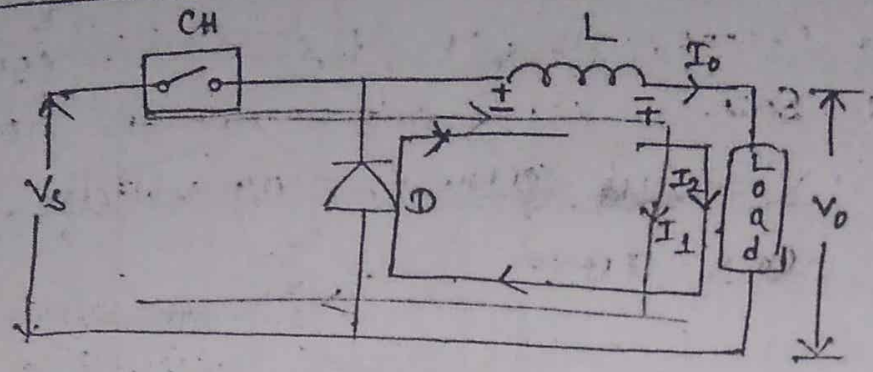
Chopper

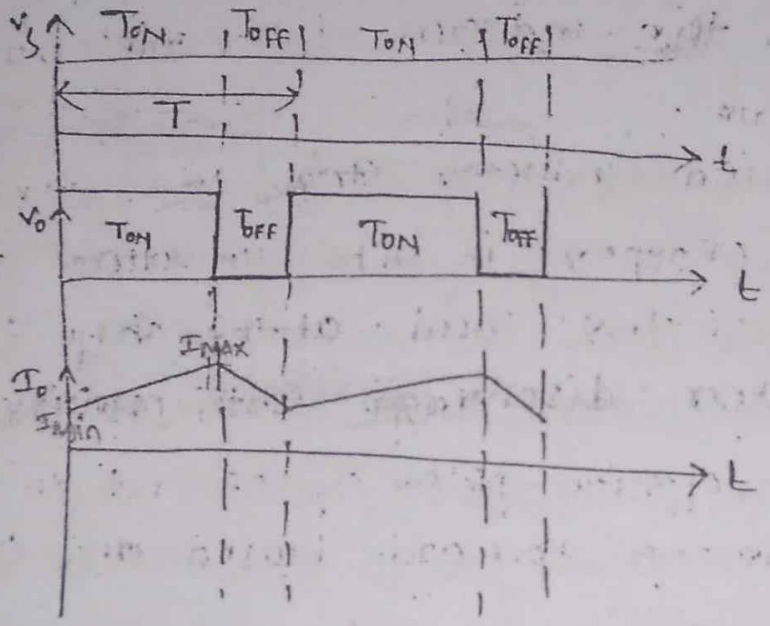
15.11.20

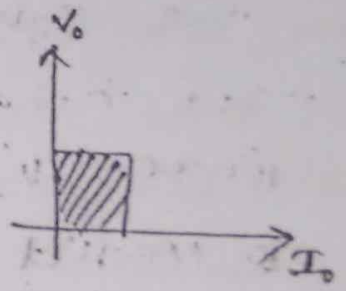
It is a power electronics device which converts Fixed DC to variable DC.

a) step down chopper
b) step up chopper.

Step down Chopper







$$V_{oavg} = V_s \left(\frac{T_{ON}}{T_{ON} + T_{OFF}}\right)$$

$$= V_s \left(\frac{T_{ON}}{T}\right)$$

$\frac{T_{ON}}{T} = D$ (Duty cycle)

$(D < 1)$

$V_{oavg} = V_s \times D$

V_s = supply voltage.

Note
In this type of chopper the o/p voltage & current both are +ve.
→ This mode of operation occurs at 1st quadrant and used as Forward Motoring action.

