrt{a_n^2 + b_n^2}$

بنعوضها

$$THD = \frac{\sqrt{C_3^2 + C_5^2 + C_7^2}}{C_1^2}$$

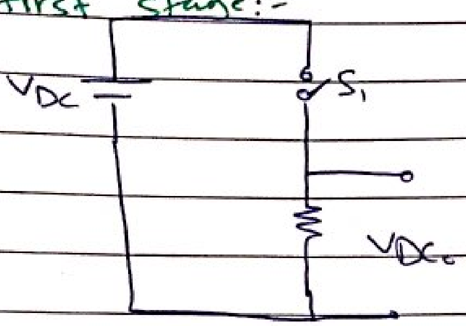
DC-DC Converters

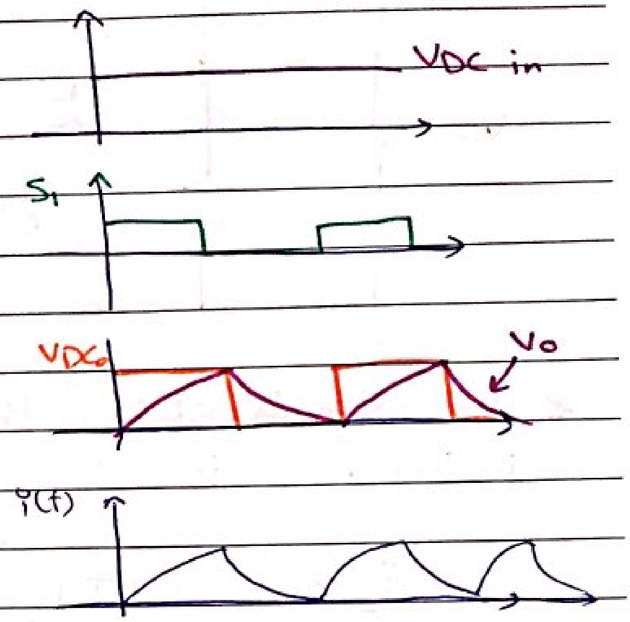
- → PV system
- → switched mode regulated DC power supplies
- → Electric / Hypri[illegible]ed / [illegible] [illegible] Vehicles

Non-Isolated.	Isolated
→ Buck [steps down]	→ Fly back
→ Boost [steps up]	→ Forward
→ Buck / Boost [up/down]	→ full and half bridge.

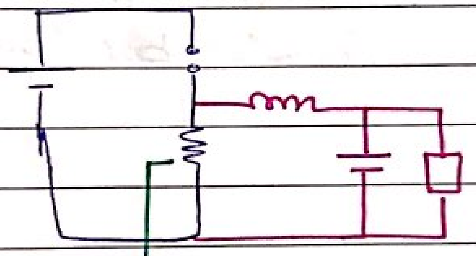
* Origin of Buck Converter :-

First stage :-



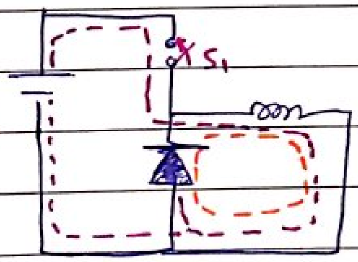


Next stage :-



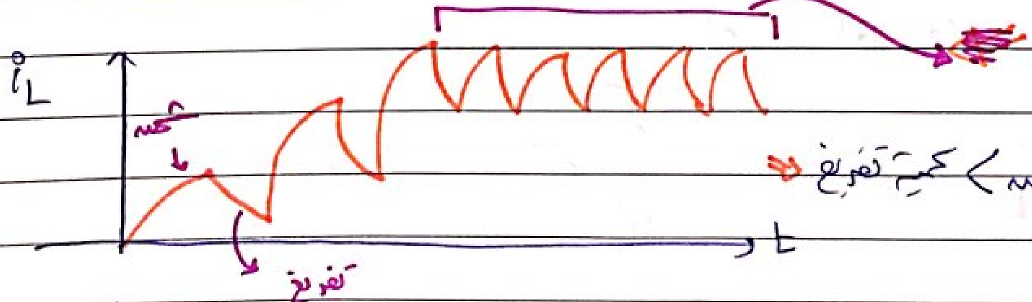
↳ Kills the effeciancy.

* عن 5 [illegible] !!



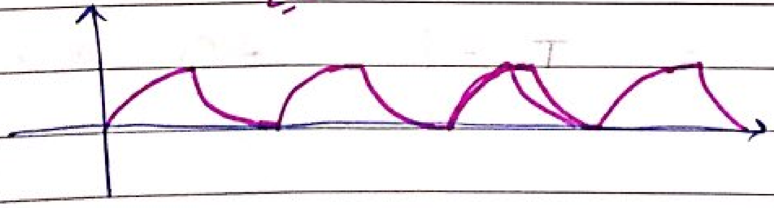
switch ON

S1 OFF



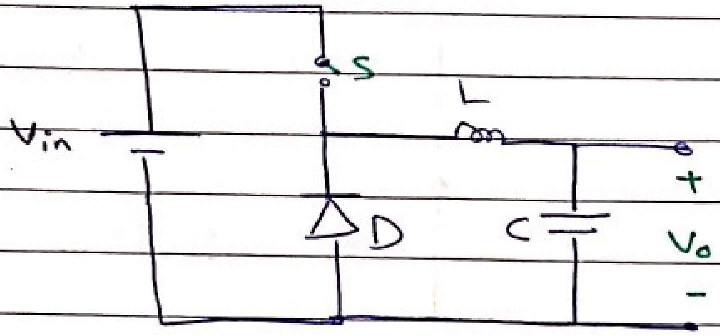
ركز الـ Steady State.

كمية الشحن > كمية تفريغ !!



⇒ كمية الشحن ≥ كمية التفريغ

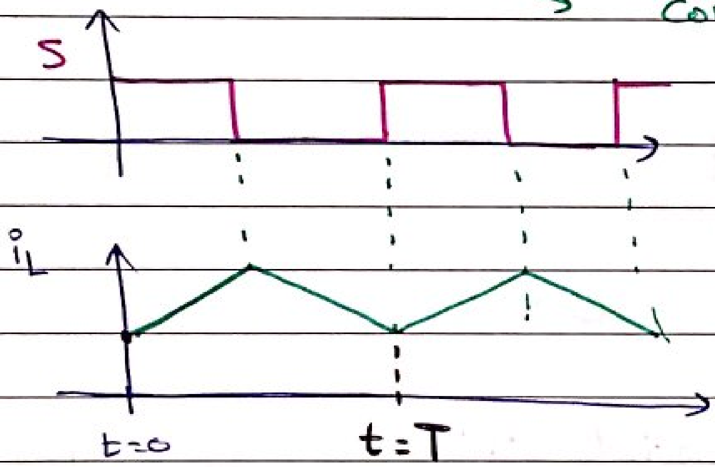
Final version of Buck convertor :-



* In steady state the average voltage across the inductor is Zero ?!!

$i_L(0) = i_L(\overset{\uparrow}{T})$ → switching period.

→ conservation of charge.
مبدأ حفظ الشحنة.

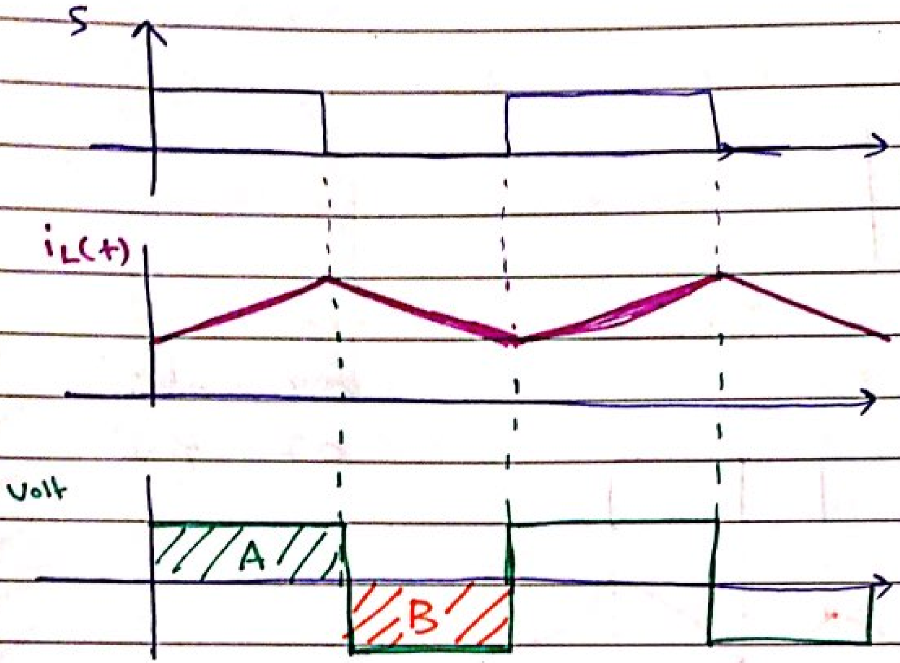


$$V_L(t) = L\,\frac{d\,i(t)}{dt}$$

$$\frac{1}{L} V_L(t)\,dt = di$$

$$\int_0^T \frac{1}{L} V_L(t)\,dt = \int_{i(0)}^{i(T)} di$$

$$\int_0^T \frac{1}{L} V_L(t)\,dt = i(T) - i(0) = 0$$ (average volt)

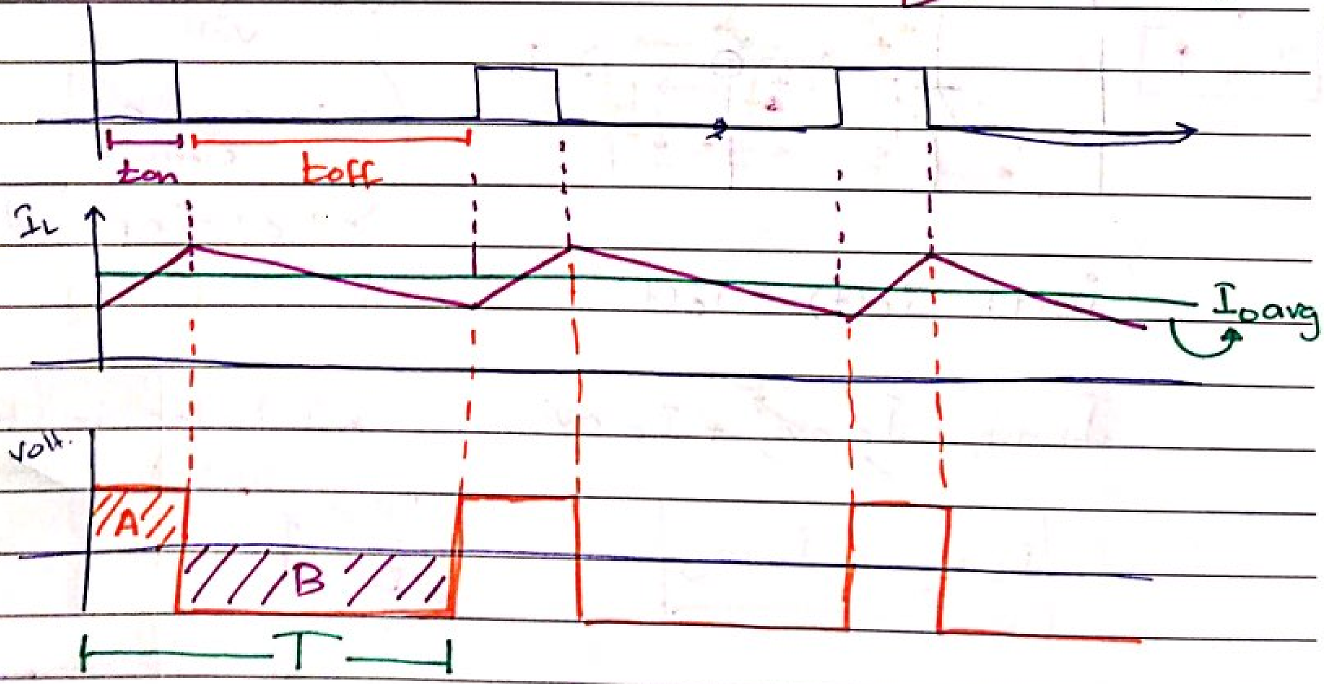


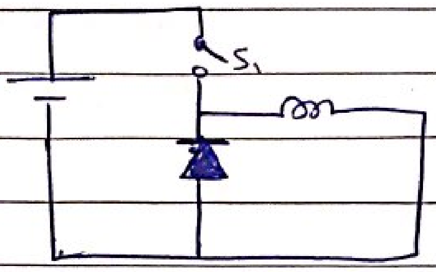
volt → مشتق
التيار

$\boxed{A = B}$

$T = t_{on} + t_{off}$

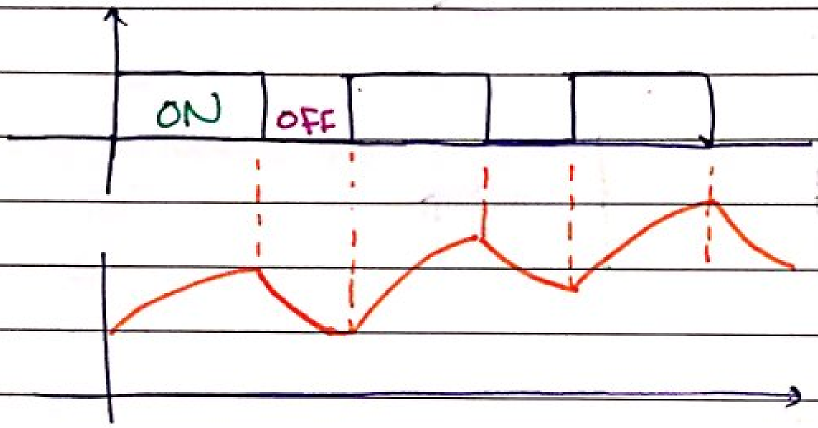
$D \triangleq \text{Duty cycle} = \frac{t_{on}}{T}$ $\boxed{0 \leq D \leq 1}$





D = 0.8   T= 1 s

0.8 = شحن
0.2 = تفريغ

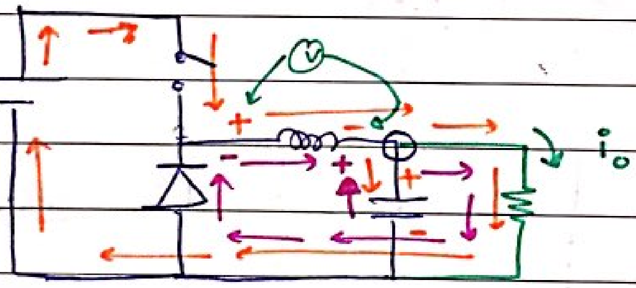


if D=0.2 → بتعبي شوي وبتفرغ كثير.

ON state.

off state ↓

$\boxed{I_{cap} \uparrow}$



⇒ average inductor = 0. volt

⇒ average capacitor = 0 current

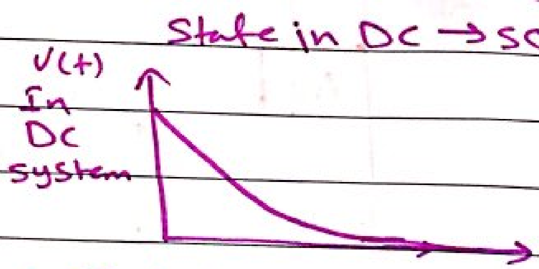
over a period.

$$i_L(t) = i_c(t) + i_o(t)$$

$$I_{L avg} = \cancel{I_{c avg}}^{0} + I_{o avg}.$$

$$\boxed{I_{L avg} = I_{o avg}}$$

* Inductor in steady State in DC → sckt

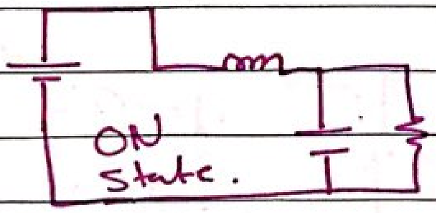


Switch ON → OFF ⇒ Inductor → ما بيصل مرحلة ال steady state

ON state :-

$V_{in}(t) = V_L(t) + V_o(t)$.

$-V_{in}(t) + V_L(t) + V_o(t) = 0$

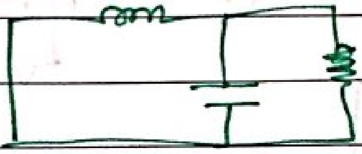


OFF state :-

* diode short ckt.

$-V_L(t) = V_o(t)$

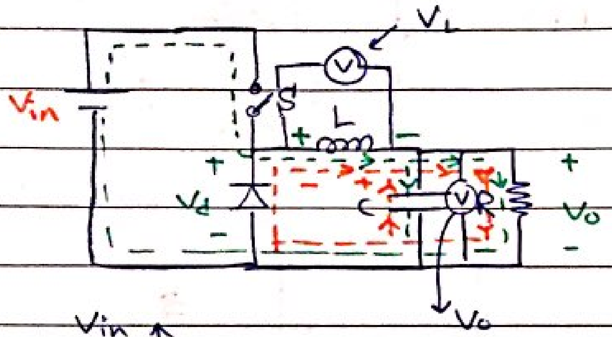
$V_L(t) + V_o(t) = 0$



$-V_L(t) = V_o(t) = V_c(t)$.

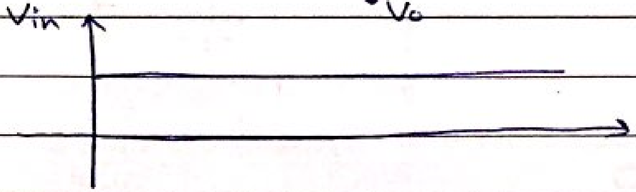
13/2 TUE

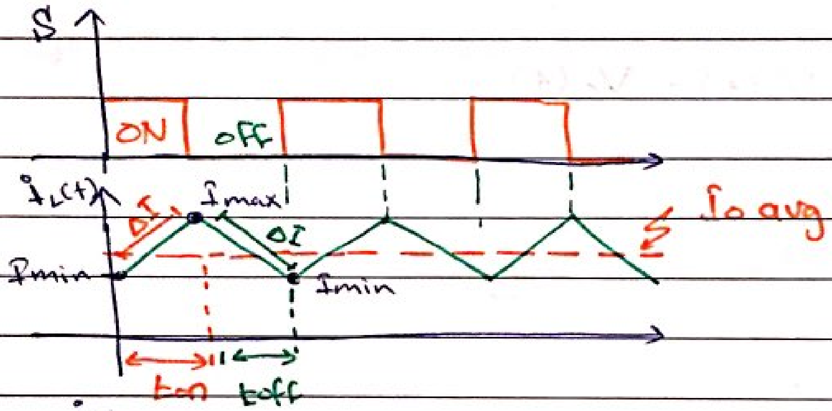
BUCK Converter



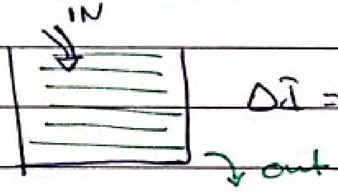
ON →

OFF

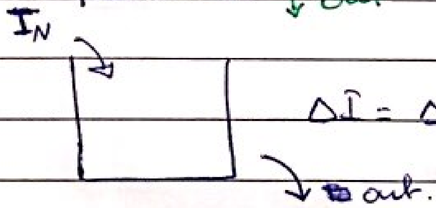




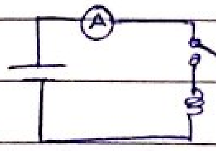
*



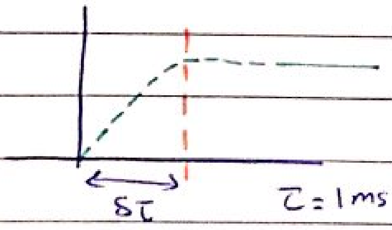
$\Delta I = \Delta Q = C$



$\Delta I = \Delta Q = C$

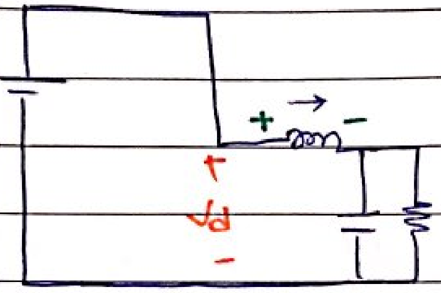


$f = 10^5$ HZ.



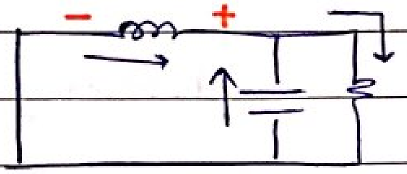
$\tau = 1ms$

ON :-



$i_L(t) = i_C(t) + i_R(t)$

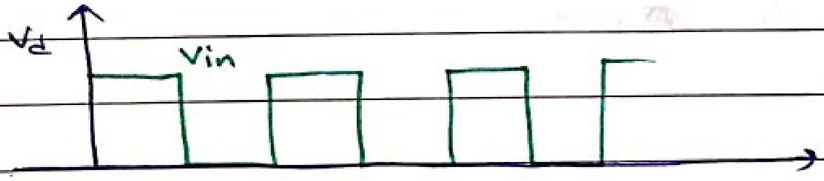
OFF :-

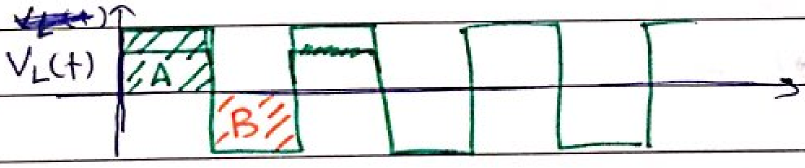


change its direction ⇒ ($i_C(t)$)

$i_L(t) = \underbrace{i_C(t)} + i_R(t)$.

$V_o\ avg = I_o avg * R$.





A=B

*

IN ~~stad~~ Stady State :-

$I_{L avg} = I_{o\ avg}$

S is ON :-

$-V_{in} + V_L + V_o = 0$

$$V_L = L\frac{di}{dt} = V_{in} - V_o \quad \dots ①$$

$$L\frac{\Delta I_1}{t_{ON}} = V_{in} - V_o \quad \dots ①$$

S is OFF

$$V_L = -V_o$$

$$|V_L| = |V_o|$$

V_L is -ve because the inductor changes polarity.

$$V_o = -V_L = -L\frac{\Delta I_2}{t_{off}} \quad \dots ②$$

$$\boxed{\Delta I_2 = -\Delta I_1}$$

from (1) :-

$$\Delta I_1 = \frac{V_{in} - V_o}{L} t_{on}$$

from (2):-

$$\Delta I_1 = \frac{V_o}{L} t_{off}$$

$$\frac{V_{in} - V_o}{L} t_{on} = \frac{V_o}{L} t_{off}$$

$$V_{in} t_{on} - V_o t_{on} = V_o t_{off}$$

$$V_{in} t_{on} = V_o(t_{on} + t_{off})$$

$T = t_{on} + t_{off}$

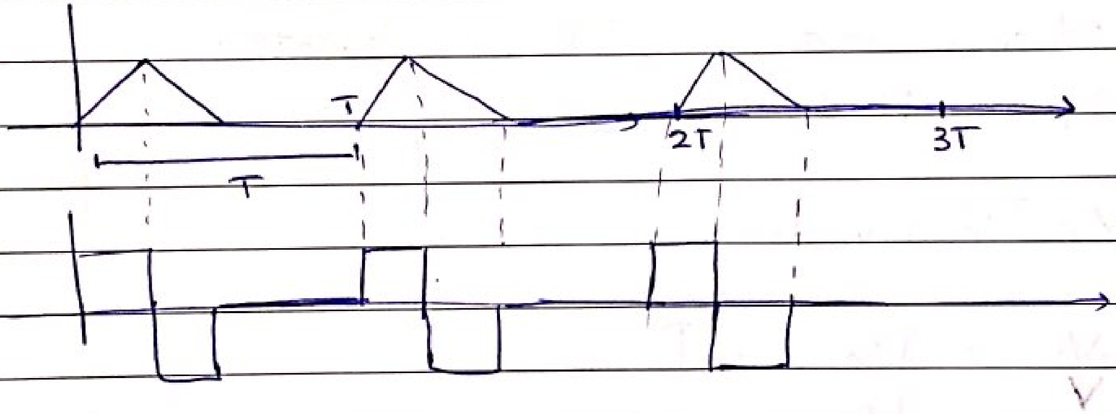
$D = \frac{t_{on}}{T}$ dutty cycle. $0 \leq D \leq 1$

$V_{in} t_{on} = V_o T$

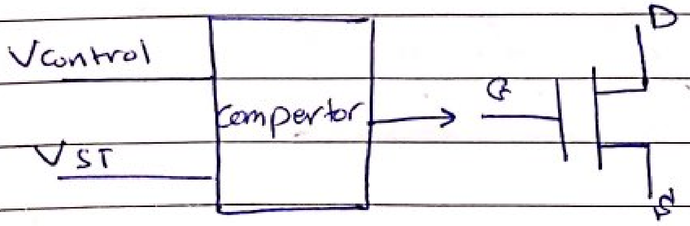
$V_o = V_{in} \frac{t_{on}}{T}$

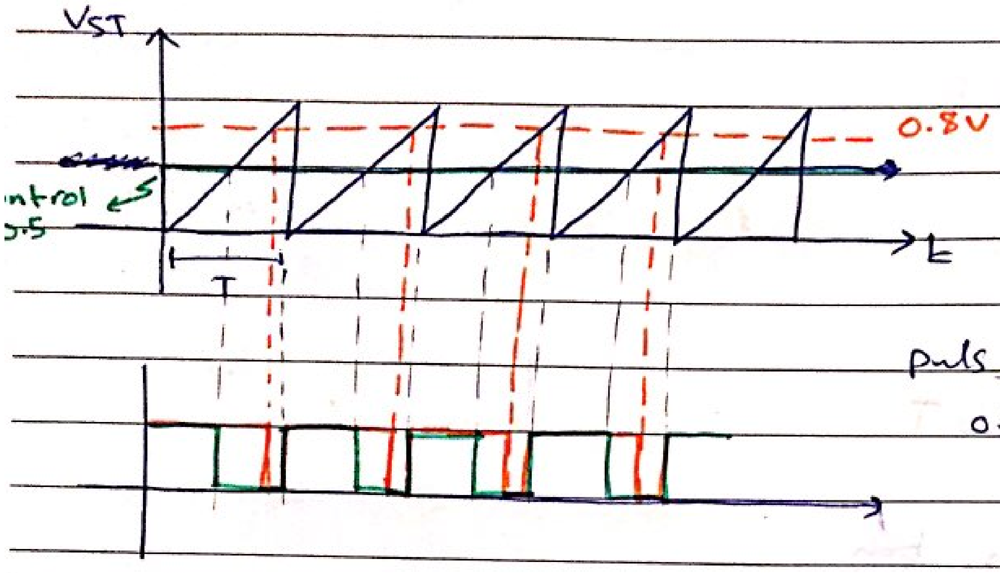
$\boxed{V_o = D V_{in}}$

↓ average output voltage.



* How to realize duty cycle Control of Switch [PWM]





زاد ال width تبع ال puls

لما صارت Vcont = 0.8

اعلى من 0.5V

بحط 1

اقل من 0.5

بحط 0.

$V_{control} > V_{ST} \Rightarrow$ Comp at $= 1$

$V_{control} < V_{ST} \Rightarrow$ Comp at $= 0$.

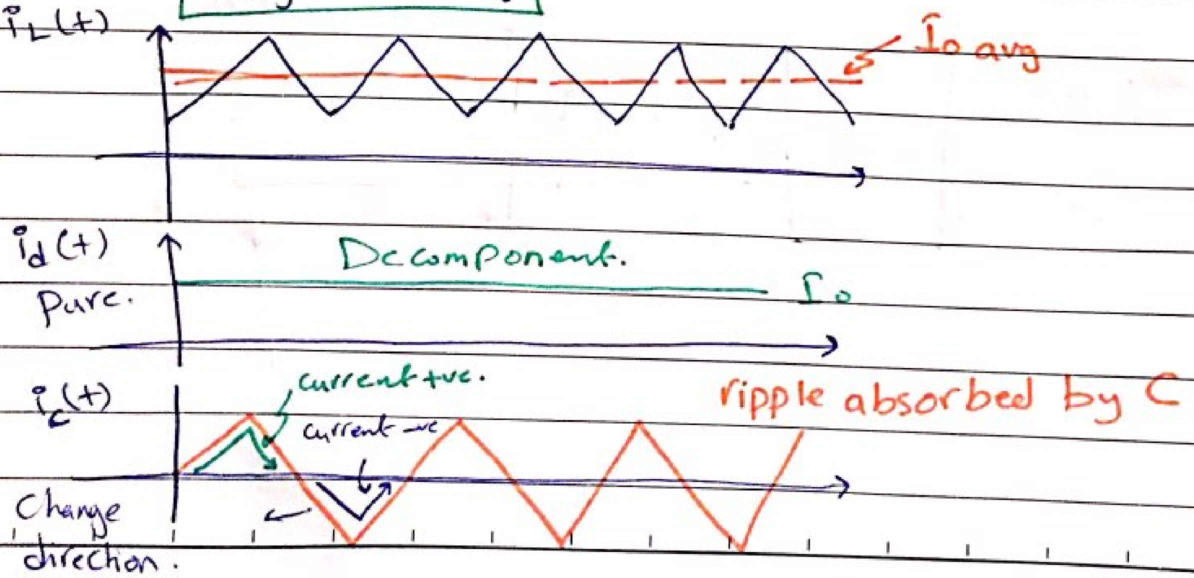
Considering alossless DC-DC converter.

$P_{in} = P_{out}$

$V_{in} I_{in} = V_o I_o$

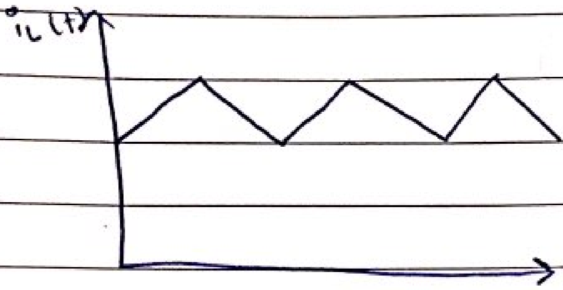
$$\frac{V_o}{V_o} = \frac{I_{in}}{I_o} = D$$

$$\boxed{I_{in_{avg}} = D \, I_{o_{avg}}}$$

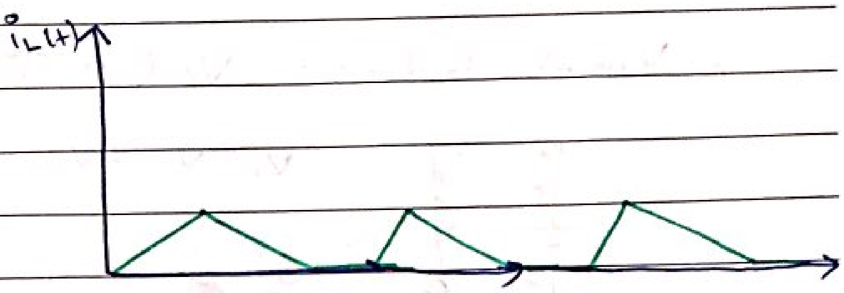


15/2 THU

2 mode of operation for a DC/DC Buck Converter.



Continouse mode.



Discontinous

Boundary

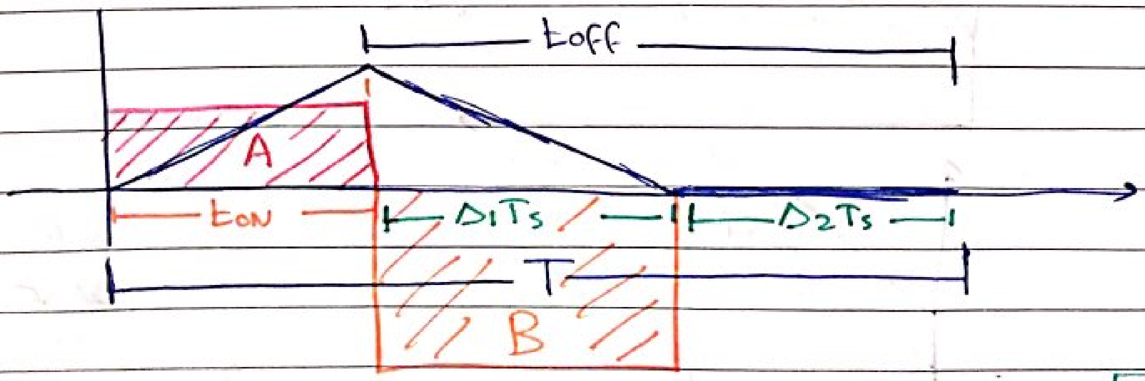
* تيار Induct يوصل للصفر
فنعتبره discontinous

* Continouse mode $\Rightarrow \frac{L}{R} = \tau \gg T$

$\rightarrow V_o = D V_{in} = \frac{t_{on}}{t_{on}+t_{off}} V_{in}$

* Discontinous ⇒ - large of time (D small).
- Low frequency.

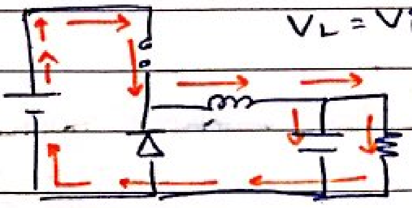
⇒ Find which mode will be having the higher output voltage ! [with same duty ratio]



Voltage – second balance

$|A| = |B|$

$(V_{in} - V_o) \cdot t_{on} = V_o(\Delta_1 T)$



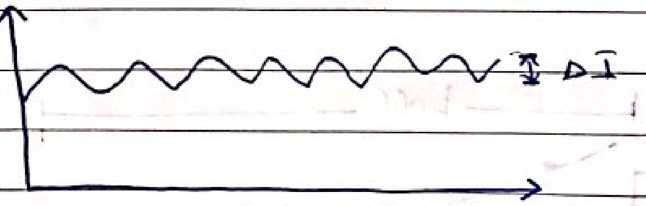
$V_{in} t_{on} - V_o t_{on} = V_o(\Delta_1 T)$

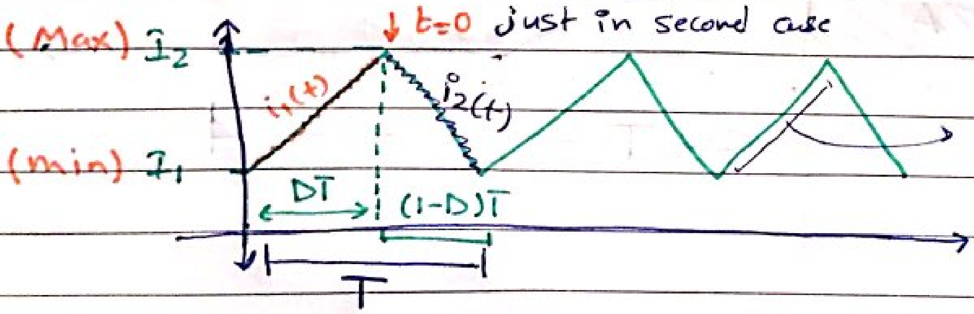
$V_{in} t_{on} = V_o(t_{on} + \Delta_1 T)$

$$\boxed{V_o = \left(\frac{t_{on}}{t_{on} + \Delta_1 T}\right) V_{in}}$$

⇒ Discontinouse mode will produce higher output voltage for the same duty cycle.

$\Delta I \downarrow \rightarrow$ تيار جودته اعلى

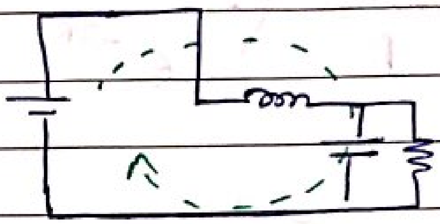




ضد exponential
بس تجاهلنا
بنرسم خطاً
مستقيم

⇒ Find I_1 and I_2 in continous mode

ON State :-



t: $0 \leq t \leq DT$

$$V_s(t) = R i_1(t) + L \frac{\delta i_1(t)}{dt}.$$

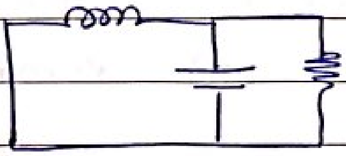
$$i_1(t) = \underbrace{I_1 e^{-\frac{tR}{L}}}_{\text{neutral}} + \underbrace{\frac{V_s}{R}\left(1-e^{-\frac{tR}{L}}\right)}_{\text{forced}}$$

$$i_1(DT) = I_2$$

at $t = DT$

$$I_2 = I_1 e^{-\frac{DTR}{L}} + \frac{V_s}{R}\left(1 - e^{-\frac{DTR}{L}}\right) \quad \ldots\ ①$$

OFF State :-



$$R i_2(t) + L \frac{\delta i_2(t)}{dt} = 0$$

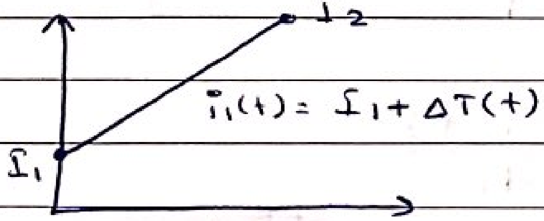
$$i_2(t) = I_2 e^{-\frac{Rt}{L}}$$

$$i_2((1-D)T) = I_1$$

$$I_1 = I_2 e^{-\frac{R\{(1-D)T\}}{L}} \quad \ldots\ ②$$

$$\boxed{I_1 = \frac{V_{in}}{R}\left(\frac{e^{\frac{DTR}{L}} - 1}{e^{\frac{TR}{L}} - 1}\right)}$$

$$\boxed{I_2 = \frac{V_{in}}{R}\left(\frac{e^{\frac{-DTR}{L}} - 1}{e^{\frac{-TR}{L}} - 1}\right)}$$



The Peak - Peak ripple 8Δ

$$\Delta I = I_2 - I_1$$

$$= \frac{V_{in}}{R}\left[\frac{(e^{\frac{-DTR}{L}} - 1)\cdot e^{\frac{+TR}{L}}}{(e^{\frac{-TR}{L}} - 1)\cdot e^{\frac{+TR}{L}}} - \frac{(e^{\frac{+DTR}{L}} - 1)}{(e^{\frac{+TR}{L}} - 1)}\right]$$

$$= \frac{V_{in}}{R}\left[\frac{1 + e^{\frac{TR}{L}} - e^{\frac{DTR}{L}} - e^{(1-D)\frac{TR}{L}}}{e^{TR/L} - 1}\right]$$

The Maximum ripple occurs:-

[which D will maxmize the ripple. $\Rightarrow$ when $\frac{d\Delta I}{dD} = 0$

$$\frac{d\Delta I}{dD} = \frac{V_{in}}{R\left[e^{\frac{TR}{L}}-1\right]}\left[\frac{TR}{L}e^{\frac{(1-D)TR}{L}} - \frac{TR}{L}e^{\frac{DTR}{L}}\right] \overset{?}{=} 0$$

$$(1-D) = D$$

$D = 0.5$ will make maximum ripple on Buck DC/DC converter.

to find $\Delta\hat{I}_{max}$ but $D=0.5$

$$\Delta\hat{I}_{max} = \frac{V_{in}}{R}\left[\frac{1+e^{\frac{TR}{L}} - e^{\frac{0.5TR}{L}} - e^{\frac{0.5TR}{L}}}{e^{\frac{TR}{L}} - 1}\right]$$

$$= \frac{V_{in}}{R}\left[\frac{\left(1-e^{\frac{0.5TR}{L}}\right)^2}{\left(e^{\frac{0.5TR}{L}}-1\right)\left(e^{\frac{0.5TR}{L}}+1\right)}\right]$$

$$= \frac{V_{in}}{R}\left[\frac{\left(1-e^{0.5\frac{TR}{L}}\right)^{2}}{\cancel{\left(1-e^{\frac{0.5TR}{L}}\right)}\left(1+e^{\frac{0.5TR}{L}}\right)}\right]$$

$$\Delta\hat{I}_{max} = \frac{V_{in}}{R}\left[\frac{e^{0.5\frac{TR}{L}}-1}{e^{0.5\frac{TR}{L}}+1}\right]$$

$$= \frac{V_{in}}{R}\tanh\frac{TR}{4L}$$

$$\boxed{\tanh x = \frac{e^{2x}-1}{e^{2x}+1}}$$

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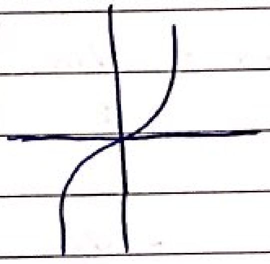
$$\Delta I = \frac{V_{in}}{R}\left[\frac{1+e^{\frac{TR}{L}} - e^{(1-D)\frac{TR}{L}} - e^{\frac{DTR}{L}}}{e^{\frac{TR}{L}}-1}\right]$$

$$\Delta I_{max}\Big|_{D=0.5} = \frac{V_{in}}{R}\tanh\frac{TR}{4L} \nearrow \frac{R}{4Lf}$$

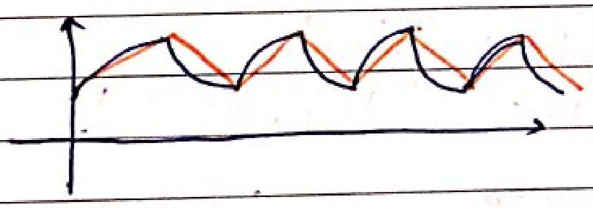
↳ High frequency.

Since $\tanh\theta = \theta$ for very small value.

$$\Delta I_{max} = \frac{V}{4fL}$$

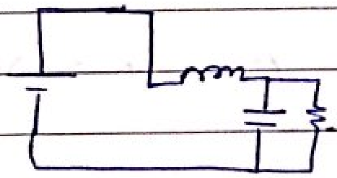


Approximate Solution:-



ON State :-

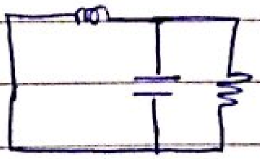
$$t_{on} = \frac{L\,\Delta I_L}{V_{in}-V_o} \quad \left[\, V_L = L\frac{\Delta I_L}{t_{on}} \,\right]$$



$$(V_{in}-V_{out}) = L\frac{\Delta I_L}{t_{on}}$$

OFF State :-

$$t_{off} = \frac{\Delta I \times L}{V_o}$$



$$T = \frac{1}{f} = t_{on} + t_{off}$$

$$= \frac{L*\Delta I*V_o}{(V_{in} - V_o)*V_o} + \frac{\Delta I * L*(V_{in}-V_o)}{V_o*(V_{in}-V_o)}$$

$$\frac{1}{f} = \frac{V_{in}\Delta I * L}{(V_{in}-V_o)\, V_o}$$

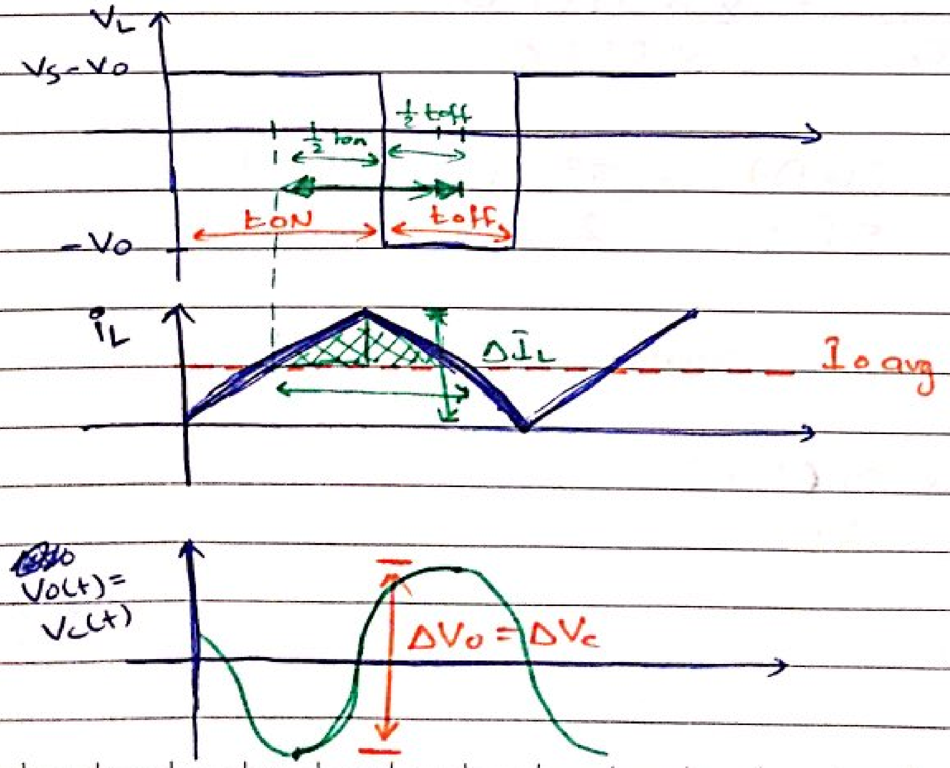
$$\Delta I = \frac{(V_{in} - V_o)\, V_o}{V_{in}\, L f}$$

$$\boxed{V_o = D\, V_{in}}$$

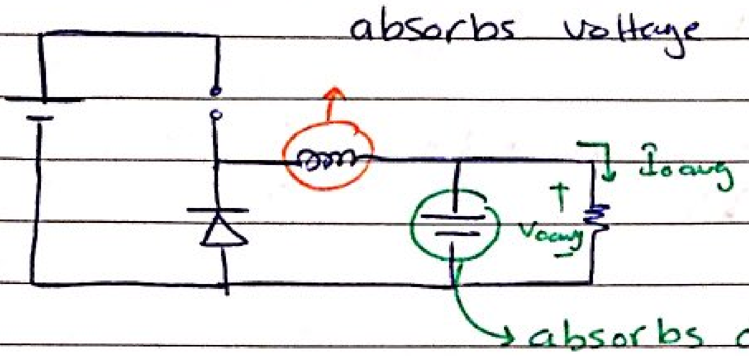
$$\boxed{\Delta I = \frac{V_{in}\,(1-D)D}{Lf}}$$

$$\boxed{\Delta I_{max}\Big|_{D=0.5} = \frac{V_{in}}{Lf}}$$

* output voltage ripple (capacitor voltage ripple) :-



absorbs voltage fluctuation.



absorbs current fluctution.

- cap → يمتص الـ ripple إلي في تيار،
ويثبت الـ volt.

Ind → يمتص الـ ripple في voltage
ويثبت الـ current

$$\Delta V_o = \Delta V_c = \frac{\Delta Q}{C} \rightarrow \text{مساحة مثلث}$$

ارتفاع * طول قاعدة

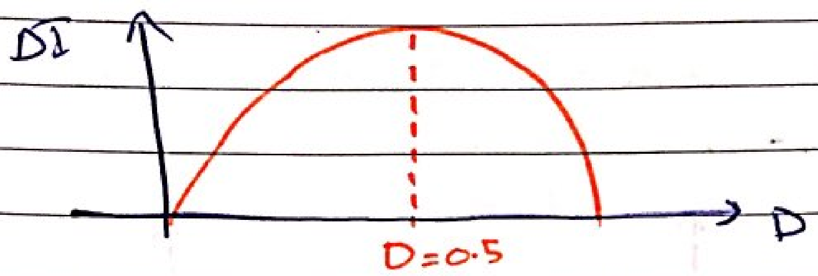
$$= \frac{\frac{1}{2} * \frac{1}{2}\Delta I_L * \frac{1}{2}T}{C}$$

$$= \frac{\Delta I_L}{8fC} = \frac{\overbrace{V_{in}\,D}^{V_o}(1-D)}{8f^2LC}$$

$$\frac{\Delta V_o}{V_o} = \frac{(1-D)}{8f^2LC} = \frac{\pi^2}{2}(1-D)\left(\frac{f_c}{f}\right)^2$$

where $f_c \equiv \frac{1}{2\pi\sqrt{LC}}$, corner frequency

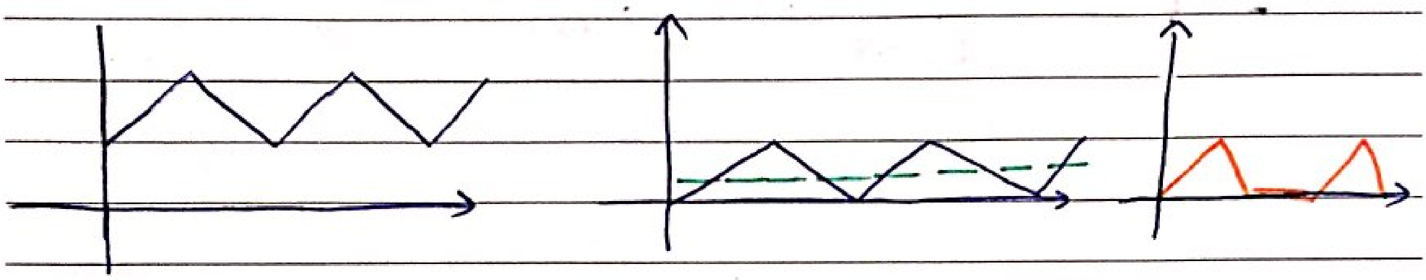
$$\Delta I = \frac{V_{in}\,D(1-D)}{fL}$$



ΔI as a function of D

20/2 TUE

Boundaryies between cont. and discont. modes of operation (DC-/DC Buck)



$I_2 - \cancel{I_1}^{0}$

$$I_{o\,avg} = \frac{1}{2}\boxed{\Delta I} = \frac{1}{2}\,\frac{V_{in}(D)(1-D)}{fL}$$

but $I_{o\,avg} = \frac{V_o}{R} = \frac{DV_{in}}{R}$

$$\frac{\cancel{D}V_{\cancel{in}}}{R} = \frac{\cancel{V_{in}}\,\cancel{D}(1-D)}{2fL}$$

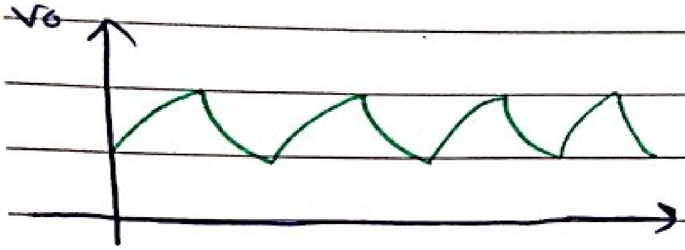
$$\boxed{L_c = \frac{R(1-D)}{2f}}$$

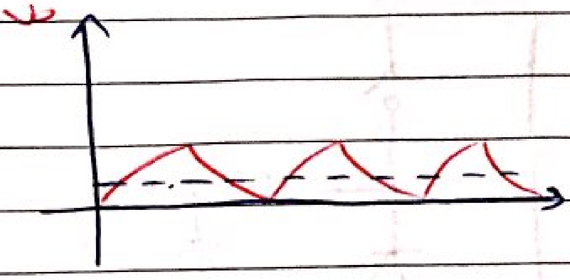
↳ critical value

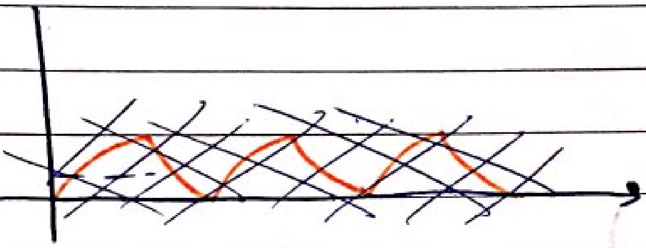
$L > L_c \Rightarrow$ continous mode.

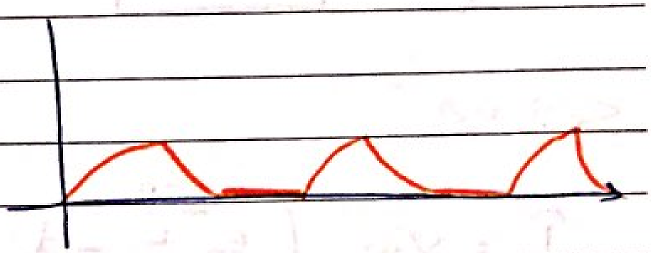
$L < L_c \Rightarrow$ Dis continous.

condition for critical value of capacitor to keep the output voltage in continous mode









$$V_o > \frac{1}{2}\Delta V_o = \frac{1}{2}\Delta V_c$$

$$\cancel{D}\cancel{V}_{in} = V_o > \frac{1}{2}\,\frac{\cancel{V_{in}}\,\cancel{D}(1-D)}{8f^2LC}$$

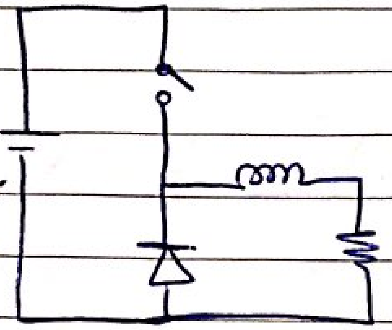
$$\boxed{C_c > \frac{1-D}{16f^2L}}$$

* $C > C_c$ ⇒ Continous mode.

* $C < C_c$ ⇒ Discontinous mode.

Ex DC-DC Buck converter is feeding as load [RL load] with $V_{in} = 220V$, $R = 5\Omega$, $L = 7.5mH$, $f = 1KHZ$, $D = 0.5$.

1 Find the min and max load current I_1, I_2 ?!



Sol 84

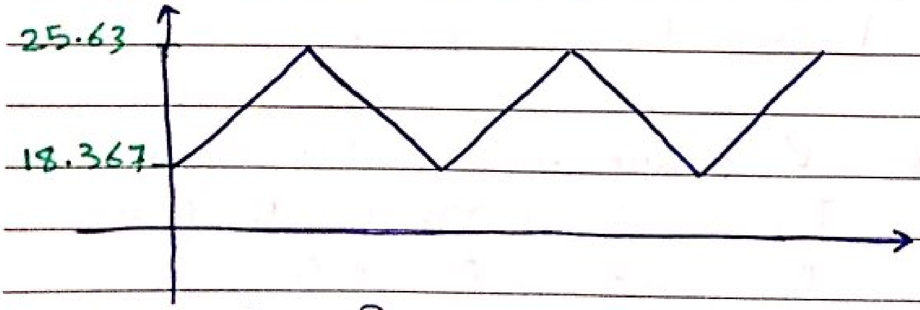
$$\hat{I}_1 = \frac{V_{in}}{R}\left(\frac{e^{\frac{DTR}{L}} - 1}{e^{\frac{TR}{L}} - 1}\right)$$

$$= \frac{220}{5}\left(\frac{e^{\frac{0.5 * 10^{-3} * 5}{7.5 * 10^{-3}}} - 1}{e^{\frac{10^{-3}.5}{7.5\times10^{-3}}} - 1}\right)$$

$$\boxed{\hat{I}_1 = 18.367 \text{ A}}$$

$$\hat{I}_2 = \frac{V_{in}}{R}\left(\frac{e^{-\frac{DTR}{L}} - 1}{e^{\frac{TR}{L}} - 1}\right)$$

$$\boxed{\hat{I}_2 = 25.63 \text{ A}}$$



Continous.

$\Rightarrow \Delta I = \hat{I}_2 - \hat{I}_1 = 7.26$ A → exact number.

$\Rightarrow \Delta \hat{I} = \frac{V_{in}\, D(1-D)}{fL} = \frac{220 * 0.5(1-0.5)}{7.5} = 7.33$ A

aproximate ← number.