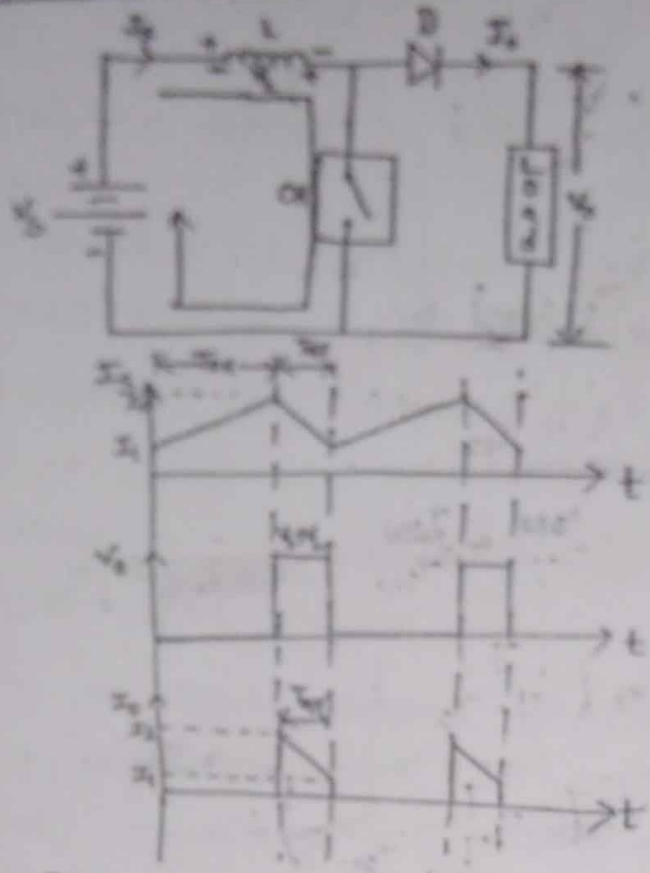
$V_{avg} < V_s$

→ a step down chopper consists of a switch, inductor and a diode
→ a chopper is basically a controlled switch.
→ The load is connected series with load the source and an inductor.
→ when the chopper is ON the load is connected with the source and o/p current flows through the load and the o/p voltage will appear across load.
→ when the current flows through the inductor it charges the inductor from min^m value to max^m value.
→ in this period inductor stores the energy.
→ when the chopper is OFF i/p voltage will not appear to the load. at the same time the inductor discharge with opposite polarity.
→ Due to the opposite polarity of inductor the diode 'D' becomes forward biased and starts to conduct.
→ Due to this F.B diode a circulating current starts to flow (From L → load → diode → L) . which is same in the direction of the previous current. and it decreases from max^m value to min^m value.
→ The average o/p voltage depends up on the duty cycle ($\alpha = \frac{T_{ON}}{T}$). The Duty cycle is always less than 1 therefore the average o/p voltage (V_{oavg}) is

always less than the supply voltage. So it is known as a step down chopper.

Step up chopper

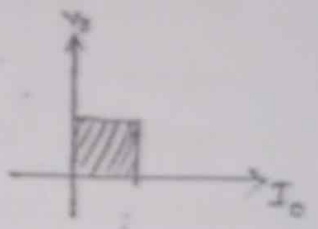
Ap-11-28



$V_s + V_L - V_o = 0$

$\Rightarrow V_o = V_s + V_L$

$\Rightarrow V_L = V_o - V_s$



Energy stored during T_{ON}.

$$E_{ON} = P_{ON} T_{ON}$$

$$= V_s I_s \times T_{ON}$$

$$= V_s \left(\frac{I_1 + I_2}{2}\right) \times T_{ON}$$

Energy released during T_{OFF}.

$$E_{OFF} = P_{OFF} T_{OFF}$$

$$= (V_o - V_s)\left(\frac{I_1 + I_2}{2}\right) \times T_{OFF}$$

$\therefore E_{ON} = E_{OFF}$

$$V_s \left(\frac{I_1 + I_2}{2}\right) \times T_{ON} = (V_o - V_s)\left(\frac{I_1 + I_2}{2}\right) \times T_{OFF}$$

$$\Rightarrow V_s \times T_{ON} = (V_o - V_s) \times T_{OFF}$$

$$\Rightarrow V_s \times T_{ON} = V_o \times T_{OFF} - V_s \times T_{OFF}$$

$$\Rightarrow V_s \times T_{ON} + V_s T_{OFF} = V_o T_{OFF}$$

$$\Rightarrow V_s(T_{ON}+T_{OFF}) = V_0 T_{OFF}$$

$$\Rightarrow V_0 = V_s\left(\frac{T_{ON}+T_{OFF}}{T_{OFF}}\right) = V_s\left(\frac{T}{T_{OFF}}\right)$$

$$= V_s\left(\frac{T_{ON}}{T_{OFF}}+1\right)$$

$$= V_s\left(\frac{T_{ON}}{(T_{ON}+T_{OFF})-T_{ON}}+1\right)$$

$$= V_s\left(\frac{T_{ON}}{T-T_{ON}}+1\right)$$

$$= V_s\left(\frac{T_{ON}}{T}\Big/\frac{T-T_{ON}}{T_{ON}}+1\right)$$

$$\Rightarrow V_0 = V_s\left(\frac{T}{T-T_{ON}}\right)$$

$$= V_s\left(\frac{1}{\frac{T}{T}-\frac{T_{ON}}{T}}\right)$$

$$\Rightarrow \boxed{V_0 = V_s\left(\frac{1}{1-D}\right)} \quad \left(\because \frac{T_{ON}}{T} = D\right)$$

The step up chopper consist of a inductor connected across supply voltage and the load side consist of a Free wheeling diode.

→ when the chopper is on their ~~load~~ is no current Flows through the load

→ At that time the supply current increase From mim^M to man^M value.

→ when the chopper is on o/p voltage does not appear across load.

→ In this period a current is Flows ~~from~~. From. $V_s \rightarrow L \rightarrow Ch \rightarrow V_s$. and inductor stores the energy.

→ when the chopper is OFF i/p voltage appears across load and at that time inductor discharge with opposite polarity.

o/p voltage (V_0) = $V_S + V_L$

→ when the chopper is OFF the diode is Forward biased.

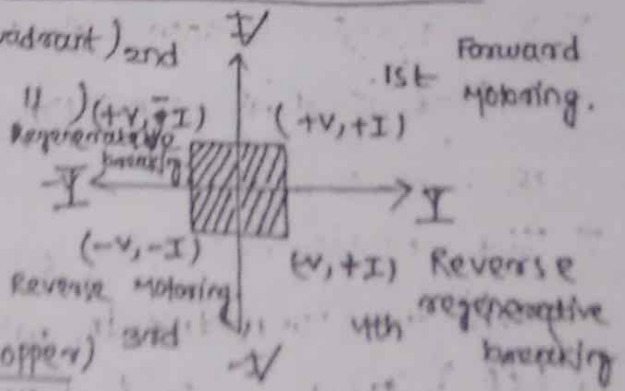
→ when the chopper is on their is no current Flows through the load and when the chopper is OFF their is a current starts to Flow same as i/p current (due to series connection OF load and supply) i.e max^m value to mim^m. value.

→ The o/p voltage depends upon ~~supply voltage~~ Duty cycle. duty cycle always less than 1 ∴ their- Fore o/p voltage is greater than supply voltage. i.e $V_0 = V_S\left(\frac{1}{1-D}\right)$ so it is called step up chopper.

21.11.20

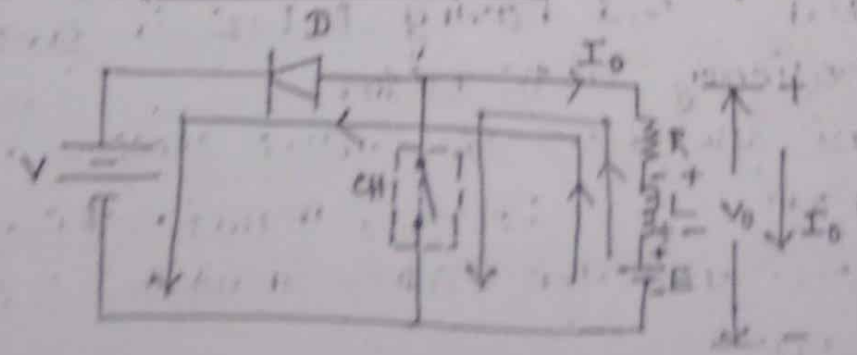
According to direction OF current & voltage / quadrant of operation