Scanned with CamScanner

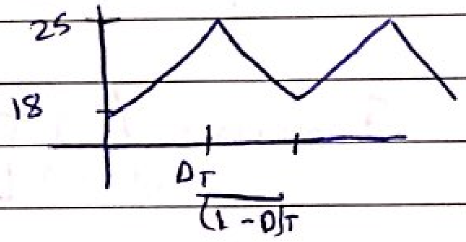
$$I_1 = I_0 - \frac{1}{2}\Delta I$$

$$= \frac{0.5 * 220}{5} - \frac{1}{2} * 7.33$$

$$I_0 = \frac{I_1 + I_2}{2} = \frac{V_o}{R} = \frac{D V_{in}}{R} = 22 A$$

$\boxed{2}$ Find the RMS value of output current ?!

$$i_1(t) = \frac{V_{in}}{R}\left(1 - e^{-\frac{TRt}{L}}\right) + I_1 e^{-\frac{TRt}{L}}$$

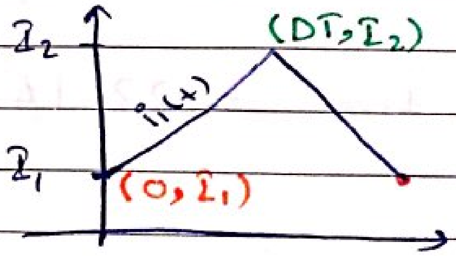


$$i_2(t) = I_2 e^{-\frac{TRt}{L}}$$

$$I_{rms\,out} = \sqrt{\frac{1}{T}\left[\int_0^{DT} i_1(t)^2 dt + \int_0^{(1-D)T} i_2(t)^2 dt\right]}$$

Aproximate Solution:-

$$i_1(t) = I_1 + \frac{\Delta I}{DT} t$$



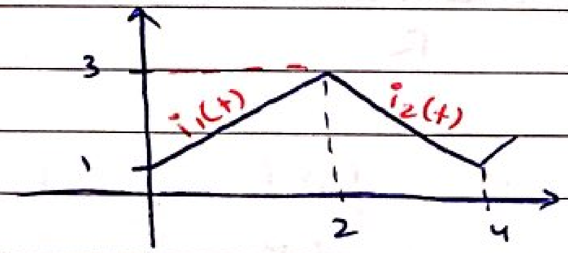
$$I_{rms(o)} = \sqrt{\frac{1}{DT}\int_0^{DT}\left(I_1 + \frac{\Delta I}{DT} t\right)^2 dt}$$

output ↲

$$i_2(t) = I_2 - \frac{\Delta I}{(1-D)T}\, t$$

$$I_{rms(o)} = \sqrt{\frac{1}{T}\left[\int_0^{DT}\left(I_1 + \frac{\Delta I}{DT}\, t\right)^2 dt + \int_0^{(1-D)T}\left(I_2 - \frac{\Delta I}{(1-D)T}\, t\right)^2 dt\right]}$$

*



$$\begin{cases} i_1(t) & 0 < \ < 2 \\ i_2(t) & 2 < \ < 4 \end{cases}$$

$$I_{rms(o)} = \sqrt{\frac{1}{4}\left[\int_0^2 i_1(t)^2\, dt + \int_2^4 i_2(t)^2\, dt\right]}$$

$$= \sqrt{\frac{1}{2}\int_0^2 i_1(t)^2\, dt}$$

Sol 2:

$$I_{rms} = \sqrt{\frac{1}{0.5*10^{-3}}\int_0^{0.5*10^{-3}}\left(18.367 + \frac{7.26}{0.5*10^{-3}}\, t\right)^2 dt}$$

$$\boxed{I_{rms} = 22.1 A}$$

3 Find the average Source current ?!

sol:-

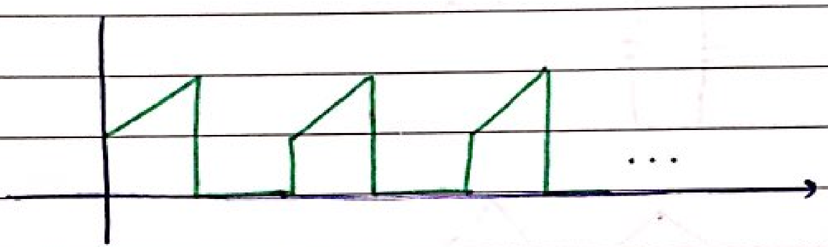
$I_{in} = D I_o = 22 * 0.5 = 11 A$

4 the effective input resistor ?!

$$R_{in} = \frac{V_{in}}{I_{in}} = \frac{220}{11}$$

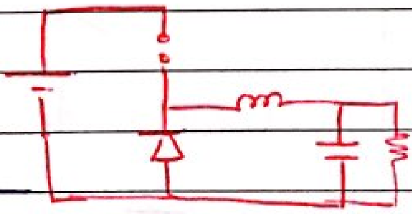
$$\boxed{R_{in} = 20\ \Omega}$$

5 The RMS value of the input current ?!



$I_{in} = I_{out} \rightarrow$ ON State

OFF state $\Rightarrow I = 0$



$$I_{rms(in)} = \sqrt{\frac{1}{T}\int_0^{DT}\left(I_1 + \frac{\Delta I}{Dt}\right)^2 dt}$$

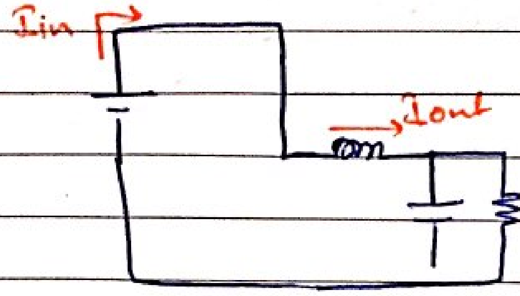
= [illegible]

$$= \sqrt{D} * I_{rms(o)}$$

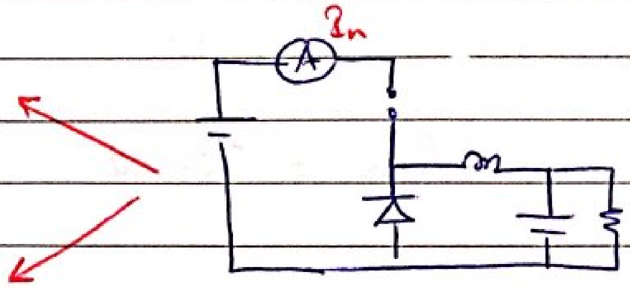
$$= \sqrt{0.5} * 22.1$$

$$= 15.63$$

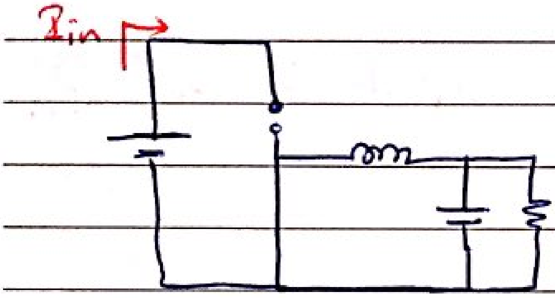
ON state :



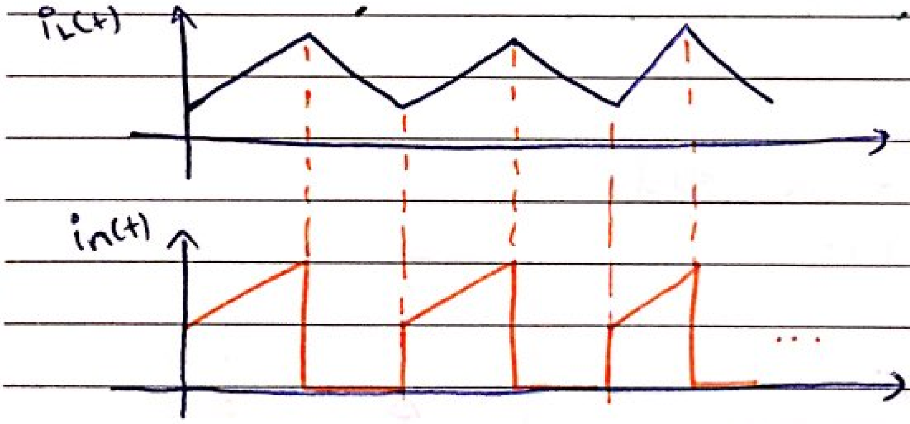
$I_{in} = I_{out}$



OFF state:-



$I_{in} = 0$



$I_{rms(in)} = \sqrt{D} * I_{rms(o)}$:

$$I_{rms(o)} = \sqrt{\frac{1}{DT}\int_0^{DT}\left(I_1 + \frac{\Delta I}{DT}t\right)^2 dt} \rightarrow i_L(t)$$

$$I_{rms(in)} = \sqrt{\frac{1}{T}\int_0^{DT}\left(I_1 + \frac{\Delta I}{DT}t\right)^2 dt} \rightarrow i_n(t)$$

Ex DC - DC Buck converter. $V_s = 550\,V$, [illegible]
$I_{o(avg)} = 200\,A$, $f = 50\,Hz$ find the value of
L (inductor) which limit the load current
ripple to 10 % of I_o ?!!

Sol:- $I_o = 200\,A$

10% of I_o = 20 A

ΔI_{max} = 20 A

$$\Delta I_{max}\Big|_{D=0.5} = \frac{V_{in}}{4fL} \Rightarrow \frac{550}{4 * 50 * L} = 20$$

[illegible]

$$\boxed{L = 20\,mH}$$

Ex Buck converter with $V_s = V_{in} = 12\,V$,
$V_o = V_a = 5V$, $R = 500$, $\Delta V_c = 20\,mV$
$f = f_s = 25\,KHz$, $\Delta I = 0.8\,A$?!

[1] Find D ?!

$$D = \frac{V_o}{V_{in}} = \frac{5}{12} = 0.4167$$

[2] Find L ?!

$$\Delta I = \frac{V_{in}(D)(1-D)}{fL} \Rightarrow L = \frac{V_{in}\,D(1-D)}{f\,\Delta I}$$

$$\boxed{L = 145.83\,MH}$$

$\boxed{3}$ Find C ?!

$$\Delta V_c = \Delta V_o = \frac{V_{in}(D)(1-D)}{8 f^2 L C}$$

$$\boxed{C = 200\ MF}$$

$\boxed{4}$ L_c and C_c ?!

$$\Rightarrow L_c = \frac{(1-D)R}{2f}.$$

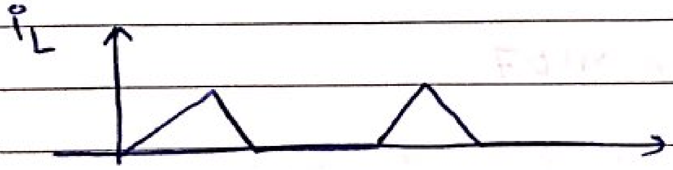
$$\boxed{L_c = 5.83\ mH}$$

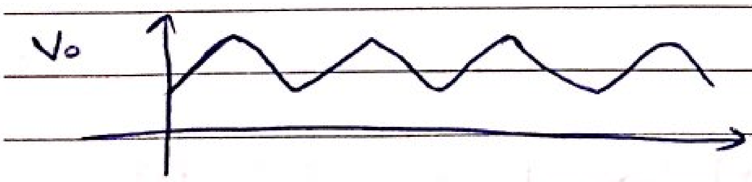
$$\Rightarrow C_c = \frac{(1-D)}{16 L f^2}$$

$$\boxed{C_c = 0.4\ MF}$$

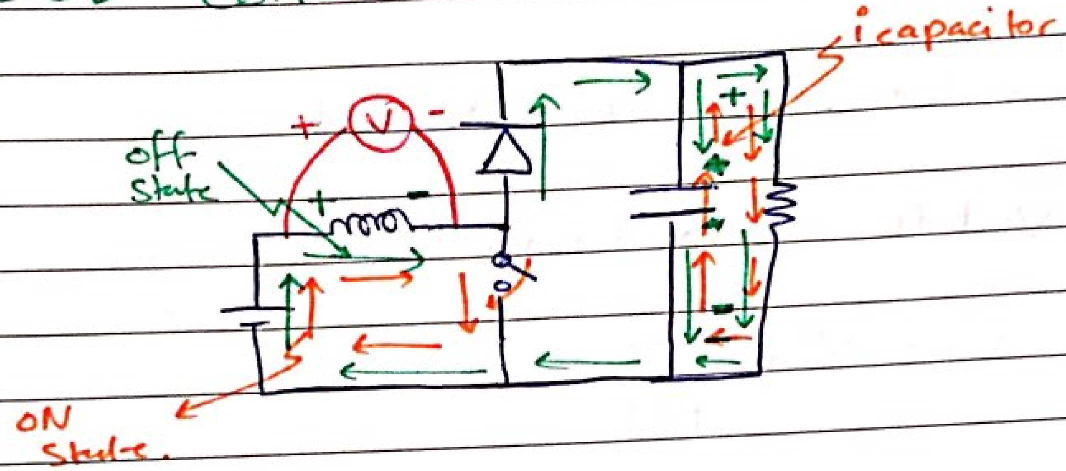
$L, L_c \Rightarrow L_c > L \Rightarrow$ Discontinous

$C, C_c \Rightarrow C > C_c \Rightarrow$ Continous. capcitor voltge.

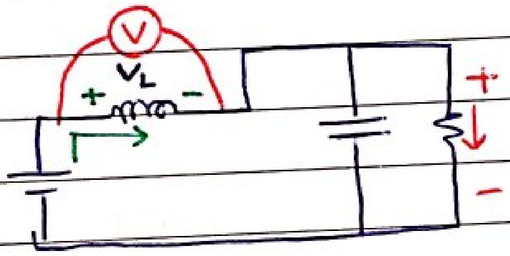




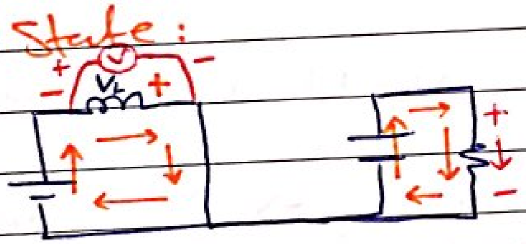
* Boost converters :-



* OFF State



* ON State :



$-V_{in} + V_L = 0$, $V_L = V_{in} = L\frac{\Delta I}{\Delta t}$

$\boxed{V_L = V_{in}.}$

$\Delta t = t_{ON}$

off State :-

$-V_{in} + V_L + V_o = 0$, $V_L = V_{in} - V_o$

$= -L\frac{\Delta I_1}{\Delta t}$

$\boxed{V_L = V_{in} - V_o}$

$\Delta t = t_{off}$

$$V_{in}\, t_{on} = (V_o - V_{in})\, t_{off}$$

$$V_{in}\, t_{on} = V_o\, t_{off} - V_{in}\, t_{off}$$

$$V_o\, t_{off} = V_{in}\,(t_{on} + t_{off})$$

$$V_o = V_{in} \frac{T}{t_{off}}.$$

$$V_o = V_{in} \frac{T}{(1-D)T}$$

$$\boxed{V_o = \frac{V_{in}}{1-D}}$$

works as a boost converter

برفعلي قيم الـ voltage.

⇒ D=1 in Buck means → switch is . always off

⇒ D is an ustable Condition. ⇒ D=1 in Boost.

ما بصير تكون قيم D=1 أو قريب منها.

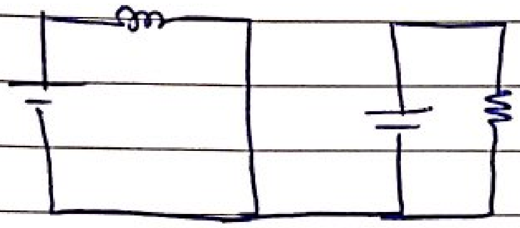
Since we consider as lossless converter

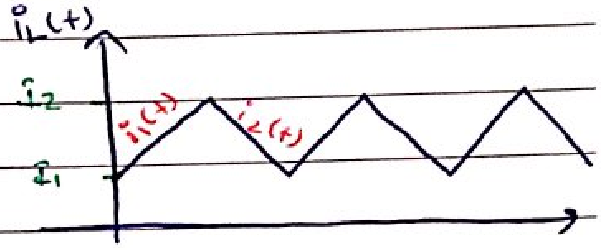
$$P_{in} = P_{out}$$

$$V_{in}\, I_{in} = V_{out}\, I_{out}.$$

$$\boxed{I_{in} = \frac{I_o}{1-D}}$$

* ON State :-



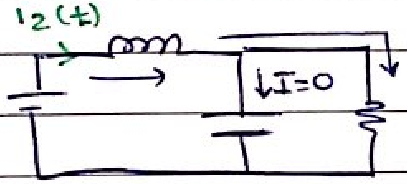


$$V_{in} = L \frac{\delta i_1(t)}{dt}$$

linear curve ?!

$$i_1(t) = \frac{V_{in}}{L} t + I_1$$

* OFF State 84



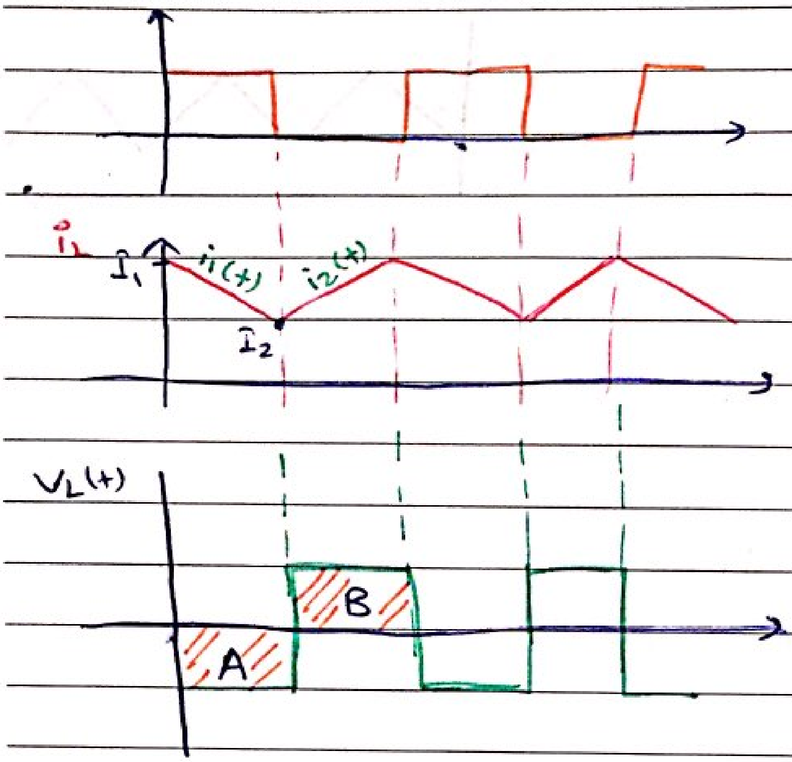
فرض انو ما في تيار في Capacitor

$$V_{in} = L \frac{\delta i_2(t)}{dt} + R\, i_2(t)$$

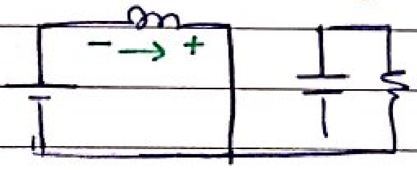
$$i_2(t) = \frac{V_{in}}{R}\left(1 - e^{\frac{-Rt}{L}}\right) + I_2 e^{-\frac{tR}{L}}$$

25/2 SUN

Boost Converters 8⊲



ON State:- charge.



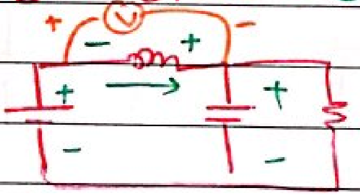
$$V_{in} = L\frac{di(t)}{dt}$$

$$i_1(t) = \frac{V_{in}}{L}t + I_1$$

at $t = DT$

$$i_1(t) = I_2 = \frac{V_{in}}{L}(DT) + I_1 \quad \dots ①$$

OFF State :- discharge



$$V_{in} = L\frac{di_2(t)}{dt} + R i_2(t)$$

$$i_2(t) = \frac{V_{in}}{R}\left(1 - e^{-\frac{tR}{L}}\right) + I_2 e^{-\frac{tR}{L}}$$

$$-V_{in} + V_L + V_o = 0$$

$$V_L = V_{in} - V_o$$

at t = (1-D)T

$$i_2((1-D)T) = \hat{I}_1$$

$$i_2(t) = \frac{V_{in}}{R}\left(1-e^{(1-D)\frac{TR}{L}}\right) + \hat{I}_2 e^{-(1-D)\frac{TR}{L}} \quad \ldots ②$$

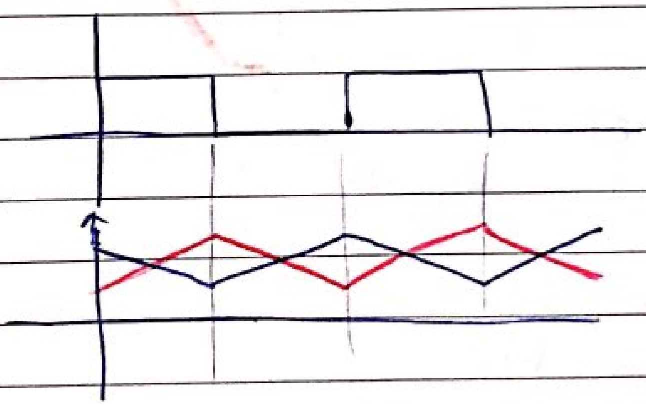
solving these tow equation for $\hat{I}_1$ and $\hat{I}_2$ =>

$$\boxed{\hat{I}_1 = \frac{V_{in}\,DT}{L} * \frac{e^{-(1-D)\frac{TR}{L}}}{1-e^{-(1-D)\frac{TR}{L}}} + \frac{V_{in}}{R}.}$$

↳ I_{min}

$$\boxed{\hat{I}_2 = \frac{V_{in}\,DT}{L} * \frac{1}{1-e^{-(1-D)\frac{TR}{L}}} + \frac{V_{in}}{R}}$$

↳ I_{max}.



peak to peck ripple :-

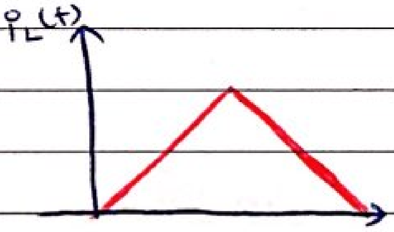
$$\Delta \hat{I} = \hat{I}_2 - \hat{I}_1$$

$$= \frac{V_{in} DT}{L}$$

$$\boxed{\Delta \hat{I} = \frac{V_{in} D}{fL}}$$

The peck to peck Capacitor Voltage &Δ

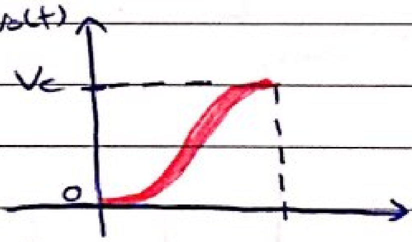
↳ considering the ON State.



$$\Delta V_o = \Delta V_c$$

$$= V_c - 0$$

$$\frac{1}{C}\int_0^{DT} i_c \, dt$$



But $i_c = i_o$

$$\Delta V_o = \Delta V_c = \frac{1}{C}\int_0^{DT} i_{o\,avg} \, dt$$

$$= \frac{i_o DT}{C} = \frac{i_o D}{fC}$$

* Condition for continous mode of Operation :-

$$I_1 > 0$$

$$I_{o\,avg} - \frac{1}{2}\Delta I > 0$$

$$\frac{V_{in}}{(1-D)R} - \frac{1}{2}\frac{V_{in}D}{fL} > 0$$

$$L > \frac{RD(1-D)}{2f}$$

$$L_c = \frac{RD(1-D)}{2f}$$

Condition for critical. C :

- $$V_o > \frac{1}{2}\Delta V_o = \frac{1}{2}\Delta V_c$$

$$V_o > \frac{1}{2}\frac{I_o D}{fC}$$

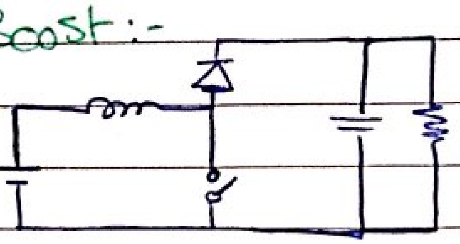
$$C > \frac{I_o D}{2 f V_o} = \frac{D}{2fR}.$$

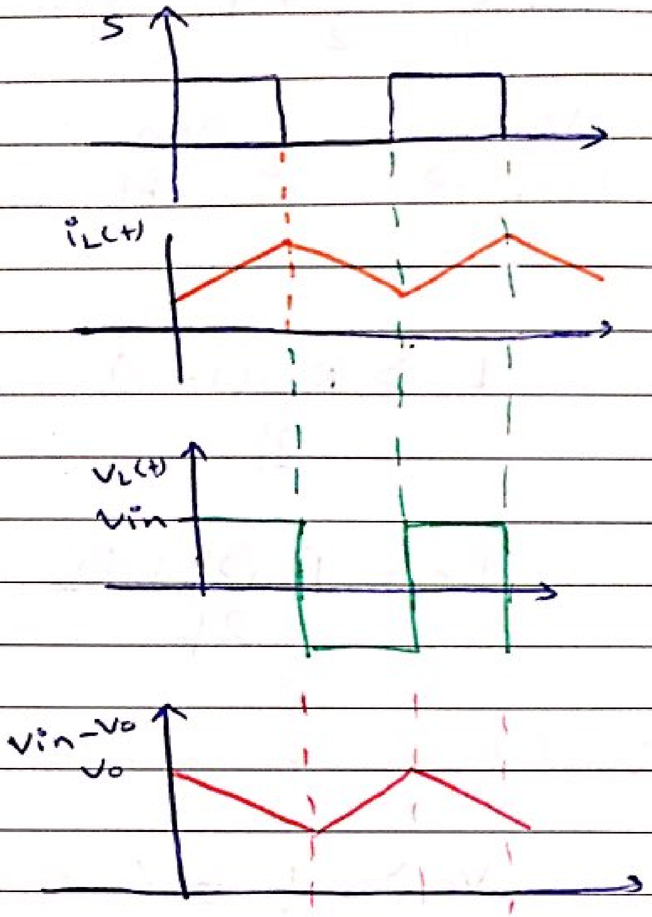
$$C_c = \frac{D}{2fR}.$$

* Reading assignment : Chapter 1
Suggested Problem : كتاب، شيم
section ch.5 → 5.1 → 5.6
5.9.1, 5.9.2 ,5.9.3 .
problems ⇒ 5.2, 5.3, 5.4, 5.6, 5.7, 5.9, 5.10, 5.11
Mohan → ~~suggested~~: section → 7 : 7.1 → 7.5
problem → 7.1, 7.5, 7.7, 7.8, 7.16.

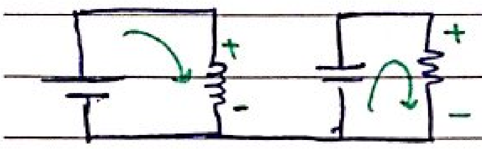
27/2 TUE

Boost:-



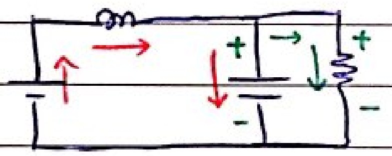


ON State:-

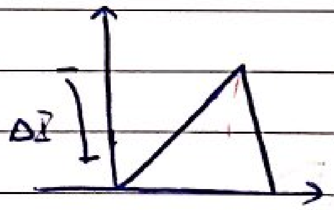


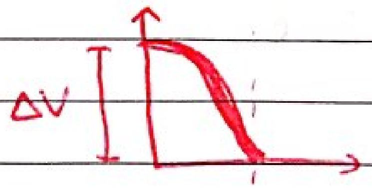
Charged.

OFF state:-

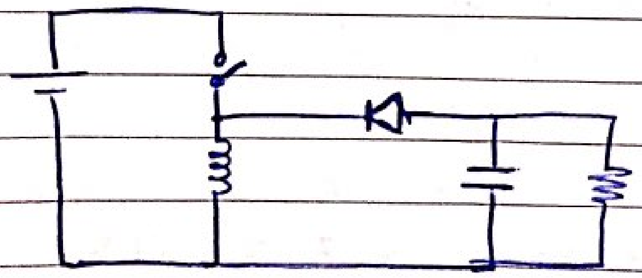


Vo(p-p)

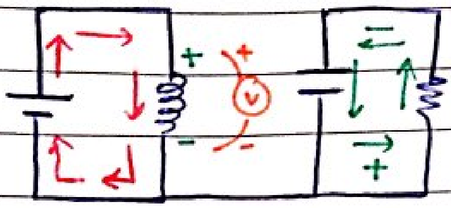




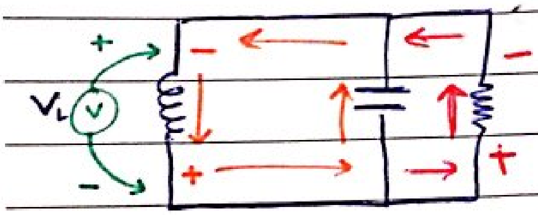
Buck-Boost converters



ON State :-



OFF state :-



ON state :-

$$-V_{in} + V_L = 0$$

$$V_L = V_{in} = L\frac{\Delta I_1}{DT} = L\frac{\Delta I_1}{t_{on}}$$

OFF state :-

$$V_L + V_o = 0$$

$$V_L = -V_o = L\frac{\Delta I_2}{t_{off}} = -L\frac{\Delta I_1}{(1-D)T}$$

$$V_o = L\frac{\Delta I_1}{(1-D)T}$$

$$\Delta I_1 = \frac{V_o(1-D)\cancel{T}}{\cancel{L}} = \frac{V_{in}D\cancel{T}}{\cancel{L}}$$

$$\boxed{V_o = \frac{D}{1-D}\ V_{in}}$$

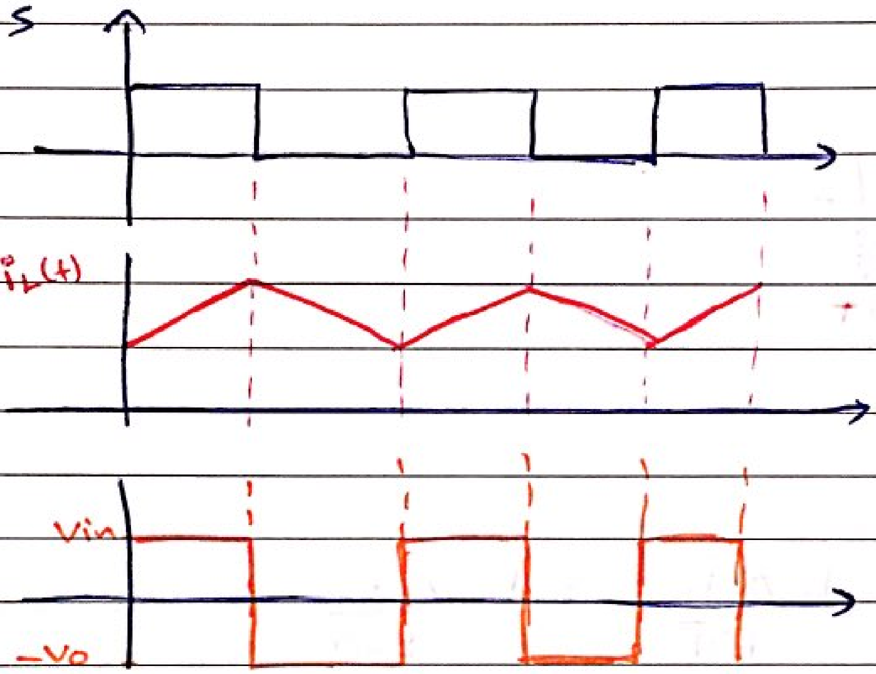
$D < 0.5 \Rightarrow$ Buck

$D > 0.5 \Rightarrow$ Boost

$D \simeq 1$ represent instable condition

Buck ⇒ $V_o = D V_{in}$

Boost ⇒ $V_o = \frac{1}{1-D} V_{in}$.



* considering alossless converter.8∆

Switch Ideal ⇒ pure element.

$$V_{in} I_{in} = V_o I_{out}$$

$$I_{in} = \frac{D}{1-D} I_o$$

Peak-Peak ripple in inductor current is

$$T = \frac{1}{f} = t_{on} + t_{off}$$

$$= \frac{L\Delta I}{V_{in}} + \frac{L\Delta I}{V_o}$$

$$\frac{1}{f} = L\,\frac{\Delta I\,(V_o + V_{in})}{V_{in}\,V_o}$$

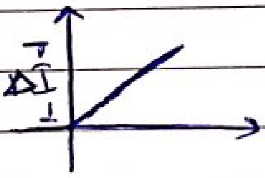
$$\Delta I = \frac{V_{in}\,V_o}{fL\,(V_o + V_{in})}$$

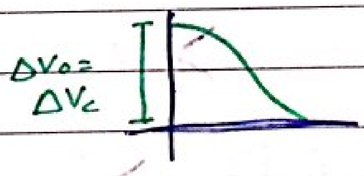
$$\Delta I = \frac{V_{in}\,V_o}{fL\left(\frac{D}{1-D} + \frac{1*(1-D)}{1*(1-D)}\right) V_{in}}$$

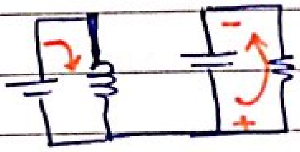
$$\Delta I = \frac{V_o\,(1-D)}{fL} = \frac{V_{in}\,D}{fL}$$

Peak-Peak Capacitor ripple Voltage $\delta\Delta$

[on State for the derivation] => off State will hold







$$\Delta V_o = \Delta V_c = \frac{1}{C}\int_0^{DT} I_c\,dt$$

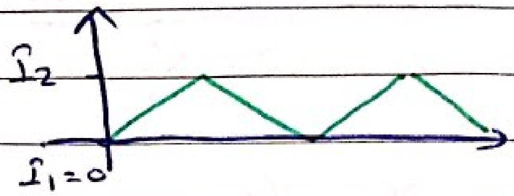
$$= \frac{1}{C}\int_0^{DT} I_{o\,avg}\,dt$$

$$= \frac{I_o\,DT}{C}$$

$$\boxed{\Delta V_o = \frac{I_o\,D}{CF}}$$

* Critical Value of L & Δ

$I_1 > 0$



$$I_{o\,avg} - \frac{1}{2}\Delta I > 0$$

$$\frac{\cancel{V_{in}} *}{(1-D)*}\frac{D\cancel{V_o}}{R} - \frac{1}{2} D \frac{\cancel{V_{in}}}{fL} > 0$$

$$\boxed{L > \frac{R(1-D)}{2f}}$$

$$\boxed{L_c = \frac{R(1-D)}{2f}}$$

* Critical value of C & Δ

$$V_o - \frac{1}{2}\Delta V_o > 0$$

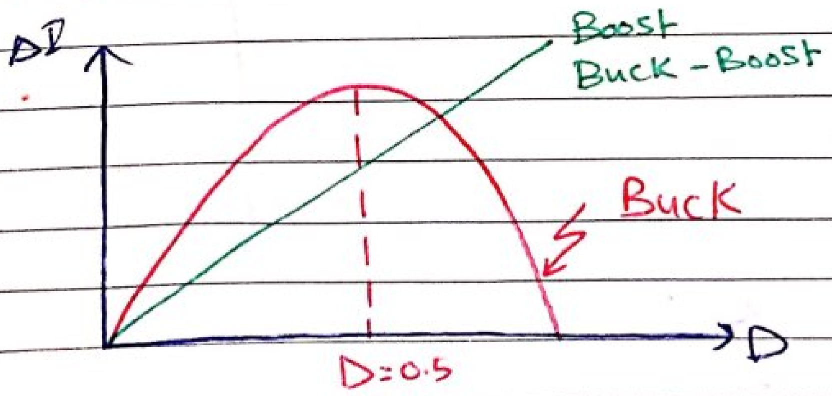
$$\frac{V_o}{I_o} - \frac{1}{2}\frac{I_o D}{Cf I_o} > 0$$

$$R - \frac{D}{2fc} > 0$$

$$\boxed{C > \frac{D}{2fR}}$$

$$\boxed{C_c = \frac{D}{2fR}}$$

	BUCK	BOOST	BUCK/Boost
Vo avg	$D\,V_{in}$	$V_{in}/(1-D)$	$\frac{D}{1-D}\,V_{in}$
Io avg	$\frac{I_{in}}{D}$	$I_{in}(1-D)$	$\frac{1-D}{D}\,I_{in}$
ΔI	$\frac{V_{in}(D)(1-D)}{fL}$	$\frac{V_{in}D}{fL}$	$\frac{V_{in}D}{fL}$.
ΔI_{max}	$\frac{V_{in}}{4fL}$ $(D=0.5)$	$\frac{V_{in}}{fL}$ $D=1$	$\frac{V_{in}}{fL}$ $D=1$
ΔV_o	$\frac{V_{in}D(1-D)}{8f^2LC}$	$\frac{I_oD}{fc}$	$\frac{I_oD}{fC}$
L_c	$\frac{R(1-D)}{2f}$	$\frac{RD(1-D)}{2f}$	$\frac{R(1-D)}{2f}$
C_c	$\frac{1-D}{16Lf^2}$	$\frac{D}{2fR}$	$\frac{D}{2fR}$



* Homework 1 8△

Design the DC-DC converter in $\boxed{\text{ex } 5.2}$

(Buck)

V_{in} = 220 V

R = 5Ω

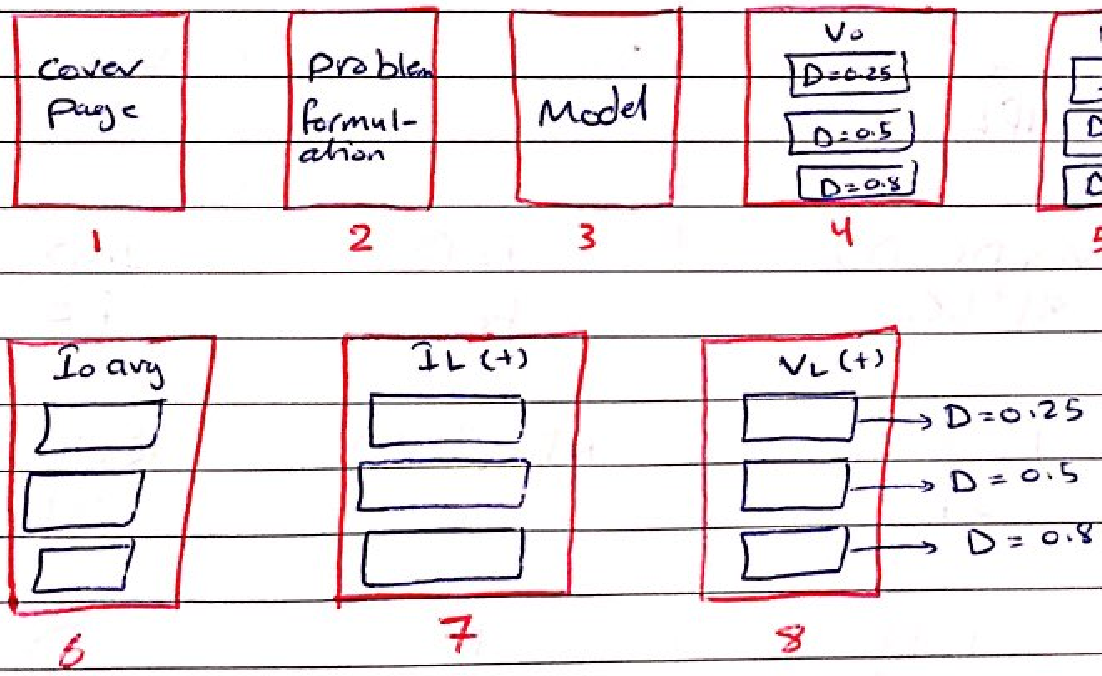
L = 7.5mH

C = 1000 μF

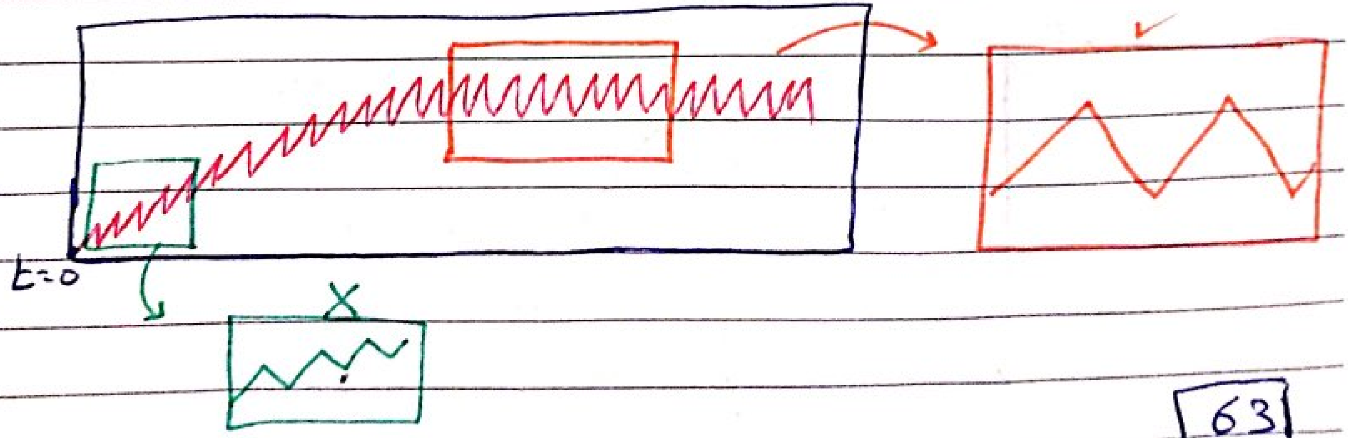
f = 10 KHZ

D = 0.25, 0.5, 0.8

Report ⇒ 8 Pages 8△



ON Matlab → $i_L(t)$ at D = 0.8



1/3 Thu

Matlab → sys box

new → simulink model → blank mold → open the sheet
→ draw a system.

* library browsel (has everything).
Simscep or sym power 3 system → power system.
→ Speacalised tech. → fund blocks → 3Φ source.
3Φ source (Gen [illegible]) → drag and drop.

Elements → 3Φ transformer → connect them
3Φ load → connect the sys.
double ~~cl~~ click on Gen → freq = 50 HZ
25K phase - phase voltage → X/R.
on TX change ~~t~~ to (250K, 50) → (25K the
voltage ~~on~~ on primary, 50K secondary) → load
power 100k.
→ change time to 1sec. → Run → error → find
power → double click in → change to discrete.
→ sample time $\left(T = \frac{1}{f} = \frac{1}{50} = 20\text{ms}\right)$. we put sample time = 1×10^{-6}
~~[illegible]~~ 1M

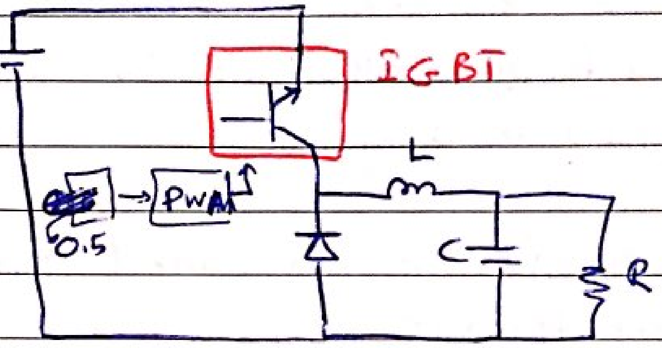
RUN → measurment blocks.
current measurment. and voltage measurment
series parallel
→ Connect the ~~Amm~~ ~~Ammeter~~ Ammeter to the CKt
→ " a scope to the ~~Ammeter~~ Ammeter.
RTDS ≡ Real time digital Simulater.
→ scope → file → plot.

DC - DC Converter:-

DC source → 100 V → library → power.

~~[illegible]~~. electronics → IGBT → double click →

show measurment → CTRL R (flips) → double → double click.



power GMI.
- discrete
- sample time
- 10m

library → elements → RLC → double click.

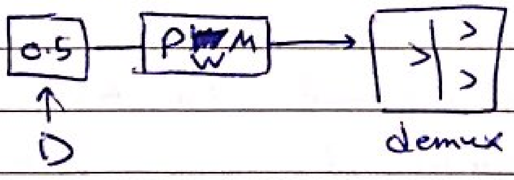
" → search PWM → D constant.

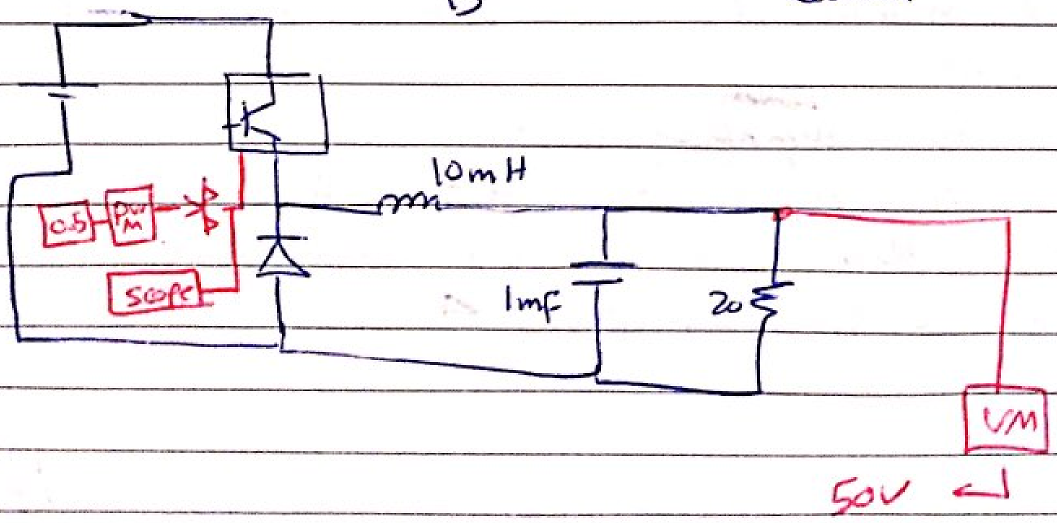
double click PWM [0, 1] freq = 10K HZ.

the constant is the width of the pulse.

(error) → PWM → double click. → 2 puls [check the dimention]

→ ~~4~~de mux →



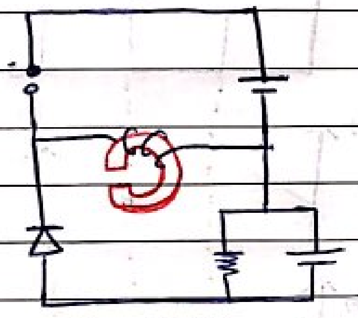


4/3 SUN

* Electrically Isolated DC-DC converter 8A

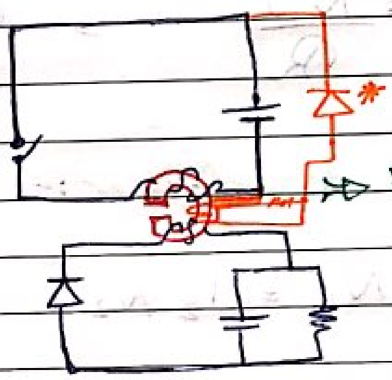
- ⇒ Fly $\overset{u}{\text{back}}$ converter derived from Buck/Boost converter
- ⇒ forward converter derived from Buck converter.
- ⇒ full and half Bridges derived from Buck converter.

Fly $\overset{u}{\text{Back}}$ converter :-



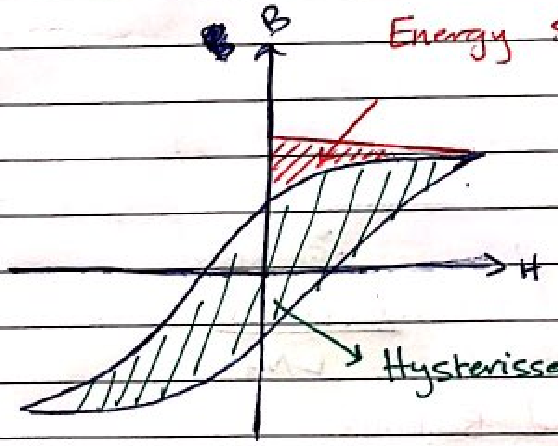
Buck/Boost

same winding : نفس ملفات



⇒ Fly$\overset{u}{\text{back}}$ بعمل تخزين و transfer.

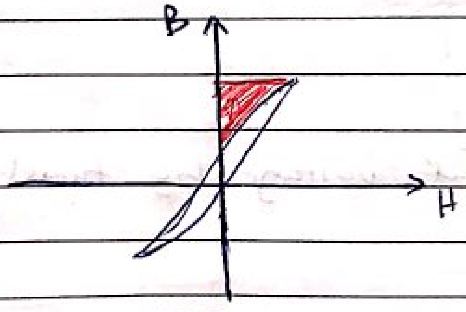
* حولت ال inductor ⟵ لـ transformer.



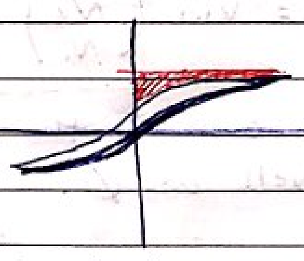
Hysterisses losses.

Energy stored and relassed.

* winding 3 ⇒ add diode ⇒ to ensure that the TR will not go to saturation (discharging of any accumilating charges)

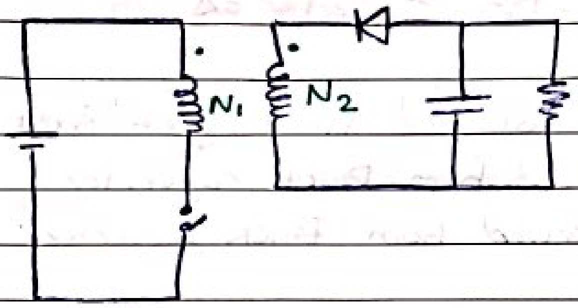


TR

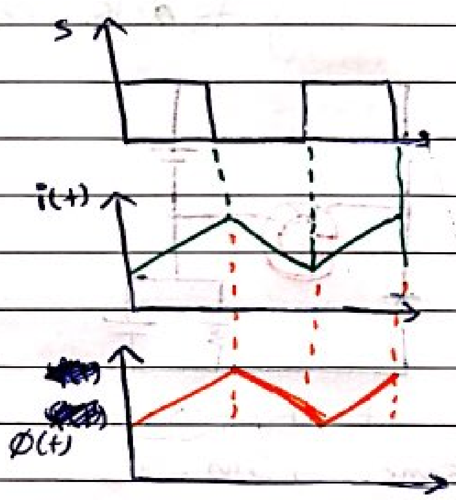


Inductor

* energy stored in inductor > (bigger) energy stored in TR



ϕ ~~ϕ~~ $= \frac{NI}{\mathcal{R}}$, $\phi \propto I$



For the transformer :-

$I_1 N_1 = I_2 N_2$

$\Delta\phi_{pp} = N \Delta I$

$$\boxed{\Delta I = \frac{\Delta\phi}{N}}$$

ΔI

ON State — OFF State

$$\frac{Vin\,DT}{LN_1} = \frac{Vo(1-D)T}{LN_2}$$

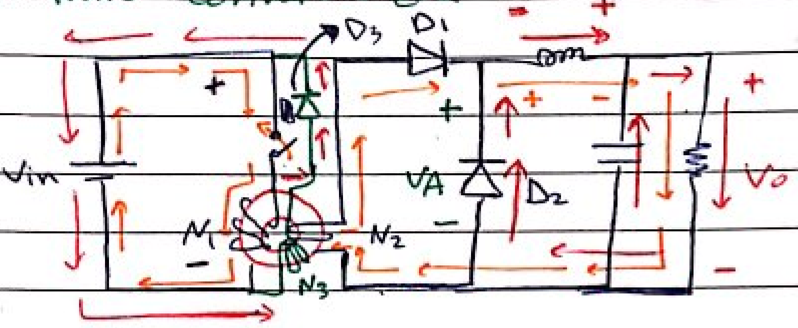
acording to voltage-second Balance

$$\boxed{Vo = vin\left(\frac{N_2}{N_1}\right)\frac{D}{1-D}}$$

⇨ I can now control the output voltage by transformation ratio as well as ϕ.

67

Forward converter 8Δ



ON State

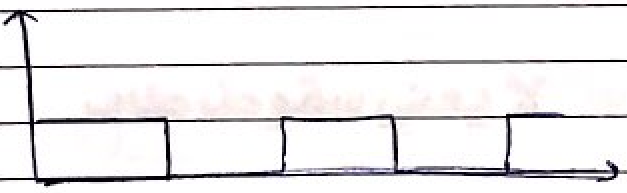
OFF State.

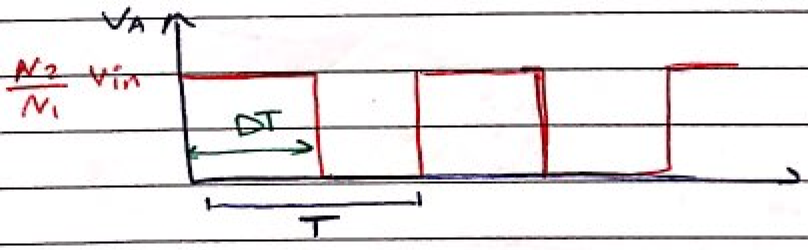
ON State :- $D_1 \Rightarrow$ F.B

$D_2, D_3 \Rightarrow$ R.B.

OFF state :- $D_1 \Rightarrow$ R.B

$D_2, D_3 \Rightarrow$ F.B





$$V_A(t) = V_L(t) + V_o(t)$$

average voltages.

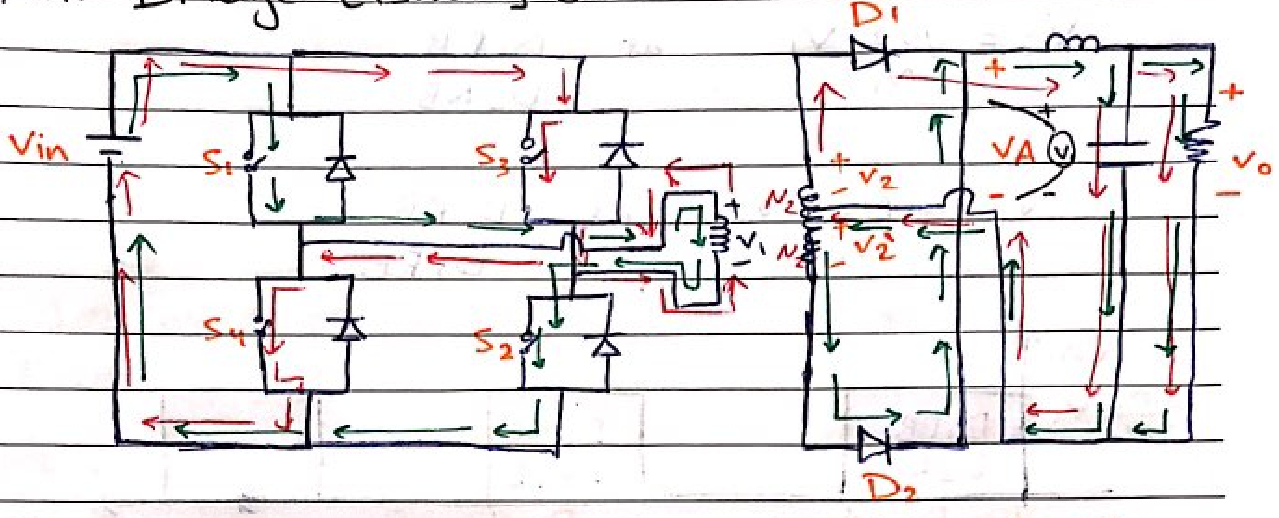
$$V_{A\,avg} = \cancelto{0}{V_{L\,avg}} + V_{o\,avg}.$$

$$\boxed{V_{A\,avg} = V_{o\,avg}}$$

$$\boxed{V_A = V_o = \frac{N_2}{N_1} D\, V_{in}}$$

6/3 Tue

* Full Bridge [Buck] 8Δ



S1, S2

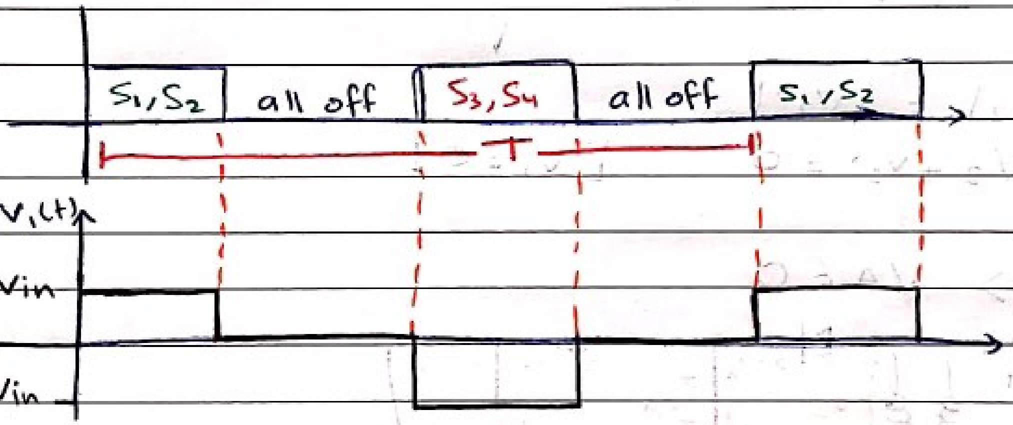
S3, S4

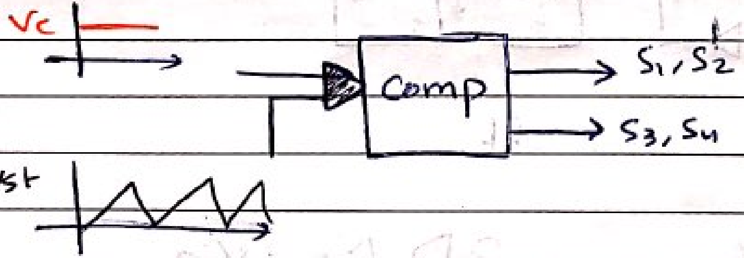
D1 RB

D2 FB

D1 FB

D2 RB





* بتحكم ب 4switch ←

كل cycle بعمل

امرين باغلاق

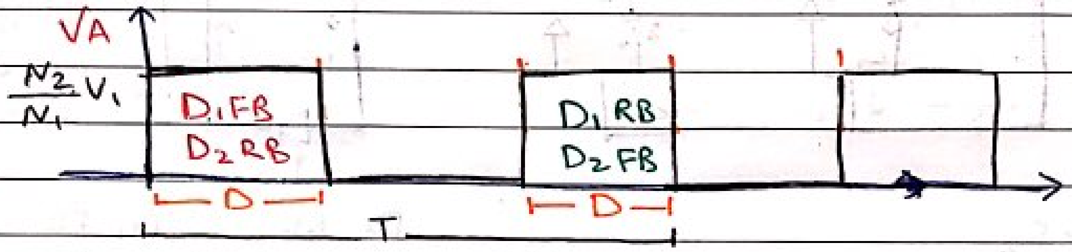
ال 2 switch

← كل T بدي امرين اغلاق.