1) class - A / Type - A (1st quadrant)
2) class - B / Type - B (2nd ")
3) class - C / Type - C
4) class - D / Type - D
5) class - E / Type - E



Type-B (2nd quadrant chopper)

(+V,-I)

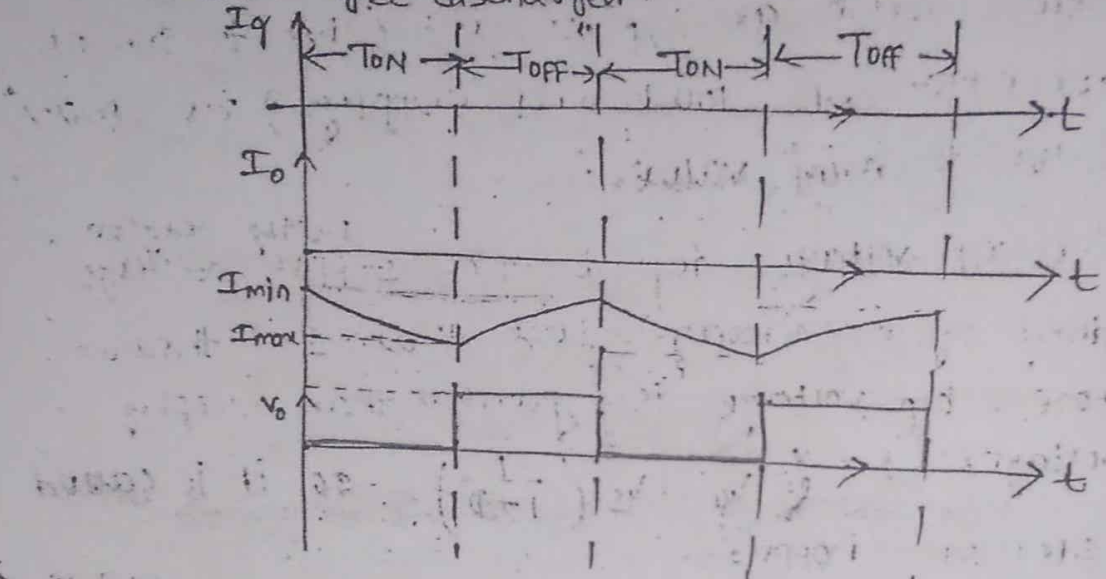


CH - ON

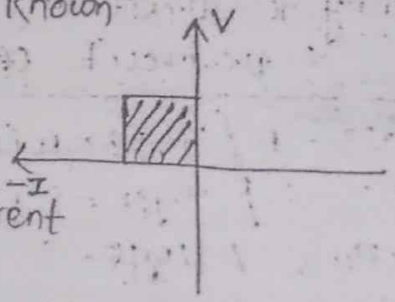
current Flows From the load (E) (+E → L → R → CH → -E)
The current opposite to the o/p current (I_o).
Inductor gets charged
o/p voltage is zero.

CH - OFF

current Flows From load to source.
(+E → L → R → D → V → -E)
Current Flows in reverse direction.
o/p voltage is equal to i/p voltage.
Inductor get discharged.



→ A class-B chopper is also known as 2nd quadrant chopper.



→ In class-B chopper the o/p voltage is +ve and o/p current is -ve.

→ The basic ckt of class-B chopper is consists of a diode connected in reverse direction, a chopper (SCR) and a load having R, L, E in series, that is basically a DC Motor.

→ The basic operation of class-B chopper explained in 2 mode i.e mode-1, in which the chopper (CH) is ON. and the mode-2 in which chopper (CH) is OFF.

Mode-1 (CH-ON)

AS the CH is ON it makes a contineous path at the load side through the CH.

→ At that time a current starts to Flow From 'E' through the CH.

→ The current starts to Flow From +E → L → R → CH → E and charges the inductor From minM value to manM value.

→ It is seen that the current is opposite to the o/p current, and taken as -ve.

→ As the chopper is ON it makes the o/p short ckt therefore the o/p voltage is zero.

Mode-2 (CH-OFF)

when the CH is OFF the inductor start to discharge with opposite polarity.

→ This makes the diode Forward biased.

→ A current starts to Flow From the load to the source through diode-D (+E → RL → R → D → V → -E)

→ At that time the inductor get discharged and it is seen that the o/p current is Flows in -ve direction.

→ As the o/p is directly connected with the source then the o/p voltage is equal to i/p supply.

From the above two mode of operation it has been observed that the average value of o/p voltage is +ve and the average value of o/p current is -ve.

→ As the current Flows From load to source this mode of operation is known as regenerative breaking.

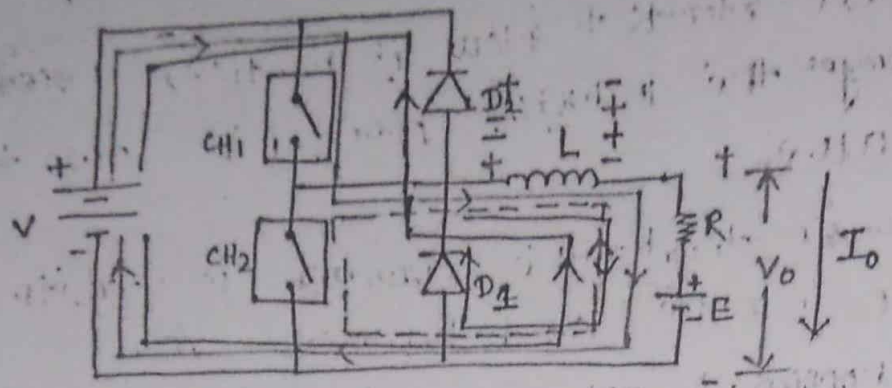
→ This ckt is used to break a dc motor.

Class-C chopper :-

It is the combination of "class-A & class-B chopper.

→ It is also called two quadrant chopper.

→ It operates on both 1st & 2nd quadrant.



CH_1 - ON

* current flows from source to load.

  i.e $V^+ \rightarrow CH_1 \rightarrow L \rightarrow R \rightarrow E \rightarrow V^-$

* As the current is same as the direction of o/p current, current is +ve.
* The o/p voltage is same as the i/p and +ve.
* The current charges the inductor.

CH_1 - OFF

* Inductor starts to discharge with opposite polarity.
* This makes the diode D_1 Forward biased.
* Then a circulating current starts to flow in the closed path i.e $L^+ \rightarrow R \rightarrow E \rightarrow D_1 \rightarrow L^-$
* As the direction of current is same as the direction of the o/p current therefore it is taken as +ve.
* The emf is appears at the o/p and is +ve.
* The CH_1 & D_1 used as a class-A chopper.