← فلازم نعمل douple freq

$V_2 = \frac{N_2}{N_1} V_1$ at D_1 FB
D_2 RB

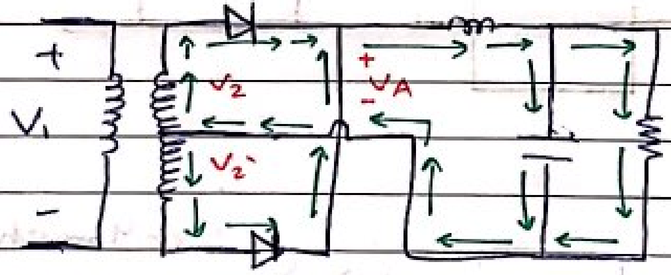
$V_2 = -\frac{N_2}{N_1} V_1$ at D_1 RB
D_2 FB



all switch are off ⇒
IN OFF STATE :-

$|V_2| = |V_2'|$
$V_2 + V_2' = 0$ $[V_1 = 0]$

⇒ $VA = 0$



$V_1 = 0$ → switch off

$V_{o\,avg} = V_{A\,avg} = 2D \frac{N_2}{N_1} V_{in}$

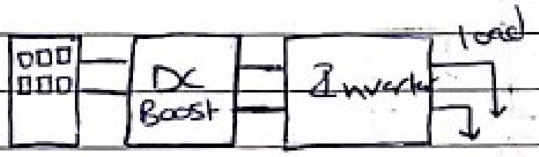
$V_A(t) = V_L(t) + V_o(t)$
$V_{A\,avg} = V_o(avg)$ $[V_{L\,avg} = 0]$

X First

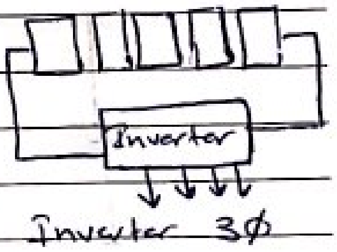
Inverters :- Inversion of DC to AC power
[PV syst 11]

Inverters

1∅ inverters
[Micro inverter]



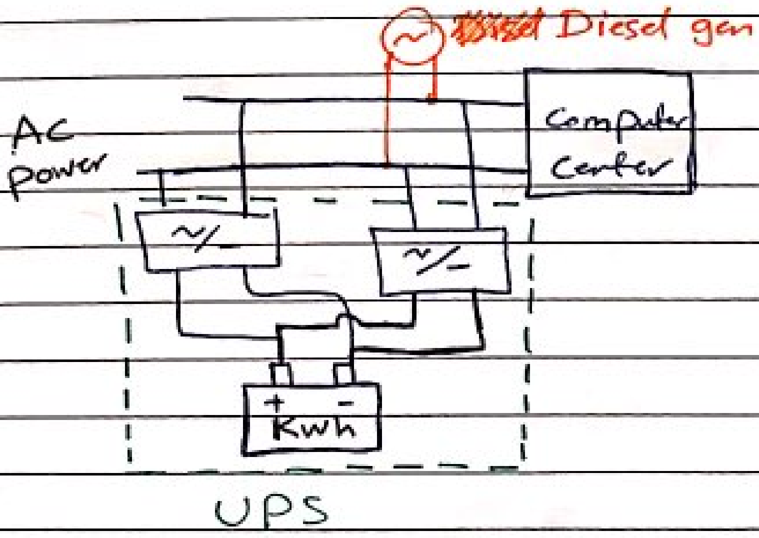
3∅ Inverters



3∅ → PWM = Pulse width modulation.
↳ SPWM = sinusoidle pulse width mod.

Applications :-

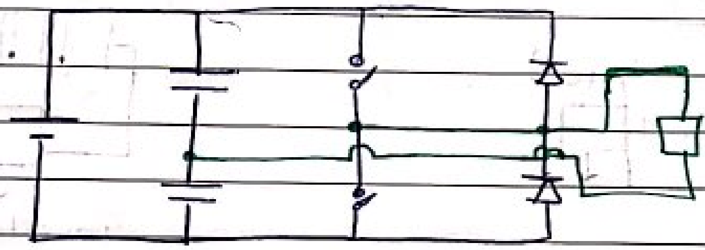
① UPS ≡ Uninterruptible Power supplies

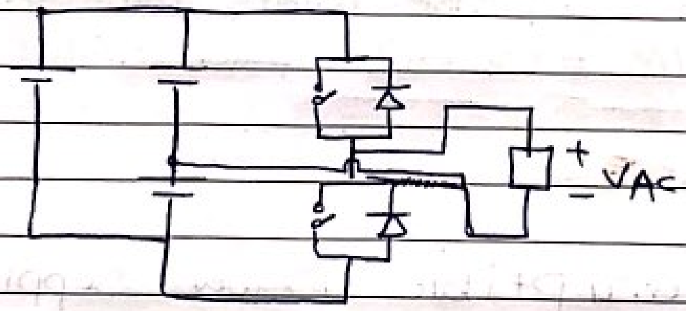


② Renewables : PV

③ AC motor drive
VFD

Single phase inversion (one leg inverter)





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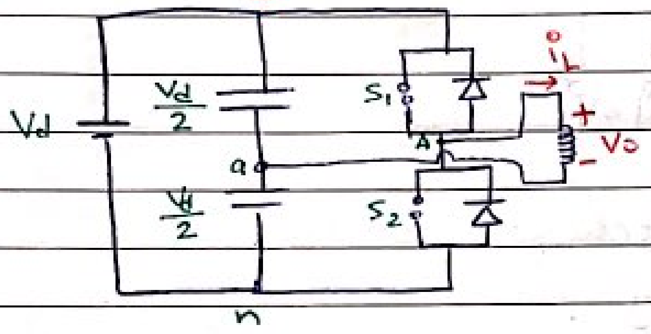
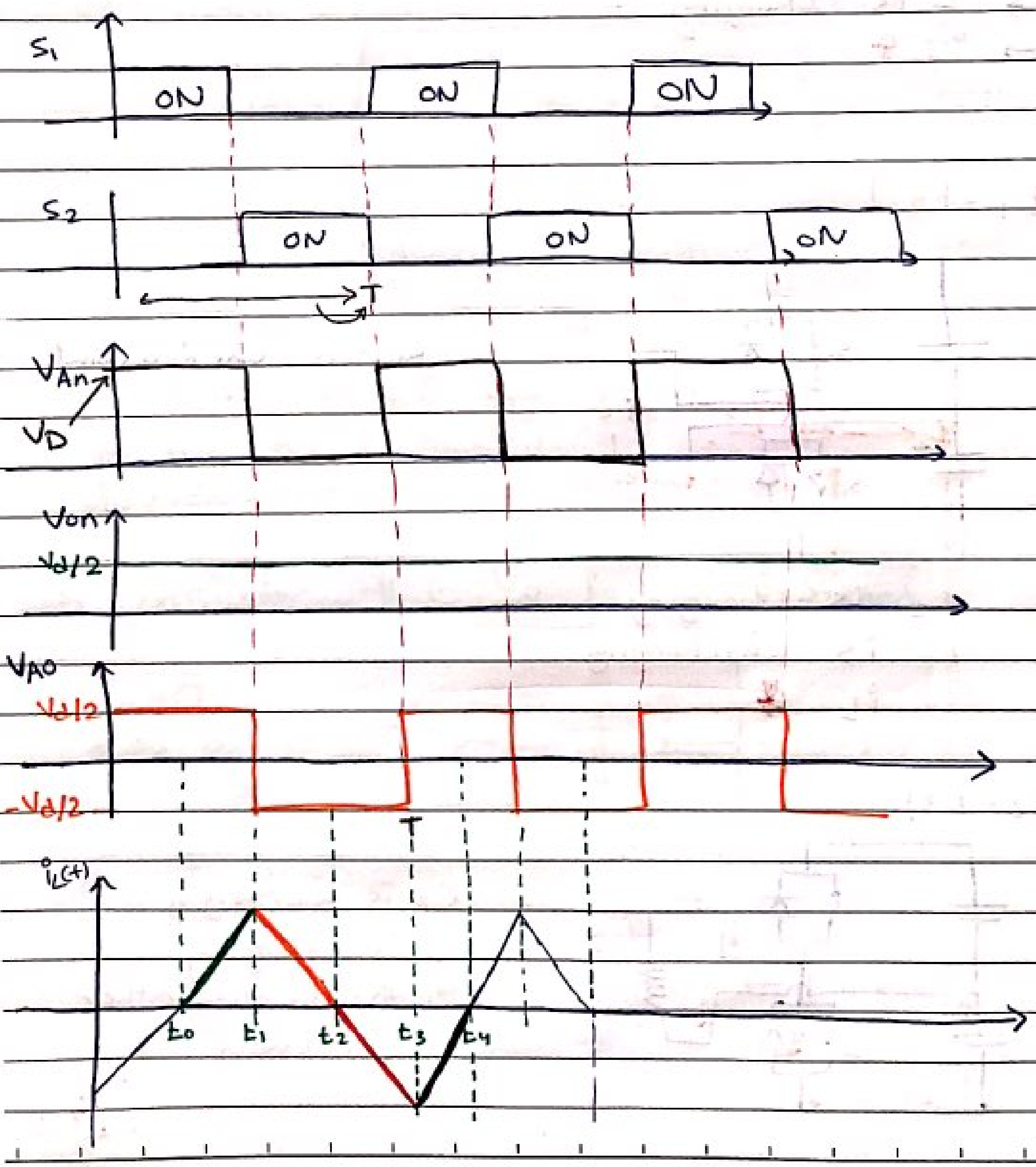
8/3 Thu

* Single phase Inverter :-

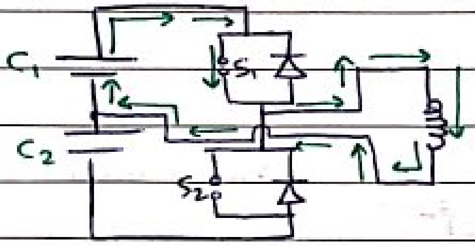
One Leg :-



$V_{AO} = V_{AN} - V_{ON}$



⇒ $(t_0 - t_1)$ S_1 is ON , S_2 is OFF



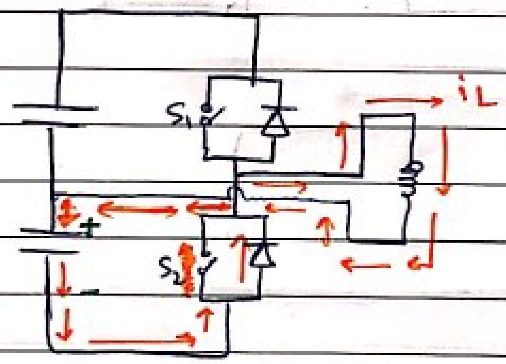
suppose we have a charging at C_1 :-

→ C_1 is discharging

→ L is charging

→ i_L ↑

⇒ $(t_1 - t_2)$



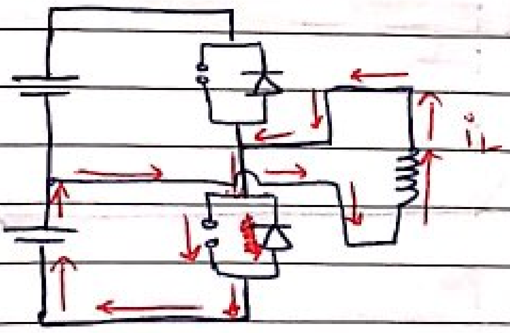
switch Uni directional.

C_2 is charging.

L is discharging.

i_L ↓

⇒ $(t_2 - t_3)$

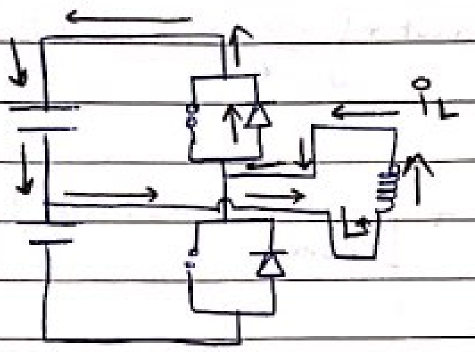


C_2 is discharging

L is charging

i_L ↑ on the other direction

$(t_3 - t_4)$



C_1 is charging
L is discharging
$i_L \downarrow$

* Vrms 8Δ

$$V_{rms(o)} = \sqrt{\frac{1}{T}\int_{0}^{T/2} \left(\frac{V_d}{2}\right)^2 dt + \int_{T/2}^{T} \left(\frac{-V_d}{2}\right)^2 dt}$$

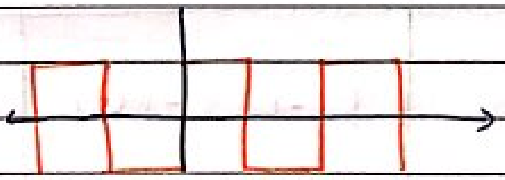
$$= \frac{V_d}{2} \Rightarrow \text{full of harmonic.}$$

⇒ We have to find the F.S of the output voltage to find the fundemental to fillter the rest of the harmonic.

⇒ consider that V_o is odd ~~f~~ Signal :-

$a_n = 0$

$a_0 = 0$



$$b_n = \frac{2}{T}\int_{0}^{T} V_d(t) \sin n\omega t \; dt$$

$$= \frac{1}{\pi}\int_{0}^{2\pi} V_o(n\omega t) \sin n\omega t \; d\omega t$$

$\boxed{75}$

$$= \frac{1}{\pi}\left[\int_0^{\pi} \frac{V_d}{2} \sin(n\omega t)\, d\omega t + \int_{\pi}^{2\pi} \frac{-V_d}{2} \sin(n\omega t)\, d\omega t\right.$$

$$= \frac{1}{\pi}\left[\frac{V_d}{2n}\left(-\cos(n\omega t)\right)\right]_0^{\pi} + \left[\frac{-V_d}{2n}\left(-\cos n\omega t\right)\right]_{\pi}^{2\pi}$$

$$= \frac{2V_d}{n\pi}$$

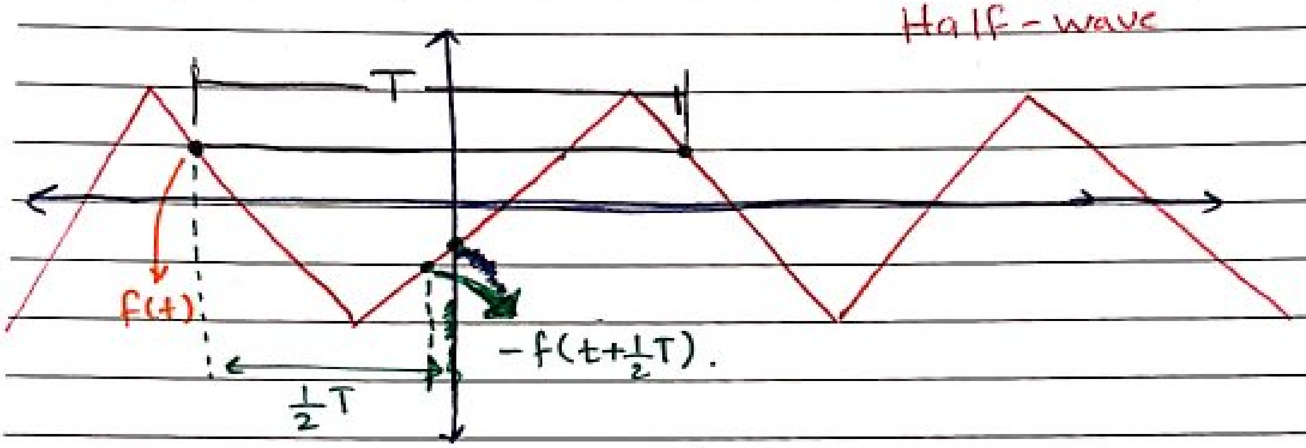
$$V_o(t) = \frac{a_0}{2} + \sum_{n=1,2}^{\infty} a_n \cos n\omega t + b_n \sin n\omega t$$

$$a_n = \frac{1}{\pi}\int_0^{2\pi} V_o(t) \cos n\omega t \; d\omega t$$

$$b_n = \frac{1}{\pi}\int_0^{2\pi} V_o(t) \sin n\omega t \; d\omega t .$$

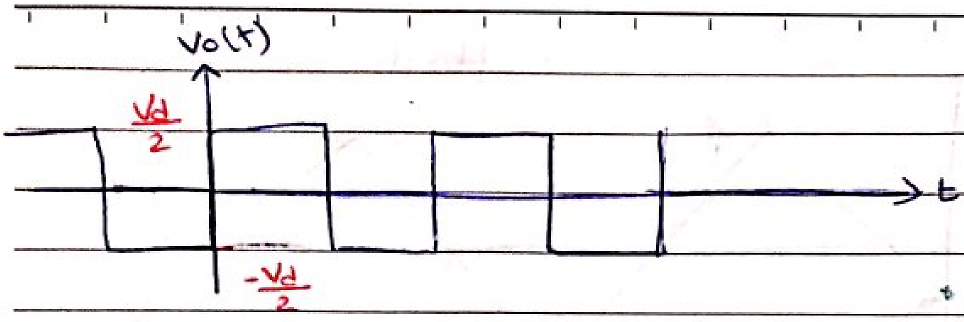
Symmetry		
Even	$f(-t) = f(t)$	$b_n = 0$ $\quad a_n = \frac{2}{\pi}\int_0^{\pi} f(t) \cos n\omega t \; dt$
odd	$f(-t) = -f(t)$	$a_n = 0$ $\quad b_n = \frac{2}{\pi}\int_0^{\pi} f(t) \sin n\omega t \; dt$
Half-wave Symmetric	$f(t) = -f(t + \frac{1}{2}T)$	$a_n = 0 = b_n$ (n even) $a_n = \frac{2}{\pi}\int_0^{\pi} f(t) \cos n\omega t \; d\omega t$ $b_n = \frac{2}{\pi}\int_0^{\pi} f(t) \sin n\omega t \; d\omega t$

Half-wave



Even quarter wave	Even and half wave	$b_n = 0$ $a_n = \begin{cases} \frac{4}{\pi}\int_0^{\pi/2} f(t)\cos n\omega t \, d\omega t & n \text{ odd} \\ 0 \, , & \text{for } n \text{ even.} \end{cases}$
odd quarter wave	odd and half wave	$a_n = 0$ $b_n = \begin{cases} 0 & \text{for } n \text{ even} \\ \frac{4}{\pi}\int_0^{\pi/2} f(t)\sin n\omega t \quad d\omega t & n \text{ odd} \end{cases}$

11/3 SUN



$$b_n = \frac{2V_d}{n\pi}$$

$$b_n = \frac{1}{\pi}\int_0^{\pi} \frac{V_d}{2}\sin(n\omega t)\,d\omega t + \int_{\pi}^{2\pi} \frac{-V_d}{2}\sin(n\omega t)\,d\omega t$$

Since the wave form is odd quarter wave

$$b_n = \frac{4}{\pi}\int_0^{\pi/2} \frac{V_d}{2}\sin(n\omega t)\,d\omega t = \frac{2V_d}{n\pi}$$

$$V_o(t) = \sum_{n=1}^{\infty} b_n \sin n\omega t$$

$$= \begin{cases} \sum_{n=1,3,5}^{\infty} \frac{2V_d}{\pi n}\sin n\omega t & , \ n \text{ is odd} \\ 0 & , \ n \text{ is even} \end{cases}$$

\# fundemental of frequency :-

$$V_1(t) = \frac{2V_d}{\pi}\sin \omega t$$

This is the one I utilize

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* RMS value of the fundemental :-

$$V_{rms} = \frac{2V_d}{\sqrt{2}\,\pi} = 0.45\,V_d$$

For an R-L load:-

$$i_o(t) = \sum_{n=1}^{\infty} \frac{2V_d}{n\pi\sqrt{R^2+(n\omega L)^2}} \sin(n\omega t - \Theta_n)$$

$$\Theta_n = \tan^{-1}\left(\frac{n\omega L}{R}\right)$$

$$\boxed{I_{o1rms} = \frac{2V_d}{\sqrt{2}\,\pi\sqrt{R^2+(\omega L)^2}}}$$

I_{o1rms} = rms value of fundumental freq of output

$$P_{o1} = I_{o1rms}^{2}\,R$$

$$* \quad \boxed{P_{o1} = \left[\frac{2V_d}{\sqrt{2}\,\pi\sqrt{R^2+(\omega L)^2}}\right]^2 R}$$

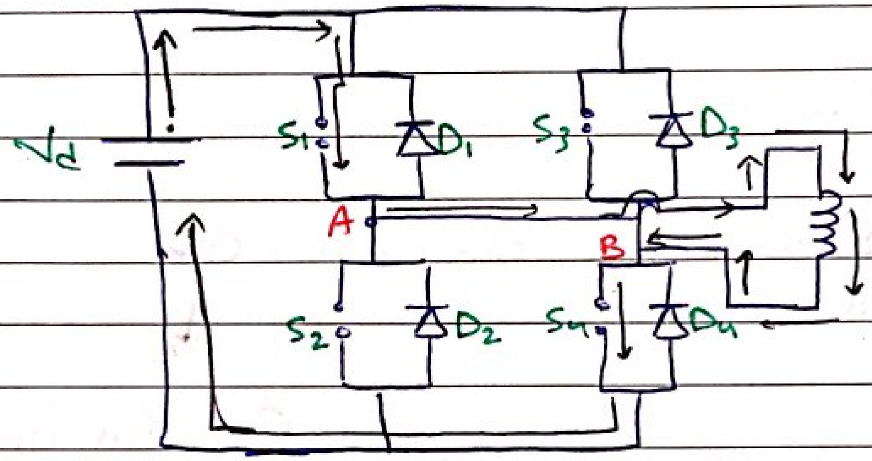
For an inductive load:-

$$i_o(t) = \frac{1}{L}\int_0^t v(\tau)\,d\tau$$

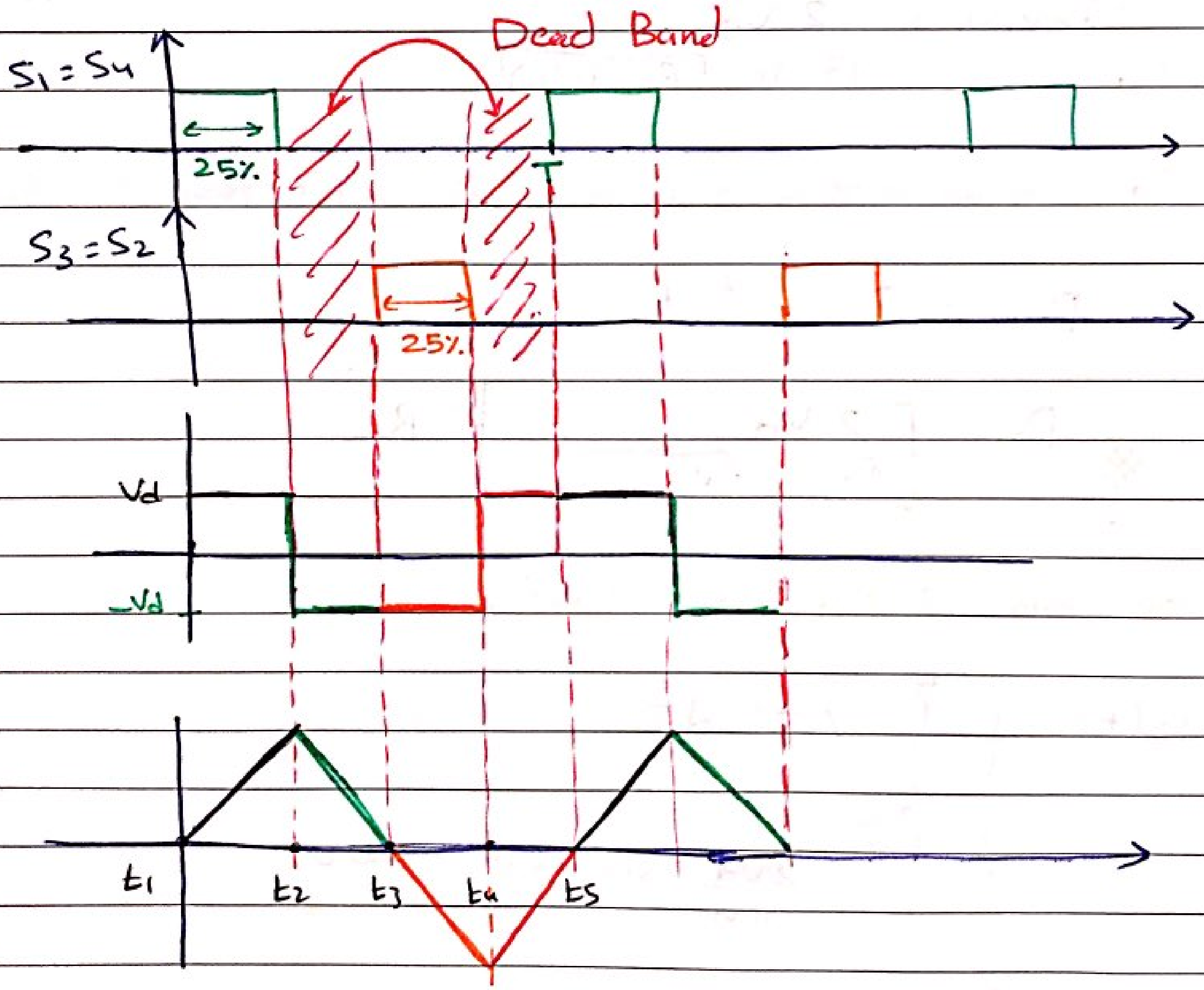
$$= \frac{1}{L}\int_0^{\frac{2\pi}{\omega}} \frac{2V_d}{\pi n} \sin(n\omega\tau)\,d\omega\tau$$

$$\boxed{f = \frac{1}{T} = \frac{\omega}{2\pi}}$$

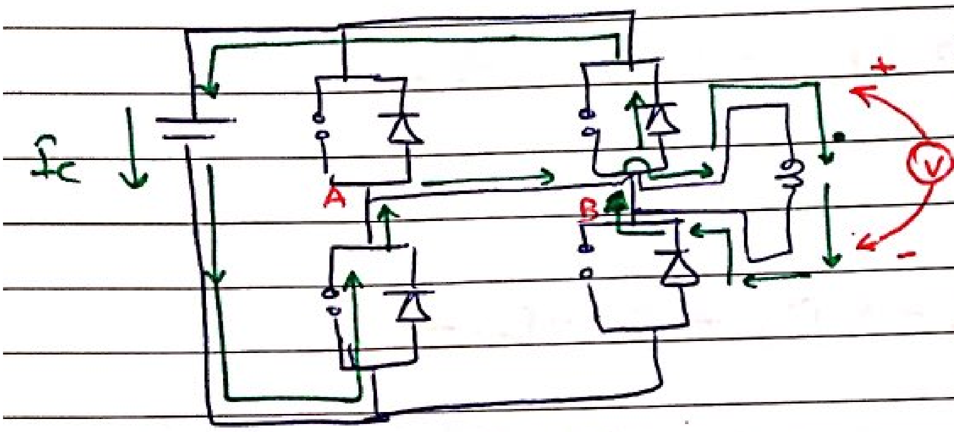
Single phase inverters 84 (Dead Band control)
↳ (H-Bridge)



$S_1 = S_4 = 1$
$[t_1 - t_2]$
Discharging C
$V_{AB} = V_d$
Charging L
$i_L \uparrow$

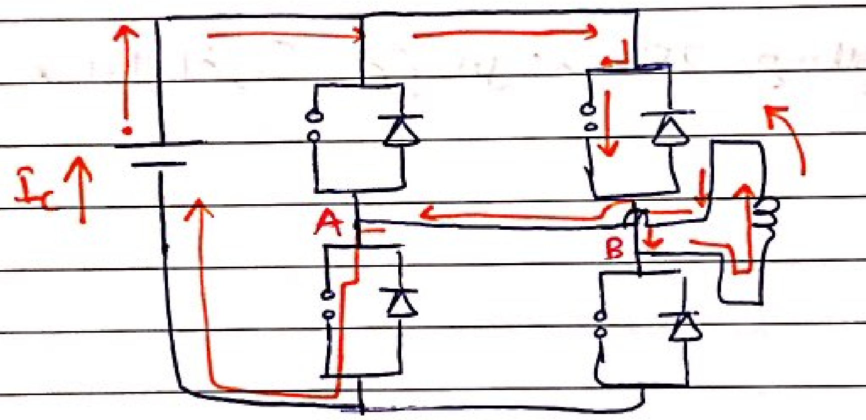


$S_x = 0$ $(t_2 - t_3)$



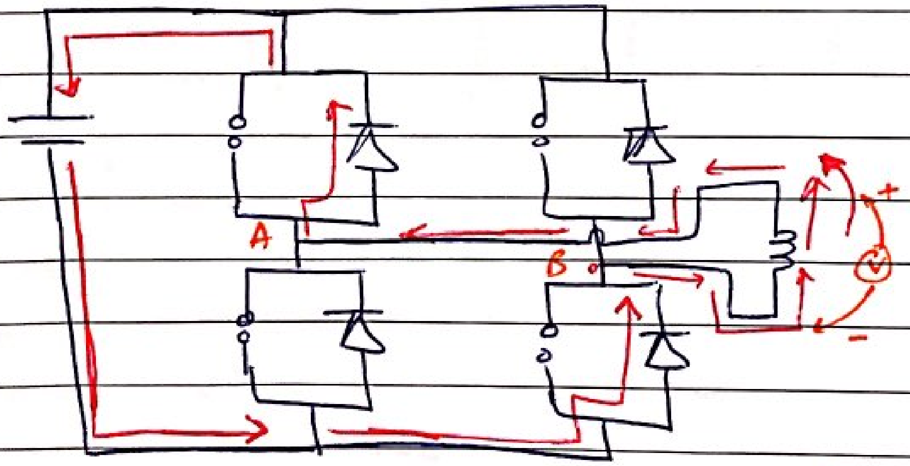
Discharging L
charging C
i_L is decreasing

$(t_3 - t_4)$ $S_2 = S_3 = 1$



charging L
discharging C
i_L is increasing
[on the other direction]

$S_x = 0$ $[t_4 - t_5]$



Charging C
discharging L
i_L is decreasing

A connect to +ve voltmeter
B " " -ve "

$t_1 - t_2$: $C \rightarrow S_1 \rightarrow L \rightarrow S_4 \rightarrow C$

$t_2 - t_3$: $L \rightarrow D_3 \rightarrow C \rightarrow D_2 \rightarrow L$

$t_3 - t_4$: $C \rightarrow S_3 \rightarrow L \rightarrow S_2 \rightarrow C$

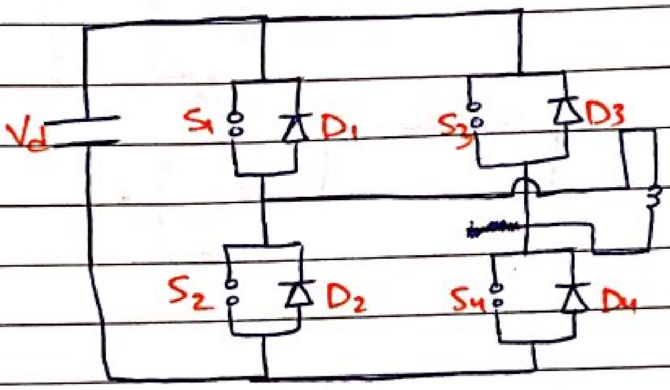
$t_4 - t_5$: $L \rightarrow D_1 \rightarrow C \rightarrow D_4 \rightarrow L$

Dead band control ckt is studied to introduce phase shift control.

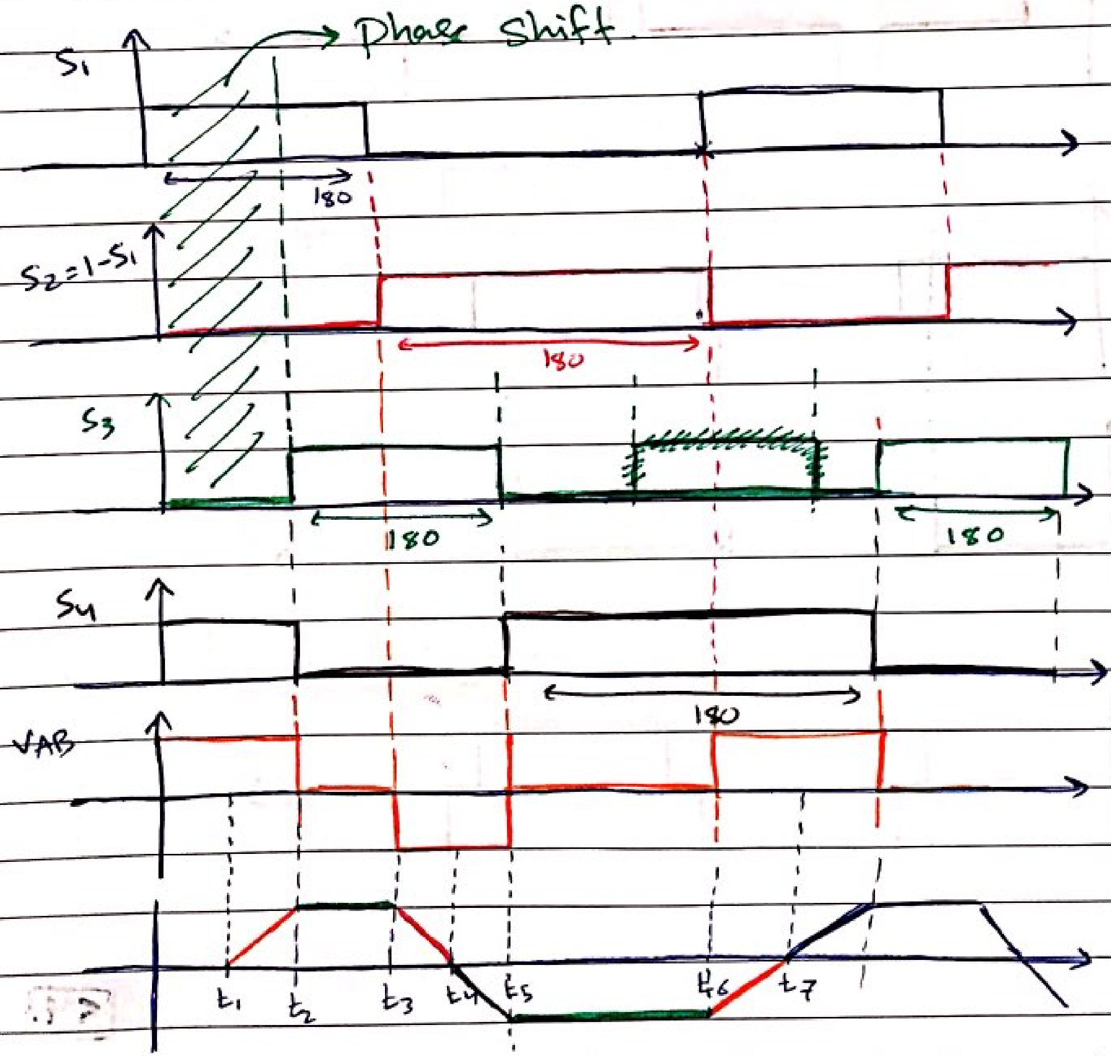
* اذا اقصرت فترة اقل من 25% رح يطلع عندي DC component

* Phase Shift control:-

→ different switching technique.



→ the Dead band control technique is not fully Controllable.

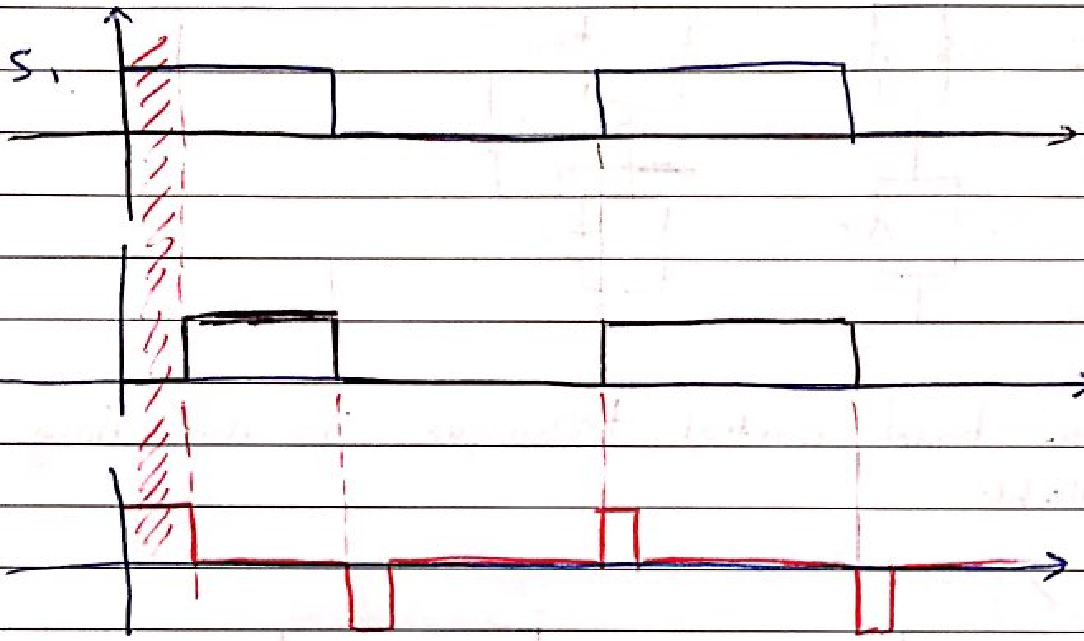


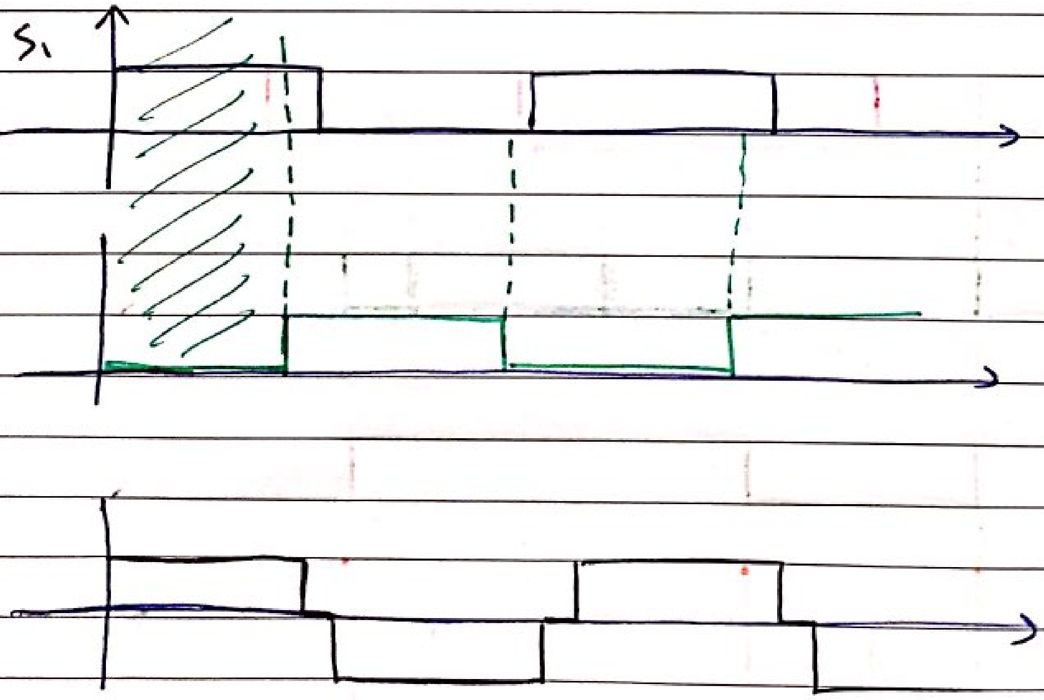
$V_{AN} = S_1 V_d$

$V_{BN} = S_3 V_d$

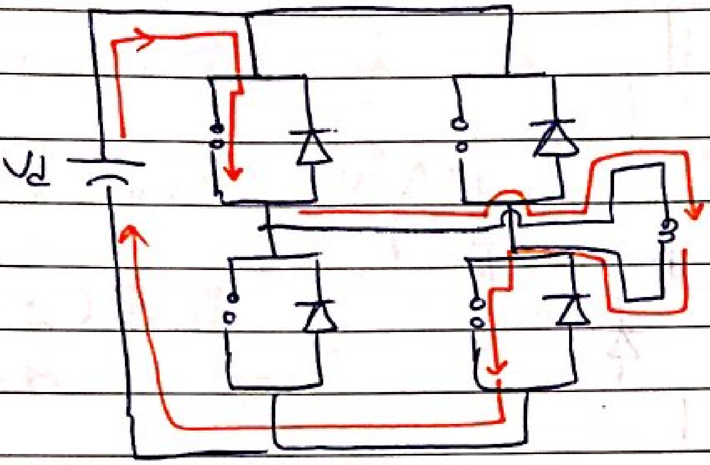
$V_{AB} = V_{AN} - V_{BN}$

$= V_d(S_1 - S_3)$





$[t_1 - t_2]$ $[S_1 = 1 = S_4]$



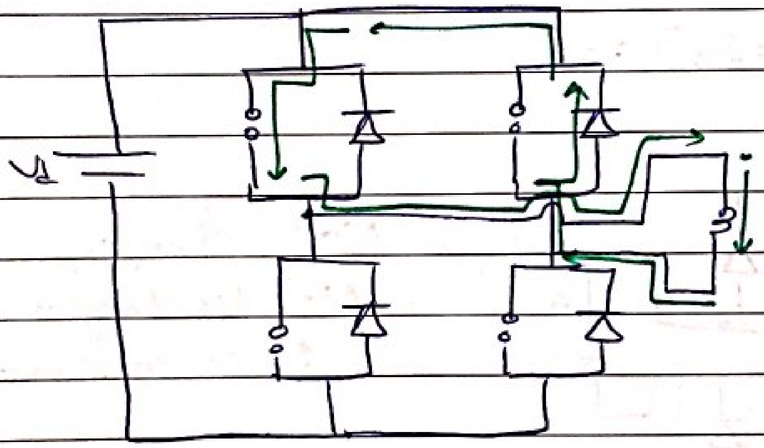
Discharge C

charging L

i_L ↑

path: L → S_4 → C → S_1 → L

$(t_2 - t_3)$ $[S_1 = 1 = S_3]$



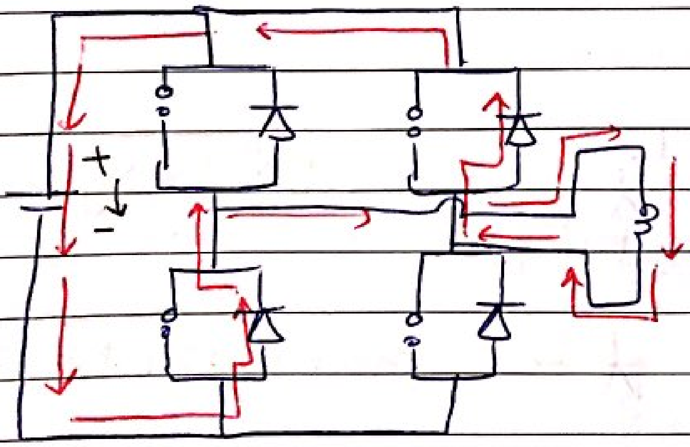
Not charging

Nor discharging

i_L is constant.

path: L → D_3 → S_1 → L

$(t_3 - t_4)$ $[S_2 = 1 = S_3]$



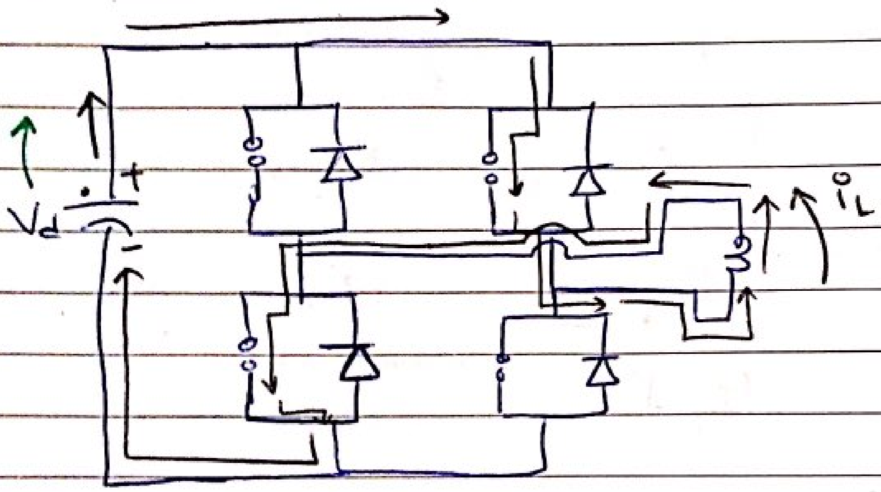
Discharging L

charging C

i_L ↓

Path: L → D_3 → C → D_2 → L

$*(t_4 - t_5)$ $(S_2 = 1 = S_3)$



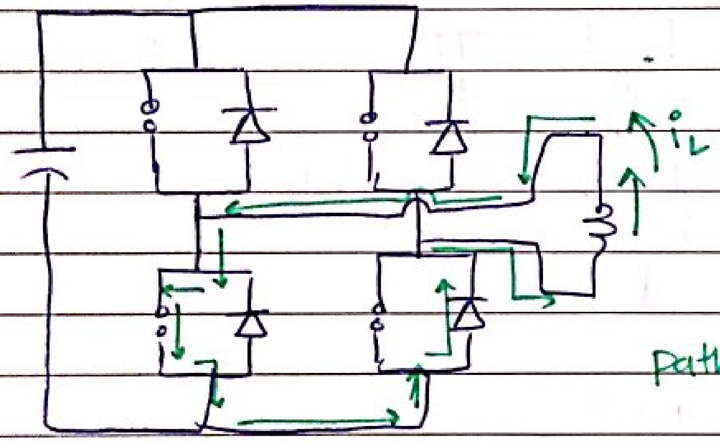
Discharging C

Charging L

i_L ↑ (with opposite direction)

path : $C \rightarrow S_3 \rightarrow L \rightarrow S_2 \rightarrow C$

$*$ $(t_5 - t_6)$ $[S_2 = 1 = S_4]$:-

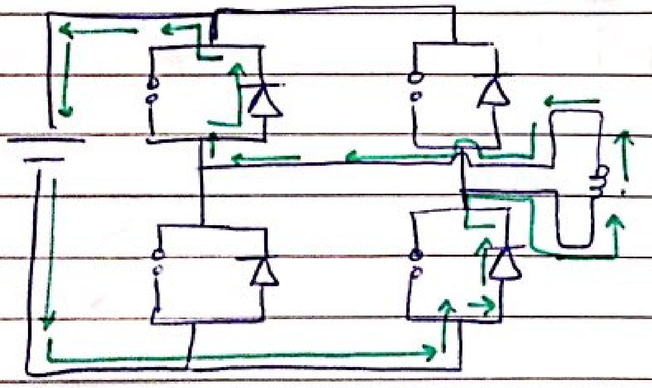


Not charging Nor discharging

i_L is constant

path: $L \rightarrow S_2 \rightarrow D_4 \rightarrow L$

$*$ $t_6 - t_7$ $(S_1 = 1 = S_4)$

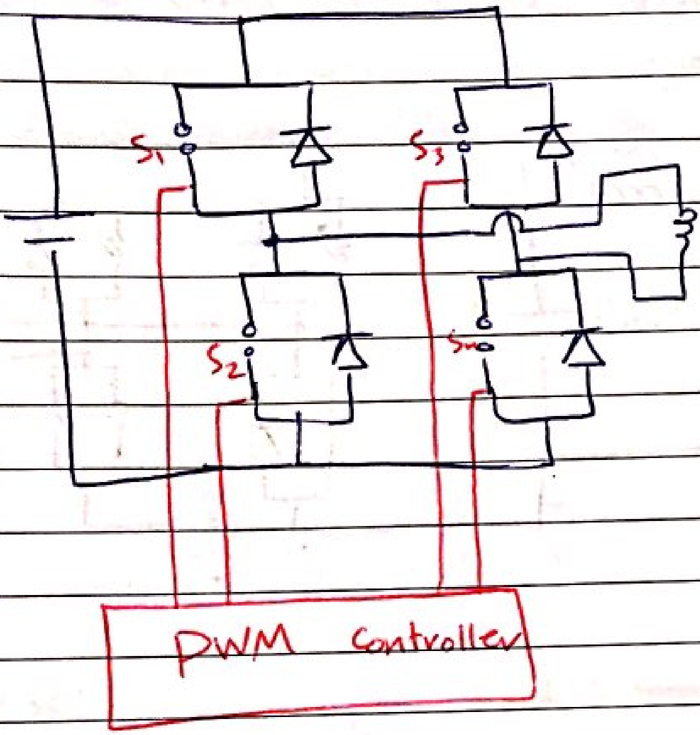


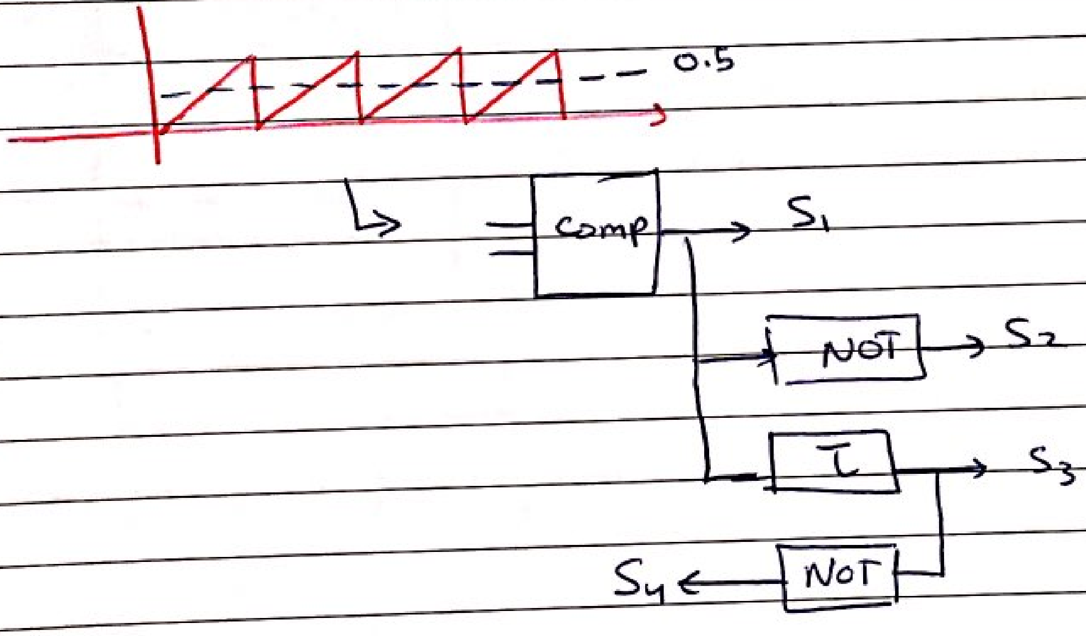
Discharging L

Charging C

i_L ↓

path: $L \rightarrow D_1 \rightarrow C \rightarrow D_4 \rightarrow L$





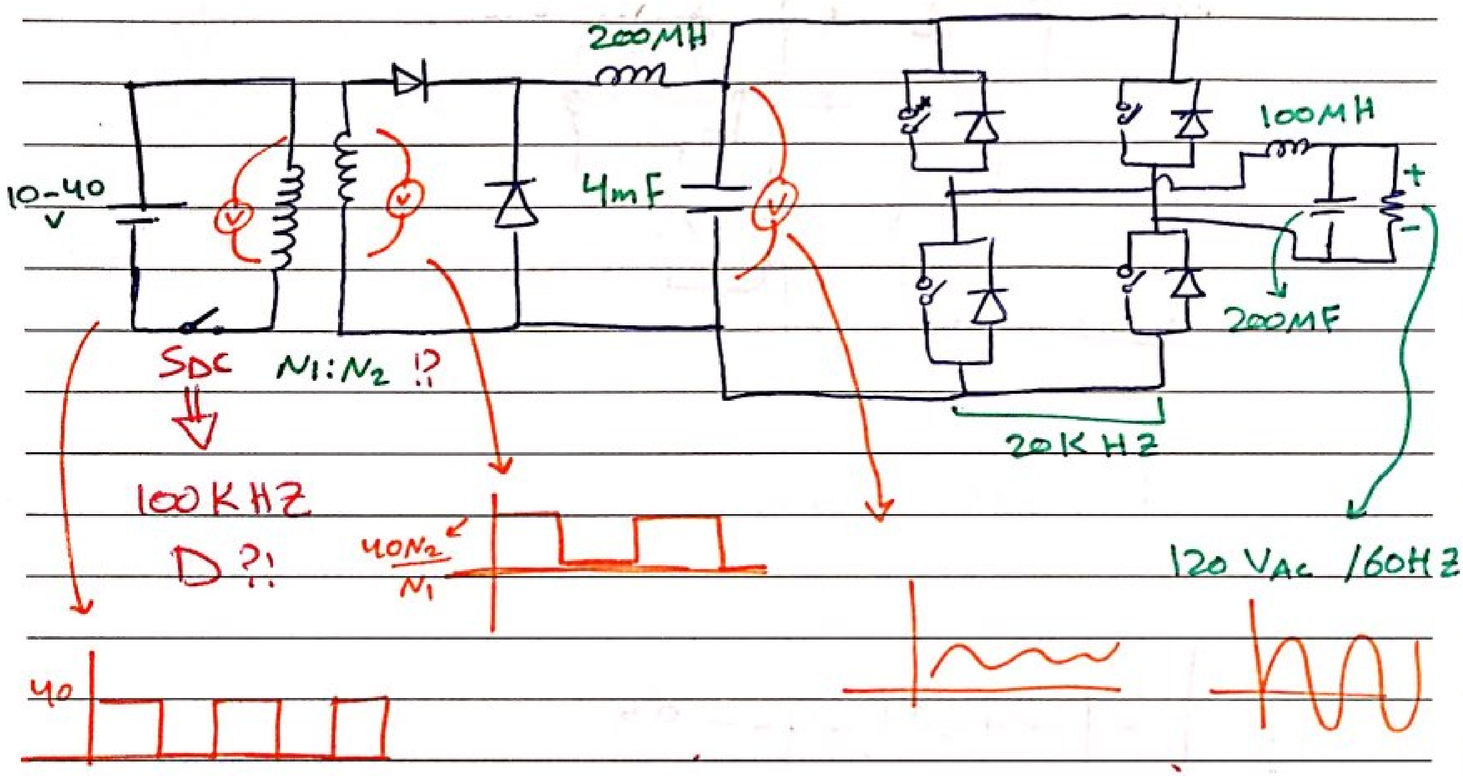
* Homework 2:

Microinverter are used in PV system to invert DC energy to single phase AC energy.