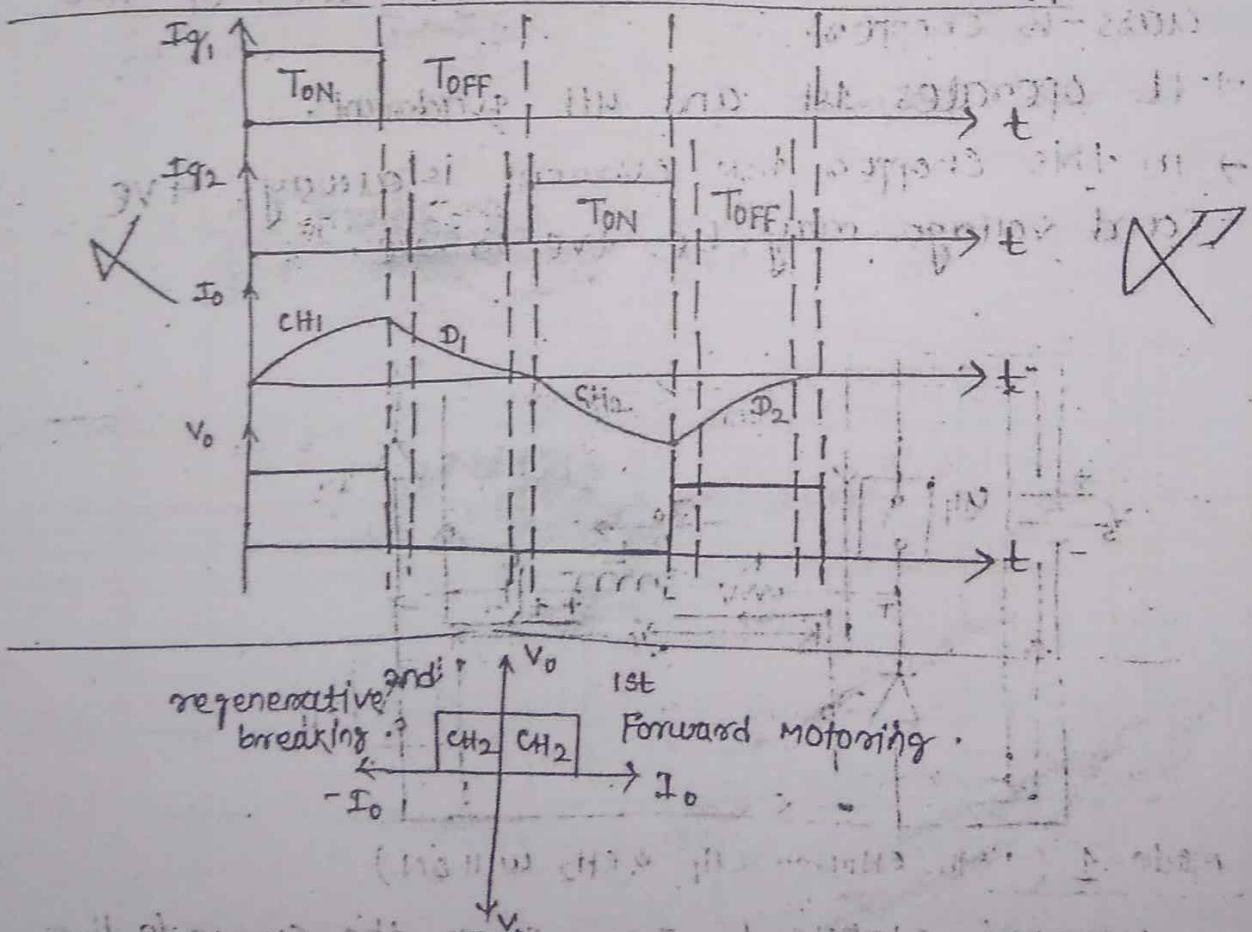
CH_2 - ON

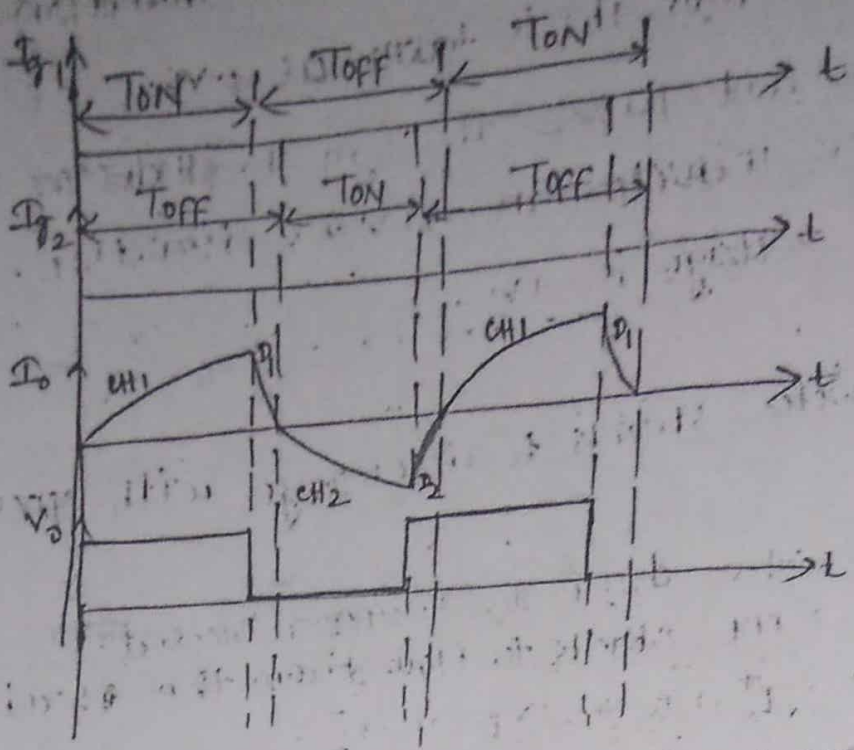
* A closed path is established at E, R, L & CH_2.
* A current starts to flow from the emf E i.e $E^+ \rightarrow R \rightarrow L \rightarrow CH_2 \rightarrow E^-$.

* As the current is opposite to the direction of o/p current then, it is taken as -ve.
* As the current passes through the inductor it charges the inductor in reverse direction.
* The o/p voltage is +ve.

CH_2 - OFF

* The inductor starts to discharge with opposite polarity.
* This makes the diode - D_2 Forward biased.