→ output voltage: 120V, 60 HZ

Vin = [10 - 40VDC]

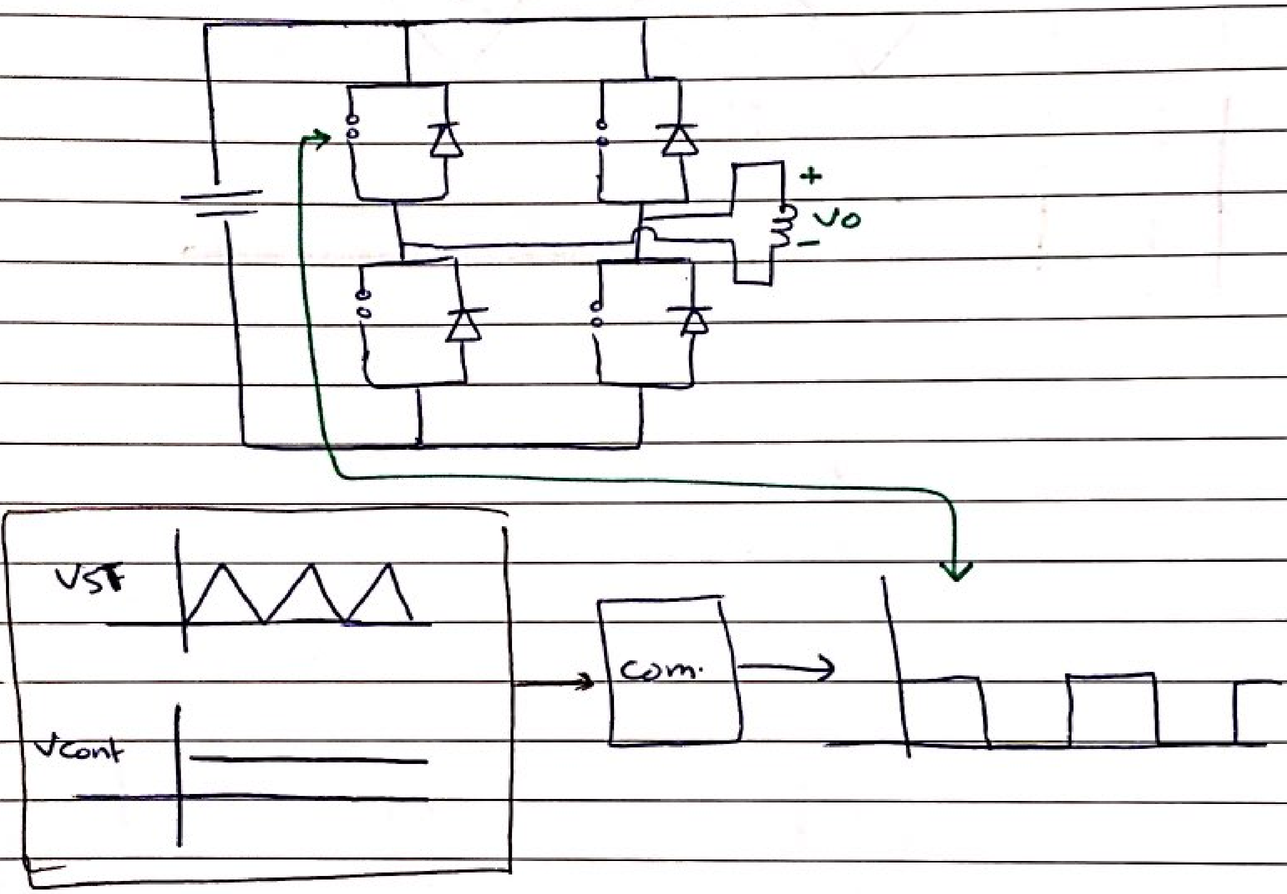
Do your own design of a PWM single phase inverter and forward DC/DC Converter to have this output voltage.

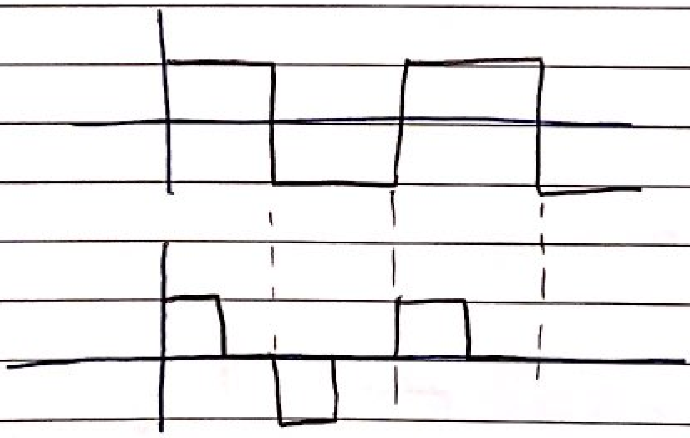


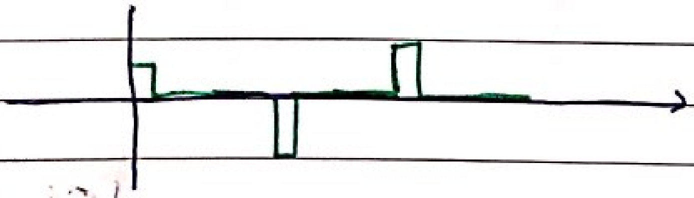
15/3 Thu

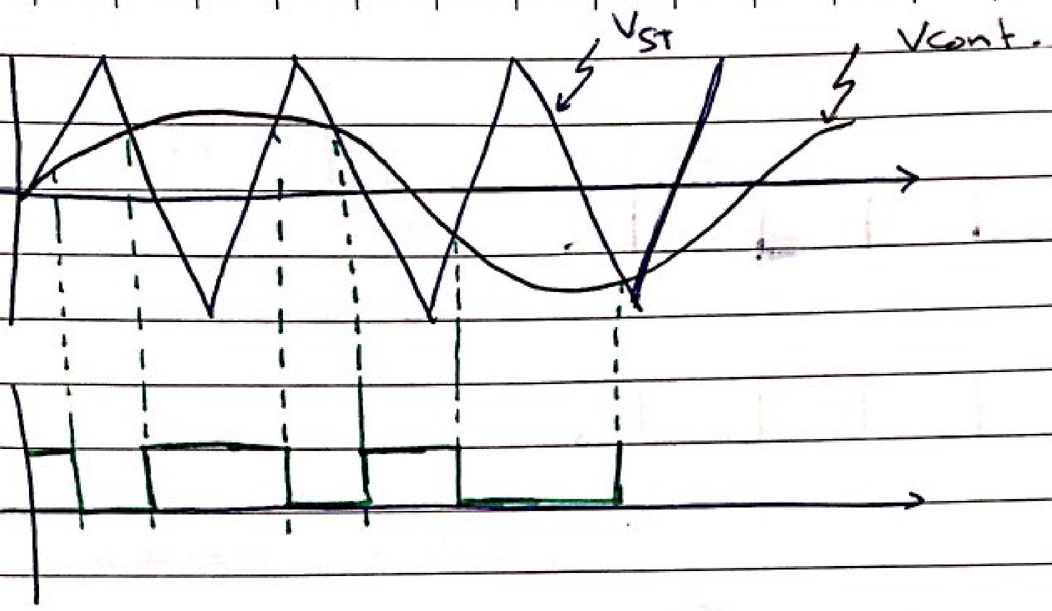
Sinusoidal PWM :-

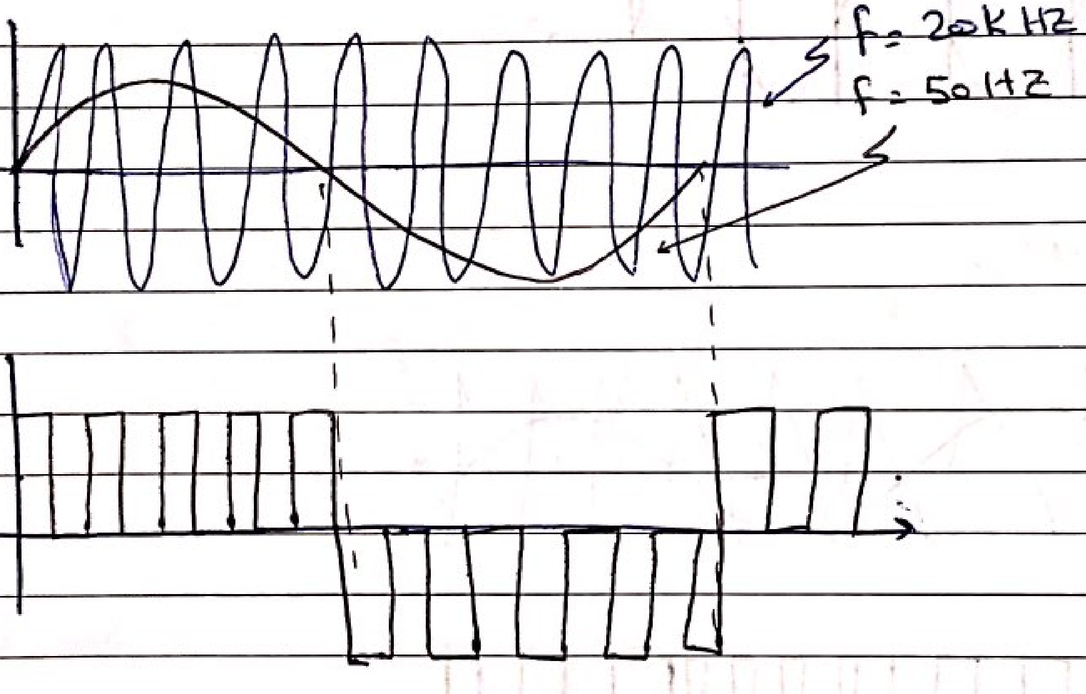
comparisum btween asinusoidal pulse insted of a constant pulse width with V_{st}



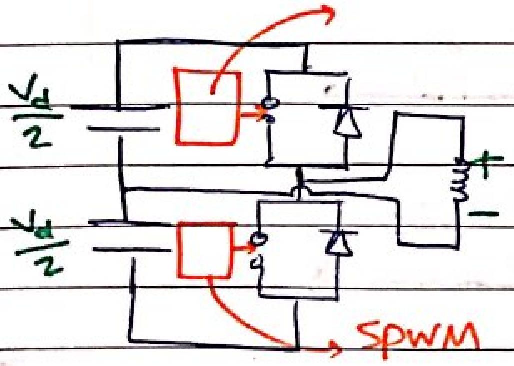








$\boxed{Ex}$ a single leg using SPWM 8Δ



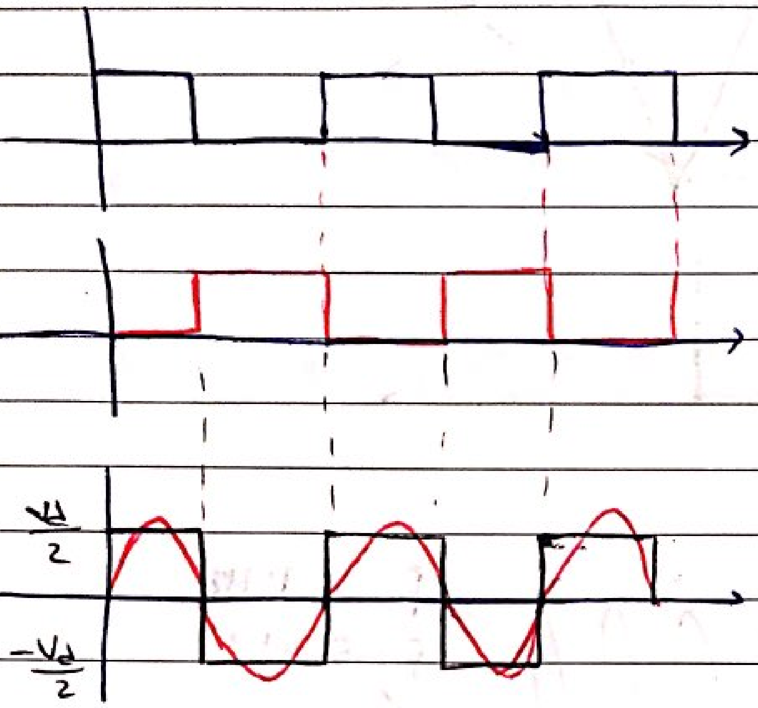
$V_{AN} = V_d \times S_i$

$V_{ON} = \frac{V_d}{2}$

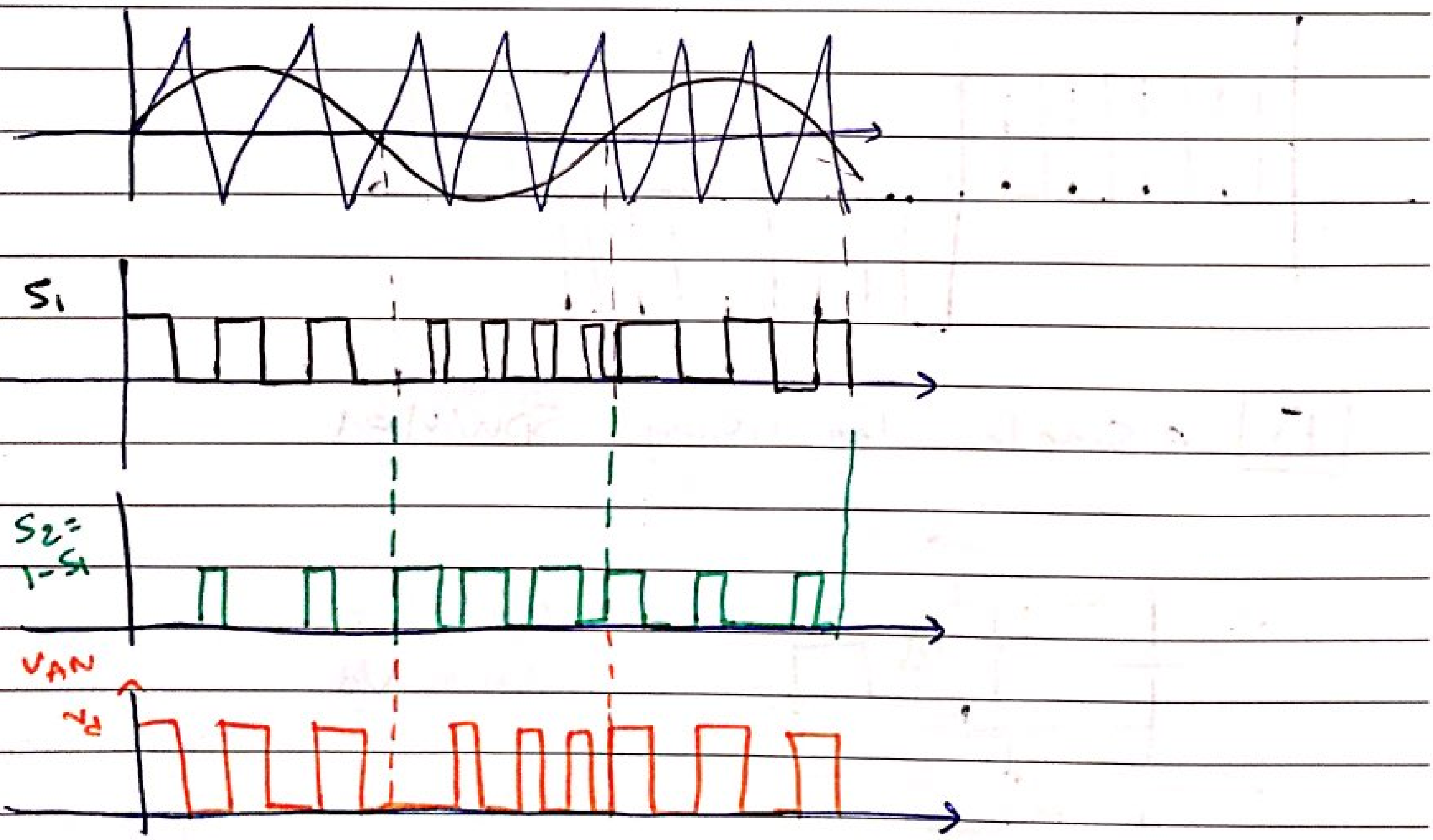
$$\boxed{V_{AO} = V_{AN} - V_{ON}}$$

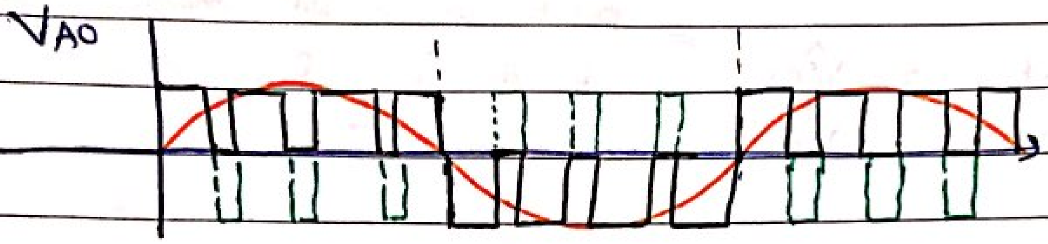
Scanned with CamScanner

PWM



SPWM:-





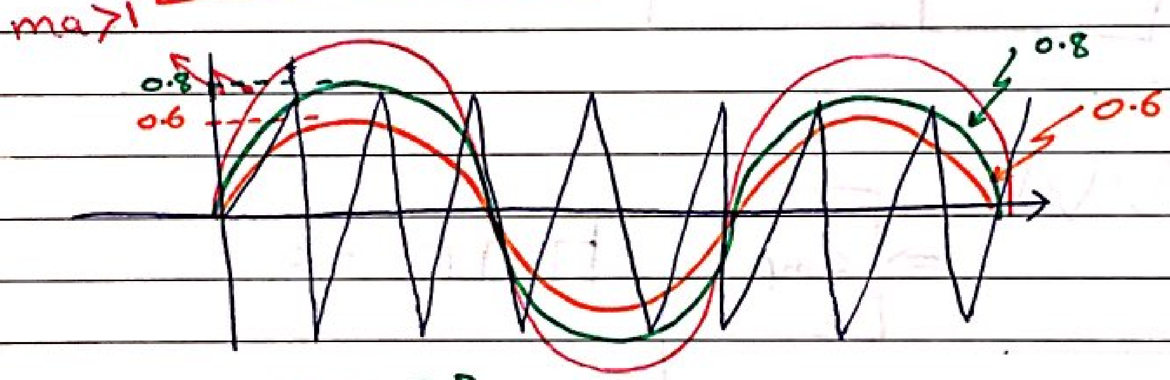
SPWM :-

* modulation index :

$$\boxed{m_a = \frac{V_{cont}}{V_{tr}}} \quad 0 \leq m_a \leq 1$$

Vcont = Vcontrol

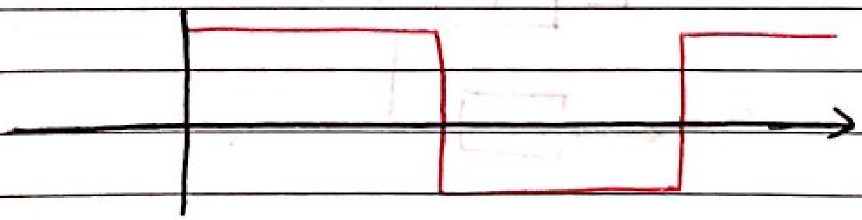
Vtr = Vtriangle



ma = 0.8

ma = 0.6

Do not over modulation :-



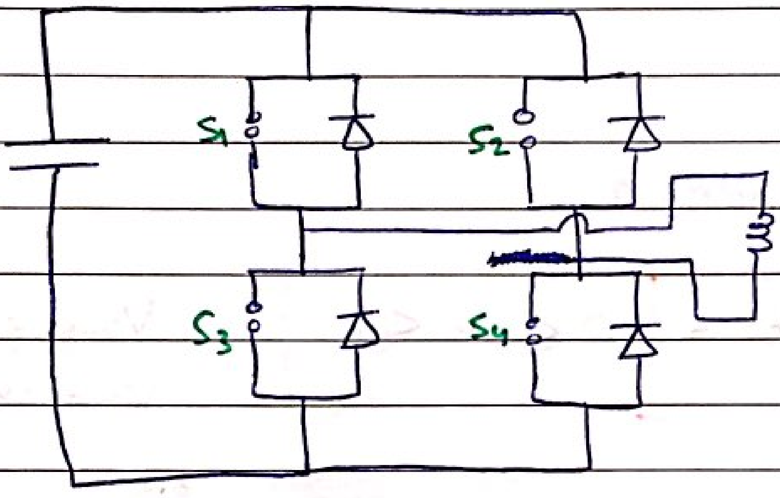
frequency Modulation :-

$$m_f = \frac{f_s \rightarrow \text{frequency of Vtriangular.}}{f_m \rightarrow \text{frequency of Vsinusiodal (control)}}$$

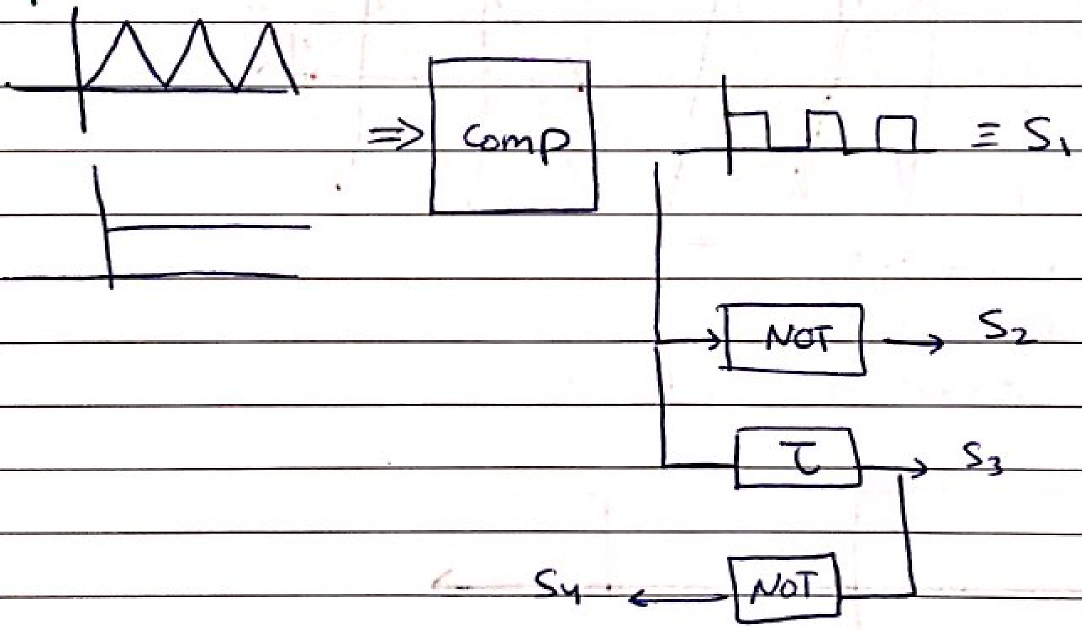
$m_f \gg 1$

$$m_a = \frac{V_{cont}}{V_{tr}} = \frac{\hat{V}_{o,1}}{V_{dc}}$$

peak value of [illegible] the fundamental freq of the output signal.

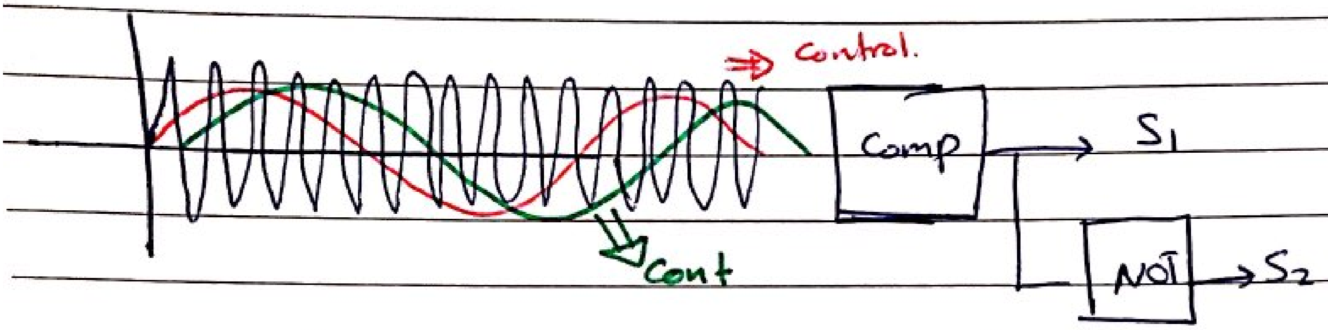


PWM:-



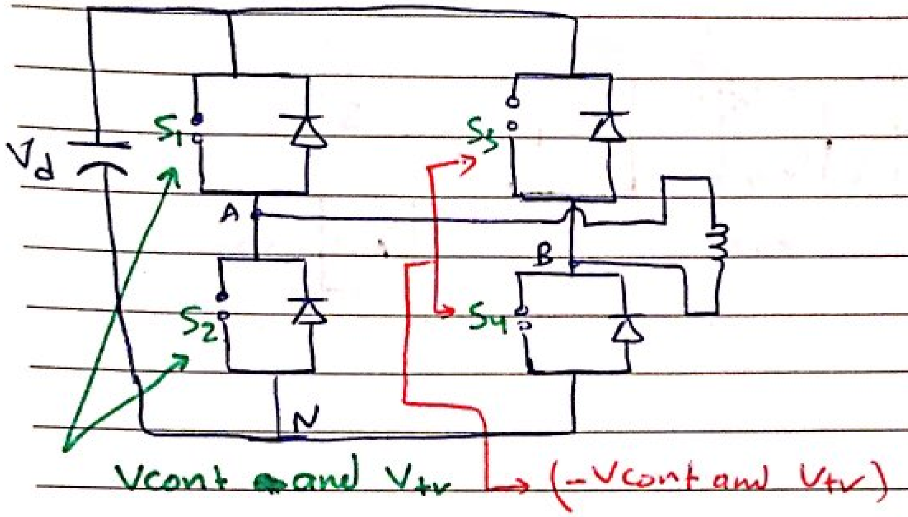
SPWM:-

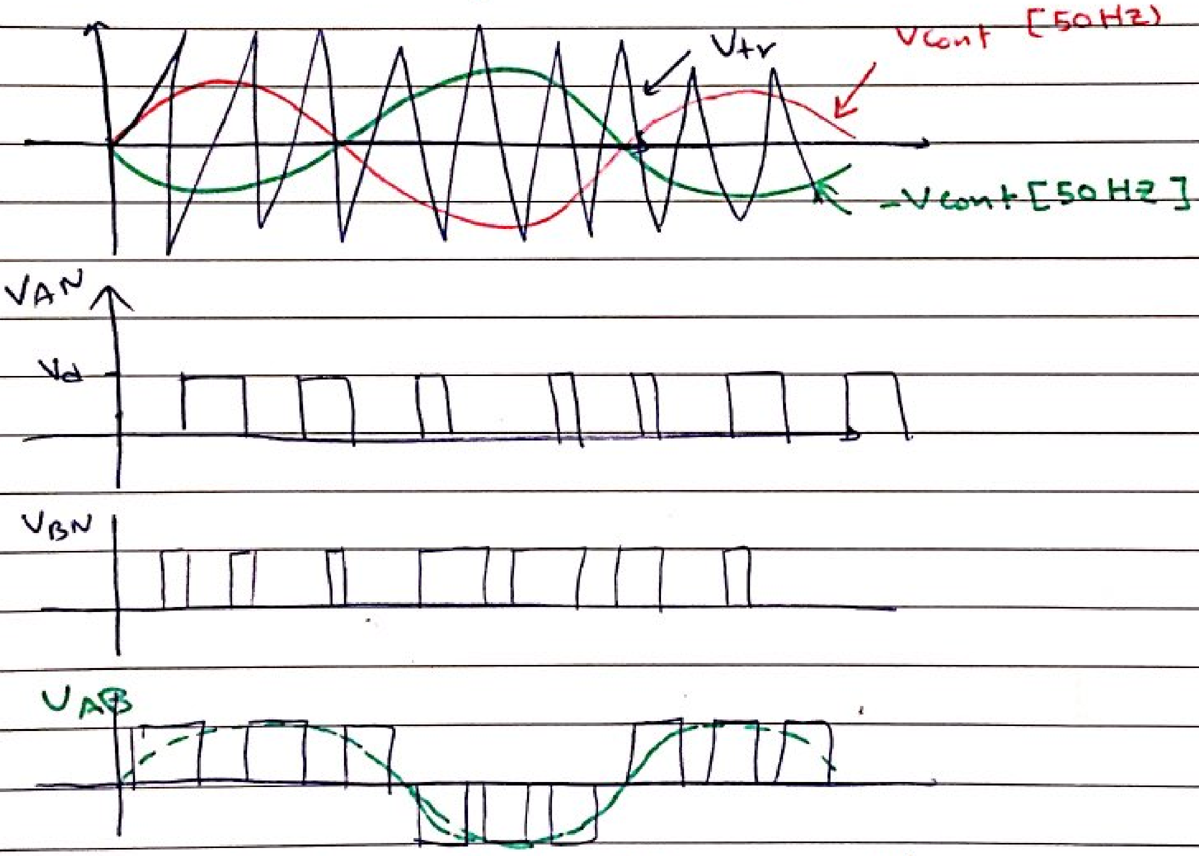
control signal



18/3 SUN

* Unipolar SPWM for Single phase Inverter 8Δ





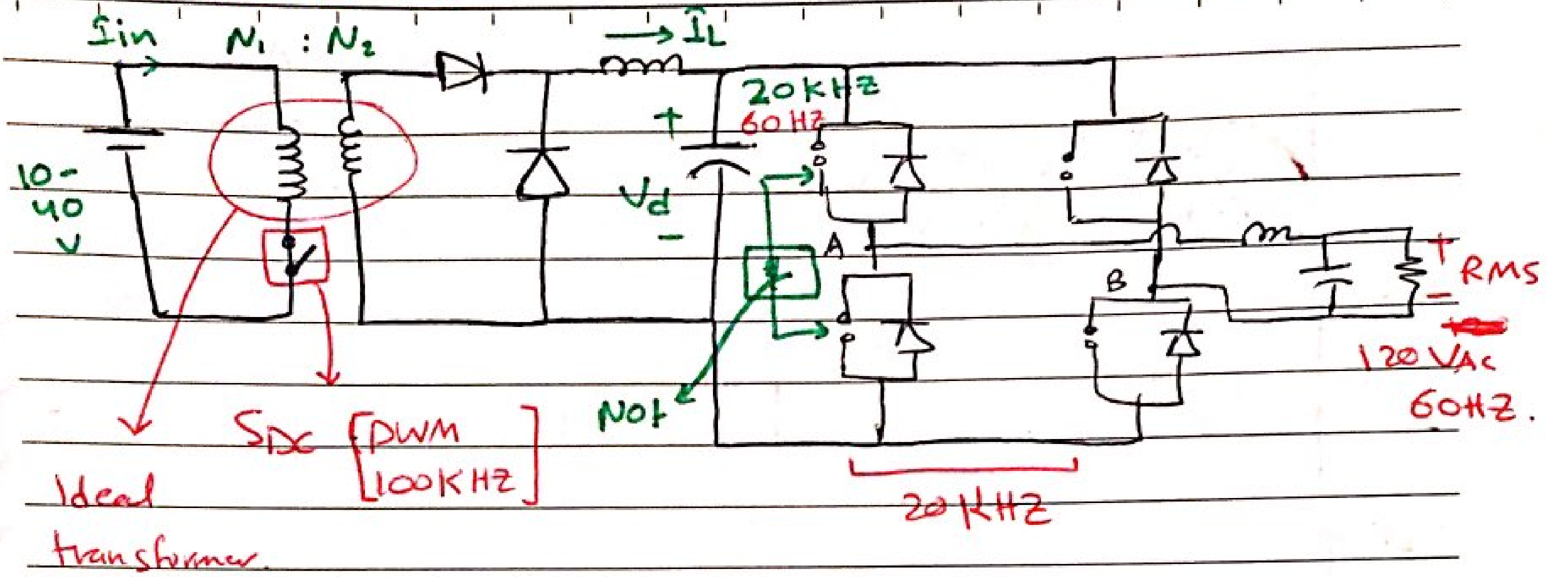
$V_{cont} > V_{tr}$: S_1 is ON $V_{AN} = V_d$

$V_{cont} < V_{tr}$: S_2 is ON $V_{AN} = 0$

$(-V_{cont}) > V_{tr}$: S_3 is ON $V_{BN} = V_d$

$(-V_{cont}) < V_{tr}$: S_4 is ON $V_{BN} = 0$

Homework 28



Choose a modulation index btween [0.85-0.9]

Take Vin = 10, 25, 40 V

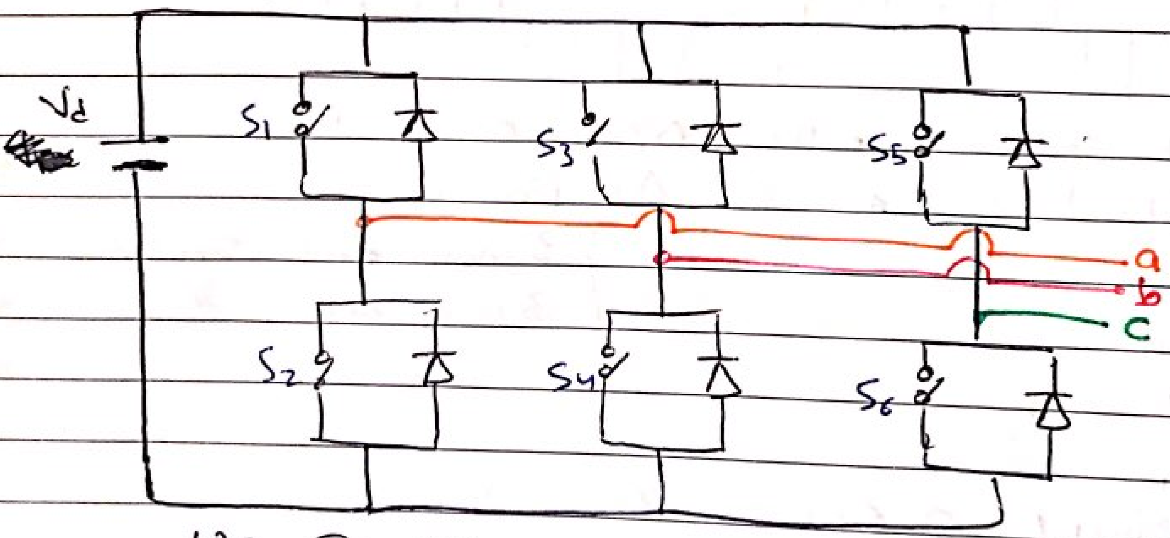
Plot Iin, Vd, VAB, Vload, IL

8 pages report :-

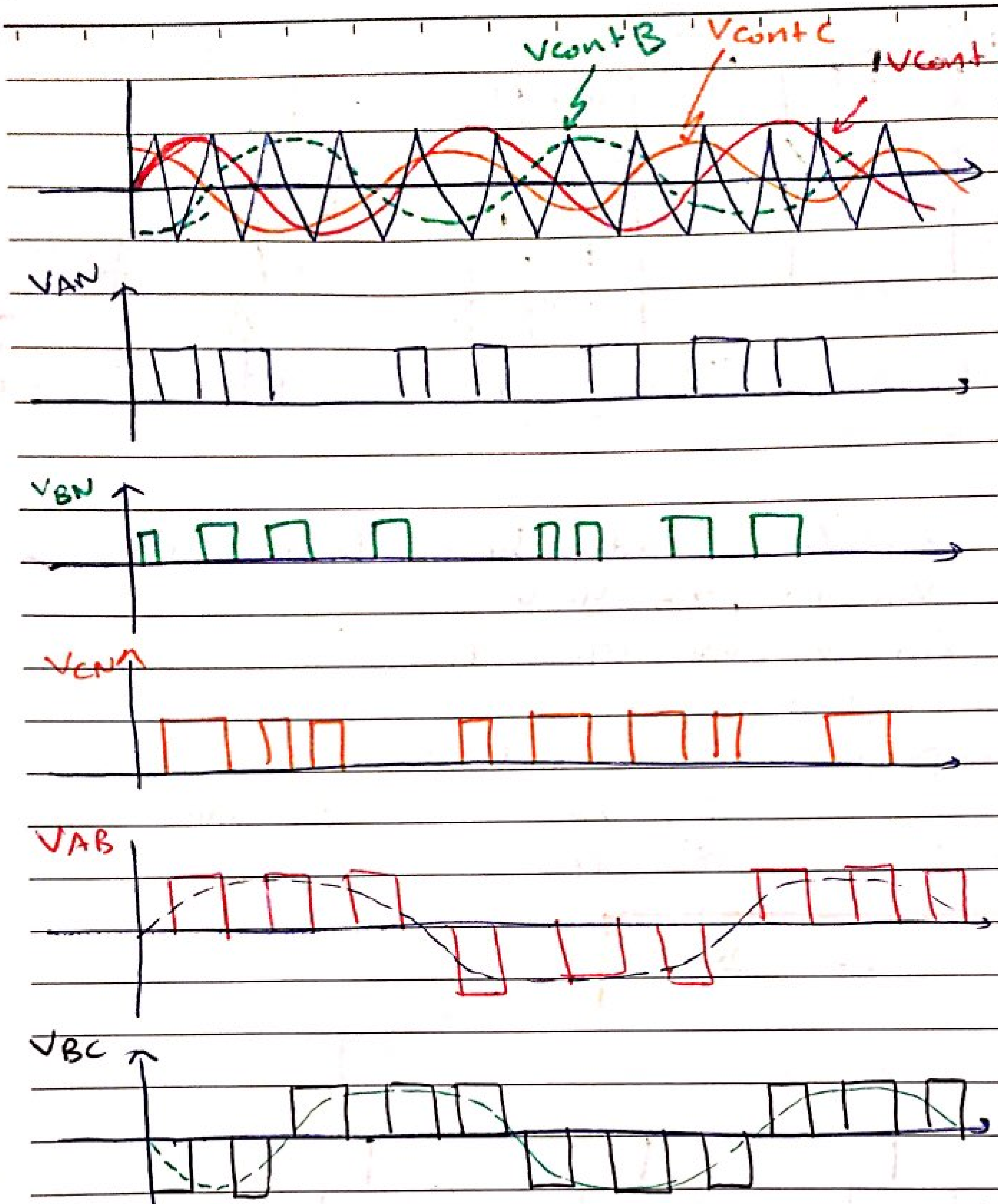
- $\boxed{1}$ cover page
- $\boxed{2}$ problem function.
- $\boxed{3}$ model.
- $\boxed{4}$ Iin
- $\boxed{5}$ Vd
- $\boxed{6}$ VAB
- $\boxed{7}$ Vload
- $\boxed{8}$ IL

Due date 29/3

Three Phase Inverter [VDC ⇒ 3Φ VAC]



Use SpWM



$m_a = \frac{V_{cont}}{V_{tr}}$

$= \frac{V_{01}}{V_d}$

must connect either ΔY Tr. or Δ load

Y load will not get AC power.

$V_{AN} = S_1 V_d$ $(S_2 = 1 - S_1)$ } 3 independent switches

$V_{BN} = S_3 V_d$ $(S_4 = 1 - S_3)$ } 3 complementry "

$V_{CN} = S_5 V_d$ $(S_6 = 1 - S_4)$

fundamental

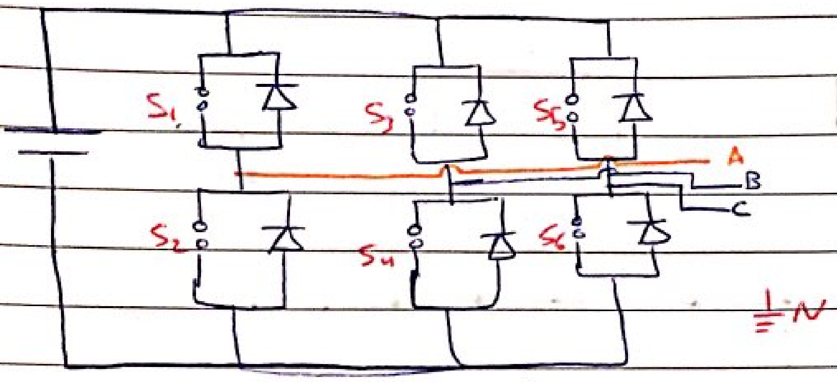
$$\boxed{\begin{aligned} V_{LL1} &= 0.612\, m_a V_d \\ V_{LL1max} &= 0.612\, V_d \end{aligned}}$$

[RMS]

$m_a = 1$

2013 TUE

3∅ inverters : Six step inversion :-



$V_{an} = S_1 V_d$ $\quad$ $S_2 = 1 - S_1$

$V_{bn} = S_3 V_d$ $\quad$ $S_4 = 1 - S_3$

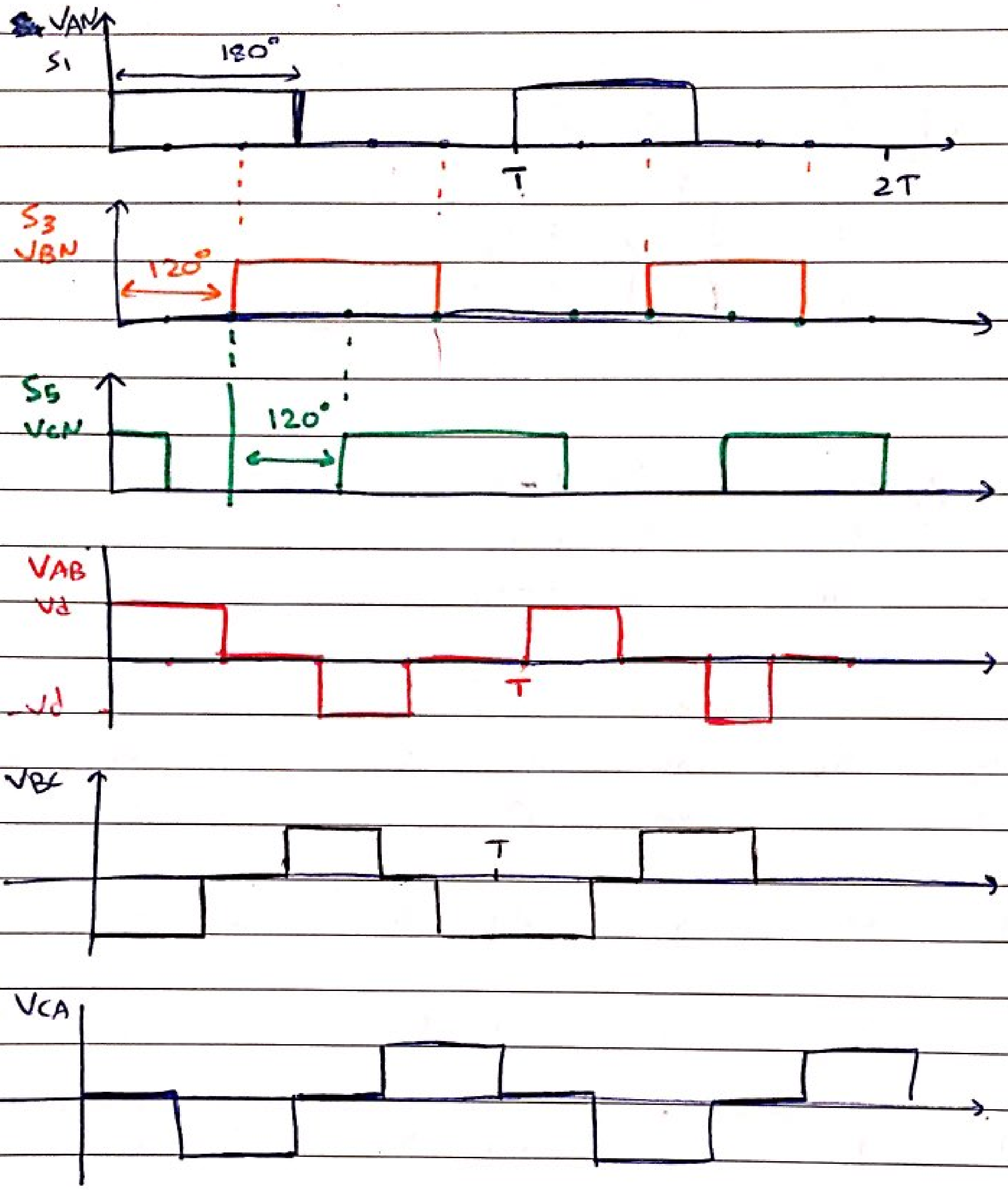
$V_{cn} = S_5 V_d$ $\quad$ $S_6 = 1 - S_5$

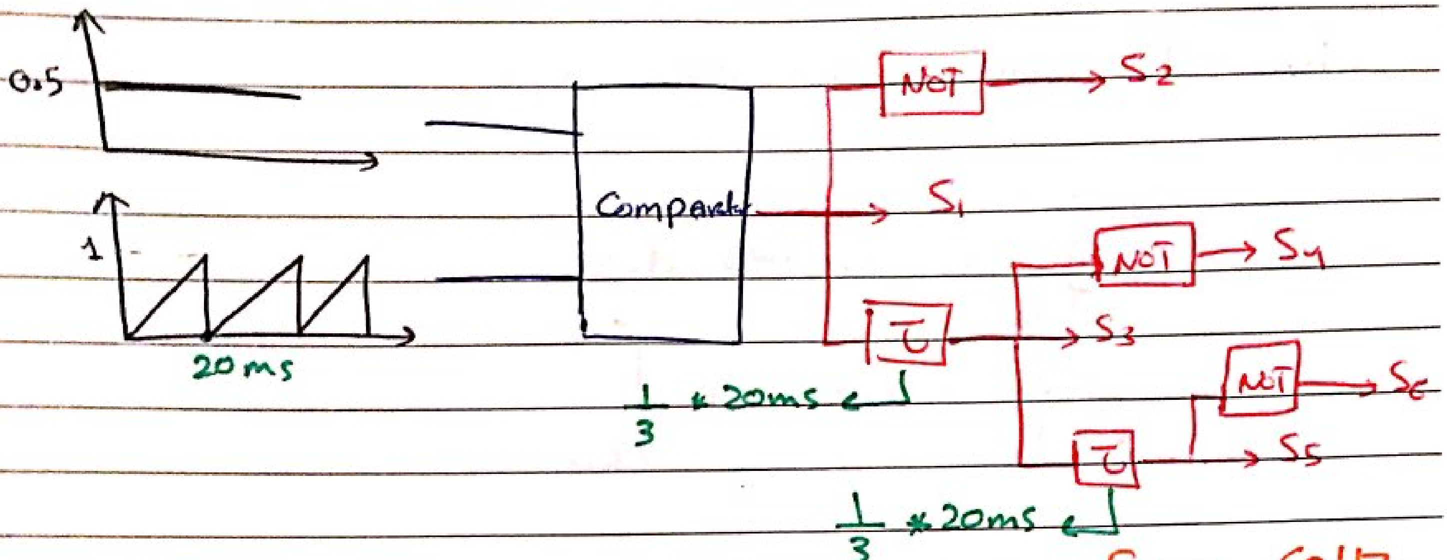
⇒ 8 switching stateses $[2^3]$

	S_1	S_3	S_5	V_{AN}	V_{BN}	V_{CN}	V_{AB}	V_{BC}	V_{CA}
①	1	0	0	V_d	0	0	V_d	0	$-V_d$
②	1	1	0	V_d	V_d	0	0	V_d	$-V_d$
③	0	1	0	0	V_d	0	$-V_d$	V_d	0
④	0	1	1	0	V_d	V_d	0	0	V_d
⑤	0	0	1	0	0	V_d	V_d	$-V_d$	V_d
⑥	1	0	1	V_d	0	V_d	0	$-V_d$	0
⑦	0	0	0	0	0	0	0	0	0
⑧	1	1	1	V_d	V_d	V_d	0	0	0

① → ⑥ Active , ⑦ → ⑧ → Non active

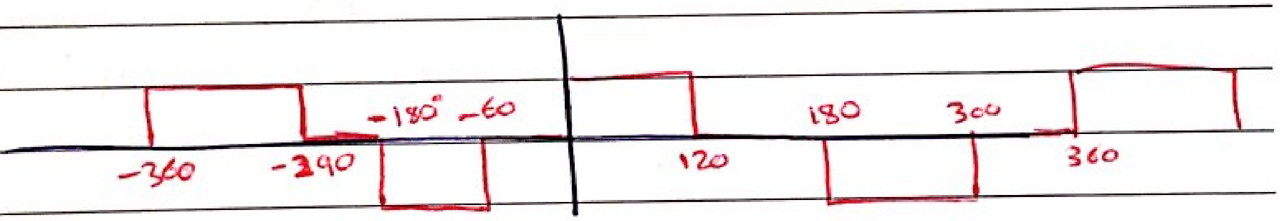
VAN = Vd S1



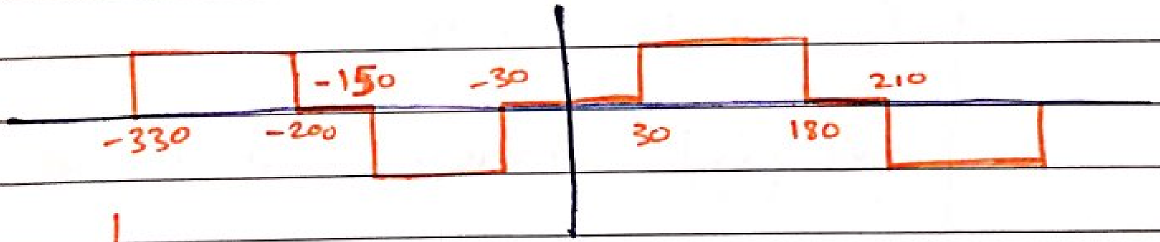


freq = 60HZ

$$V_{ab} = \frac{a_0}{2} + \sum_{n=1}^{\infty} a_n \cos n\omega t + b_n \sin n\omega t$$



$\Downarrow$



↳ odd quarter wave Symmetric.

$a_n = 0 = a_0$

$b_n = 0$ for n even.

$$b_n = \frac{4}{\pi}\int_{0}^{\pi/2} V_{AB}(t)\ \sin n\omega t\ d\omega t$$

$$= \frac{4}{\pi}\int_{\pi/6}^{\pi/2} V_d\ \sin n\omega t\ d\omega t$$

$$= \frac{4V_d}{\pi n}\ -\cos n\omega t\ \Big]_{\pi/6}^{\pi/2}$$

$$= \frac{4V_d}{n\pi}\left[\cos\frac{n\pi}{6} - \cos\frac{n\pi}{3}\right]$$

$$= \frac{4V_d}{n\pi}\sin\left(\frac{n\pi}{2}\right)\underbrace{\sin\left(\frac{n\pi}{3}\right)}_{}$$

$= 0$ for $n = 3, 6, 9$
triplen

$$b_n = \begin{cases} 0 & n \text{ even.} \\ 0 & n = 3, 6, 9, 12, 15 \\ \frac{4V_d}{n\pi}\left(\frac{\sqrt{3}}{2}\right) & \text{else wher } [1, 5, 7, 11, 13, 17, 19] \end{cases}$$

عشان الازاحة

$$V_{ab} = \sum_{n=1,5,7}^{\infty} \frac{4V_d}{n\pi}\left(\frac{\sqrt{3}}{2}\right)\sin\left[n\left(\omega t + \frac{\pi}{6}\right)\right]$$

$$V_{bc} = \sum_{n=1,5,7}^{\infty} \frac{4V_d}{n\pi}\left(\frac{\sqrt{3}}{2}\right)\sin\left[n\left(\omega t - \frac{\pi}{2}\right)\right]$$

$$V_{ca} = \sum_{n=1,7,5}^{\infty} \frac{4V_d}{n\pi}\left(\frac{\sqrt{3}}{2}\right)\sin\left[n\left(\omega t - \frac{7\pi}{6}\right)\right]$$

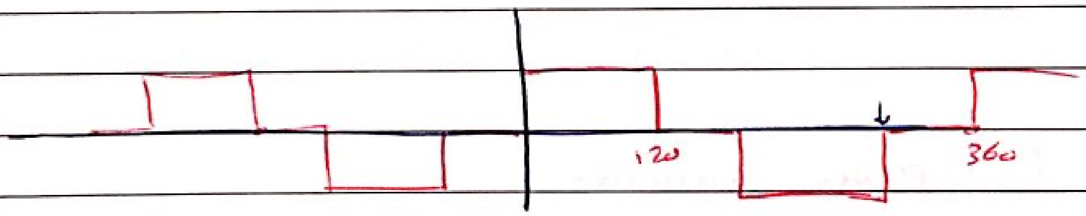
$$V_{ab(1)} = \frac{4V_d}{\pi}\left(\frac{\sqrt{3}}{2}\right)\sin\left(\omega t + \frac{\pi}{6}\right)$$

The RMS value of the fundemental :

$$V_{ab(1)_{rms}} = \frac{4V_d}{\pi\sqrt{2}}\left(\frac{\sqrt{3}}{2}\right) = \underbrace{0.7796\,V_d}_{\Downarrow}$$

the highest value from DC - 3∅ AC inversion.

The RMS value of the output Signal [VAB]



$$V_{rms} = \sqrt{\frac{1}{2\pi}\left[\int_0^{2\pi/3}(V_d)^2\,d\omega t + \int_{\pi}^{\frac{5\pi}{3}}(-V_d)^2\,d\omega t\right.}$$

$$= \sqrt{\frac{2}{2\pi}\int_0^{2\pi/3}(V_d)^2\,d\omega t}$$

$$= 0.8165\,V_d$$

22/3 Thu

* Comparision between 6-Step & SPWM

- → six step has no zero states while SPWM has.
- → switching frequency :-

SPWM → $f_s \gg f_{fundemental}$.

6-Step → $f_s = f_{fundemental}$.

- → 6 step has lower order.
- → 6 step has less lower order harmonics in its output voltage.

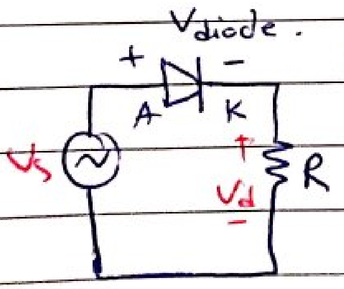
6-step ⇒ $V_{LL}(n) = \frac{0.78 V_d}{n}$ $n = 1, 5, 7, 11$

SPWM ⇒ $V_{LL}(n) = \frac{0.61 V_d}{n}$ $n = 1, 3, 5, 7, 9$

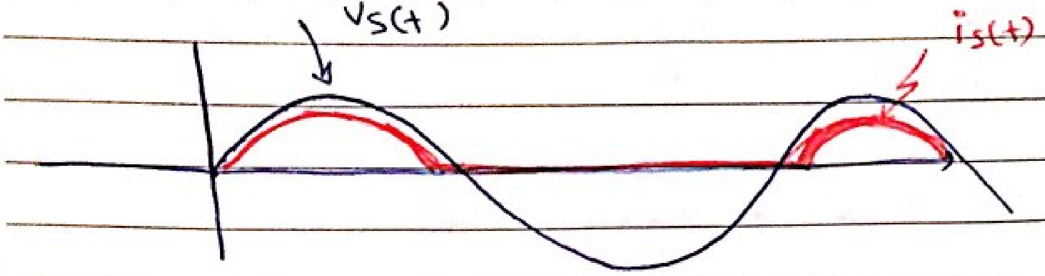
* AC to DC Convasion [Rectification] &◁

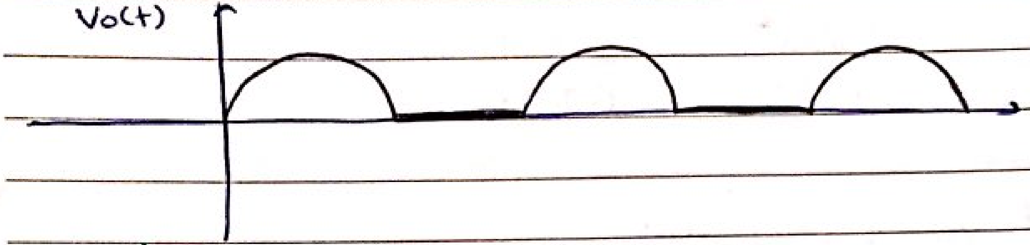
- → DC power supplies
- → Utility to DC microgrids
- → Electronics and home application.
- → HVDC

Basic Rectifier Circuit :-

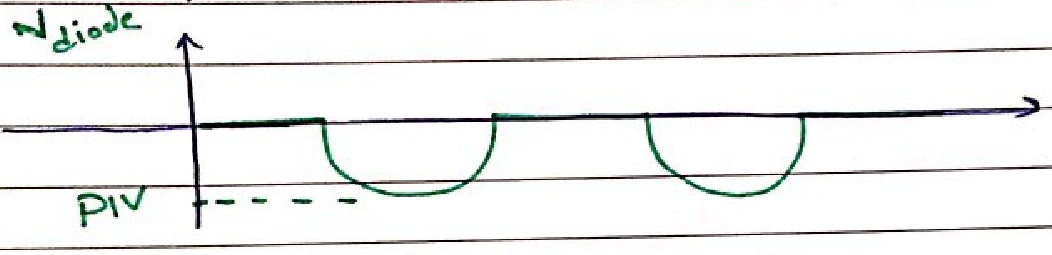


→ it works when it is FB [$V_A > V_K$] and its prevent the current flow when [$V_K > V_A$]





$V_o(t) = i_s(t)\,R.$



PIV = Peak Inverse voltage.

$$V_s(t) = \sqrt{2}\;V_{rms}\;\sin wt$$
$$= V_m\;\sin wt$$

$$i(t) = \begin{cases} \dfrac{\sqrt{2}\;V_{rms}\;\sin wt}{R} & 0 < wt < \pi \\ 0 & \text{else} \end{cases}$$

$$I_{o\,avg} = \frac{1}{2\pi}\int_0^{\pi} \frac{\sqrt{2}\;V_{rms}\;\sin(wt)}{R}\,dwt = \frac{\sqrt{2}\;V_{rms}}{2\pi R}\Big[-\cos wt\Big]_0^{\pi}$$

$$\boxed{I_{o\,avg} = \frac{\sqrt{2}\,V_{rms}}{R\pi} = \frac{V_m}{R\pi}}$$

$$V_{o\,avg} = \frac{1}{2\pi}\int_0^{\pi} \sqrt{2}\;V_{rms}\;\sin wt\;dwt$$

$$\boxed{V_{oavg} = \frac{\sqrt{2}\,V_{rms}}{\pi} = \frac{V_m}{\pi}}$$

$$P_{oavg} = P_{DC} = I_{oavg} * V_{oavg}$$

$$\boxed{P_{oavg} = \frac{2V_{rm}^2}{R\pi^2} = \frac{V_m^2}{R\pi^2}}$$

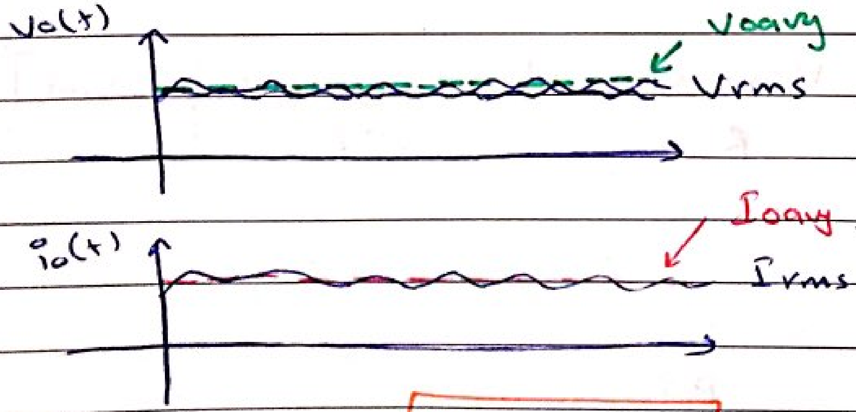
$$V_{orms} = \sqrt{\frac{1}{2\pi}\int_0^{\pi} V_m^2 \sin^2\omega t \; d\omega t}$$

$$\boxed{V_{orms} = \frac{V_m}{2} = \frac{V_{rms}}{\sqrt{2}}}$$

$$\Rightarrow \boxed{I_{orms} = \frac{V_{orms}}{R} = \frac{V_m}{2R} = \frac{V_{rms}}{\sqrt{2}\,R}}$$

$$P_{ac} = V_{rms} I_{rms}$$

$$\Rightarrow \boxed{P_{AC} = \frac{V_m^2}{4R} = \frac{V_{rms}^2}{2R}}$$



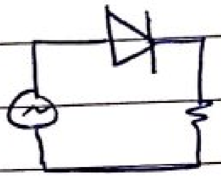
$P_{DC} = V_{oavg} * I_{oavg}$

$P_{AC} = V_{rms} * I_{rms}$

$$\boxed{\eta = \frac{P_{DC}}{P_{AC}}}$$

η = conversion efficiecy

Ex Find the performance parameter for a single phase Half wave rectifier.



1 η ?!

$$\eta = \frac{P_{DC}}{P_{AC}} = \frac{V_m^2/R\pi^2}{V_m^2/4R} = 40.53\%$$

2 Find the form factor:-

$$FF = \frac{V_{rms}}{V_{DC}} \quad [\text{need to be } 1]$$

$$FF = \frac{V_m/2}{V_m/\pi} = \pi/2 = 1.57$$

$FF = 1 \rightarrow V_{rms} = V_{dc}$ (good conversion)

3 Find the ripple factor ?!

$$RF = \sqrt{\frac{(V_{rms})^2}{V_{dc}^2} - 1} = \sqrt{(FF)^2 - 1} = \sqrt{(1.57)^2 - 1}$$

$$\boxed{RF = 1.211}$$

4 PIV of Diodes ?!

$PIV = V_m = \sqrt{2}\, V_{rms}$

5 Find the power factor of the ckt.

$$PF \triangleq \frac{\text{Real power}}{\text{apperant power}} = \frac{P}{S}$$

RMS value of output

$$PF = \frac{V_{orms} \cdot I_{orms}}{V_{sin} \times I_{sin}} = \frac{V_{rms}/\sqrt{2} \times V_{rms}/R\sqrt{2}}{V_{rms} \times V_{rms}/\sqrt{2}\,R} = \frac{1}{\sqrt{2}}$$

RMS value of the input

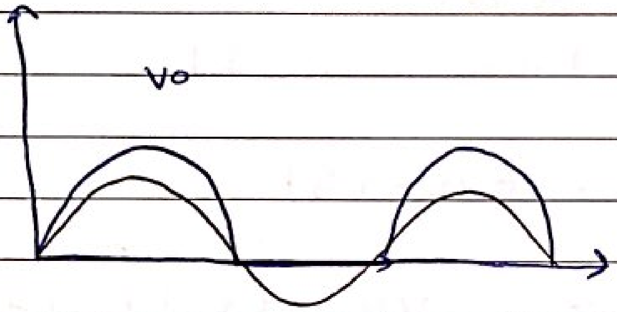
$$\boxed{PF = 0.707}$$

* we only use RMS value in Real life.

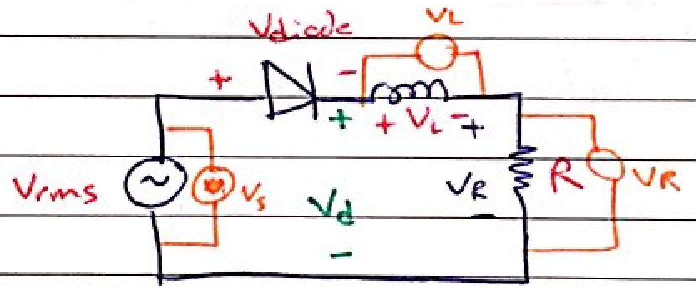
25/13 SUN

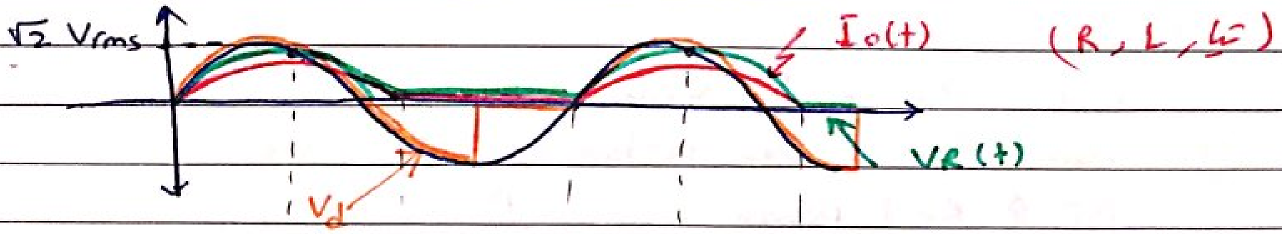
* $THD_c = \sqrt{\dfrac{I_0^2 - I_{01}^2}{I_{s1}^2}} = \dfrac{\sqrt{\sum_{n=2}^{\infty} I_n^2}}{|I_{n1}|}$

* $THD_v = \sqrt{\dfrac{V_0^2 - V_{01}^2}{V_{s1}^2}} = \dfrac{\sqrt{\sum_{n=2}^{\infty} V_n^2}}{|V_{n1}|}$



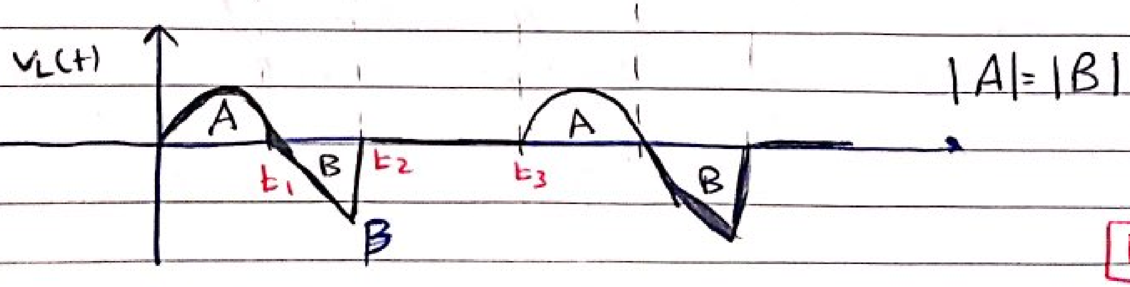
* HWR with R-L Load





Inductor بعكس voltage عشان يحافظ ع تيار.

$V_L = V_s - V_R$



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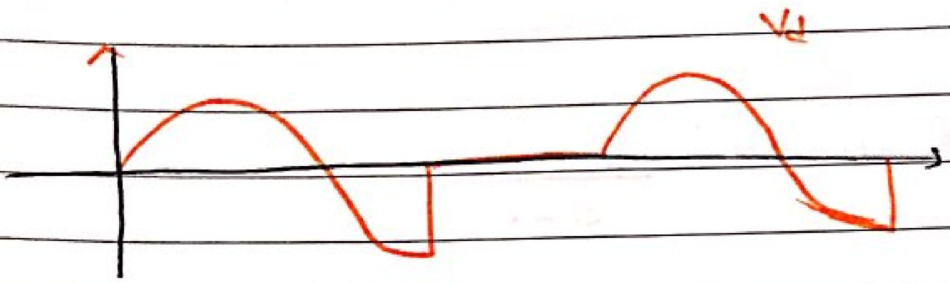
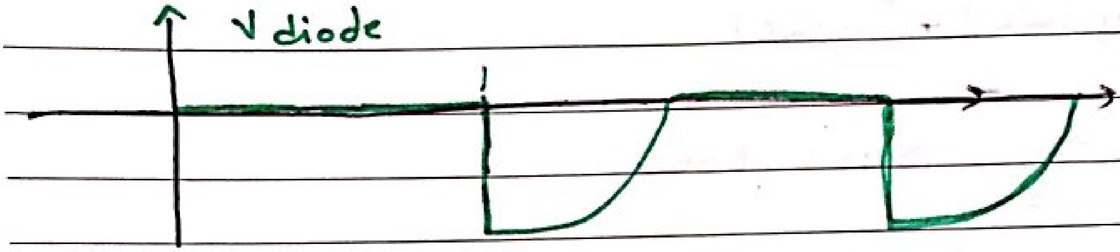




* Inductor will not change its current abrubtly it will change its polarity instantanesly when the diode is ON 8Δ

$$V_L(t) = V_S(t) + V_R(t)$$

$$V_L(t) = L \frac{di_L(t)}{dt}$$

" 0 mean initial ~~Contion~~ condition not zero."

$$i_L(t) = \frac{1}{L} \int_{\boxed{0}}^{\tau} v_L(\tau)\, d\tau.$$

* $\int_{\boxed{0}}^{\tau} \sin\omega t \quad = -\cos\omega t \Big]_0^{\tau} = \cos\omega t - 1$?!

$\boxed{0} \longrightarrow$ I.C

$$i_L(t) = \frac{1}{L} \int_0^{t_3} v_L(\tau)\, d\tau$$

$$= \underbrace{\frac{1}{L} \int_0^{t_1} v_L(\tau)\, d\tau}_{A} + \underbrace{\frac{1}{L} \int_{t_1}^{t_2} v_L(\tau)\, d\tau}_{B}$$

$|A| = |B|$

$\boxed{108}$

$V_m = \sqrt{2}\ V_{rms}$

$$V_m \sin(\omega t) = R\, i(\omega t) + L \frac{di(\omega t)}{d\omega t}$$

$$i(\omega t) = i_f(\omega t) + i_n(\omega t)$$

$$\Rightarrow i_f(\omega t) = \frac{V_m}{Z} \sin(\omega t - \theta)$$

$$\Rightarrow i_n(\omega t) = A e^{\frac{-\omega t}{\omega \tau}}$$

$$Z = \sqrt{R^2 + (\omega L)^2}$$

$$\boxed{\theta = \tan^{-1}\left(\frac{\omega L}{R}\right)} \qquad \boxed{\tau = \frac{L}{R}}$$

$$i(0) = 0 = \frac{V_m}{Z} \sin(-\theta) + A$$

$$\boxed{A = \frac{V_m}{Z} \sin\theta}$$

$$i(\omega t) = \frac{V_m}{Z}\left[\sin(\omega t - \theta) + \sin(\theta) e^{\frac{-\omega t}{\omega \tau}}\right]$$

$$i(\beta) = 0 = \frac{V_m}{Z}\left[\sin(\beta - \theta) + \sin(\theta) e^{-\beta/\omega\tau}\right]$$

$$\sin(\beta - \theta) + \sin(\theta) e^{-\beta/\omega\tau} = 0$$

$\theta = \pi/3,\ \omega = 2\pi f,\ \tau = 10^{-3}$

Solve $\left[\sin\left(X - \frac{\pi}{3}\right) + \sin\left(\frac{\pi}{3}\right) e^{-X/2\pi f \times 10^{-3}}\right] \Rightarrow X_{\text{initial}} = \beta = 225°$

$$i(\omega t) = \begin{cases} \frac{V_m}{Z} \sin(\omega t - \theta) + \sin\theta \, e^{\frac{-\omega t}{\omega \tau}}] , & 0 \leq \omega t \leq \beta \\ 0 , & \beta < \omega t < 2\pi \end{cases}$$

$$V_{d\,avg} = \frac{1}{2\pi} \int_0^\beta V_m \sin(\omega t) \cdot d\omega t = \frac{V_m}{2\pi} [1 - \cos(\beta)]$$

$$I_{o\,avg} = \frac{V_{o\,avg}}{\sqrt{R^2 + (\omega L)^2}} = \frac{V_m [1 - \cos\beta]}{2\pi \sqrt{R^2 + (\omega L)^2}}$$

$$= \frac{1}{2\pi} \int_0^\beta i(\omega t) \, d\omega t.$$

$$V_{rms} = \sqrt{\frac{1}{2\pi} \int_0^\beta V_m^2 \sin^2(\omega t) \, d\omega t}$$

$$= \sqrt{\frac{1}{2\pi} \int_0^\beta V_m^2 \left(\frac{1}{2} - \frac{1}{2} \cos(2\omega t) \, d\omega t\right.}$$

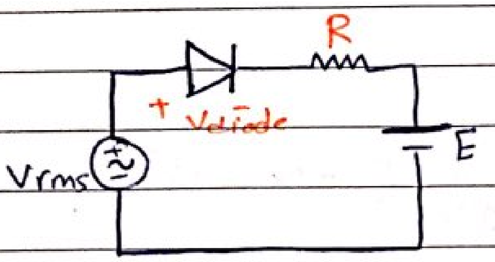
$$= \sqrt{\frac{V_m^2}{2\pi} \left[\frac{1}{2}\beta - \frac{1}{4} \sin 2\beta\right]}$$

$$= \frac{V_m}{2\sqrt{\pi}} \sqrt{\underbrace{\beta}_{\downarrow \text{ Radian}} - \frac{1}{2} \sin(2\beta)}$$

27/3 TUE

* HWR with E&Δ

↳ Battary



$-V_m \sin \omega t + V_{diode} + E = 0$

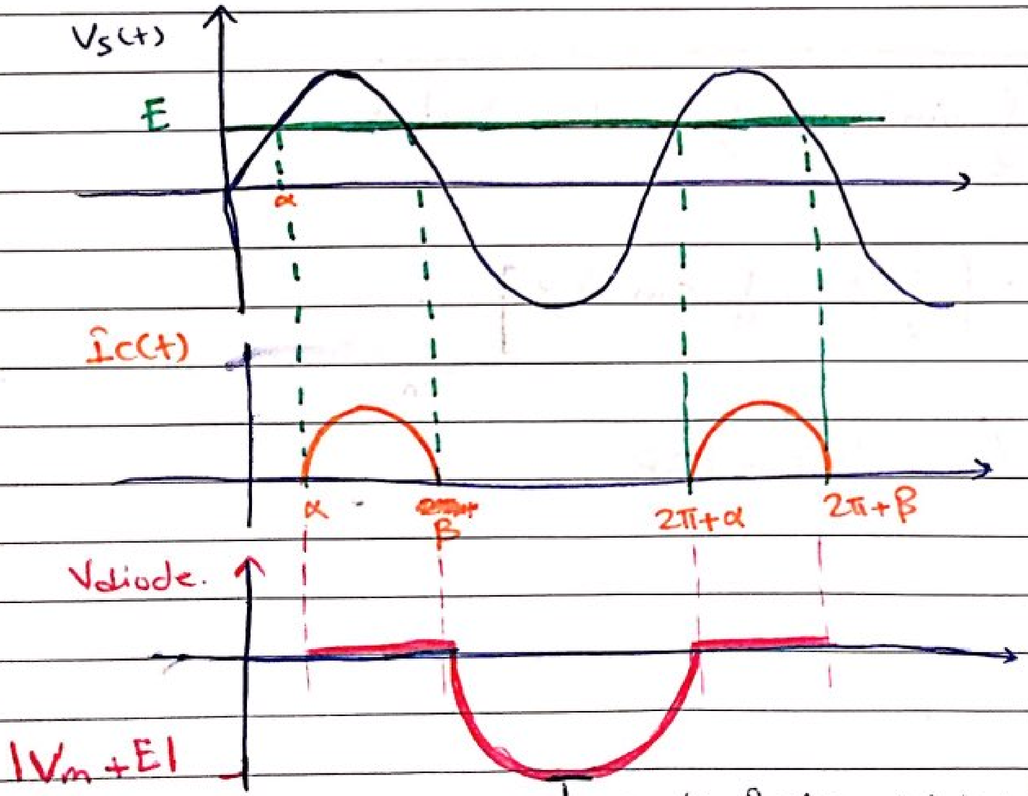
$V_{diode} = V_m \sin \omega t - E$

Charging a battary from AC source.

- The Diode works when $V_m \sin \alpha = E$

$\alpha = \sin^{-1}\left(\frac{E}{V_m}\right)$

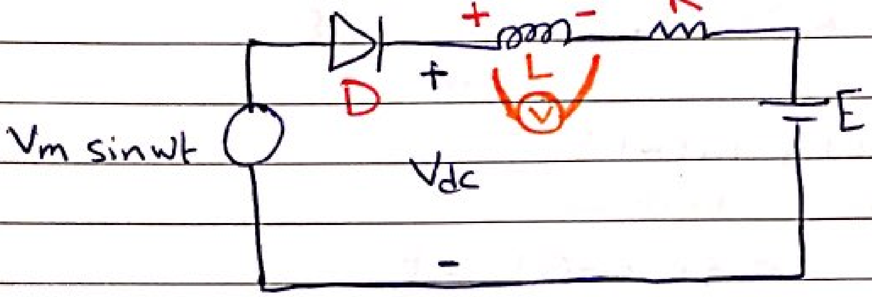
and turns off on $\boxed{\beta = \pi - \alpha}$



↳ peak inverse Value (PIV) = Vm+E

$$I_{o,peak} = \frac{V_m - E}{R}$$

* HWR with E and RL 8Δ



* التفريغ لن يكون الا عزاج ال inductor

* Two driving forces E / Vm

$$-V_m \sin wt + V_{diode} + E = 0$$

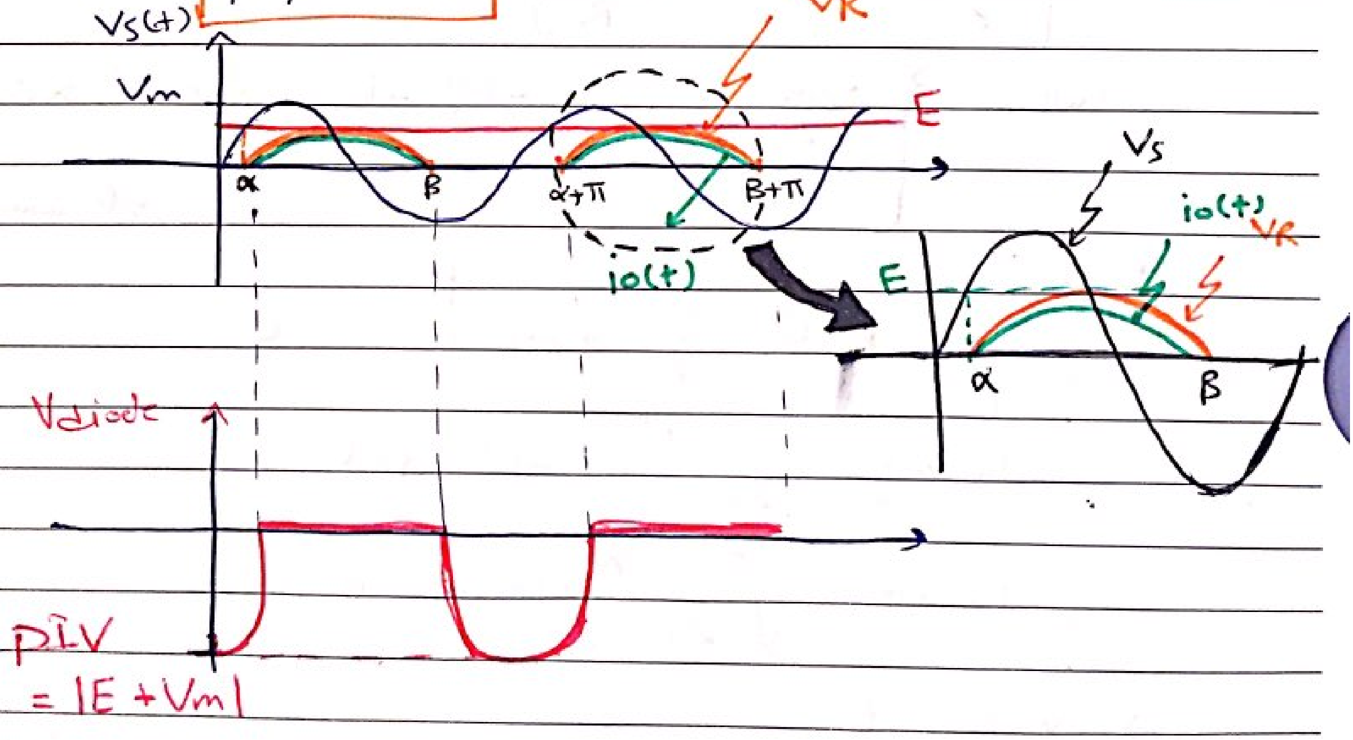
$$V_{diode} = V_m \sin wt - E.$$

* ما في تيار ، ـسـا ، صفر voltage ← $(V_{R,L} = 0)$

$$\alpha = \sin^{-1}\left(\frac{E}{V_m}\right)$$

$$i(\beta) = 0$$

$$\boxed{\beta \neq \pi - \alpha}$$



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$$V_{diode} = \begin{cases} 0 & \alpha \leq \omega t \leq \beta \\ V_m \sin \omega t - E & \text{elsewhere.} \end{cases}$$

* Applying KVL's .

$$V_m \sin(\omega t) = R\, i(\omega t) + L \frac{di(\omega t)}{d\,\omega t} + E$$

$$i(\omega t) = i_f(\omega t) + i_n(\omega t)$$

↳ Forced ↳ natural.

$$i_f(\omega t) = \frac{V_m}{Z} \sin(\omega t - \Theta) - \frac{E}{R}$$

$$i_n(\omega t) = A\, e^{-\frac{\omega t}{\omega \tau}}$$

$$\boxed{Z = \sqrt{R^2 + (\omega L)^2}} \quad \boxed{\Theta = \tan^{-1}\left(\frac{\omega L}{R}\right)} \quad \boxed{\tau = \frac{L}{R}}$$

Applaying initial condition :-

I.c $[i(\alpha) = 0]$

$$A = \left[\frac{V_m}{Z} \sin(-\alpha + \Theta) + \frac{E}{R}\right] e^{\alpha / \omega \tau}$$

$$i(\omega t) = \begin{cases} \frac{V_m}{2} \sin(\omega t - \Theta) - \frac{E}{R} + A\, e^{-\frac{\omega t}{\omega \tau}}, & \alpha \leq \omega t \leq \beta \\ 0 & \text{elsewhere} \end{cases}$$

$\beta \triangleq i(\beta) = 0$

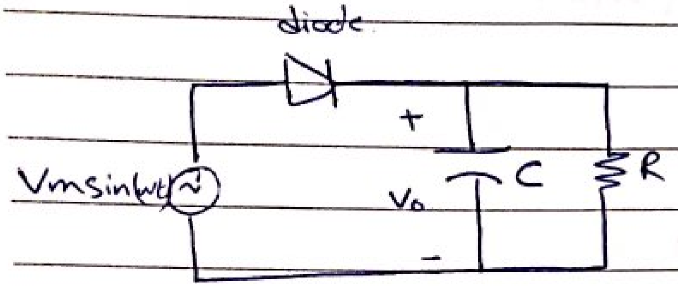
$$\frac{V_m}{2} \sin(\beta - \Theta) - \frac{E}{R} + A e^{-\frac{\beta}{\omega \tau}} = 0$$

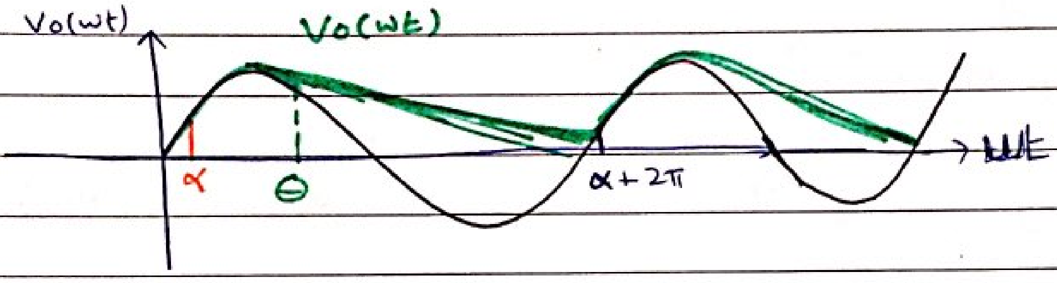
$$\boxed{\begin{aligned} I_{o\,avg} &= \frac{1}{2\pi} \int_{\alpha}^{\beta} i(\omega t)\; d\omega t \\ I_{o,rms} &= \sqrt{\frac{1}{2\pi} \int_{\alpha}^{\beta} i^2(\omega t)\; d\omega t} \end{aligned}}$$

تجاوز $\begin{cases} V_{o\,avg} = E \\ V_{o,rms} = E \end{cases}$

3/4 TUE

* HWR with RC Load:-





voltage across capacitor does not change abroutly (بتغير مفاجئ)

$\alpha \rightarrow$ 2curve. بيفترق منحنيا ال

$\theta \rightarrow$ 2curve. بيلتقي منحنيا ال

$$V_o(wt) = \begin{cases} V_m \sin(wt) & D \text{ is ON} \\ V_\theta \, e^{-(wt-\theta)/wRC} & D \text{ is OFF} \end{cases}$$

$$V_\theta = V(\theta) = V_m \sin(\theta)$$

$\hookrightarrow$ at $wt = \theta$

$$\frac{d}{dwt} V_m \sin wt = \frac{d}{dwt} V_\theta \, e^{-(wt-\theta)/wRC}$$

$$V_m \cos wt = V_m \sin\theta \left(\frac{-1}{wRC}\right) e^{-(wt-\theta)/wRC}$$

Scanned with CamScanner

$$V_m \cos\theta = V_m \sin\theta \left(\frac{-1}{WRC}\right) e^{-(\theta-\theta)/WRC}$$

$$\frac{1}{\tan\theta} = \frac{-1}{WRC}$$

$$\boxed{\begin{array}{l}\theta = \tan^{-1}(-WRC)\\ \theta = -\tan^{-1}(WRC)\end{array}}$$

$\rightarrow \theta > 90^\circ$

((الزاوية عا تطلع سالب بجمعلو π))

at $Wt = 2\pi + \alpha$

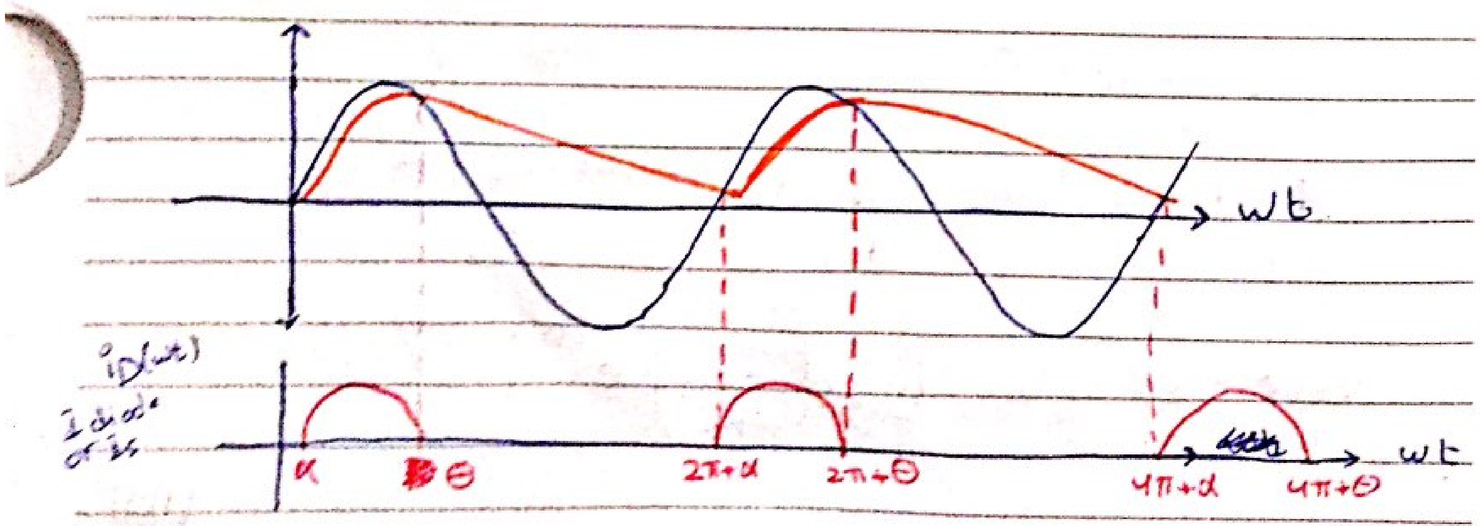
$$V_m \sin(2\pi+\alpha) = (V_m \sin\theta)\, e^{-(2\pi+\alpha)/WRC}$$

$$\sin\alpha - \underset{\uparrow}{\sin\theta}\, e^{-\underbrace{(2\pi+\alpha-\theta)}_{\text{radian}}/WRC} = 0$$

radian/degree ← الافضل ز rad

in exponential the θ in radian.

$V_o > V_{in}$ → diode R.B



$$i_c(\omega t) = C\,\frac{dV_c(t)}{dt} = \omega C\,\frac{d\,V_c(\omega t)}{d\omega t}$$

$$i_c(\omega t = \begin{cases} \omega C\, V_m \cos(\omega t) & D \text{ is ON} \quad \alpha < \omega t \le \theta \\ \dfrac{-V_m \sin\theta}{R}\, e^{-(\omega t-\theta)/\omega RC} & D \text{ is OFF} \quad \text{otherwise} \end{cases}$$

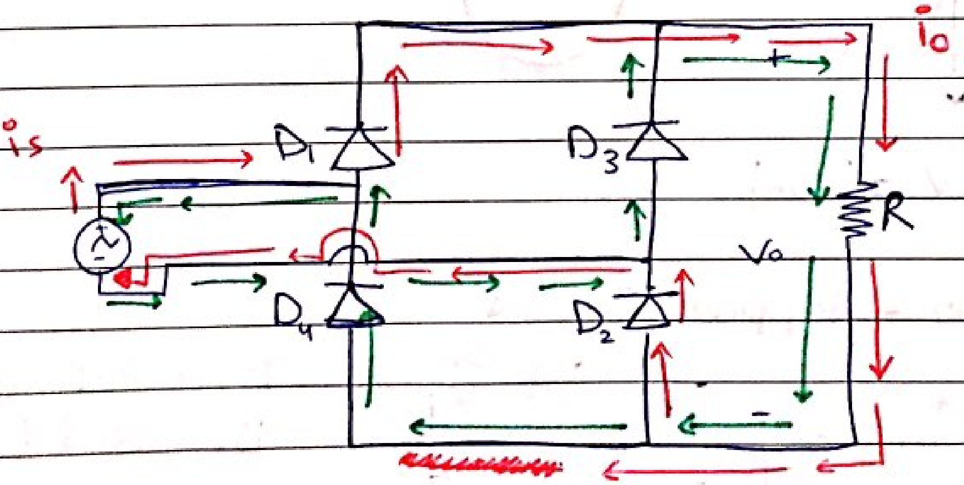
$$i_s(\omega t) = i_D(\omega t) = i_c(\omega t) + i_R(\omega t)$$

$$\boxed{I_{s\,avg} = I_{D\,avg} = I_{R\,avg}}$$

* $V_{o\,avg} = \int_{\alpha}^{\theta} \quad + \int_{\alpha}^{2\pi+\alpha}$

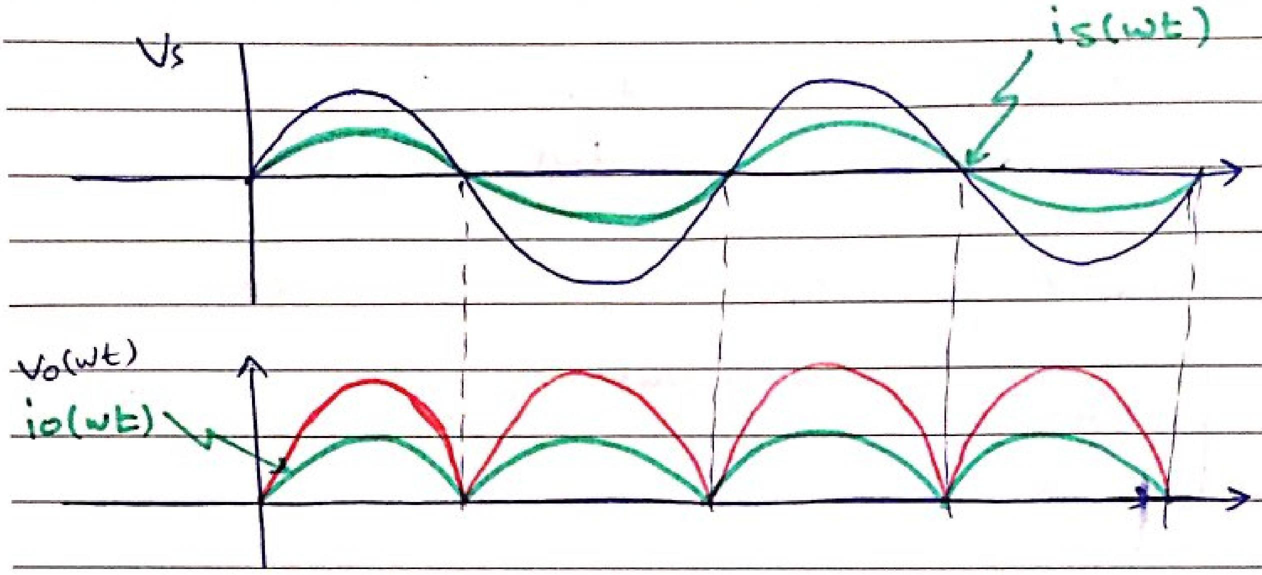
* $I_{o\,avg} = \dfrac{V_{o\,avg}}{R}$

* FWR with R-Load 8Δ

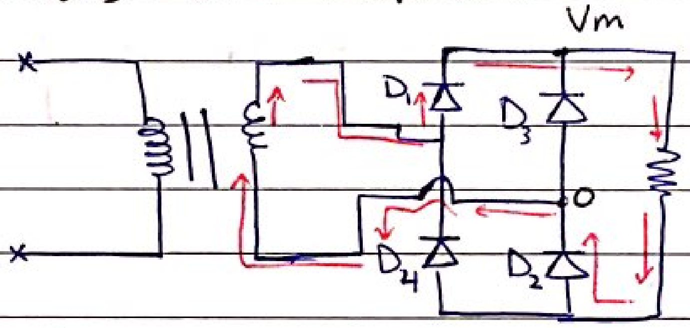


\+ +ve cycle

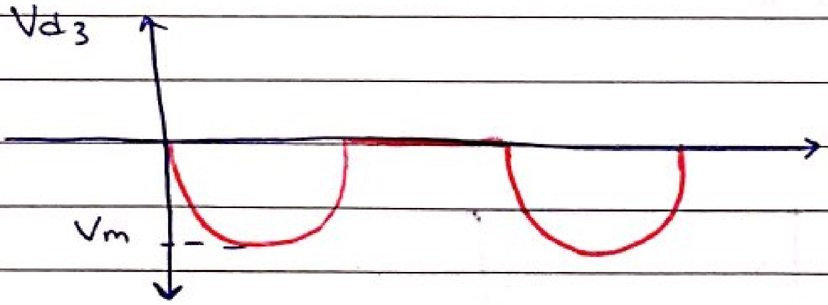
-ve cycle



2 approaches For FWR 8Δ

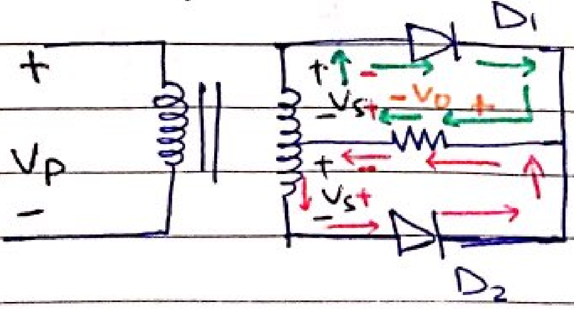


FW bridge Rectifier.



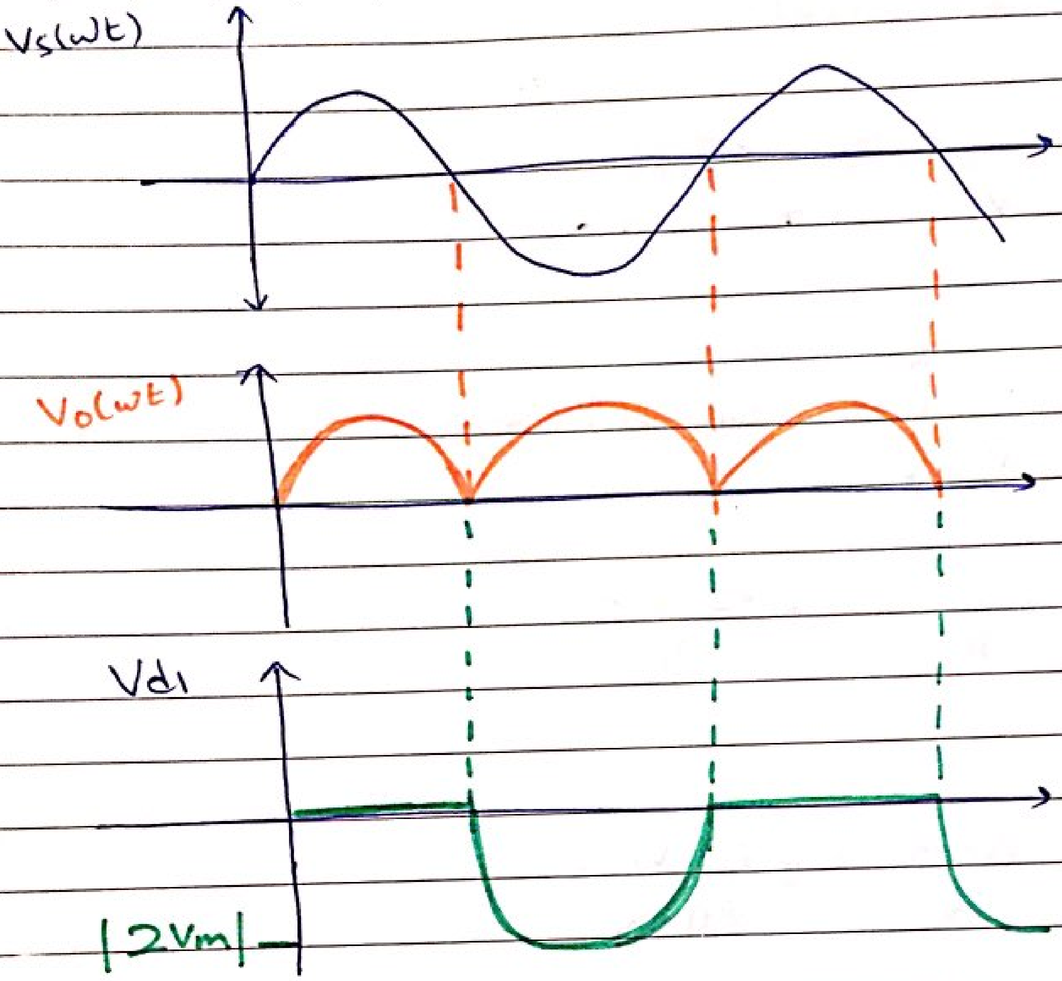
$PIV = |V_m|$

* Center - tapped TR 8Δ



D2 → R.B (+ve cycle)

D1 → R.B (-ve half cycle)



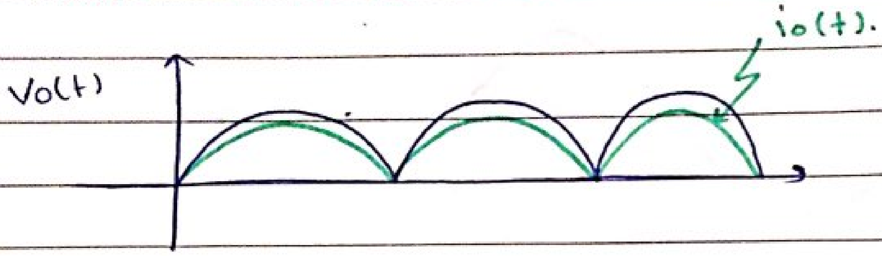
$V_o + V_s + V_d = 0$

$V_d = V_o - V_s$

$V_d = -2V_o = |2V_o|$

5/4 Thu

FWR with R Loads:-



$$V_{o\,avg} = \frac{1}{\pi}\int_0^{\pi} V_m \sin(\omega t)\, d\omega t.$$

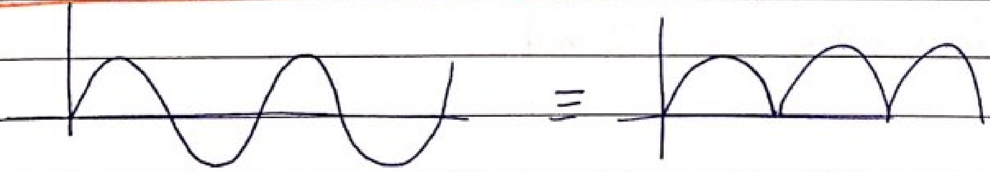
$$= \frac{2V_m}{\pi} = \frac{2\sqrt{2}\, V_{rms}}{\pi}$$

V_m = peak value.

$$I_{o\,avg} = \frac{V_{o\,avg}}{R} = \frac{2\sqrt{2}\, V_{rms}}{\pi R}$$

$$V_{rms} = \sqrt{\frac{1}{\pi}\int_0^{\pi} V_m \sin^2(\omega t)\, d\omega t}.$$

$$\boxed{V_{rms} = \frac{V_m}{\sqrt{2}} = V_{rms}.}$$



للرسمتين الـ Vrms نفسها اذا الهم نفس peak.

$$\boxed{I_{rms(o)} = \frac{V_{rms}}{R} = \frac{V_m}{\sqrt{2}\, R}.}$$

* Study the Performence Parameter :-

$\boxed{1}$ $\eta = \frac{P_{DC(o)}}{P_{AC(o)}}$

$$\eta = \frac{V_{oavg} \cdot I_{oavg}}{V_{orms}\ I_{o\,rms}} = \frac{\frac{2\cancel{V_m}}{\pi} * \frac{2\cancel{V_m}}{\pi \cancel{R}}}{\frac{\cancel{V_m}}{\sqrt{2}} * \frac{\cancel{V_m}}{\cancel{R}\sqrt{2}}} = \frac{8}{\pi^2} = 81.2\%$$

$\boxed{2}$ $FF = \frac{V_{rms\,(o)}}{V_{o\,avg}}$

$$= \frac{V_m/\sqrt{2}}{2V_m/\pi} = 1.11$$

$\boxed{3}$ $RF \ \sqrt{FF^2 - 1} = 0.483.$

$\boxed{4}$ $pF = \frac{V_{rmso} * I_{rmso}}{V_{rms\,in} * I_{rms\,in}} = 1$

$\boxed{Ex}$ Finding FoS of output voltage for FWR ?!

$$V_o(t) = V_{DC} + \sum_{n=1}^{\infty} a_n \cos n\omega t + b_n \sin n\omega t.$$

$$V_{dc} = V_{oavg} = \frac{2V_m}{\pi} = \frac{1}{\pi}\int_0^{\pi} V_m \sin \omega t \, d\omega t.$$

$$a_n = \frac{1}{\pi}\int_0^{2\pi} V_o \cos n\omega t \, d\omega t$$

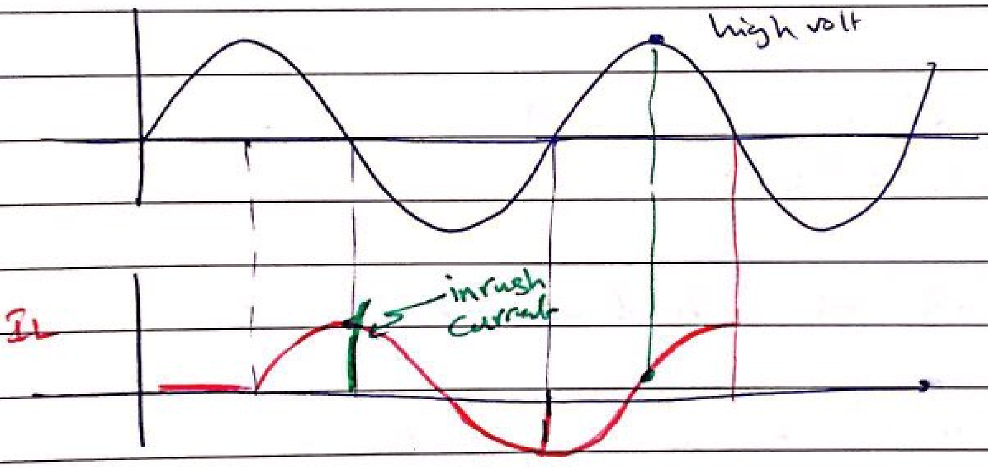
$$= \frac{2}{\pi}\int_0^{\pi} V_m \sin \omega t \cos \omega t \, d\omega t$$

$$\Rightarrow a_n = \begin{cases} \frac{4V_m}{\pi} \sum_{n=2,4,6}^{\infty} \frac{-1}{(n-1)(n+1)} & , n = 2,4,6 \\ 0 & , n = 1,3,5 \end{cases}$$

$$\Rightarrow b_n = \frac{1}{\pi}\int_0^{2\pi} V_o \sin n\omega t \; d\omega t.$$

$$\frac{2}{\pi}\int_0^{\pi} V_m \sin n\omega t \sin n\omega t \; d\omega t = 0$$

$$V_o(t) = \frac{2V_m}{\pi} - \frac{4V_m}{3\pi}\cos 2\omega t - \frac{4V_m}{15\pi}\cos 4\omega t + \cdots$$

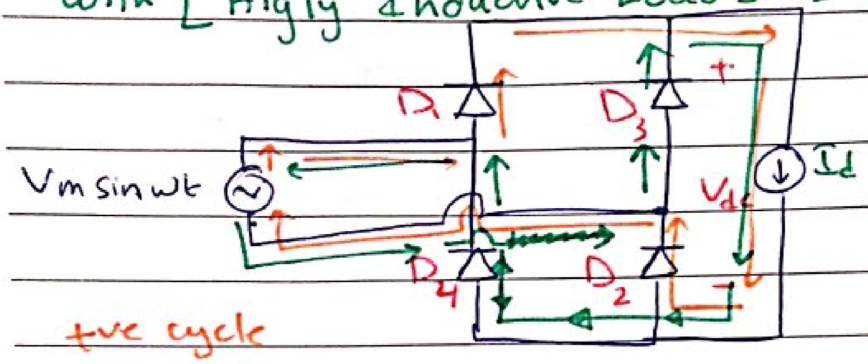


* Inrush current = Ac + Dc.
at point → high volt and Low current that's no inrush current.

→ Inrush current have second harmonic.

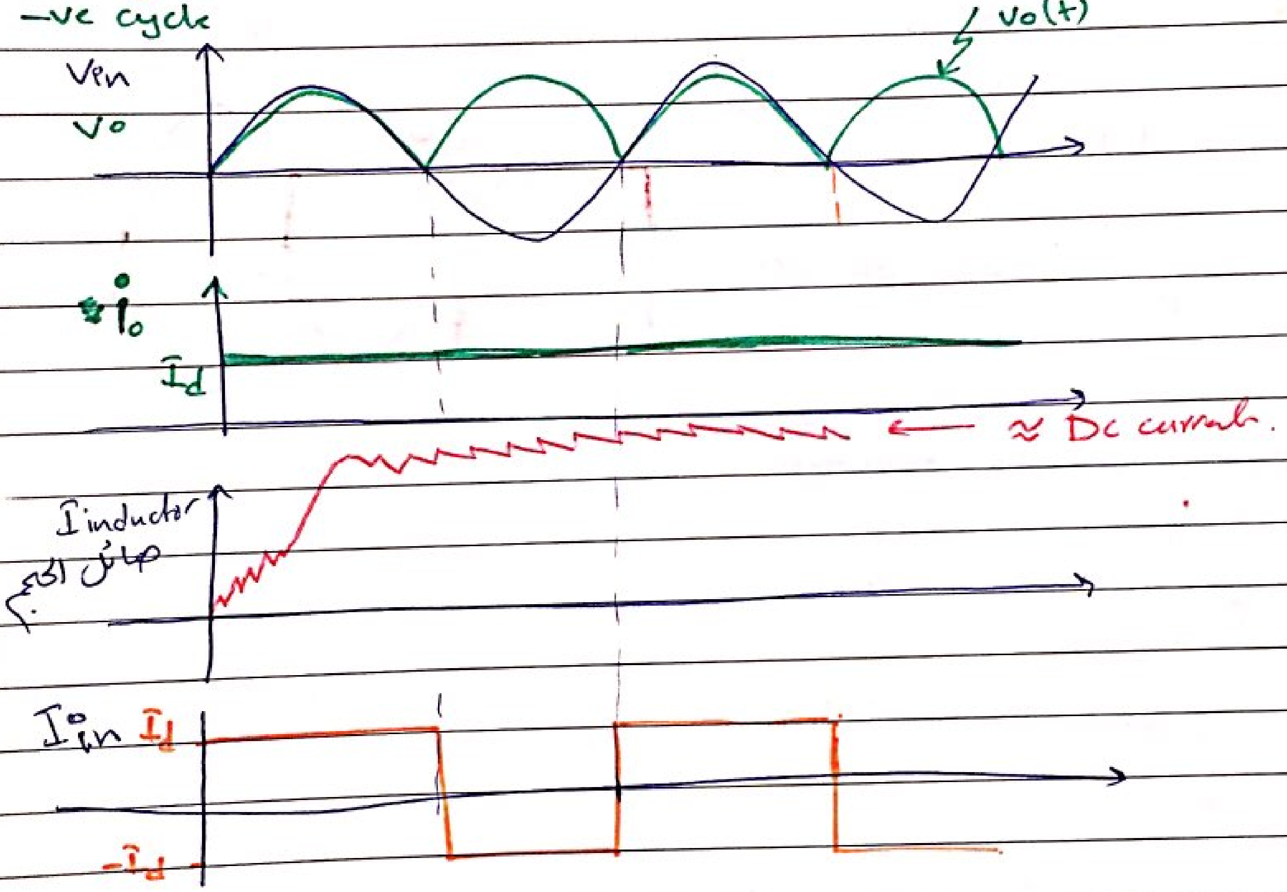
FWR with constant current Load :Δ

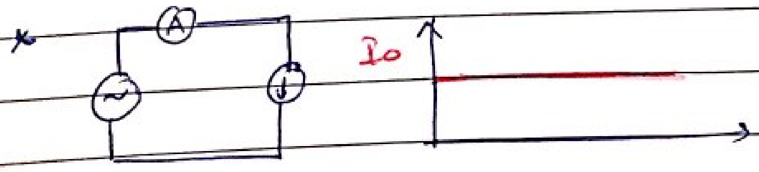
with [Higly Inductive Load] ≡ constant current.



* تيار ما بينقطع عن ال Load

+ve cycle
-ve cycle

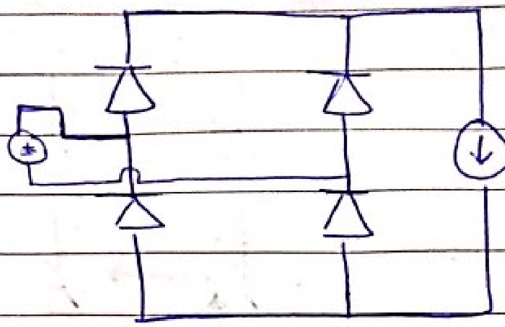




(بتحكم Load
تيار)

8/M SUN

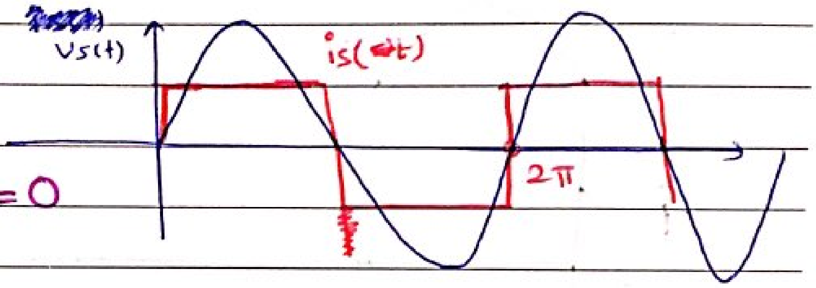
In practice, the source current can not be 100% constant (rect) and the source will supply the sum of fourier series of current.



$$i_s(t) = I_{dc} + \sum_{n=1}^{\infty} a_n \cos(n\omega t) + b_n \sin(n\omega t)$$

$$\frac{a_0}{2} = \hat{I}_d$$

$$= \frac{1}{2\pi}\int_0^{2\pi} i_s(\omega t)\, d\omega t = 0$$



$\boxed{a_n = 0}$ ⇒ odd function

$$b_n = \frac{2}{\pi}\int_0^{\pi} I_d \sin(n\omega t)\, d\omega t.$$

$$\boxed{b_n = \frac{4 I_d}{n\pi} \quad \text{for } n = 1, 3, 5, \ldots}$$

$$i_s(t) = \frac{4 \hat{I}_d}{\pi}\left(\sin(\omega t) + \sin\left(\frac{3\omega t}{3}\right) + \sin\left(\frac{5\omega t}{5}\right) + \ldots\right)$$

$$I_{s_1} = \frac{4 \hat{I}_d}{\pi} \sin\omega t$$

source PF ≜

btween Vs and I_{s_1}

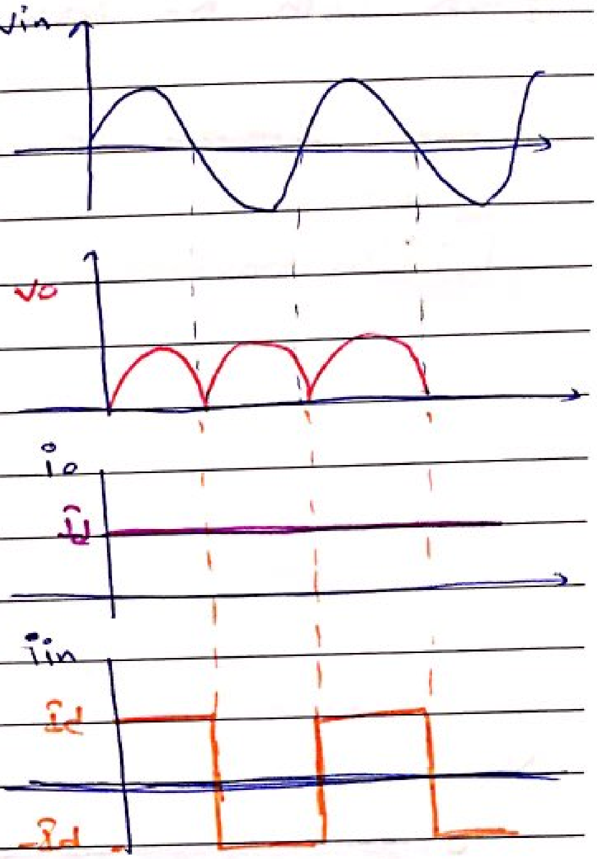
$$p = \frac{P}{S} = \frac{V_s \hat{I}_{s_1} \cos\theta}{V_s \hat{I}_s}$$

conventional PF (Displacment PF)

$$= \frac{\hat{I}_{s_1}}{I_s} \cos\Theta$$

$$\boxed{P = \frac{\hat{I}_{s1}}{\hat{I}_s} \; DPF}$$

اذا كان عندي hermenic
بستخدم هذا القانون



$$\hat{I}_{s1,rms} = \frac{4\,\hat{I}_d}{\pi\sqrt{2}} = 0.9\,\hat{I}_d$$

$$V_{o\,avg} = \frac{2V_m}{\pi}$$

$$V_{rms\,(in)} = \frac{V_m}{\sqrt{2}}$$

$$\hat{I}_{o\,rms} = \hat{I}_{o\,avg} = \hat{I}_d$$

$$P_{o\,avg} = \frac{2V_m}{\pi} * \hat{I}_d$$

$$P_{in\,avg} = \frac{V_m}{\sqrt{2}} * \frac{4\,\hat{I}_d}{\sqrt{2}\,\pi}$$

$$= \frac{2V_m}{\pi}\,\hat{I}_d = P_{o\,avg} \; [P_{in} = P_{oa}] \text{ No Phase Shift}$$

$$PF = \frac{I_{s1,rms}}{I_{s\,rms}} \cdot DPF$$

$$= \frac{4\,\hat{I}_d/\sqrt{2}\pi}{\hat{I}_d} \cdot 1$$

$$= 0.9$$

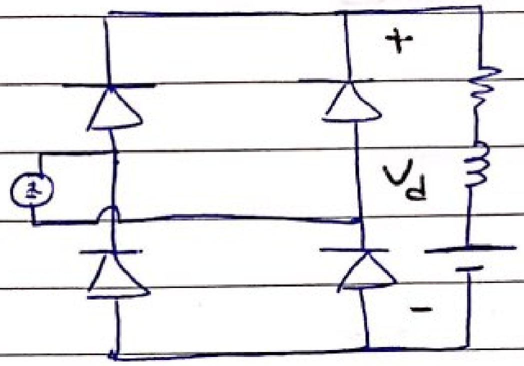
* حساب PF و P بـ rms value

* الـ ind بعمل ازاحة بالـ rect
فما بتطلع DPF =1 .

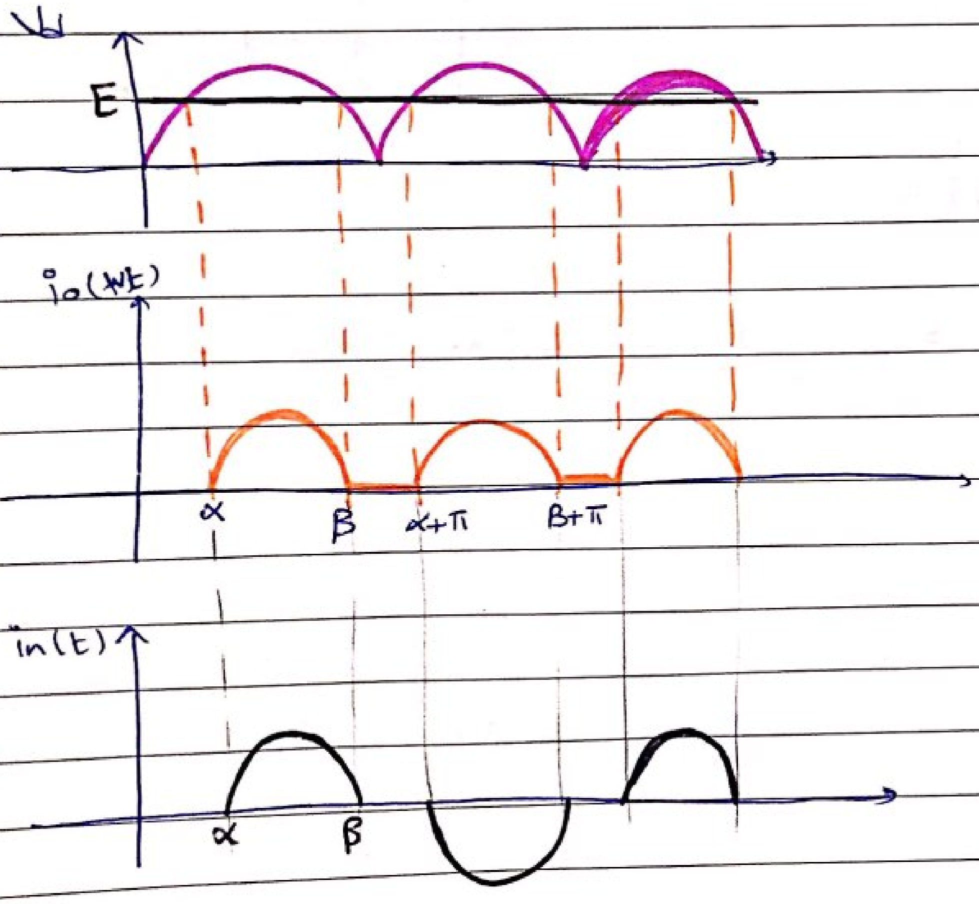
FWR with RL load with E &Δ

I have 2 modes of operations

1. continous
2. Dis continous.

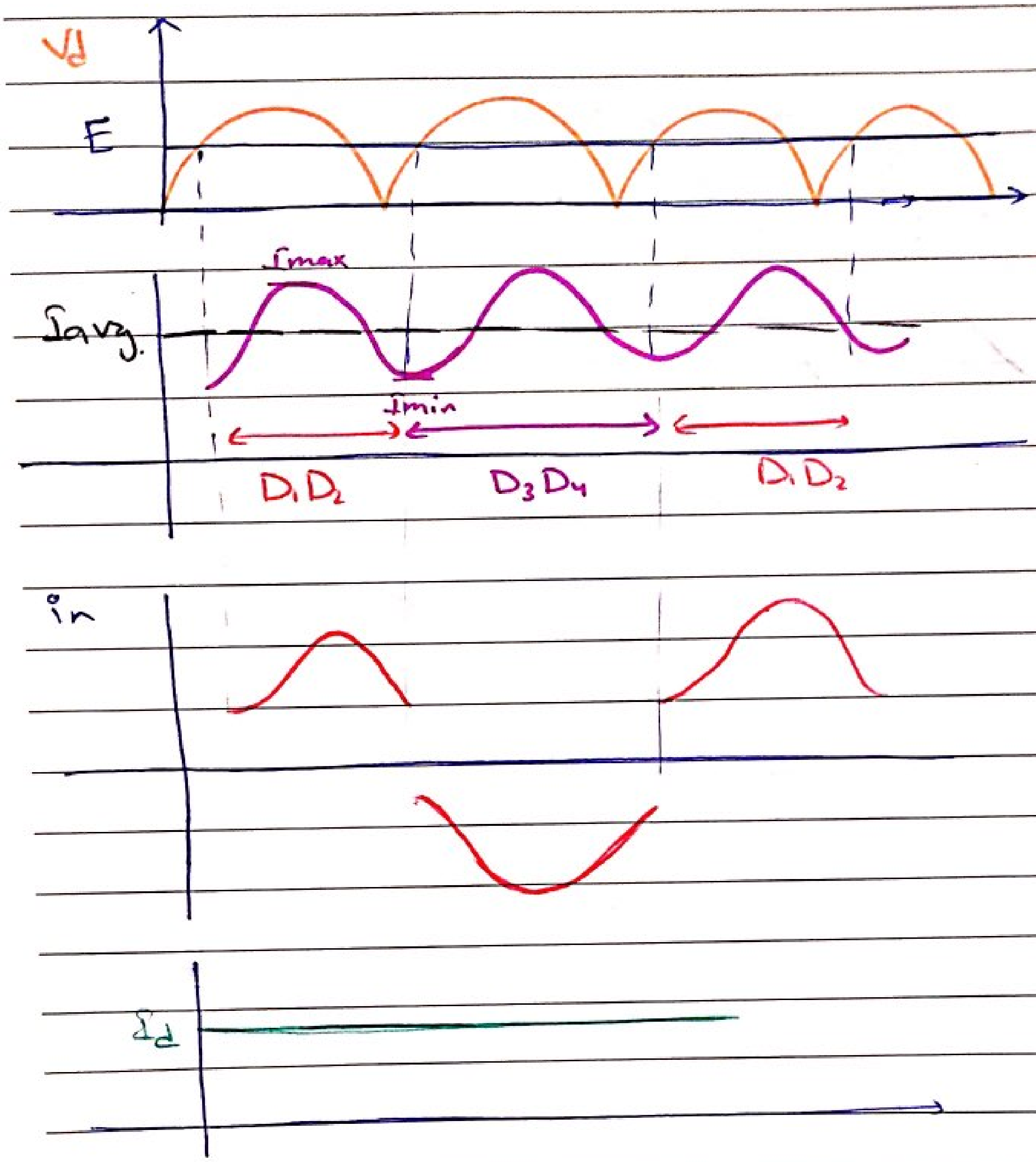


Dis continous :-

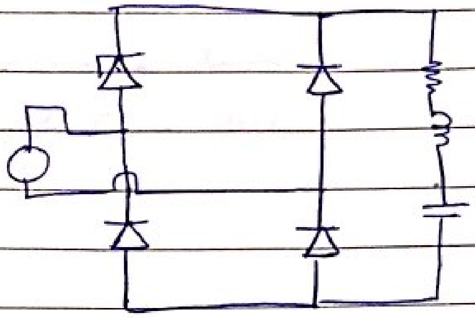


β ⇒ القيم إلي بصير
عندها تيار =0 .

* CONTINOUS 8Δ

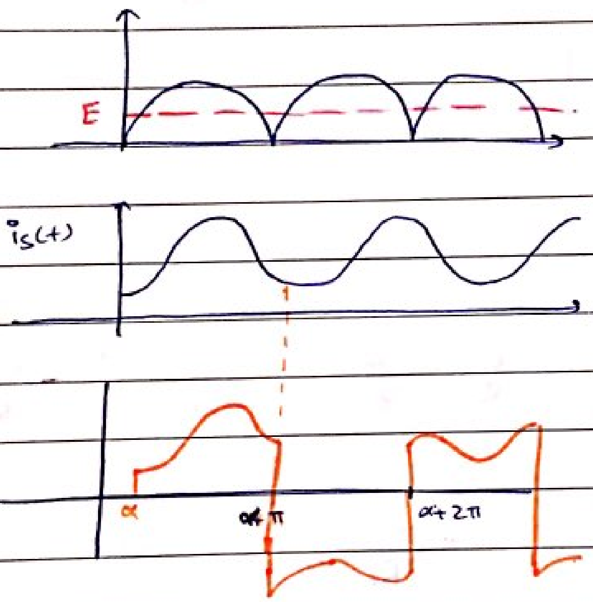


10/4 TUE



علشان ما فرغ ما حوصل لل next cycle.

عشانه صار باخذ ب FWR ⌐ contin / discont.



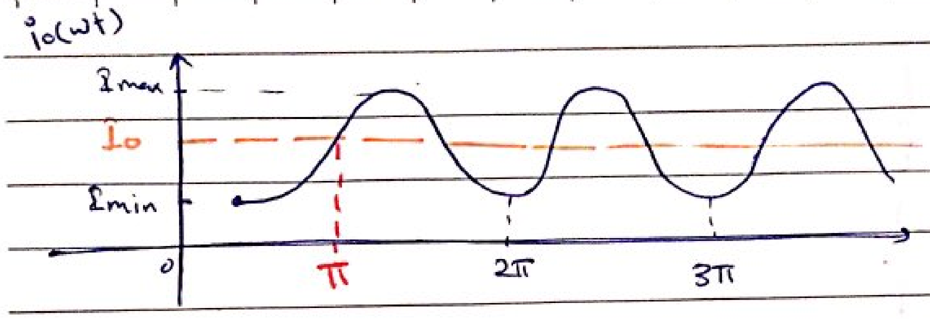
Continous Mode.

$$L\frac{di_o(\omega t)}{d\omega t}+R\,i_o(\omega t)+E=|V_m\sin\omega t|$$

$$i_o(t)=\left|\frac{V_m}{Z}\sin(\omega t-\theta)\right|+A_1e^{\frac{-\omega t}{\omega\tau}}-\frac{E}{R}$$

$$Z=\sqrt{R^2+(\omega L)^2}\qquad \theta=\tan^{-1}\left(\frac{\omega L}{R}\right)\qquad \tau=\frac{L}{R}$$

127



بيكرر نفسها Signal

كل π ← FWR

· at $\omega t = \pi \longrightarrow i_o(\omega t) = I_o$

$$i_o(\pi) = I_o = \left| \frac{V_m}{Z} \sin(\pi - \theta) \right| + A_1 e^{-\pi/\omega\tau} - \frac{E}{R}$$

$$\boxed{A_1 = \left[I_o + \frac{E}{R} - \frac{V_m}{Z} \sin\theta \right]}$$

$i_o(2\pi) = I_o$

$i_o(\theta) = I_o$

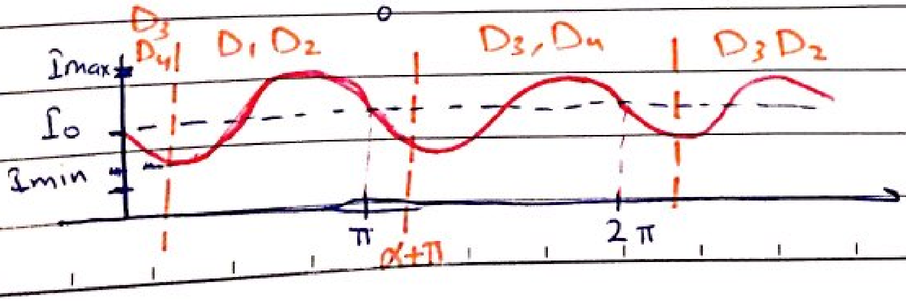
$$= \left| \frac{V_m}{Z} \sin(-\theta) \right| + \left[I_o + \frac{E}{R} - \frac{V_m}{Z} \sin\theta \right] e^{-\pi/\omega\tau} - \frac{E}{R}$$

$$I_o = \frac{V_m}{Z} \sin\theta \, \frac{1 + e^{-\frac{\pi}{\omega\tau}}}{1 - e^{-\frac{\pi}{\omega\tau}}} - \frac{E}{R}$$

$$\boxed{i_o(\omega t) = \frac{V_m}{Z} \left[\sin(\omega t - \theta) + \frac{2}{1 - e^{-\pi/\omega\tau}} \sin\theta \, e^{\frac{-\omega t}{\omega\tau}} \right] - \frac{E}{R}}$$

for $0 \leq \omega t - \theta \leq \pi$

$$I_{o\,avg} = \frac{1}{\pi} \int_0^{\pi} i_o(\omega t) \, d\omega t$$

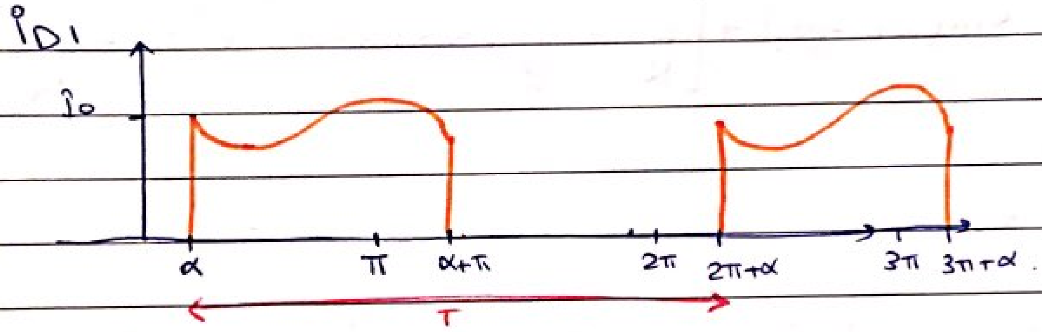


$i_o(\omega t) = 5\sin(\omega t) + 3e^{-\frac{\omega t}{0.005}} - 5$

↳ $I_{o\,avg} \neq 5$

$I_{o\,avg} = \frac{1}{\pi}\int_0^{\pi} 5\sin \cdots$

➡ $I_{D\,avg} = \frac{1}{2\pi}\int_0^{\pi} i_o(\omega t)\, d\omega t.$



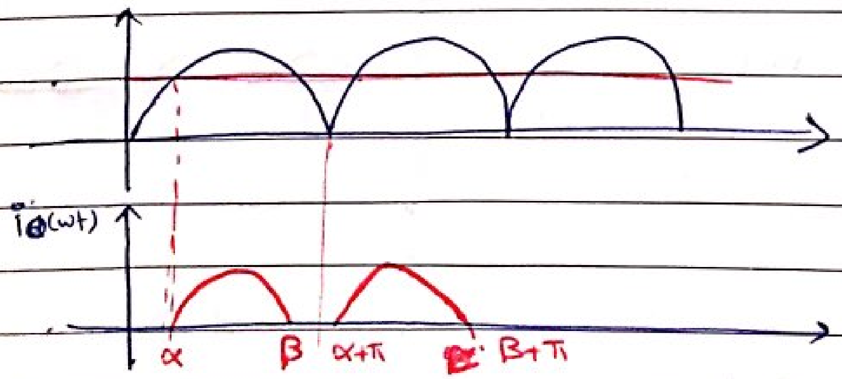
average = area

➡ $I_{D\,rms} = \sqrt{\frac{1}{2\pi}\int_0^{\pi} i_D^2(\omega t)\, d\omega t}.$

↓
1 2 3 4

➡ $I_{o\,rms} = \sqrt{I_{D1\,rms}^2 + I_{D3\,rms}^2} = \sqrt{2}\; I_{D\,rms}.$

Dis continous MODE 8Δ



$i_o(\omega t = \alpha) = 0$

$$0 = \frac{V_m}{Z} \sin(\alpha - \theta) + A e^{\frac{-\alpha}{\omega \tau}} - \frac{E}{R}$$

$$\boxed{A = \left[\frac{E}{R} - \frac{V_m}{Z} \sin(\alpha - \theta)\right] e^{\frac{\alpha}{\omega \tau}}}$$

$$\boxed{i_o(\omega t) = \frac{V_m}{Z} \sin(\omega t - \theta) + \left[\frac{E}{R} - \frac{V_m}{Z} \sin(\alpha - \theta)\right] e^{\frac{\alpha}{\omega \tau}} - \frac{E}{R}}$$

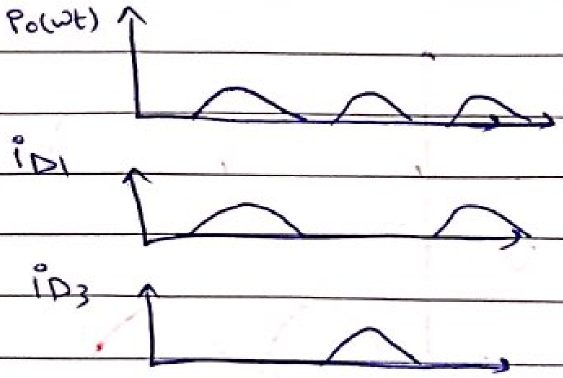
$i_o(\omega t = \beta) = 0$.

$$\frac{V_m}{Z} \sin(\beta - \theta) + \left[\frac{E}{R} - \frac{V_m}{Z} \sin(\alpha - \theta)\right] e^{\frac{\alpha - \beta}{\omega \tau}} - \frac{E}{R} = 0$$

β is defined as δ∆

$$\sin(\beta - \theta) + \left[\frac{E}{V_m \cos\theta} - \sin(\alpha - \theta)\right] e^{\frac{\alpha - \beta}{\omega \tau}} - \frac{E}{V_m \cos\theta} = 0$$

$$\boxed{\cos\theta = \frac{R}{Z}}$$



* $\boxed{I_{D\,avg} = \frac{1}{2\pi} \int_{\alpha}^{\beta} i_o(\omega t)\, d\omega t}$

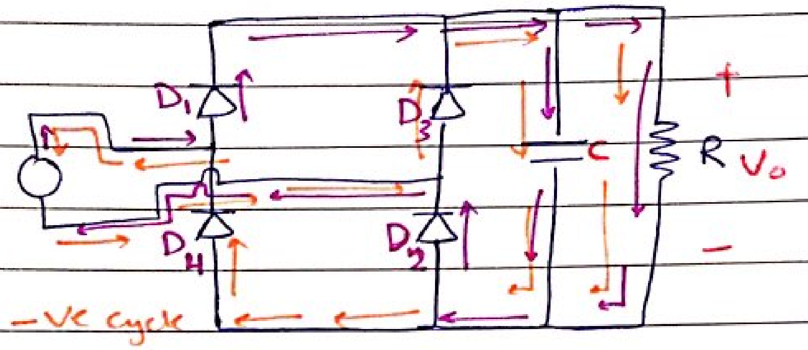
* $\boxed{I_{o\,avg} = 2 * I_{D\,avg}}$.

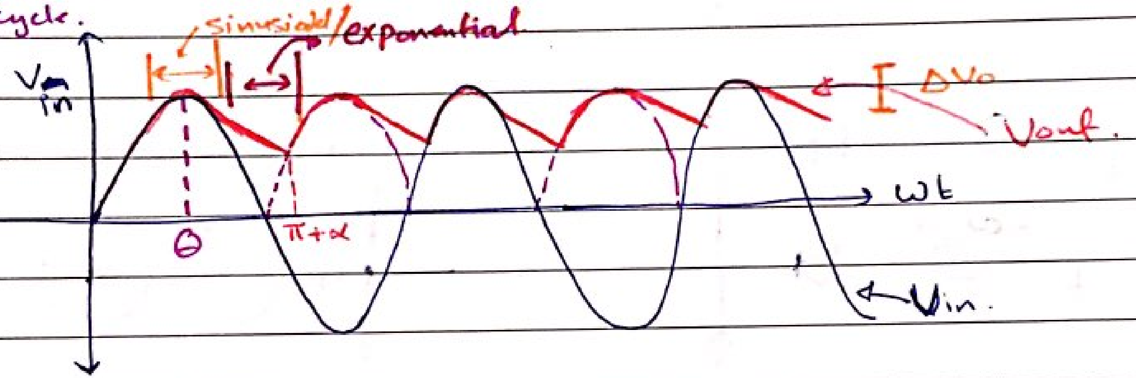
* $\boxed{I_{D\,rms} = \sqrt{\frac{1}{2\pi} \int_{\alpha}^{\beta} i_o^2(\omega t)\, d\omega t}}$

* $\boxed{I_{o\,rms} = \sqrt{2}\, I_{D\,rms}}$.

12/4 ThU

* FWR with an output capacitor 8Δ





$$\Delta V_o = V_m - |V_m \sin(\pi+\alpha)|$$
$$= V_m(1 - \sin\alpha)$$

$$V_o(\omega t) = \begin{cases} |V_m \sin \omega t| & \pi+\alpha \leq \omega t \leq \pi+\theta \\ V_m \sin\theta \; e^{-\frac{(\omega t-\theta)}{\omega RC}} & \theta \leq \omega t \leq \pi+\alpha \end{cases}$$

$\theta = \tan^{-1}(-\omega RC)$

$= \pi - \tan^{-1}(\omega RC)$ {by equating the derevaties}

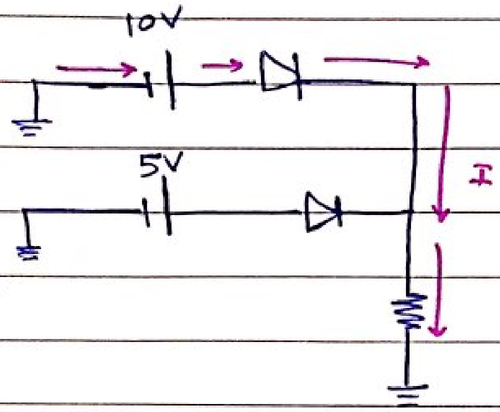
* HOW to Find α?

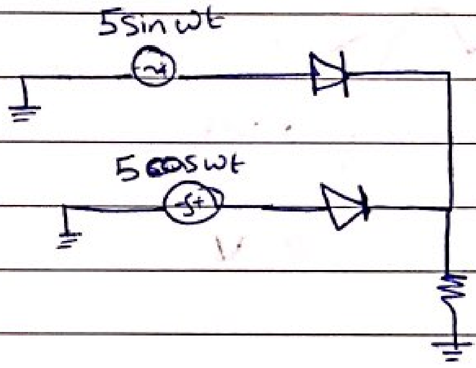
$$|V_m \sin(\alpha+\pi)| = V_m \sin\theta \; e^{-\frac{(\pi+\alpha-\theta)}{\omega RC}}$$

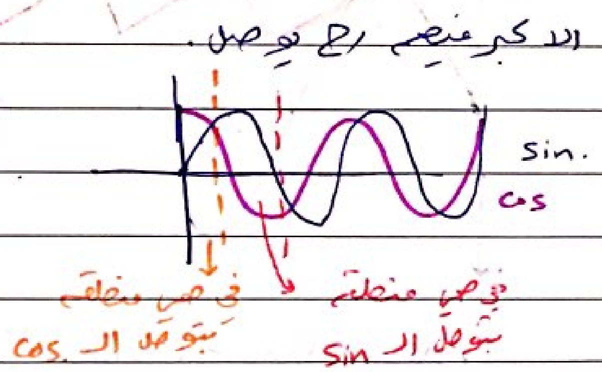
$$\sin\theta \, e^{-\frac{(\pi+\alpha-\theta)}{\omega RC}} - \sin\alpha = 0$$

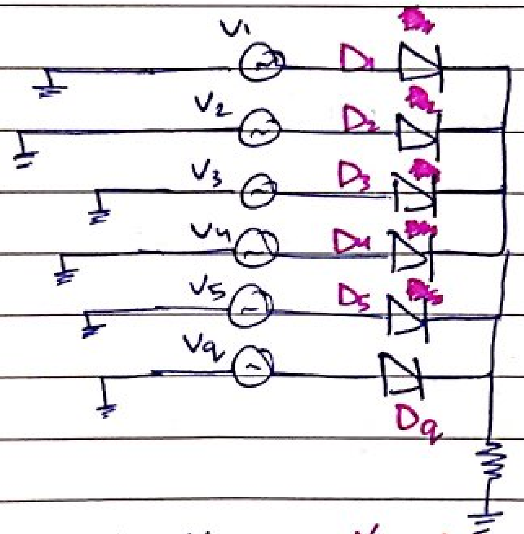
initial value of $\alpha = 200°$

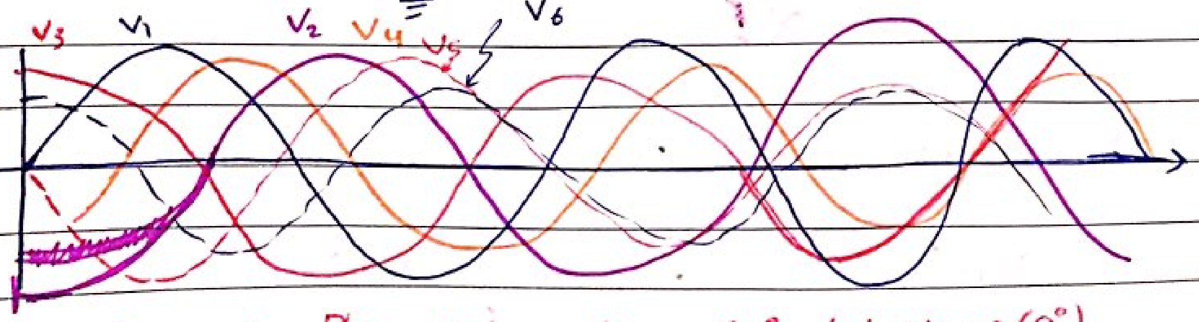
* Multi-phase Diode Rectefication 81



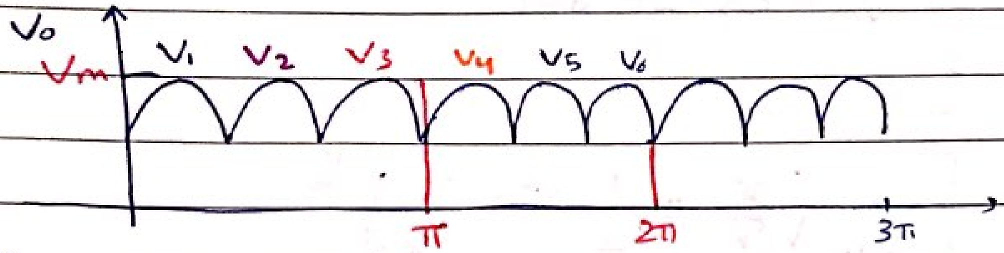




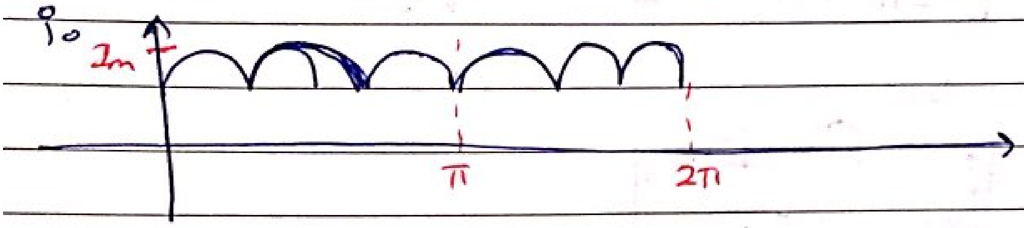




6 signal Phase between them 60° (V1, V2 → 60°)

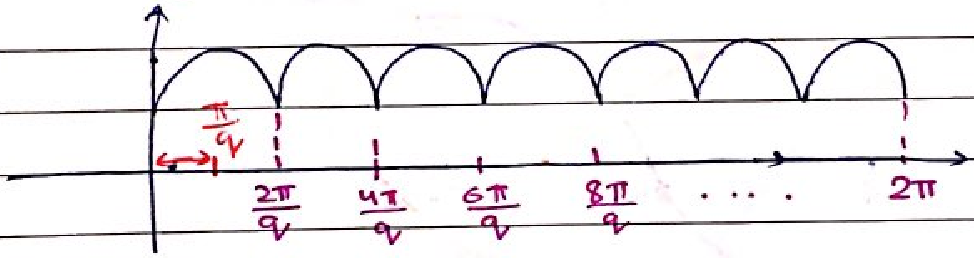


عدد قمم ب
عدد ال q

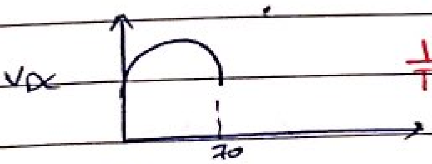


$$\boxed{I_m = \frac{V_m}{R}}$$

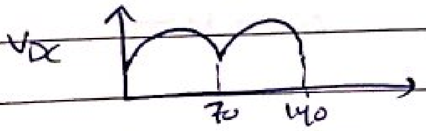
IN GENERAL



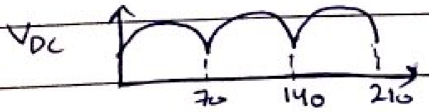
$$V_{DC} = \frac{1}{\pi/q}\int_0^{\pi/q} V_m \cos \omega t = V_m \frac{q}{\pi} \sin \frac{\pi}{q}.$$



$\frac{1}{T}\int_0^{70} v(\omega t)\, d\omega t$ $\boxed{V_{DC} \text{ value the same}}$



$\frac{1}{2T}\left[\int_0^{70} v(\omega t)\, d\omega t + \int_{70}^{140} v(\omega t)\, d\omega t\right.$



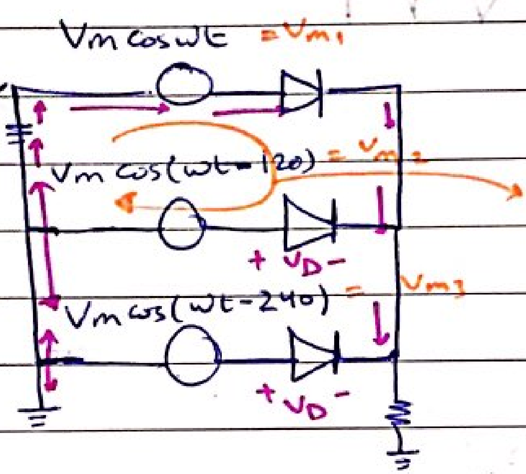
$\frac{1}{3T}$ . . .

$$\boxed{\text{OUR assumption} \quad V_1 = V_m \cos \omega t}$$

$$V_{rms} = \sqrt{\frac{q}{\pi}\int_0^{\pi/q} V_m^2 \cos^2\omega t \, d\omega t}$$

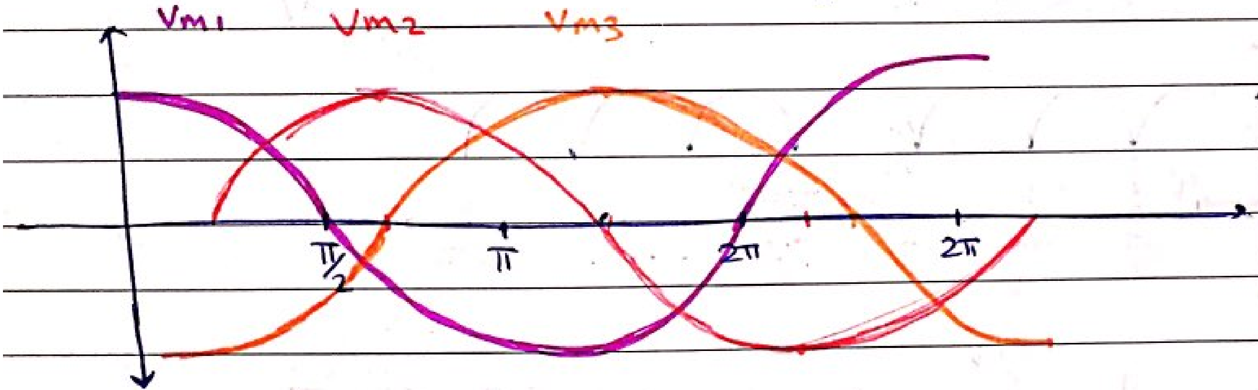
$$\boxed{V_{rms} = V_m \left[\frac{q}{2\pi}\left(\frac{\pi}{q} + \frac{1}{2}\sin\frac{2\pi}{q}\right)\right]^{1/2}}$$

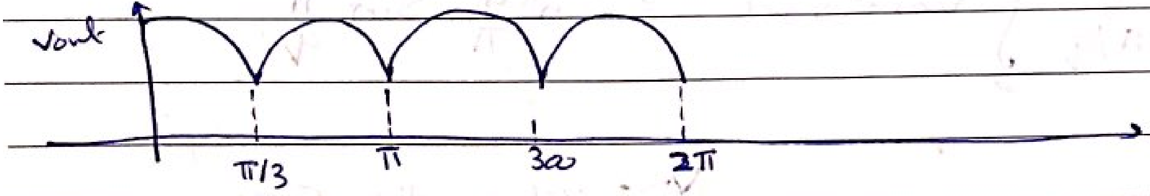
$\Rightarrow \boxed{q = 3}$



$V_D + V_{an} - V_{bn} = 0$

$V_D = |V_{ab}|$





$$V_{DC} = \frac{1}{\pi/3}\int_0^{\pi/3} V_m \cos\omega t \, d\omega t.$$

$$= \frac{1}{2\pi/3}\int_{\pi/3}^{\pi} V_m \cos(\omega t - 120^\circ)\, d\omega t$$

Vm1 , Vm2
تساوي عند 60°

$$\boxed{V_{DC} = \frac{3V_m \sin\frac{\pi}{3}}{\pi} = 0.827\,V_m}$$

$$\boxed{I_{DC} = \frac{0.827\ V_m}{R}}$$

$$V_{rms} = \sqrt{\frac{1}{\pi/3} \int_{0}^{\pi/3} V_m^2 \cos^2(\omega t)\, d\omega t}$$

$$= 0.84068\ V_m.$$

$$I_{rms} = \frac{V_{rms}}{R}$$

$$V_{rms} = V_m \left[\frac{q}{2\pi} \left(\frac{\pi}{q} + \frac{1}{2} \sin \frac{2\pi}{q} \right) \right]^{1/2}$$

⇒ PV System " download "

$$\boxed{I_{rms} = 0.84068 \frac{V_m}{R}}$$

$P_{DC} = V_{DC}\, I_{DC} =$ [redacted]

$$\boxed{P_{DC} = (0.827)^2 \frac{V_m^2}{R}}$$

$P_{AC} = V_{rms} \cdot I_{rms}$

$$\boxed{P_{AC} = (0.84068)^2 \frac{V_m^2}{R}}$$

$\eta = \frac{P_{DC}}{P_{AC}} = 96.77\ \%$

17/4 TUE

$$\Rightarrow FF = \frac{V_{rms}}{V_{DC}} = \frac{0.84068}{0.827} = 1.0165$$

$$\Rightarrow RF = \sqrt{FF^2 - 1}$$

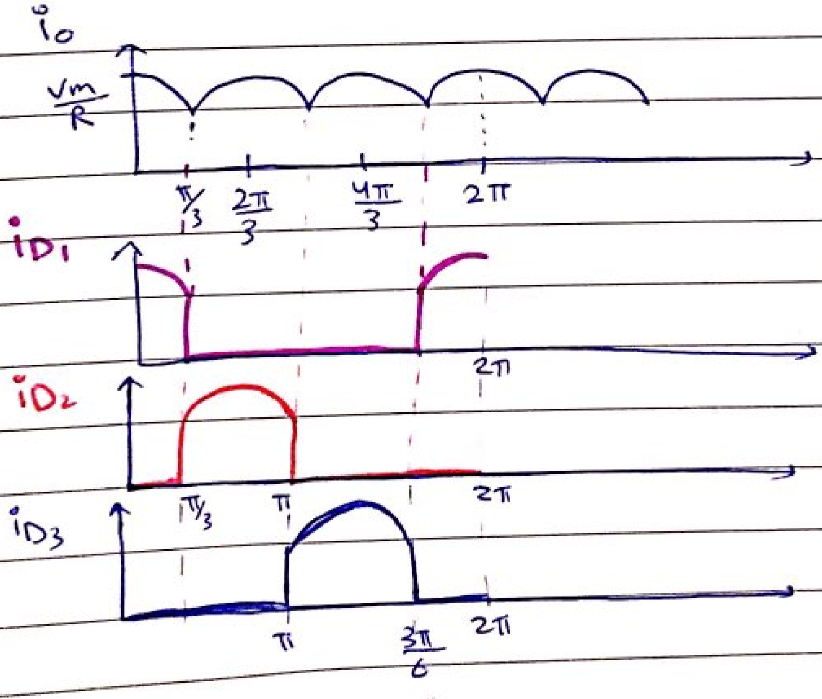
$$= 18.24\%$$

PIV of diode is : V_{LC} (Peak value)

$\sqrt{2}\,\sqrt{3}\,V_{an} \rightarrow$ RMS value for single phase.

$$PF = \frac{V_{rms(o)} * I_{rms(o)}}{3\, V_{rms(o)}\, I_{rms(in)}}$$

$$= \frac{(0.84068)(0.84068)\, V_m^2/R}{3 * V_m/\sqrt{3}}$$



$$I_{rms(D)} = \sqrt{\frac{1}{2\pi R} \int_{\pi/3}^{\pi} V_m^2 \cos^2(\omega t \mp 120)}$$

$$= \frac{1}{\sqrt{3}} \quad I_{o(rms)}$$

$$I_{rms} = 0.84068 \; \frac{V_m}{R}$$

$$I_{diode} = I_{source}$$

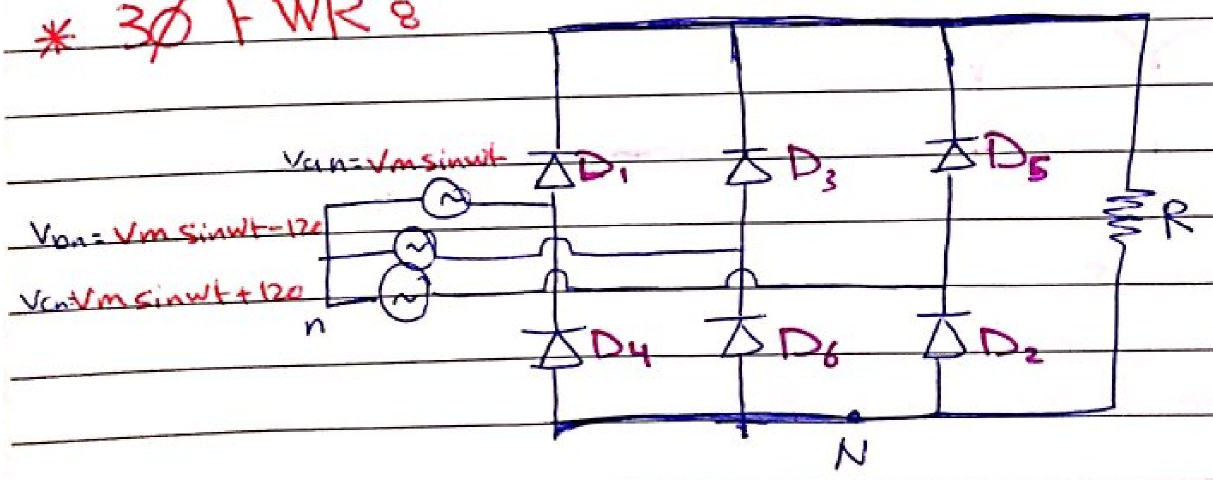
$$= 0.84068 \; \frac{V_m}{\sqrt{3}\,R}$$

$$= 0.4854 \; \frac{V_m}{R}$$

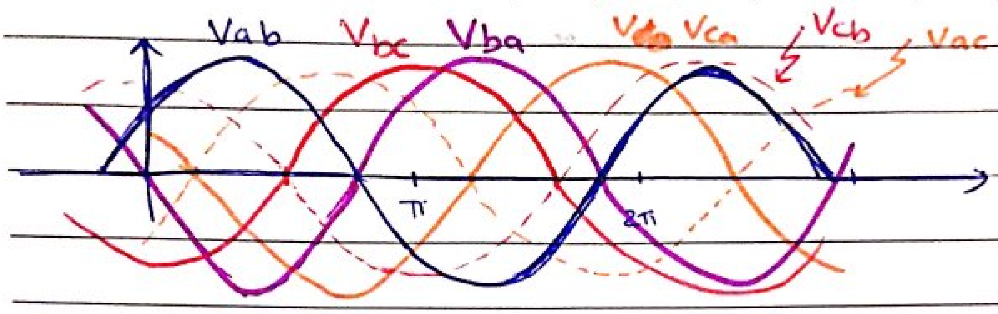
$$PF = \frac{(0.84068)\,(0.84068)\;V_m^2/R}{3 * \frac{V_m}{\sqrt{2}} * 0.4854 \; \frac{V_m}{R}}$$

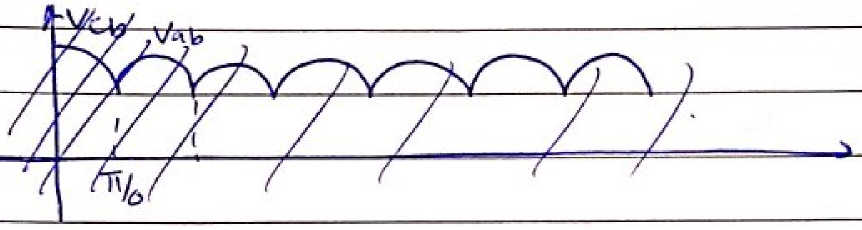
$$\boxed{PF = 0.6844}$$

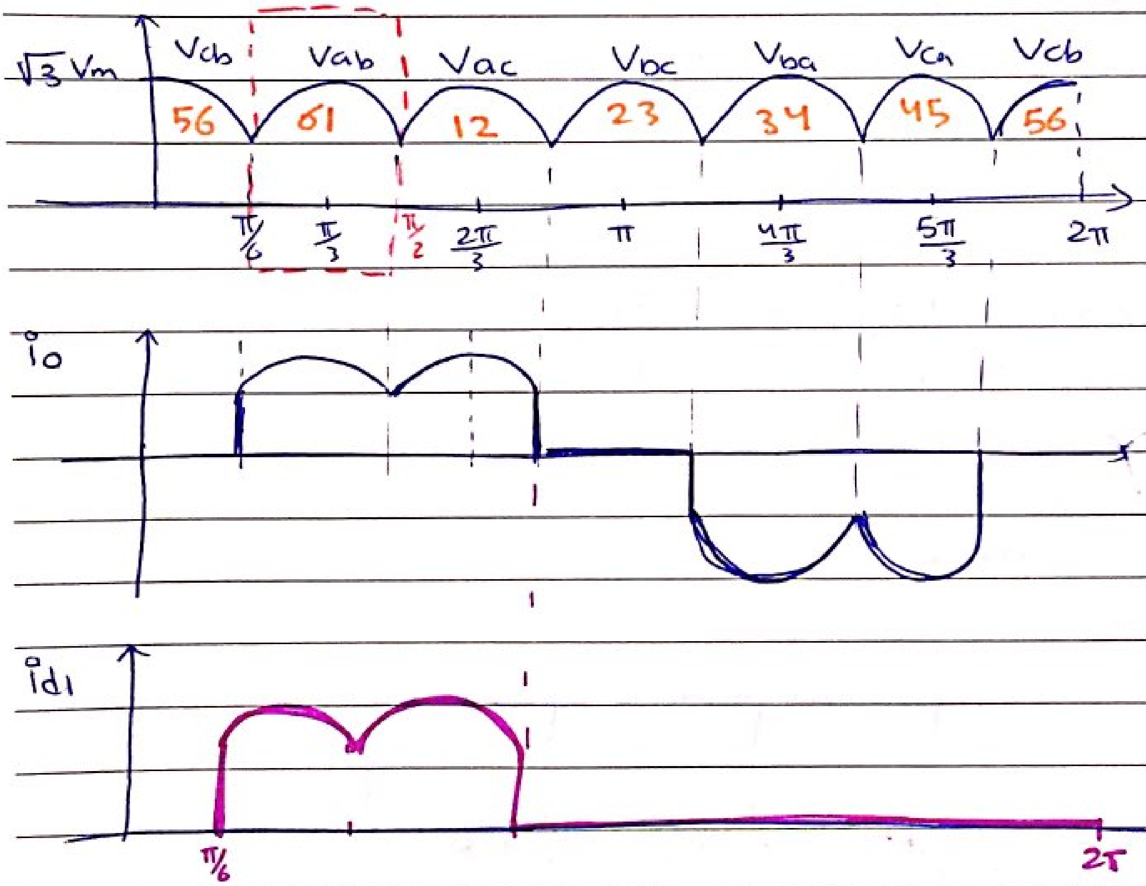
* 3Ø FWR 8



each pair of diodes will conduct when the instantinous L-L voltage is highest.







$$V_{an} = V_m \sin \omega t$$

$$V_{ab} = \sqrt{3} V_m \sin(\omega t + 30)$$

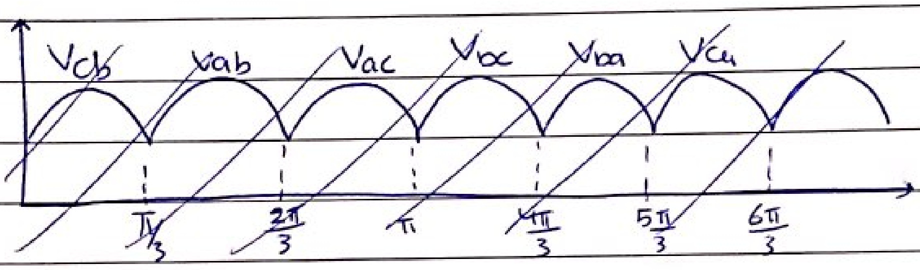
$$V_{DC(o)} = \frac{1}{\pi/3} \int_{\pi/6}^{\pi/2} \sqrt{3} V_m \sin(\omega t + 30)\, d\omega t$$

$V_{bc} = \sqrt{3}\ V_m \sin(\omega t - 90)$

$V_{cb} = \sqrt{3}\ V_m \sin(\omega t + 90)$

$= \sqrt{3}\ V_m \cos(\omega t)$

$$V_{DC(o)} = \frac{1}{\pi/6} \int_0^{\pi/6} \sqrt{3}\ V_m \cos\omega t \, d\omega t.$$



19/4 Thu

$$V_{DC} = \frac{6}{\pi}\int_{0}^{\pi/6} \sqrt{3}\, V_m \cos\omega t \; d\omega t$$

$$= \frac{3\sqrt{3}}{\pi}\, V_m$$

$$\boxed{V_{DC} = 1.654\, V_m}$$

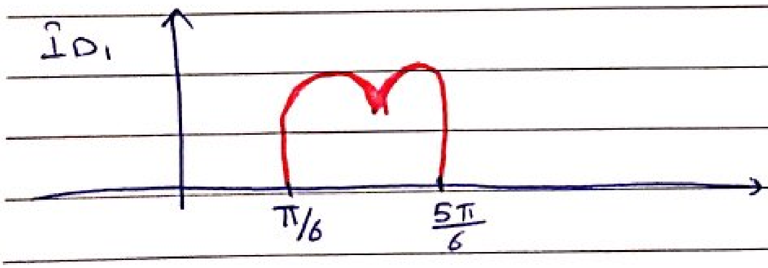
$$\boxed{I_{DC} = \frac{V_{DC}}{R}}$$

$$V_{rms} = \sqrt{\frac{6}{\pi}\int_{0}^{\pi/6} (\sqrt{3}\, V_m)^2 \cos^2\omega t \; d\omega t}$$

$$= \left(\frac{3}{2} + \frac{9\sqrt{3}}{4\pi}\right)^{1/2} V_m$$

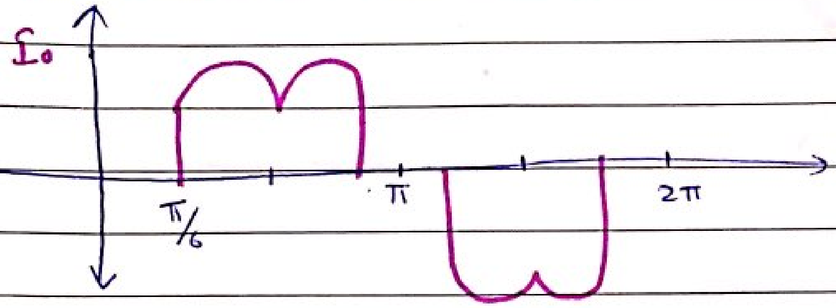
$$\boxed{V_{rms} = 1.6554\, V_m}$$

$$\boxed{I_{rms} = \frac{V_{rms}}{R}}$$



$$I_{D\,rms} = \sqrt{\frac{1}{2\pi * R^2} * 2 \int_{\pi/6}^{\pi/2} (\sqrt{3}\, V_m)^2 \sin^2(\omega t - 30)\; d\omega t}$$

$$\boxed{I_{Drms} = 0.5518\ I_m} \curvearrowright \frac{\sqrt{3}\,V_m}{R}$$

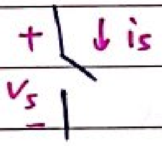


$$I_{orms} \sqrt{\frac{8}{2\pi}\int_0^{\pi/6} I_m^2 \cos^2\omega t \, d\omega t}$$

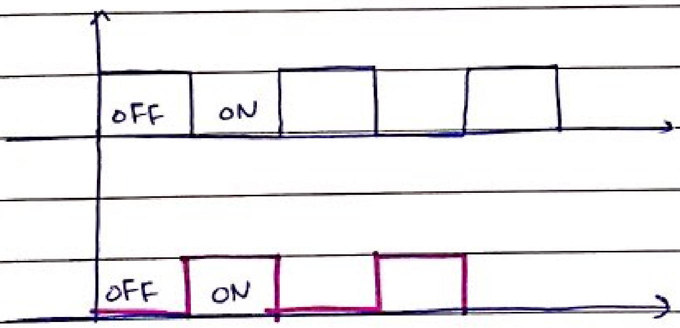
$$\boxed{I_{orms} = 0.7804\ I_m}$$

Switching Devices:

[A] Ideal switch



Power losses = 0



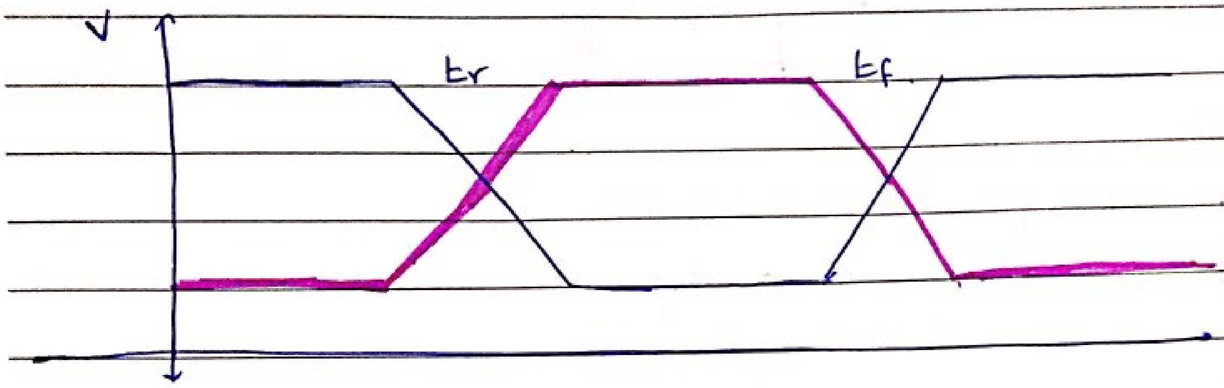
[B] Real switches:

↱ can not be neglected

when S is ON: $V_s \neq 0$ ⟶ Conduction loss

S is off: $I_s \neq 0$ ⟶ leakage loss

I_s can be ignored



t_r = revers time
t_f = forward time

$w_{on} = \frac{1}{2} V_s$ is t_r

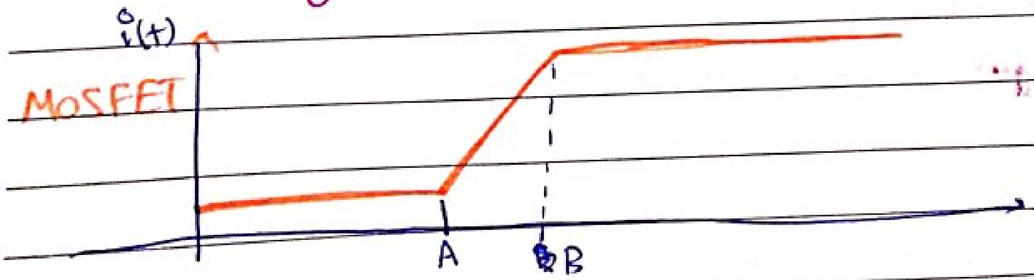
$w_{off} = \frac{1}{2} V_s$ is t_f

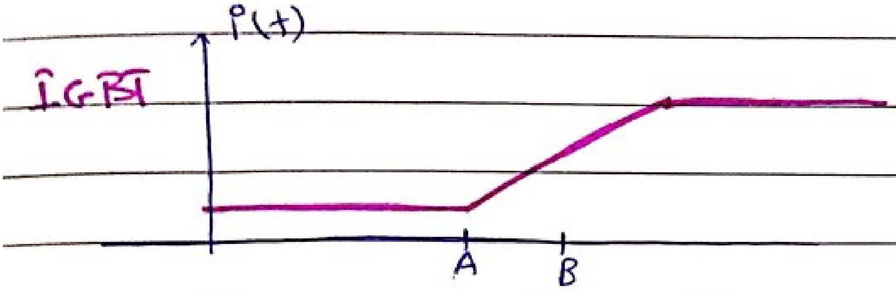
$$\boxed{P_{loss} = \frac{W_{on}}{T_s} = W_{on} f_s}$$

IGBT 1200V at 300A
$V_s = 2V$
$t_r = 1\text{-}2\ \mu s$

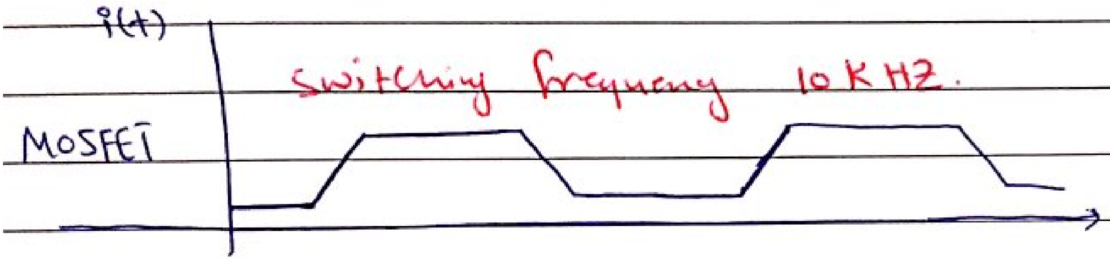
MOSFET 100ns:-
100 ns

Switching Speed Vs Switching Frequensy 8Δ





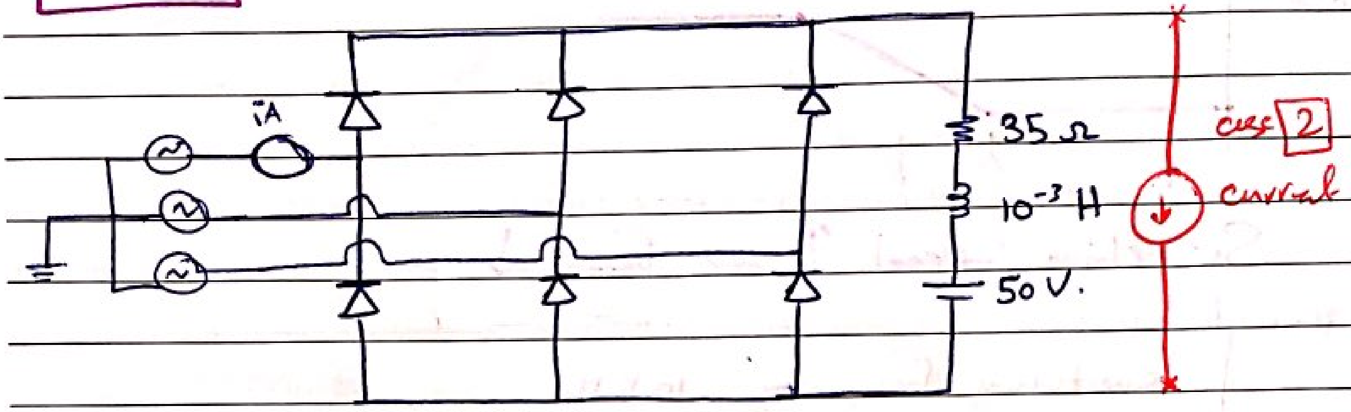
Switching Speed ↑ → losses ↓



Switching freq ↑ → losses ↓

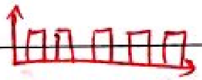
22/4 SUN

HW38



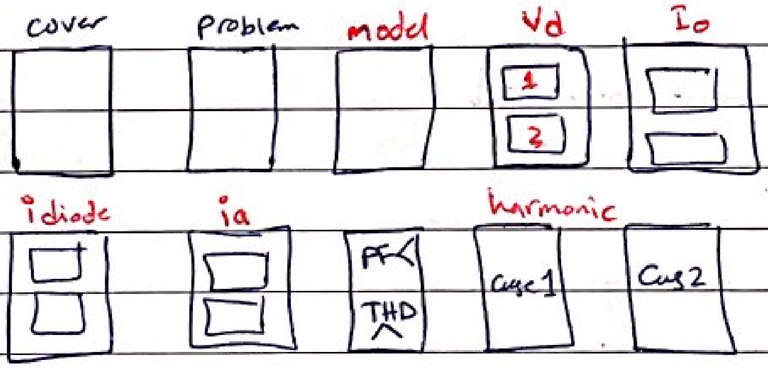
$V_{LL} = 208$

1 plot :



Vd , io , idiode , ia , pF , THD , Harmonic.

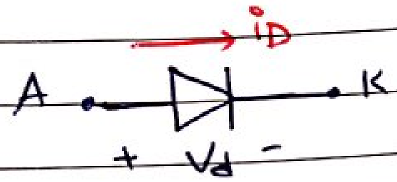
2 repeat above for 10A current Source.

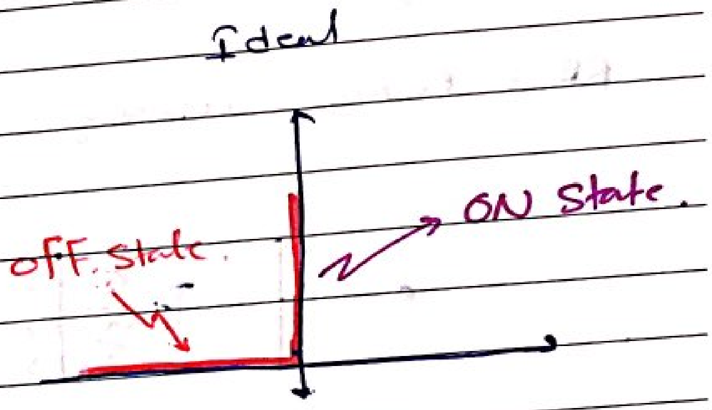


10 pages report

29/4 ← HW تسليم

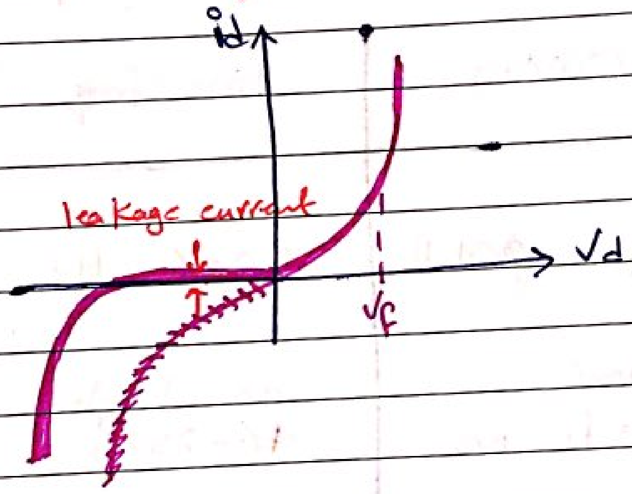
* Power Diode :Δ

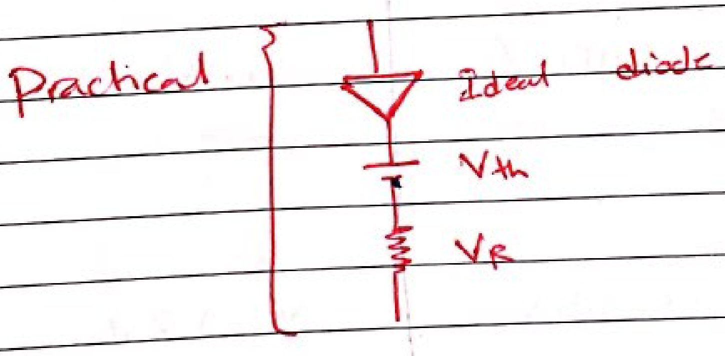




↳ Unidirectional.

↳ uncontrolable.

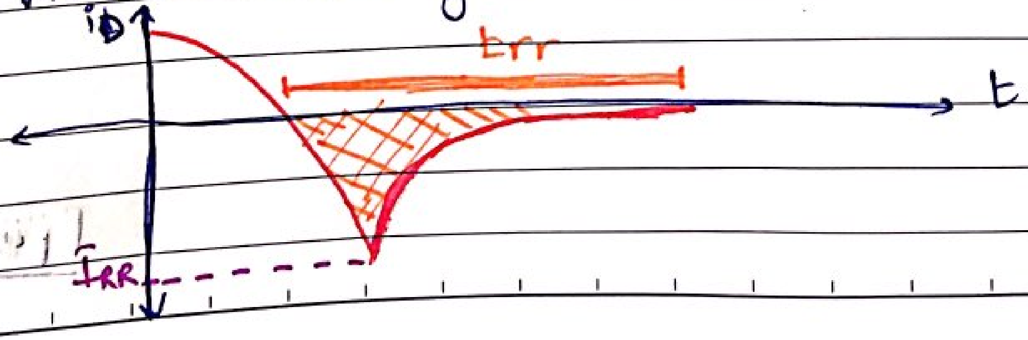




$V_{Th} \downarrow \rightarrow T \uparrow$

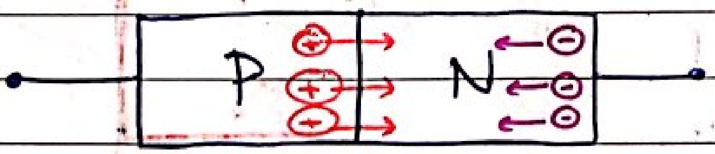
$V_R \uparrow \rightarrow T \uparrow$

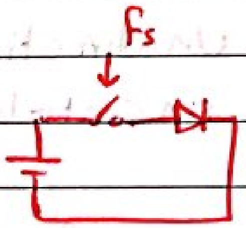
* Reverse Recovery :Δ



$Q_{RR} = \frac{1}{2} I_{RR} * t_{rr}$

RR ≡ reverse recovery.





Schottky	Fast recovery	line freq
switching freq fs = very high	fs: high up to 20KHZ	50 - 60 Hz
trr → extremely Low (nano second)	trr low 0.1 Ms → few nano	trr high 16 - 25 Ms
power rating 100V, 300 A	6000V, 1100 A من كتاب رشيد طبعة 2014	6000 V, 3500A
Vf : at 30KHZ Vf = 0.6 V	Vf = 0.8 - 1.5 V	Vf = 1.2 V

* Thyristors 8Δ → SCR ≡
↳ silicon controled Rectifier

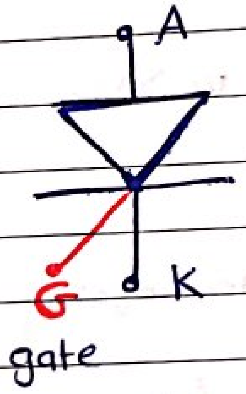
↳ Uni directional

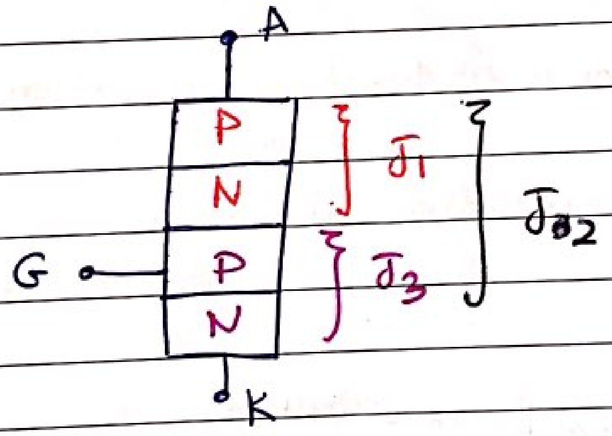
↳ controled ON only

كلو Switching off بعمل reverse bias في *

↳ Low ON-state.

↳ multi Kilo HZ Switching





J = Junction.

If $V_A > V_K$

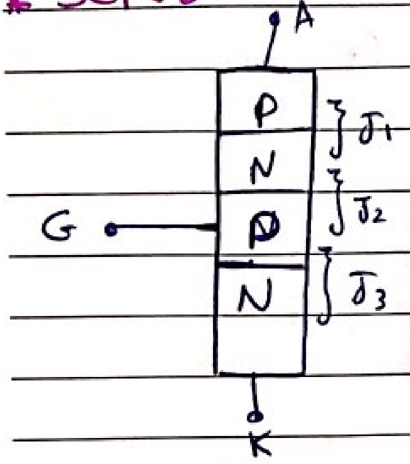
J_1 and J_3 are F.B
J_2 is R.D

only small leakage current flows from anode to cathode [leakage current]

➡ This will make the device in forward blocking condition.

24/4 TUE

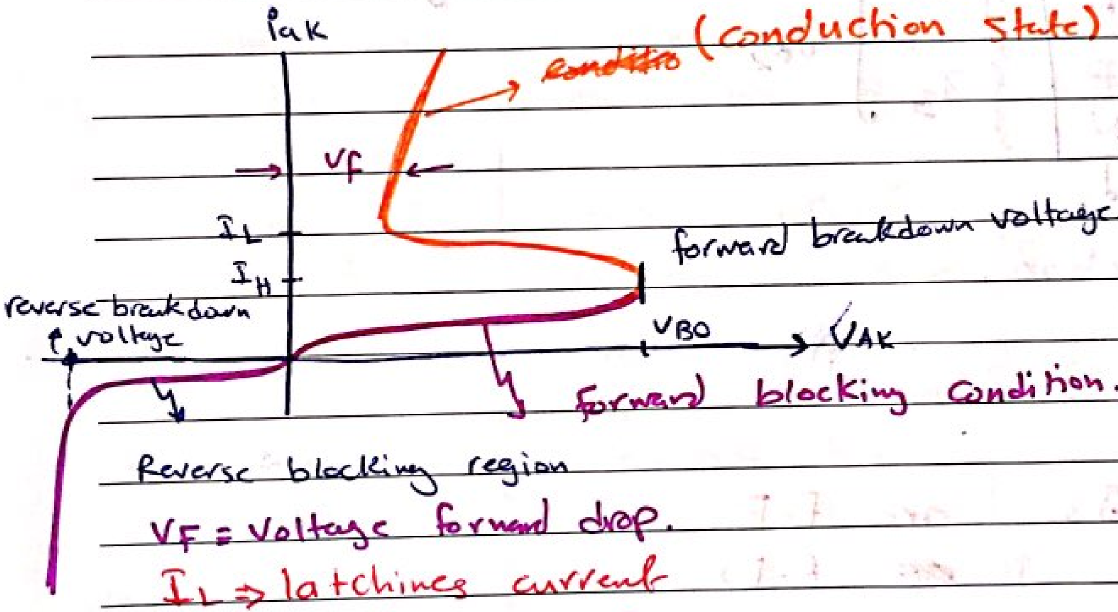
* SCR :



If $V_A > V_K$ J1 and J3 : F.B

J2 : R.B

→ leakages cutoff ~0 [Forward blocking condition]



V_F = Voltage forward drop.

I_L ⇒ latchines current

I_H ⇒ Holding current.

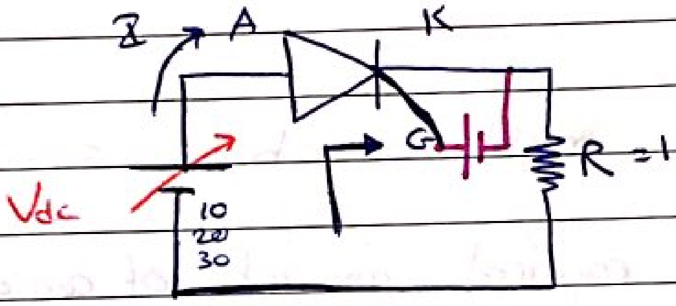
If VAK is increased to a suffeciently large value J2 brakes ⇒ avalanche break down

⇒ large Forward anode current. [conduction state]

typically $V_F = 1V$

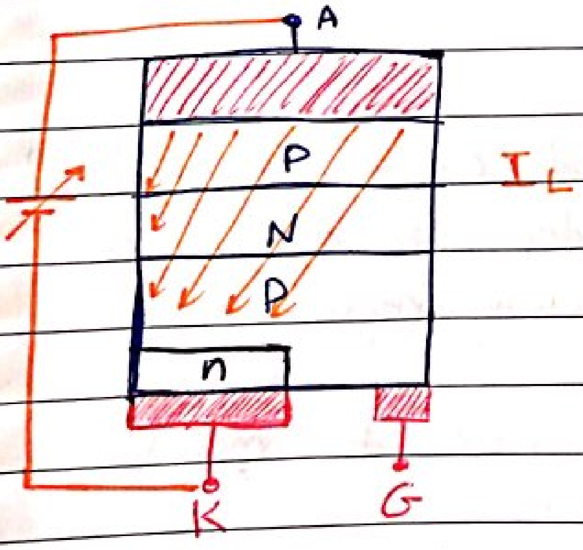
⇒ SCR can be turned ON by increasing the forward voltage (V_{AK}) beyond V_{BO}. But this will be destructive.

⇒ In practice, forward voltage is maintained below V_{BO}, the voltage is applied between the gate and the cathode.



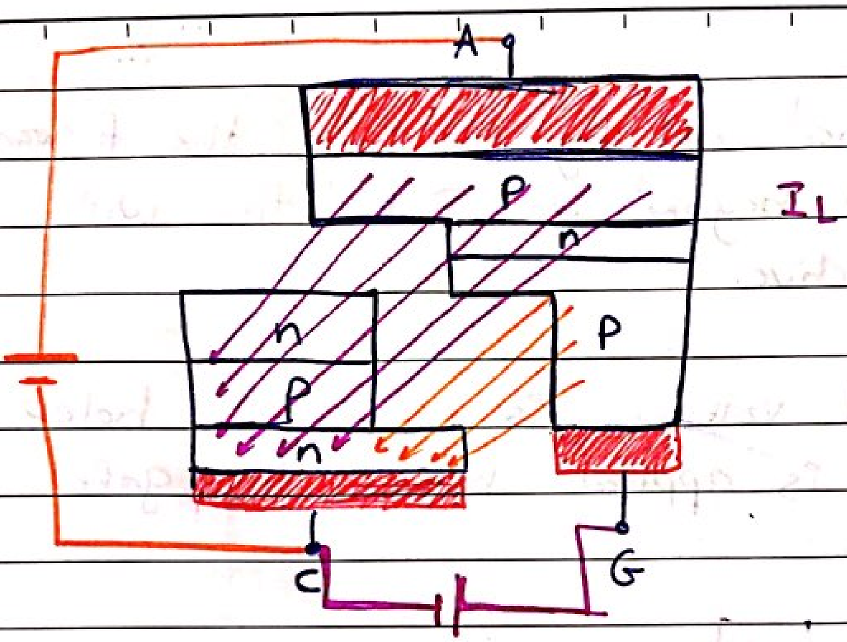
$$I = \frac{100}{R}$$

For turning on the SCR
↳ F.B
↳ apply I_{gate} (+ve voltage btween the gate and the cathode.
  ↳ the starting current > I_L



I_L 2 layer approch

PNPN structure



Sections of pNP and NpN

⇒ The anode current must be above some certain value (I_L) to maintaine the required amount of carrier flow across the junction or the device will revert to blocking condition.

I_L is the minimum current required to maintain the SCR in the on-state immediatly after the SCR is turned ON the gate and has been removed.

* During conduction, if the anode current is reduced below (I_H) there will be a depletion region across J_2 and the SCR is in blocking region

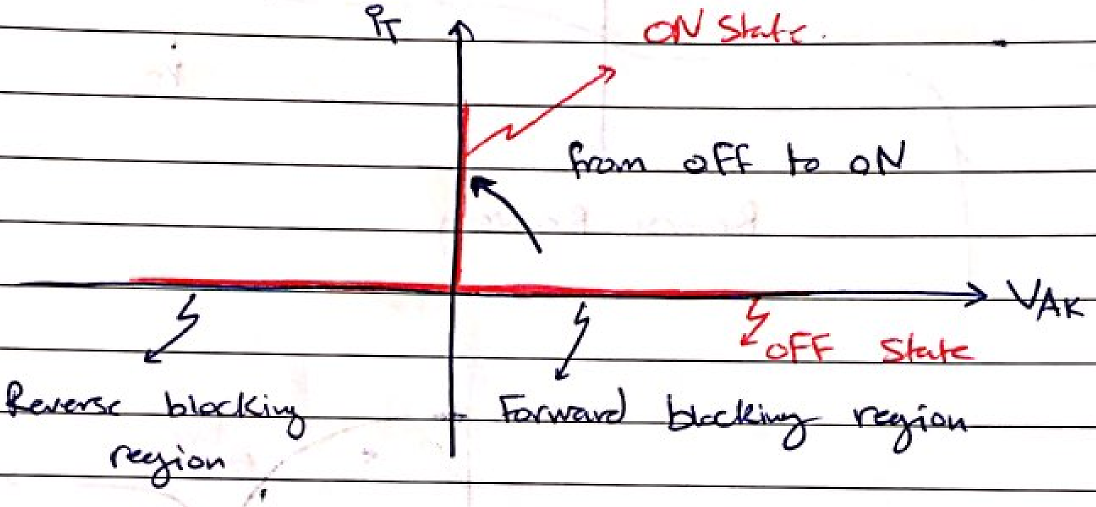
I_H is the minimum current to maintain the SCR in the ON-state

$$I_H < I_L$$

※ SCR has a bidirectional blocking capability.

قدرتو على منع الـ volt

* Ideal SCR Char :



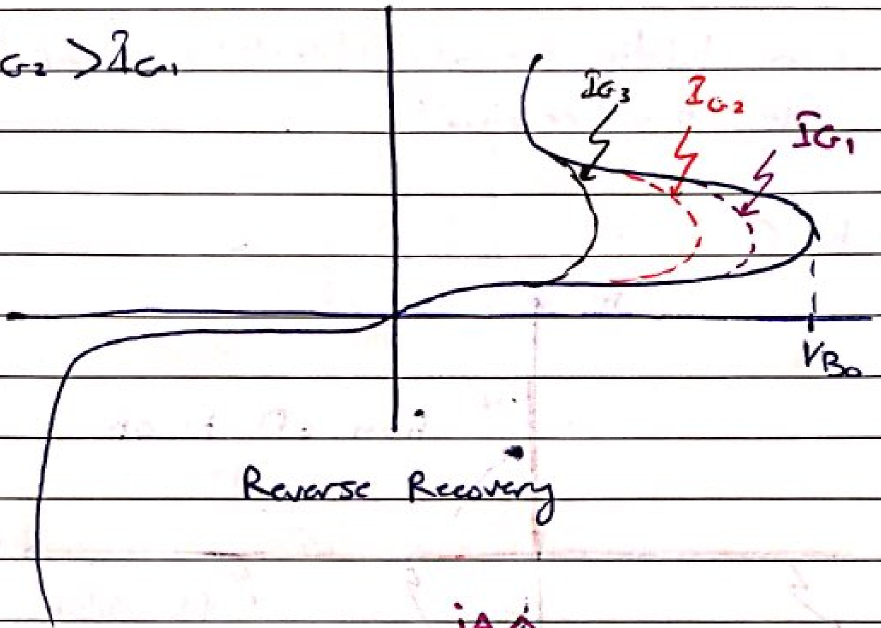
※ Usually Forward blocking voltage = reverse blocking voltage.

※ turn off is not by the gate

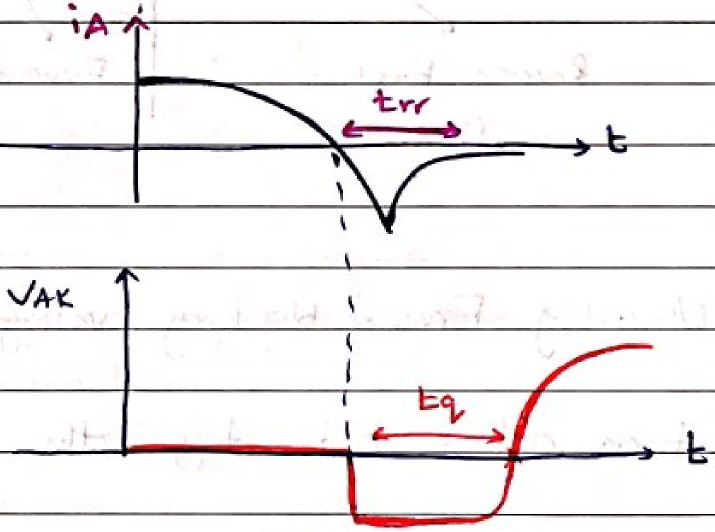
↳ uncontrolled off.

26/4 Thur

$I_{G3} > I_{G2} > I_{G1}$

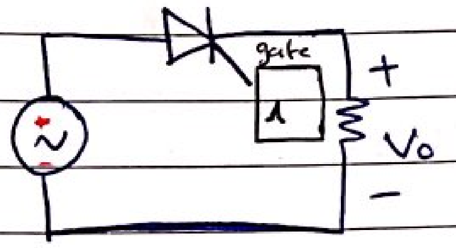


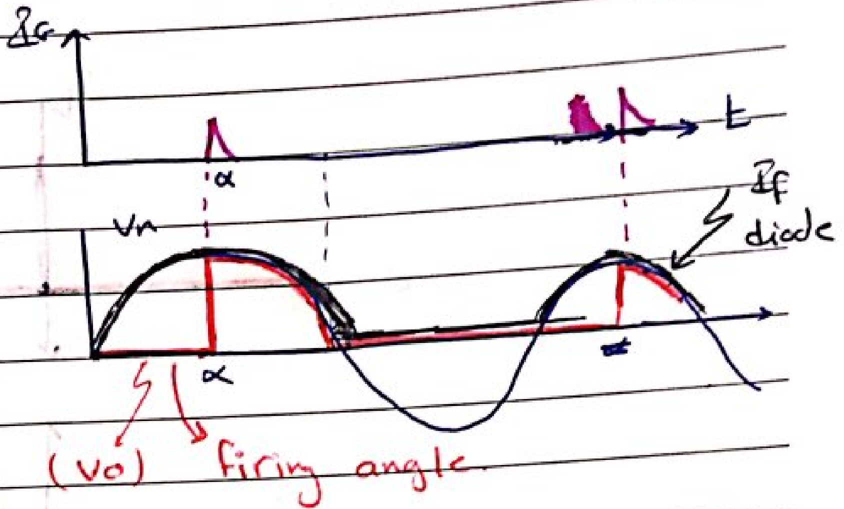
Reverse Recovery



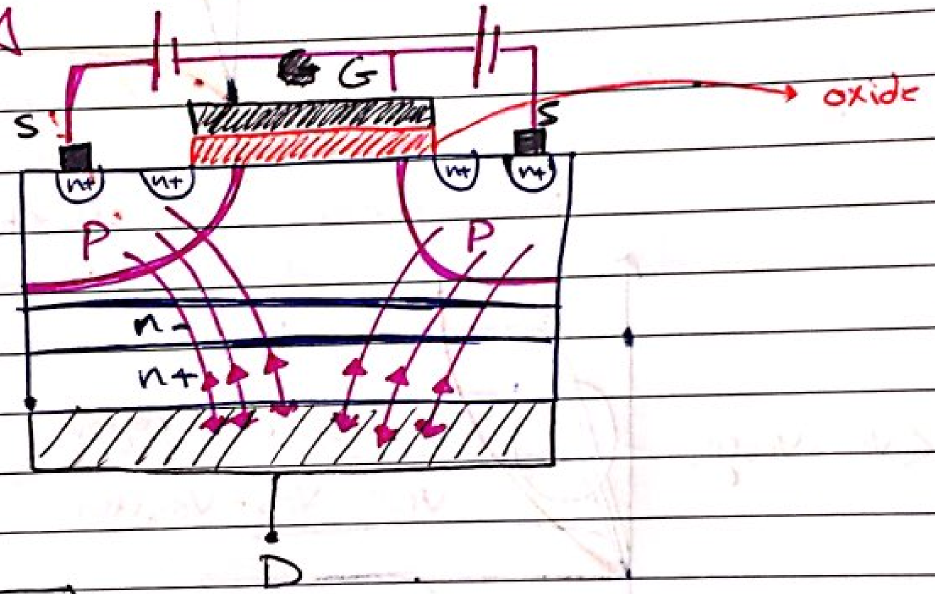
↳ t_q = from Zero cross over of current to Zero ~~a~~ cross over of voltage.

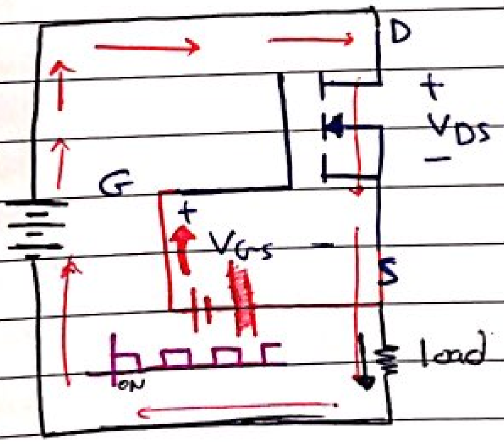
↳ During t_q ⇒ a reverse voltage must be maintained across the device capable of blocking aforward voltage without going into its on state.





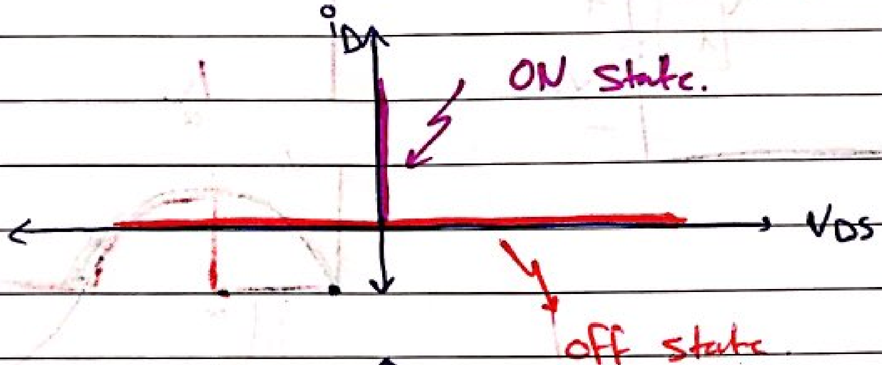
* MOSFET 84

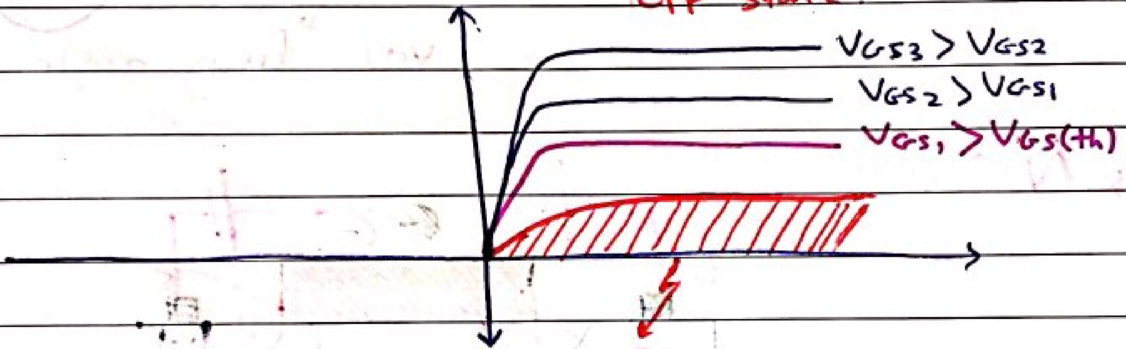


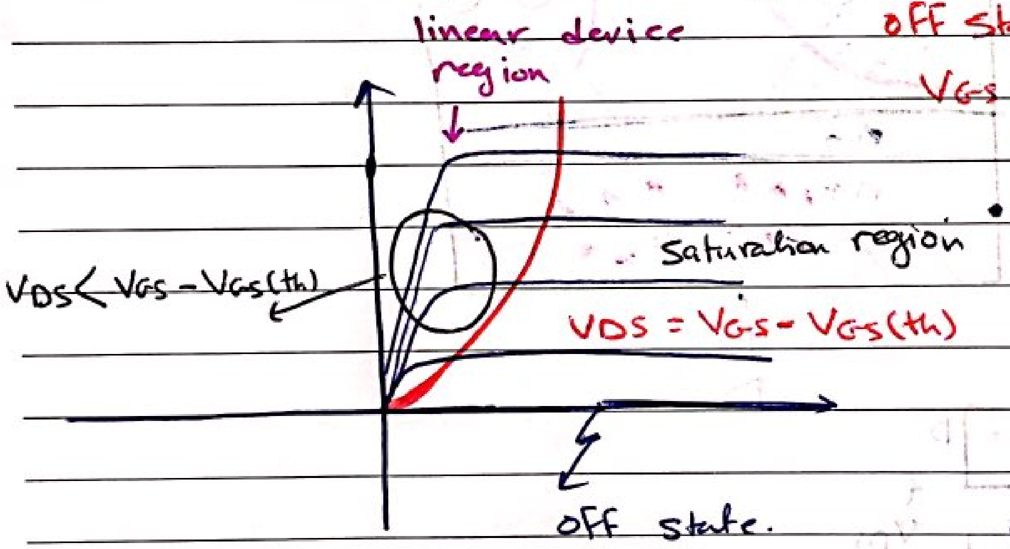


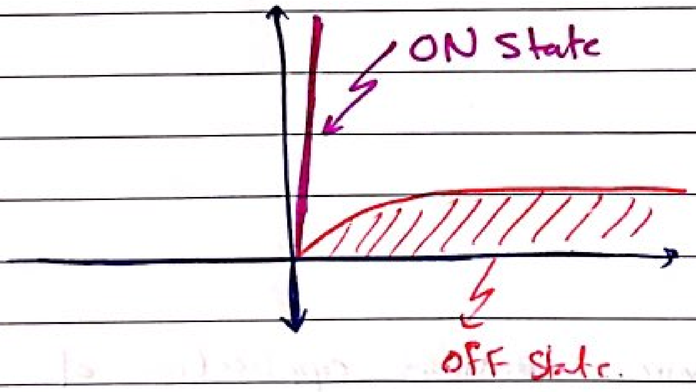
↳ This device will require continuous application of voltage between gate and source. to stay in the ON-state.

Ideal char :-


iD
ON State.
VDS
off state


VGS3 > VGS2
VGS2 > VGS1
VGS1 > VGS(th)
OFF State
VGS < VGS(th)


linear device region
Saturation region
VDS < VGS - VGS(th)
VDS = VGS - VGS(th)
OFF state.


ON State
OFF State.

Comment:

* voltage controlled device.

* No reverse voltage blocking capability [Forward only]

* Unidirectional device.

* In the ohmic region

$$V_{ds} = \underset{20m\Omega}{R_{ds\_ON}} * I_{DS}$$

* in the ON state the device Can be model as [redacted]. resister

* Switching time is in the range of few hundreds of nano seconds.

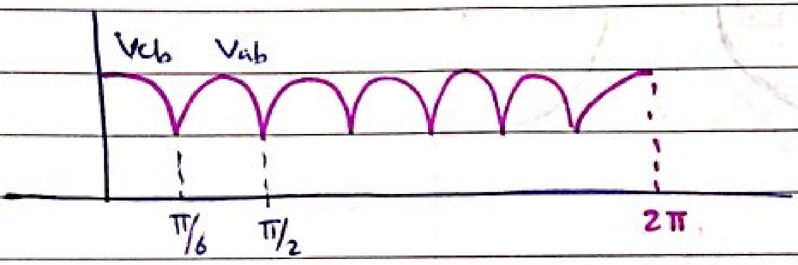
* typical rating 1000 V and 100 A

* $V_{GS} = \pm 5V$

$V_{an} = V_m \sin \omega t$

$V_{ab} = \sqrt{3}\ V_m \sin(\omega t + 30)$

$V_{cb} = \sqrt{3}\ V_m \cos(\omega t)$



$$v_{out} = \frac{12}{2\pi} \int_0^{\pi/6} \sqrt{3}\ V_m \cos \omega t \ d\omega t$$

$$= \frac{6\sqrt{3}V_m}{\pi}\left[\frac{1}{2}\right] = \frac{3\sqrt{3}\ V_m}{\pi}$$

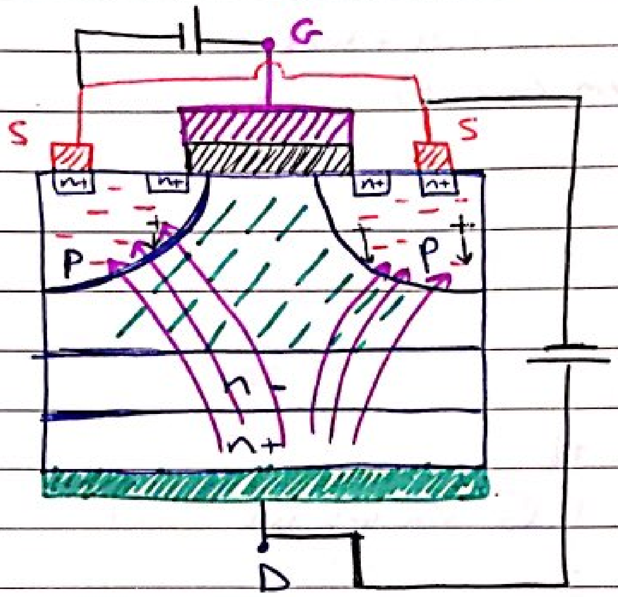
$$V_{out} = \frac{6}{2\pi} \int_{\pi/6}^{\pi/2} \sqrt{3}\ V_m \sin(\omega t + 30)\ d\omega t$$

$$= \frac{3\sqrt{3}V_m}{\pi}\left[-\cos(\omega t - \pi/6) \Big]_{\pi/6}^{\pi/2} \right]$$

$$= \frac{3\sqrt{3}\ V_m}{\pi}\left[0.5 + 0.5\right]$$

$$= \frac{3\sqrt{3}\ V_m}{\pi}$$

MOSFET 8Δ



vertical channel

$V_{ds} = R_{d\text{-}ON} * I_D$

↑ thickniss → ↑ power.

" power MOSFET "

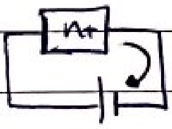
V or U

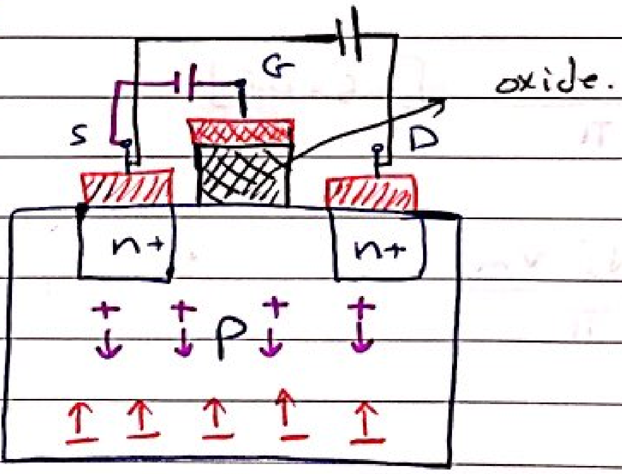
MOSFET UMOSFET

[2] enhancment MOSFET

n- type

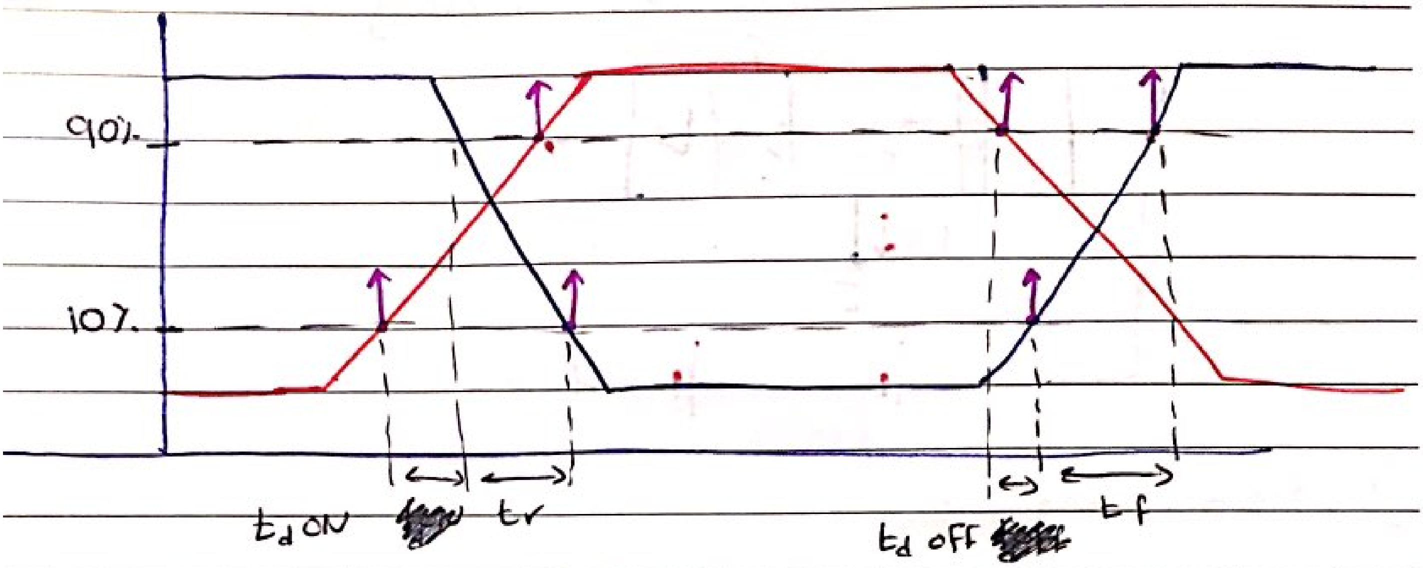
1 w





※ No reverse blocking capability → only forward blocking.

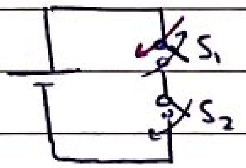
MOSFET Switching waveforms



$t_{d}\,ON + t_r < t_{d}off + t_f$

turning the switch ON is faster than turning it OFF

$S_2 = 1 - S_1$

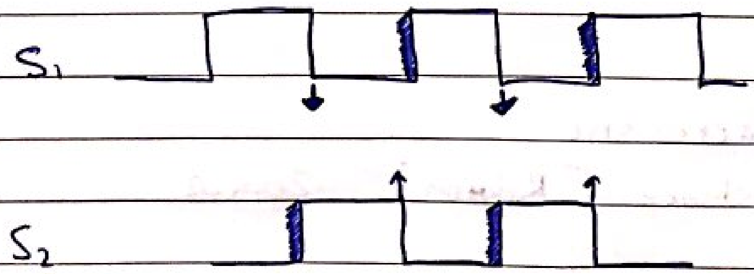


Problem:-

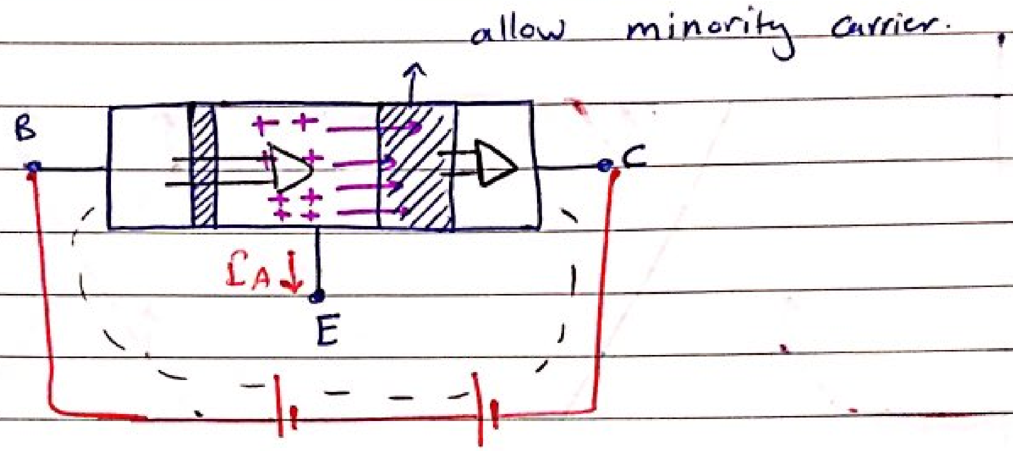
MosFET in series will short ckt the source.

solution:-

use of dead band



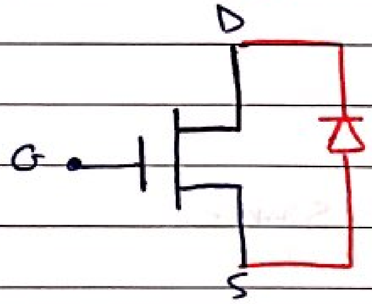
BJT's



Disadvantages:-

- current - controlled
- low input Impedance [We need Large energy to run]
- Bad in charge handing
- Low switching speed.

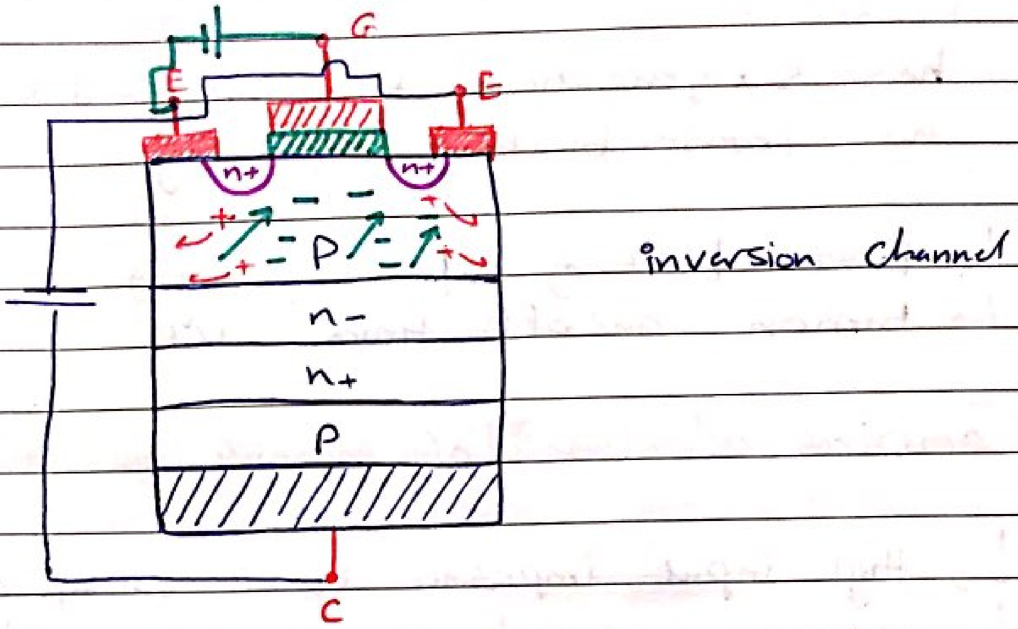
MOSFET's



Disadvantage:-

- Body Diode
- Bad conduction characteristic
- high-ON-State resistance [Rds on] 20mΩ

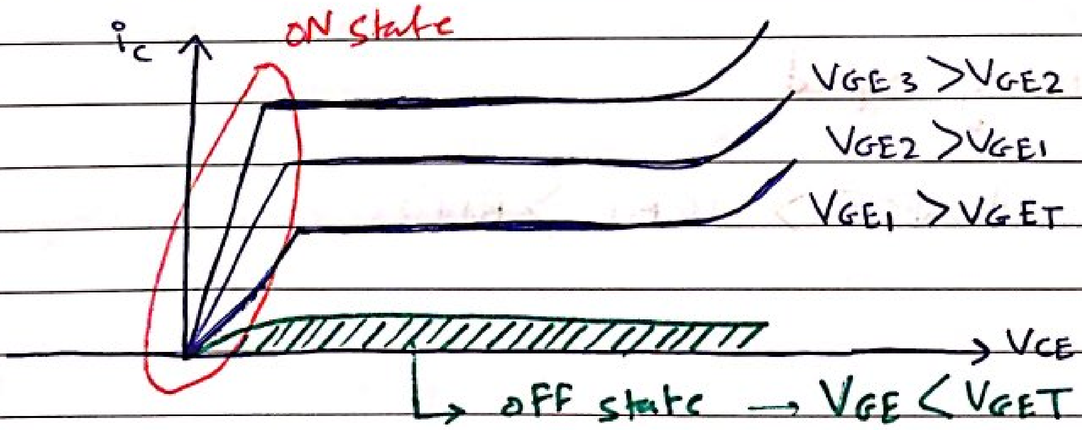
IGBT :Δ



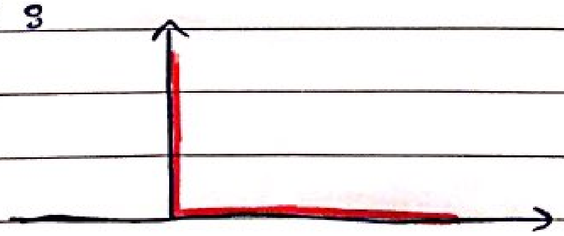
↳ voltage controlled device (apply VGE the device will conduct).

↳ It requires continous application of VGE inorder to stay in the ON-State mode.

↳ Unidirectional device.



Ideal :



IGBT :-

has six generations, the up-to-date version has no reverse blocking capability

↳ Forward blocking capability Only
↳ turnon and off times 1Ms

Combires advantage of MOSFET and BJT :-

↳ High input impedance (small voltage cause large energy)
↳ voltage controlled device (power and control ckt are completly independent)
↳ Vf is small like BJT.

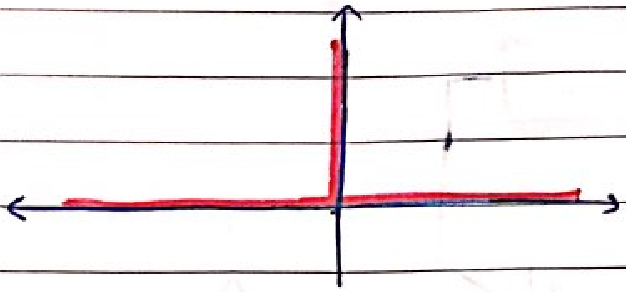
Current rating of

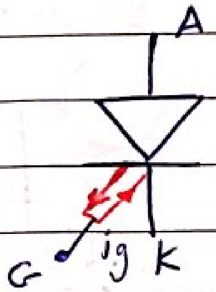
BJT > IGBT > MOSFET .

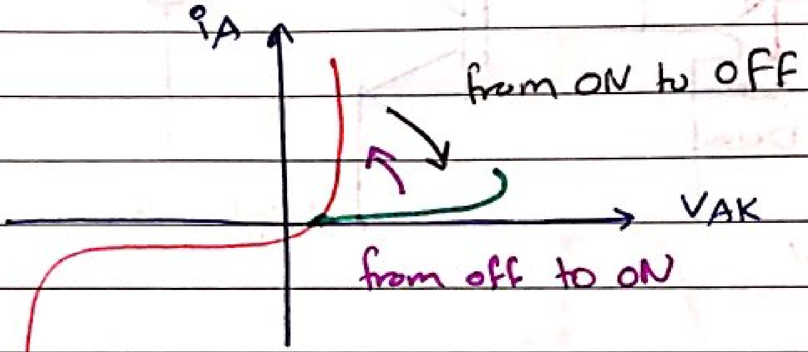
Switching Speed

MOSFET > IGBT > BJT.

GTO: Gate turn-off Thyristor.







↳ $V_f = (2-3)\,V$

↳ Switching Speed few μs – 25 μs

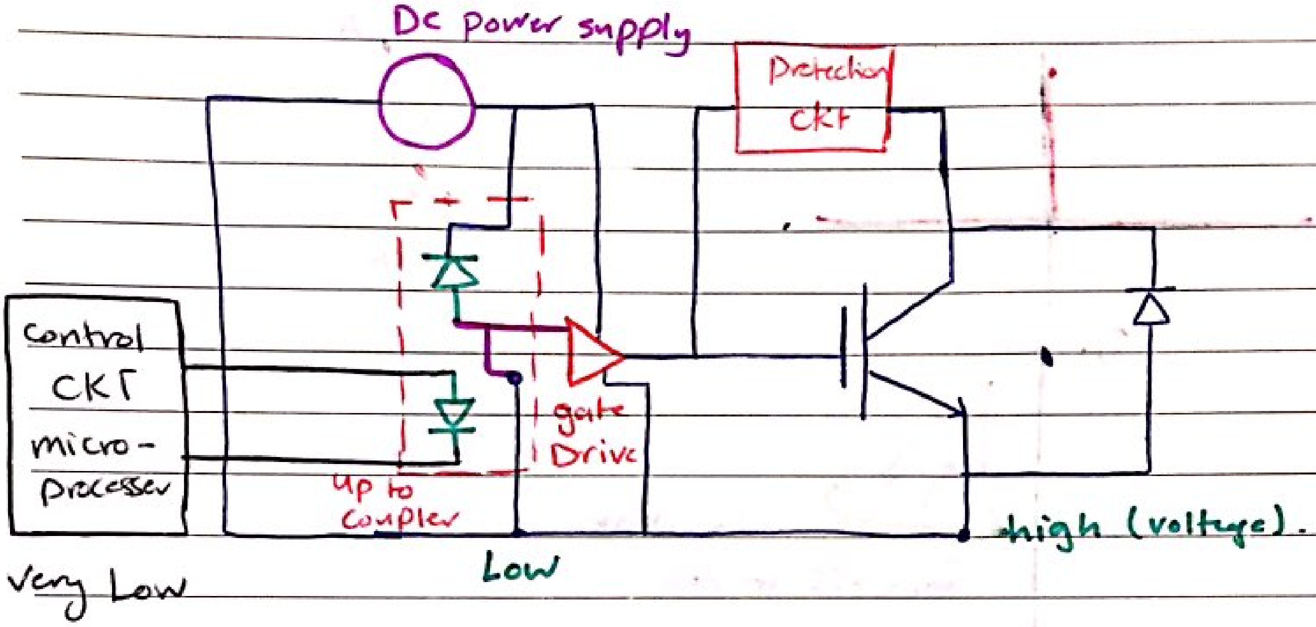
↳ V I Rating [4.5 KV – few KA]
  ↳ Voltage → current

↳ Gate current turn ON, only in the Begining (Small value)

↳ Gate can be turned off by applying very large negative gate current $\left[\frac{1}{3}\, i_A\right]$ by applying −ve V_{GC}

↳ this large current needs to flow for few seconds

Gate Drive 8∆



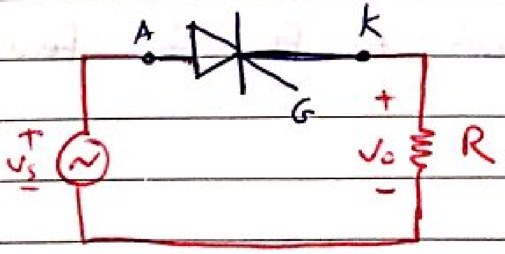
Disadvantage:-

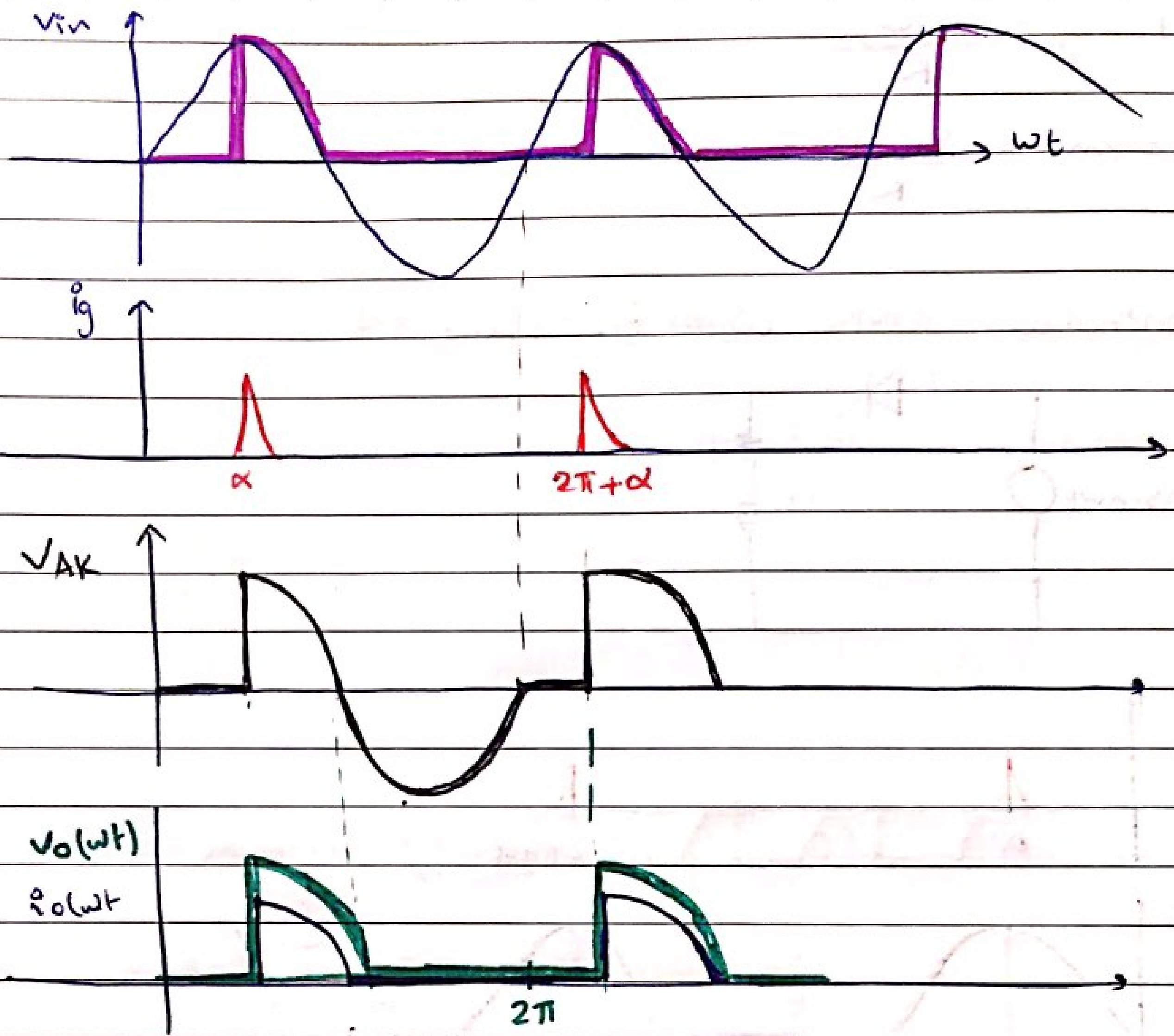
- turn ON and turn off the switch
- protect the device in cause of different type of failure
- Control the speed.

The Controlled HWR 8∆

SCR:-

- FB
- current must be applied to the gate at firing angle.





$$V_o = \frac{1}{2\pi}\int_{\alpha}^{\pi} V_m \sin(\omega t)\, d\omega t.$$

$$\boxed{V_o = \frac{V_m}{2\pi}\left[1+\cos\alpha\right]}$$

not $\alpha = 0$ $\quad V_o = \frac{V_m}{2\pi}$

$$V_{orms} = \sqrt{\frac{1}{2\pi}\int_{\alpha}^{\pi} V_m^2 \sin^2\omega t \; d\omega t}$$

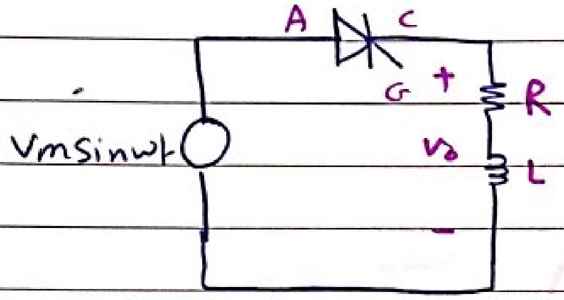
$$= \frac{V_m}{2}\sqrt{1 - \frac{\alpha}{\pi} + \frac{\sin(2\alpha)}{2\pi}}$$

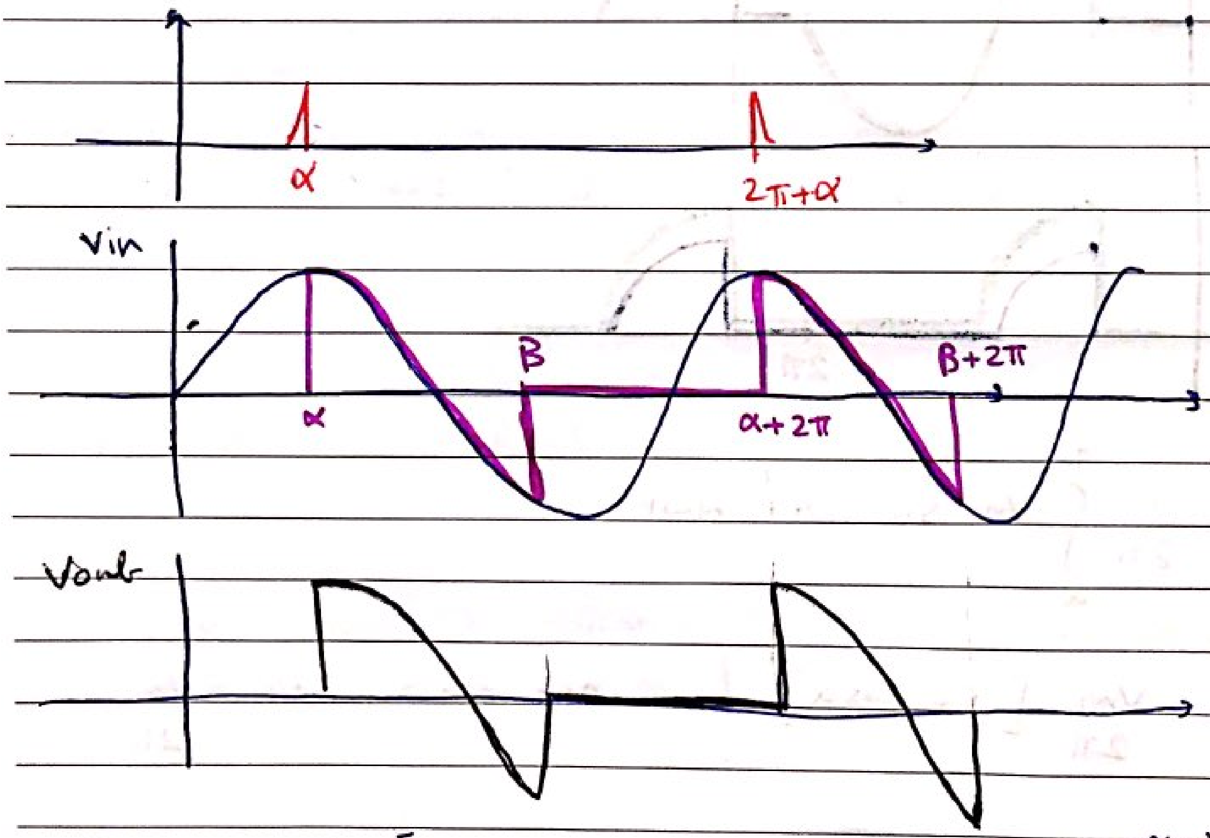
radians

$$I_{o\,avg} = \frac{V_{o\,avg}}{R}$$

$$I_{o\,rms} = \frac{V_{o\,rms}}{R}$$

Controlled HWR with RL-Load 8Δ





$$i_{in} = i_o(\omega t) = \begin{cases} \frac{V_m}{Z}\sin(\omega t-\theta) - \frac{V_m}{Z}\sin(\alpha-\theta)\, e^{\frac{\alpha-\omega t}{\omega \tau}} & \alpha \leq \omega t \leq \beta \\ 0 & \text{elsewhere} \end{cases}$$

$$V_{out\,avg} = \frac{1}{2\pi}\int_{\alpha}^{\beta} V_m \sin(\omega t)\, d\omega t = \frac{V_m}{2\pi}\left[\cos\alpha - \cos\beta\right]$$

$$V_{o\,rms} = \sqrt{\frac{1}{2\pi}\int_{\alpha}^{\beta} V_m^2 \sin^2(\omega t)\, d\omega t}$$

$$I_{o\,avg} = \frac{1}{2\pi}\int_{\alpha}^{\beta} i_o(\omega t)\ d\omega t$$

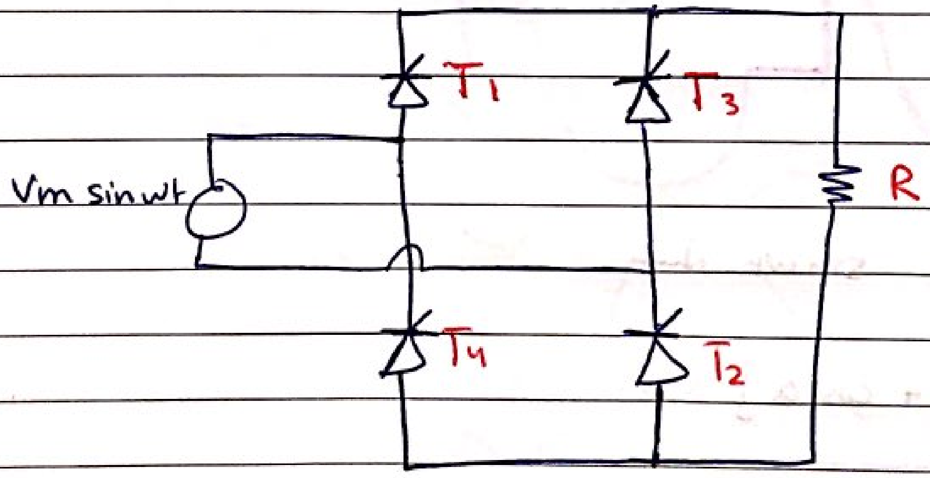
$$I_{o\,rms} = \sqrt{\frac{1}{2\pi}\int_{\alpha}^{\beta} i_o^2(\omega t)\ d\omega t}$$

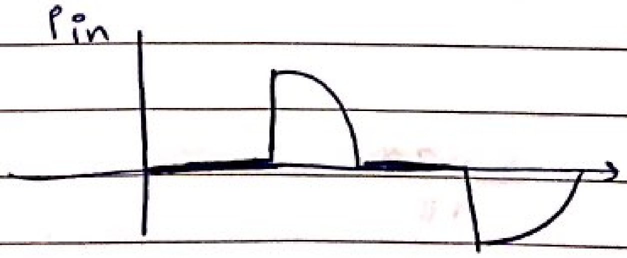
$$Z = \sqrt{R^2 + \omega L^2} \qquad \theta = \tan^{-1}\left(\frac{\omega L}{R}\right) \qquad \tau = \frac{L}{R}$$

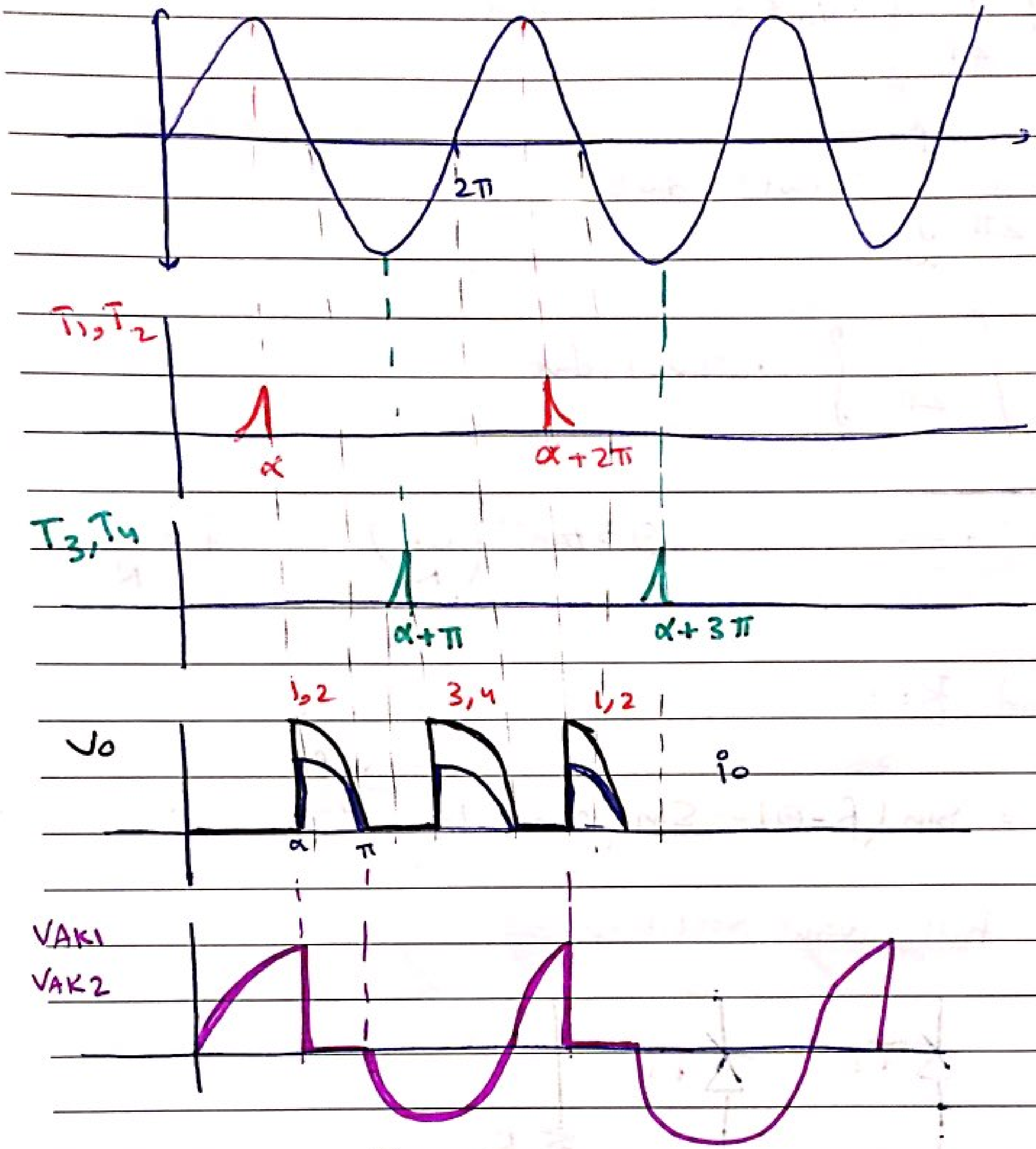
How to find β:-

$$i(\beta) = 0 = \sin(\beta - \theta) - \sin(\alpha - \theta)\, e^{\frac{(\alpha - \beta)}{\omega\tau}}$$

* Controlled Full wave Rectifier :-







$$V_{o\,avg} = \frac{1}{\pi}\int_{\alpha}^{\pi} V_m \sin\omega t \, d\omega t$$

$$= \frac{V_m}{\pi}\left[1 + \cos\alpha\right]$$

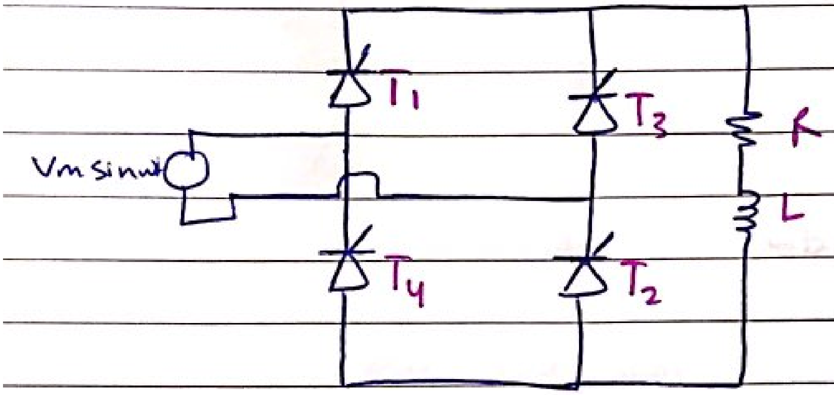
$$V_{o\,rms} = \sqrt{\frac{1}{\pi}\int_{\alpha}^{\pi} V_m^2 \sin^2\omega t \, d\omega t}$$

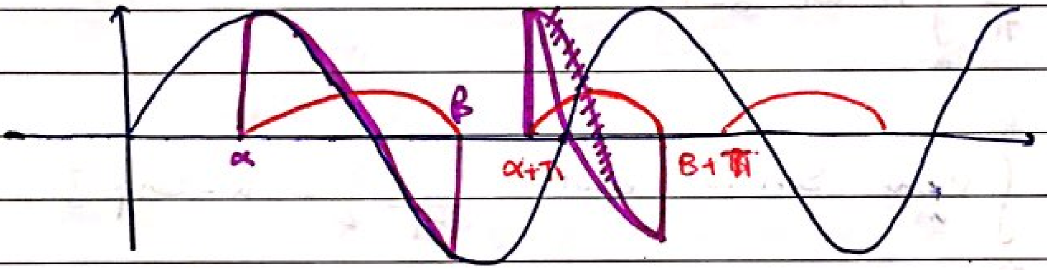
$$= V_m\sqrt{\frac{1}{2} - \frac{\alpha}{2\pi} + \frac{\sin 2\alpha}{4\pi}}$$

radian

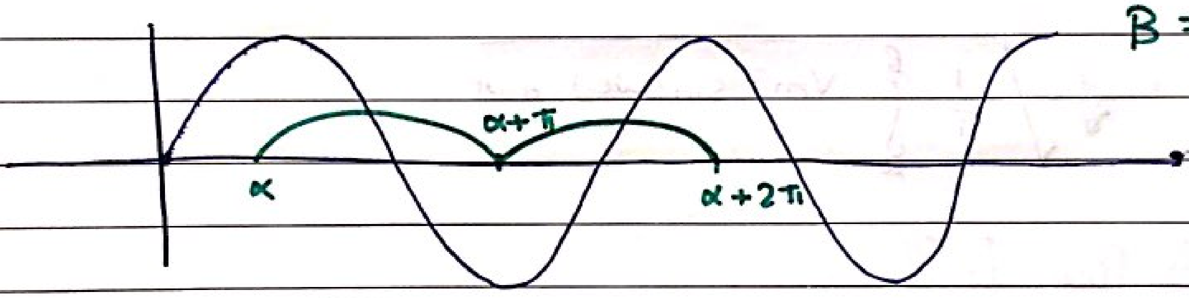
$I_{oavg} = \frac{V_{oavg}}{R}$ $I_{o\,rms} = \frac{V_{o\,rms}}{R}$.

Controlled Full wave rectifier with R-L Load :-

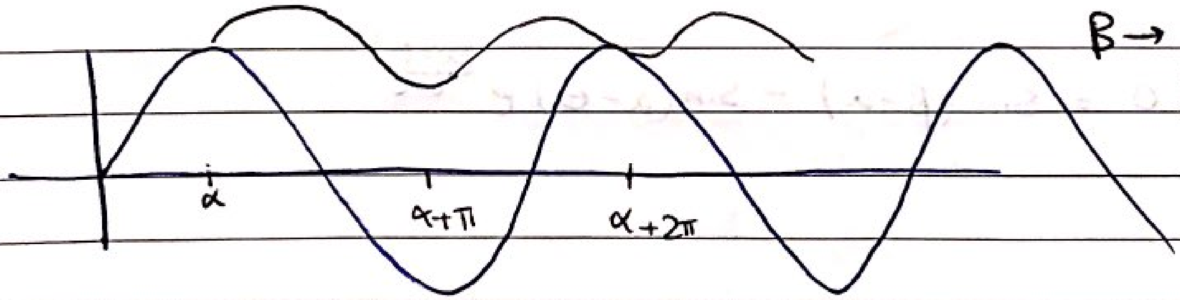




$\beta < \alpha + \pi$



$\beta = \pi + \alpha$



$\beta \rightarrow$ [illegible]

اختفت

Discontinous Mode :Δ

$$i_o(\omega t) = \begin{cases} \frac{V_m}{Z}\left[\sin(\omega t-\theta) - \sin(\alpha-\theta)e^{\left(\frac{\alpha-\omega t}{\omega\tau}\right)}\right] & \alpha \le \omega t \le \beta \\ \emptyset & \text{elsewhere.} \end{cases}$$

$$I_{o\,avg} = \frac{1}{\pi}\int_{\alpha}^{\beta} i_o(\omega t)\, d\omega t$$

$$I_{o\,rms} = \sqrt{\frac{1}{\pi}\int_{\alpha}^{\beta} i_o^2 \omega t \, d\omega t}$$

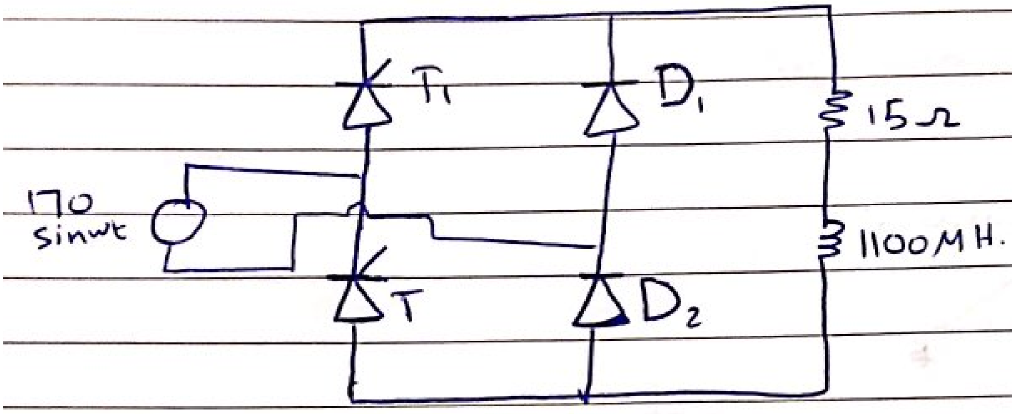
$$V_{o\,avg} = \frac{1}{\pi}\int_{\alpha}^{\beta} V_{\cancel{max}\,m} \sin \omega t \, d\omega t = \frac{V_m}{\pi}\left[\cos\alpha - \cos\beta\right]$$

$$V_{o\,rms} = \sqrt{\frac{1}{\pi}\int_{\alpha}^{\beta} V_m^2 \sin^2(\omega t)\, d\omega t}$$

How to Find β ?!

$$i(\beta) = 0 = \sin(\beta-\alpha) - \sin(\alpha-\theta)\, e^{\frac{(\alpha-\beta)}{\omega\tau}}$$

Home work 48Δ.



Simulate the ckt Shown:

T1 ~~\$~~is triggred at 45°

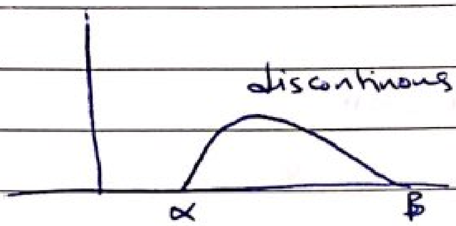
T2 is " " 225°

Show the result for :-

1. is and Vs [source current and voltage.]
2. vo avg and Vo rms
3. repeat the above with a constant current Source [10A] replaces the RL load.

Full wave controlled Rectifier with R-L 8Δ

↳ dis continous mode 8Δ



↳ $\sin(\beta-\theta) - \sin(\alpha-\theta)\, e^{\frac{-\alpha-\beta}{\omega\tau}} = 0$

For continous Mode 8Δ

$i_o(\omega t) > 0$

For $\omega t = \alpha + \pi$

$$\frac{V_m}{Z}\left[\sin(\pi+\alpha-\theta) - \sin(\alpha-\theta)\, e^{-\frac{\alpha-\pi+\alpha}{\omega\tau}}\right] > 0$$

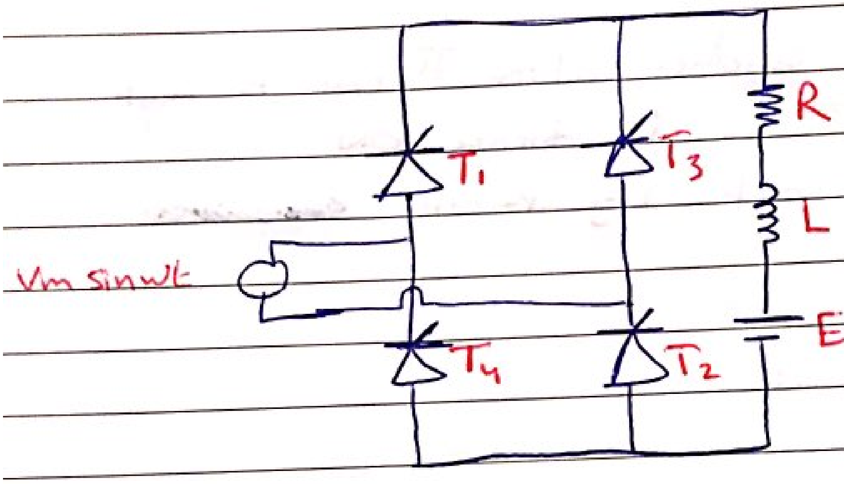
$$\sin(\theta-\alpha)\left[1 + \sin(\theta-\alpha)\, e^{-\pi/\omega\tau}\right] > 0$$

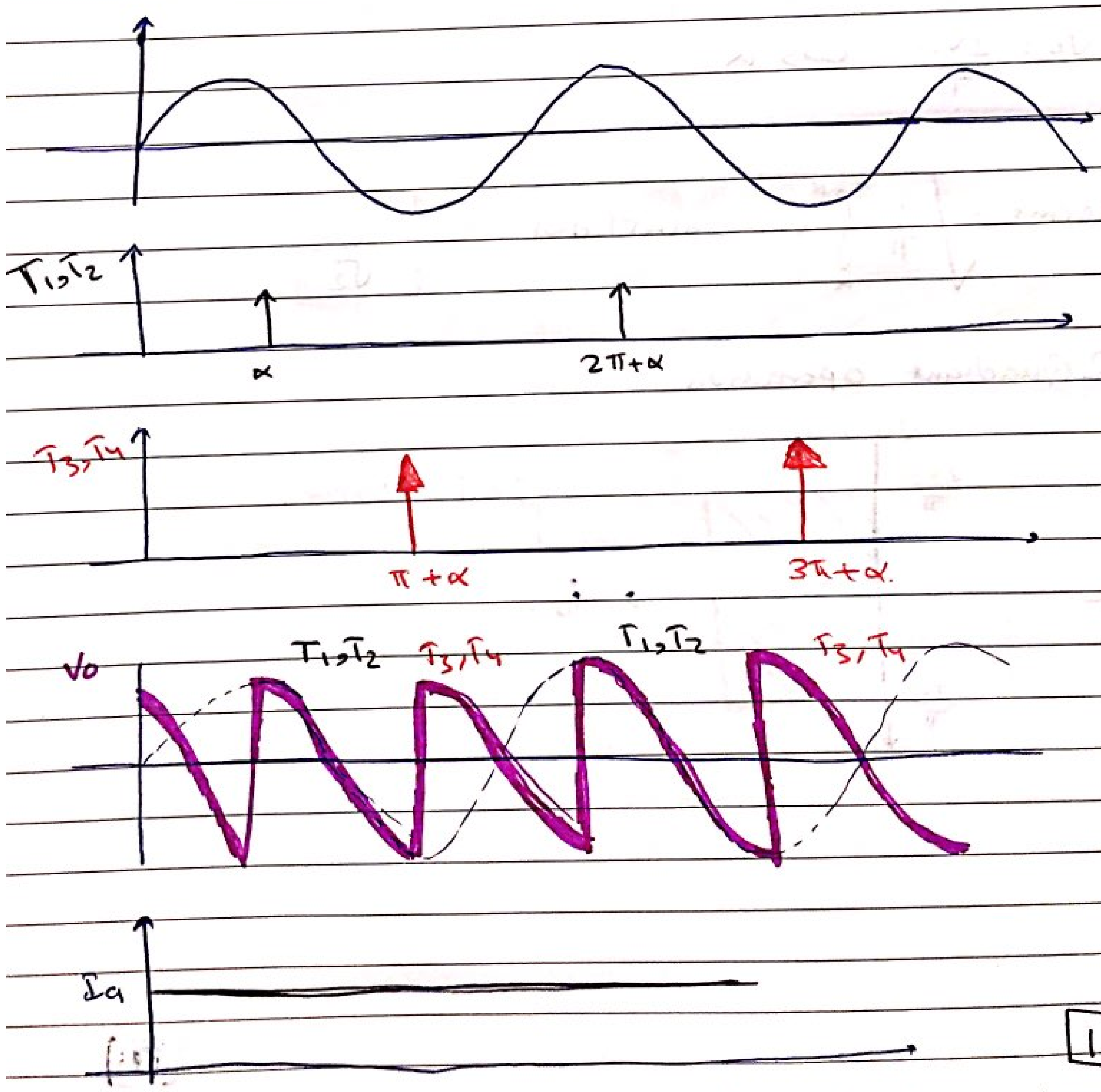
$$\sin(\theta-\alpha) > 0$$

$$\alpha < \theta$$

$$\boxed{\alpha < \tan^{-1}\frac{\omega L}{R}}$$

FW controlled rectifier with RL load [highly inductace] a battery





Triggering occured at α when α is grater than $\sin^{-1}\left(\frac{E}{V_m}\right)$

T_1, T_2 continous to conduct after π due to high inductance, until T_3, T_4 is turned ON

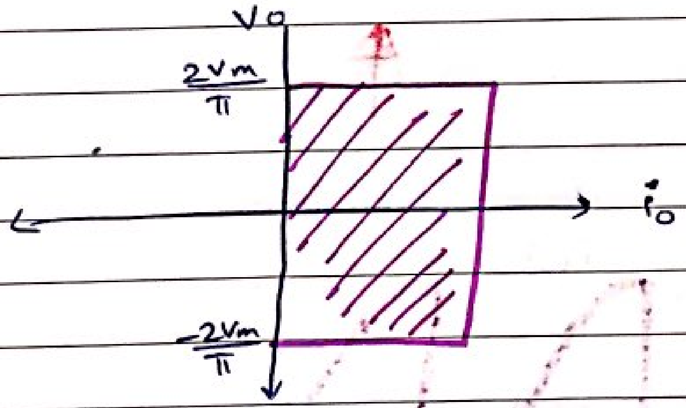
T_1, T_2 are turned off by natural conmetation

$$V_o = \frac{1}{\pi}\int_{\alpha}^{\pi+\alpha} V_m \sin wt \; dwt$$

$$\boxed{V_o = \frac{2V_m}{\pi} \cos\alpha}$$

$$V_{orms} = \sqrt{\frac{1}{\pi}\int_{\alpha}^{\pi+\alpha} V_m \sin(wt)\; dwt} = \boxed{\frac{V_m}{\sqrt{2}}}$$

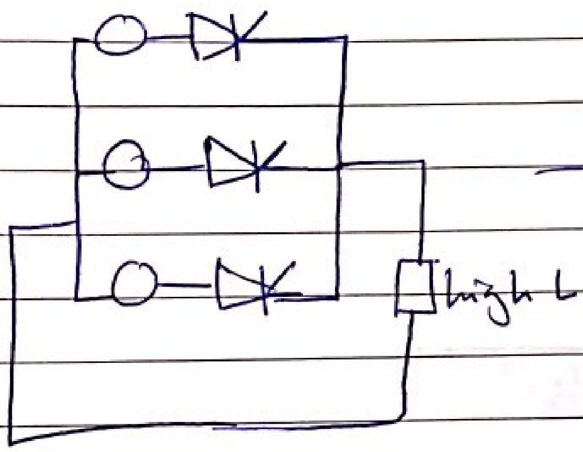
* 2 Quadiant operation.

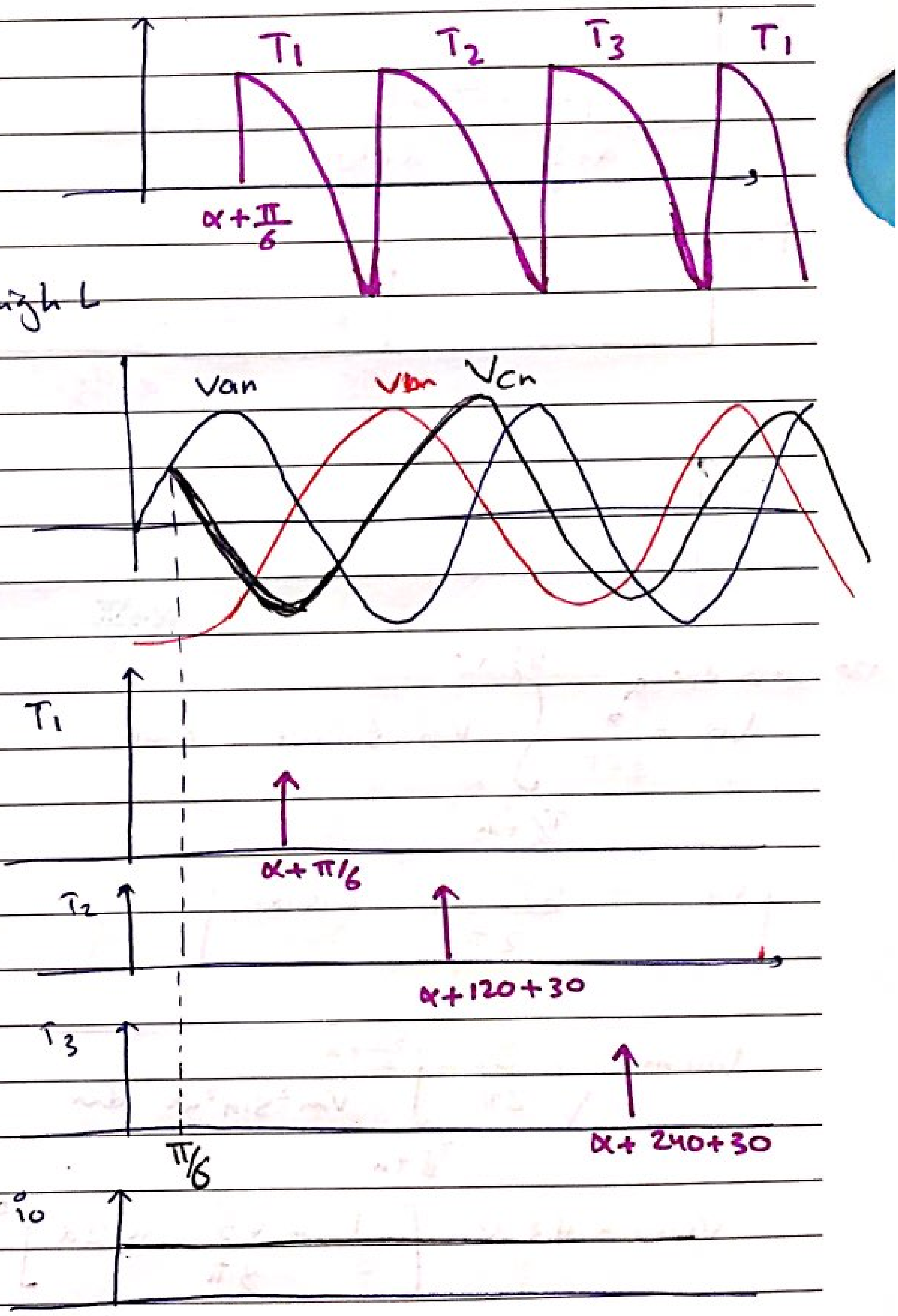


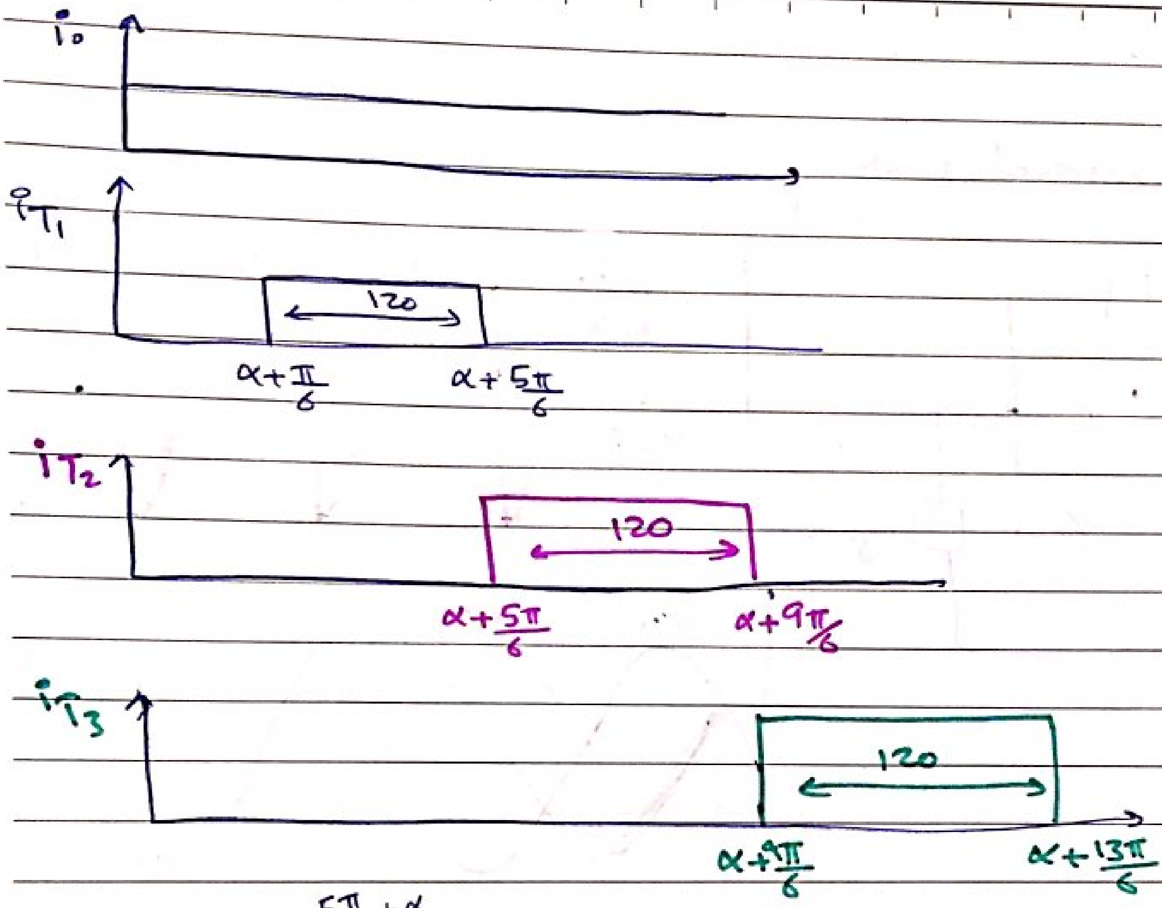
Semi inverter.

Ex 10.1

3ϕ controlled HWR.







الفترة كاملة 120°

$$V_{dc} = \frac{3}{2\pi}\int_{\pi/6+\alpha}^{\frac{5\pi}{6}+\alpha} V_m \sin\omega t \quad d\omega t$$

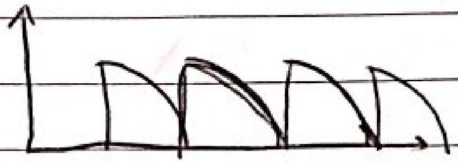
$$\boxed{V_{dc} = \frac{3\sqrt{3}\,V_m}{2\pi}\cos\alpha}$$

$$V_{orms} = \sqrt{\frac{3}{2\pi}\int_{\pi/6+\alpha}^{\frac{5\pi}{6}+\alpha} V_m^2\sin^2\omega t \quad d\omega t}$$

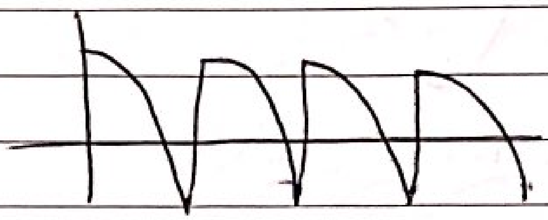
$$V_{orms} = \sqrt{3}\,V_m\left[\frac{1}{6}+\frac{\sqrt{3}}{8\pi}\cos 2\alpha\right]^{0.5}$$

HWR

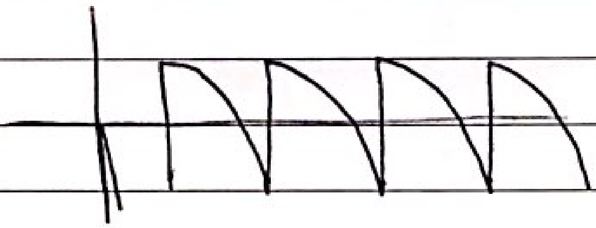
$\alpha = 30$



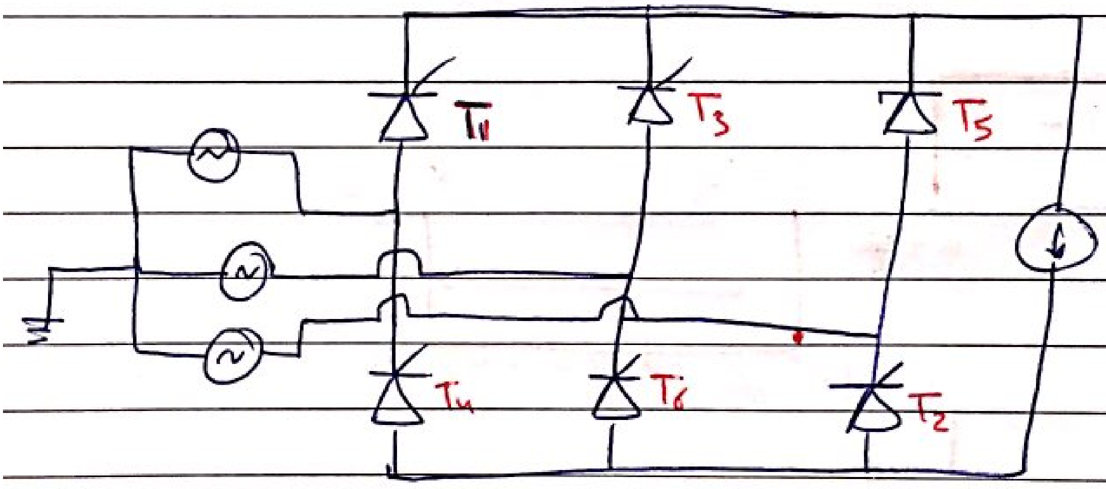
$\alpha = 60$

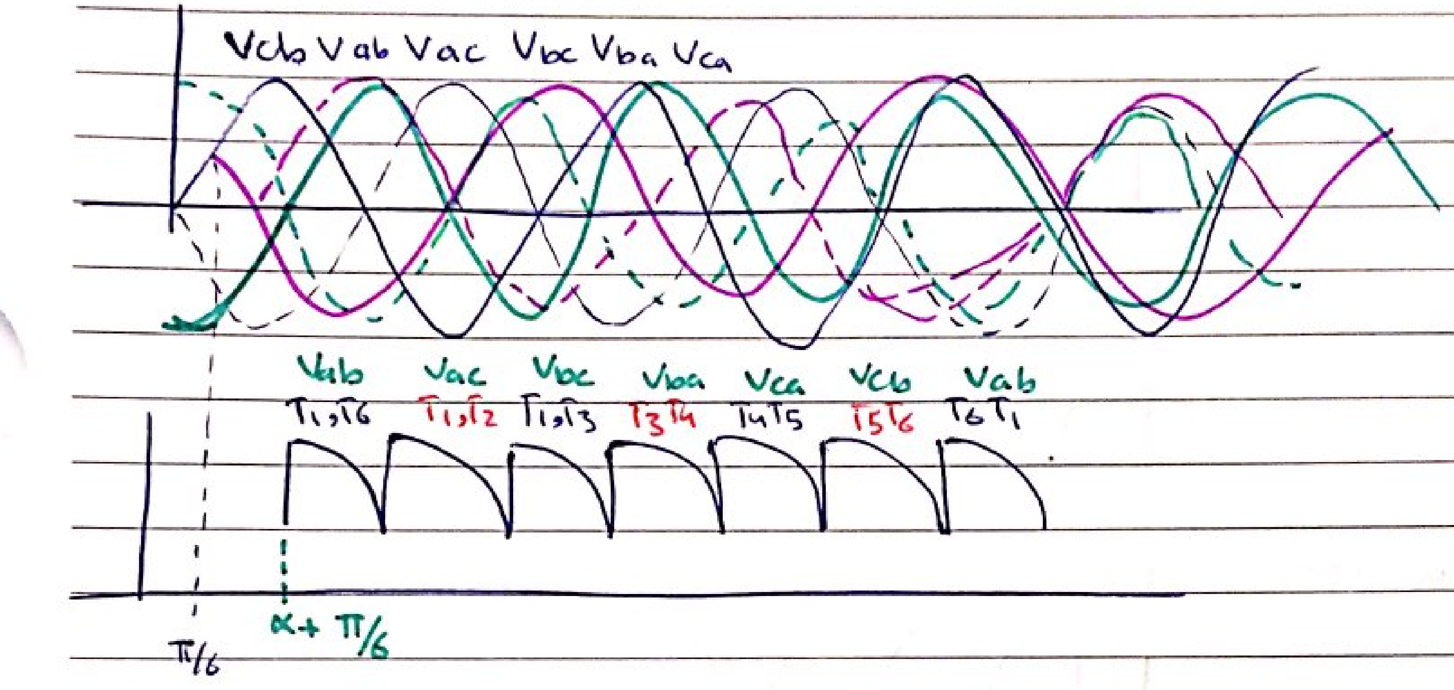


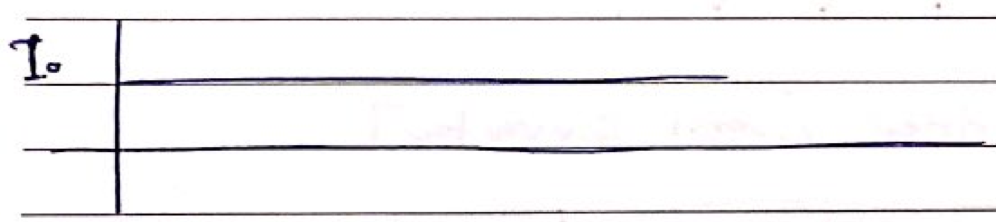
$\alpha = 90$

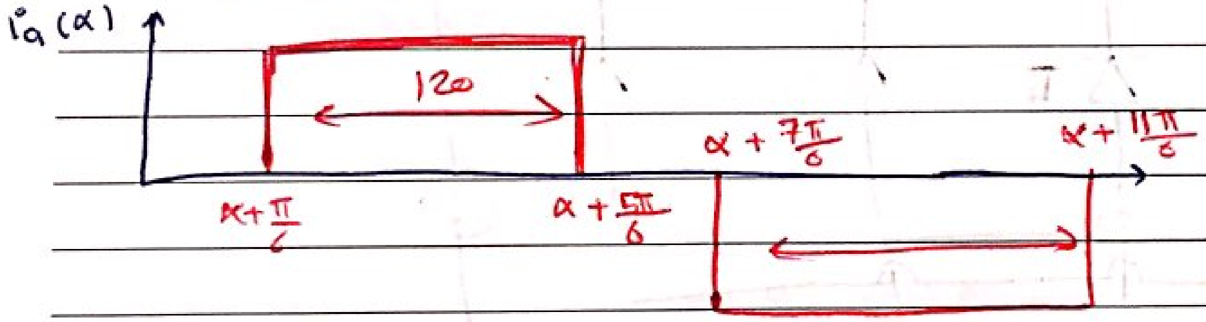


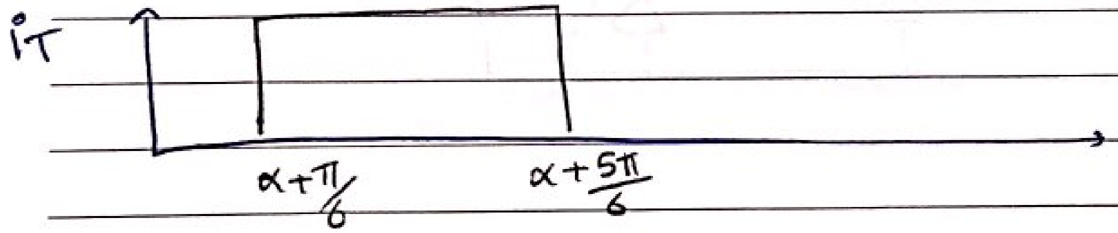
3Ø controlled rectifier [semi converter]





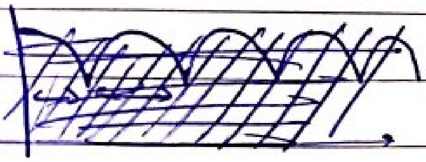




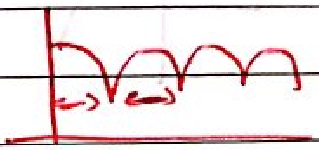


$$V_{dc} = V_{oavg} = \frac{3}{\pi}\int_{\alpha+\pi/6}^{\alpha+\frac{\pi}{2}} V_{ab}\; d\omega t$$

$$= \frac{3}{\pi}\int_{\alpha+\pi/6}^{\alpha+\pi/2} \sqrt{3}\; V_m \sin(\omega t + \pi/6)\; d\omega t$$



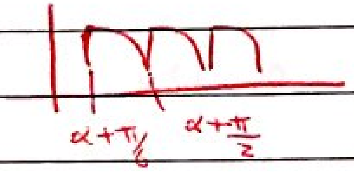
$$\boxed{V_{DC} = \sqrt{3}\,\frac{3\,V_m}{\pi}\cos\alpha}$$



$V_{an} = V_m \sin\omega t$

$V_{ab} = \sqrt{3}\, V_m \sin(\omega t + 30)$

$V_{cb} = \sqrt{3}\, V_m \cos(\omega t)$

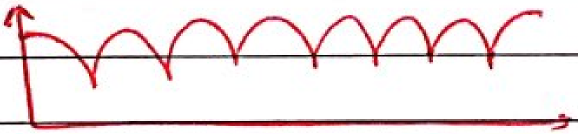


$$V_{rms} = \sqrt{\frac{3}{\pi}\int_{\alpha+\pi/6}^{\alpha+\pi/2} V_{ab}^2 \, d\omega t}$$

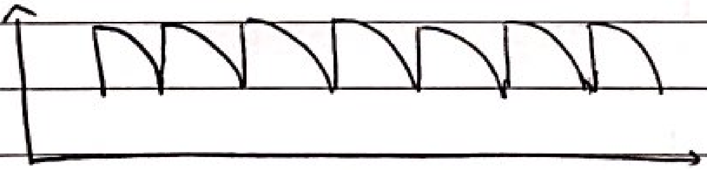
$$\boxed{V_{rms} = \sqrt{3}\, V_m \left[\frac{1}{2} + \frac{3\sqrt{3}}{4\pi}\cos 2\alpha\right]^{1/2}}$$

3ϕ controlled rectifier [semi converter]:

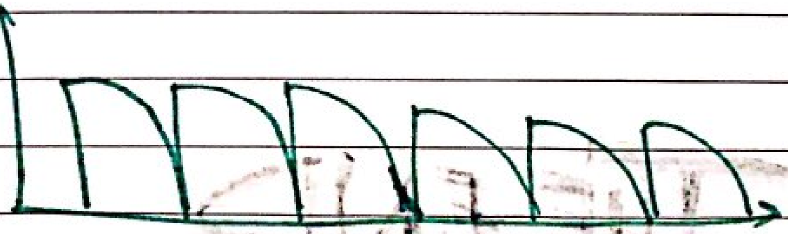
$\alpha = 0$



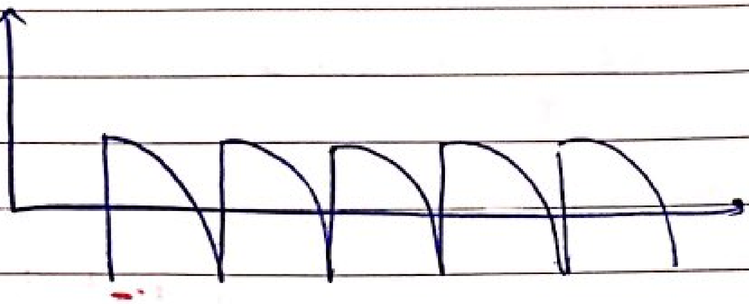
$\alpha = 30$



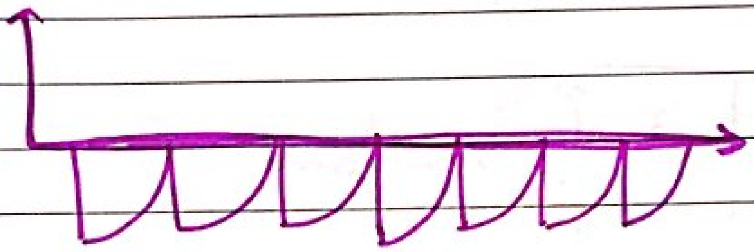
$\alpha = 60$



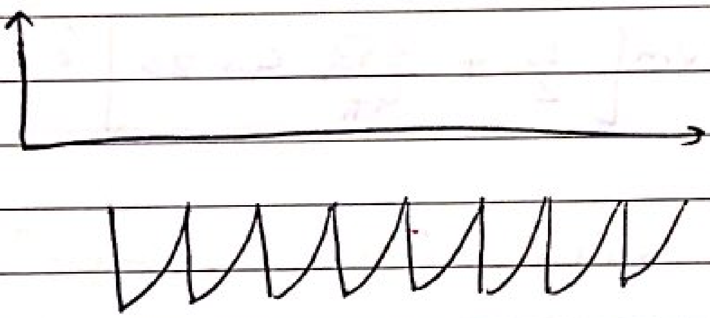
$\alpha = 90$



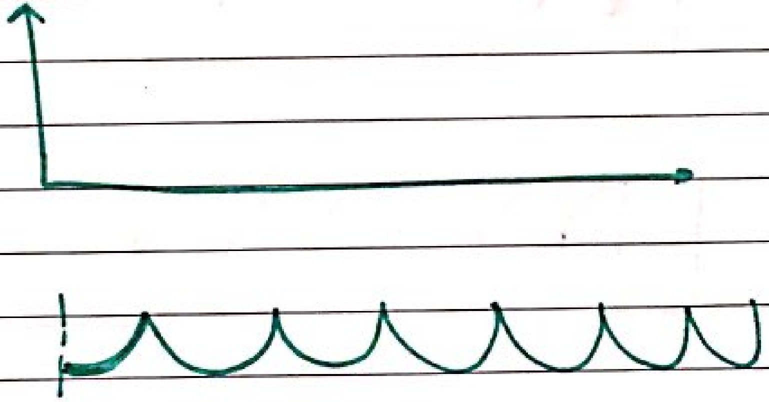
$\alpha = 120$



$\alpha = 150$



$\alpha = 180$



THE END