* Then a current starts to Flow From the Load to source i.e $L^+ \rightarrow D_2 \rightarrow V \rightarrow E \rightarrow R \rightarrow L^-$.
* As thie current is opposite to the o/p then it is taken as -ve.
* The o/p voltage is +ve and same as i/p.





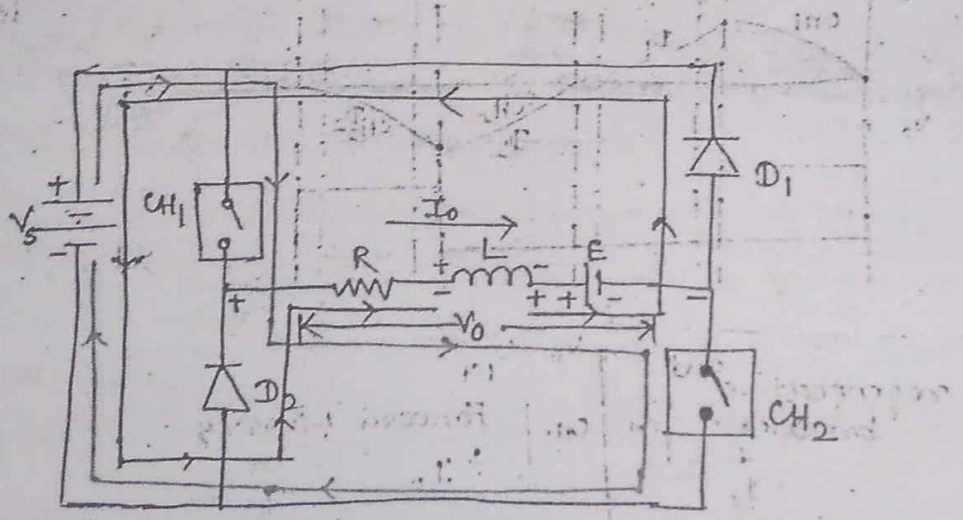
→ class-C chopper used for forward motoring and regenerative breaking.

class-D chopper:-

It is a two quadrant chopper, combination of two class-B chopper.

→ It operates 1st and 4th quadrant.

→ In this chopper the current is always +ve and voltage may be +ve or -ve.



Mode-1 (Both chopper CH1 & CH2 will ON)

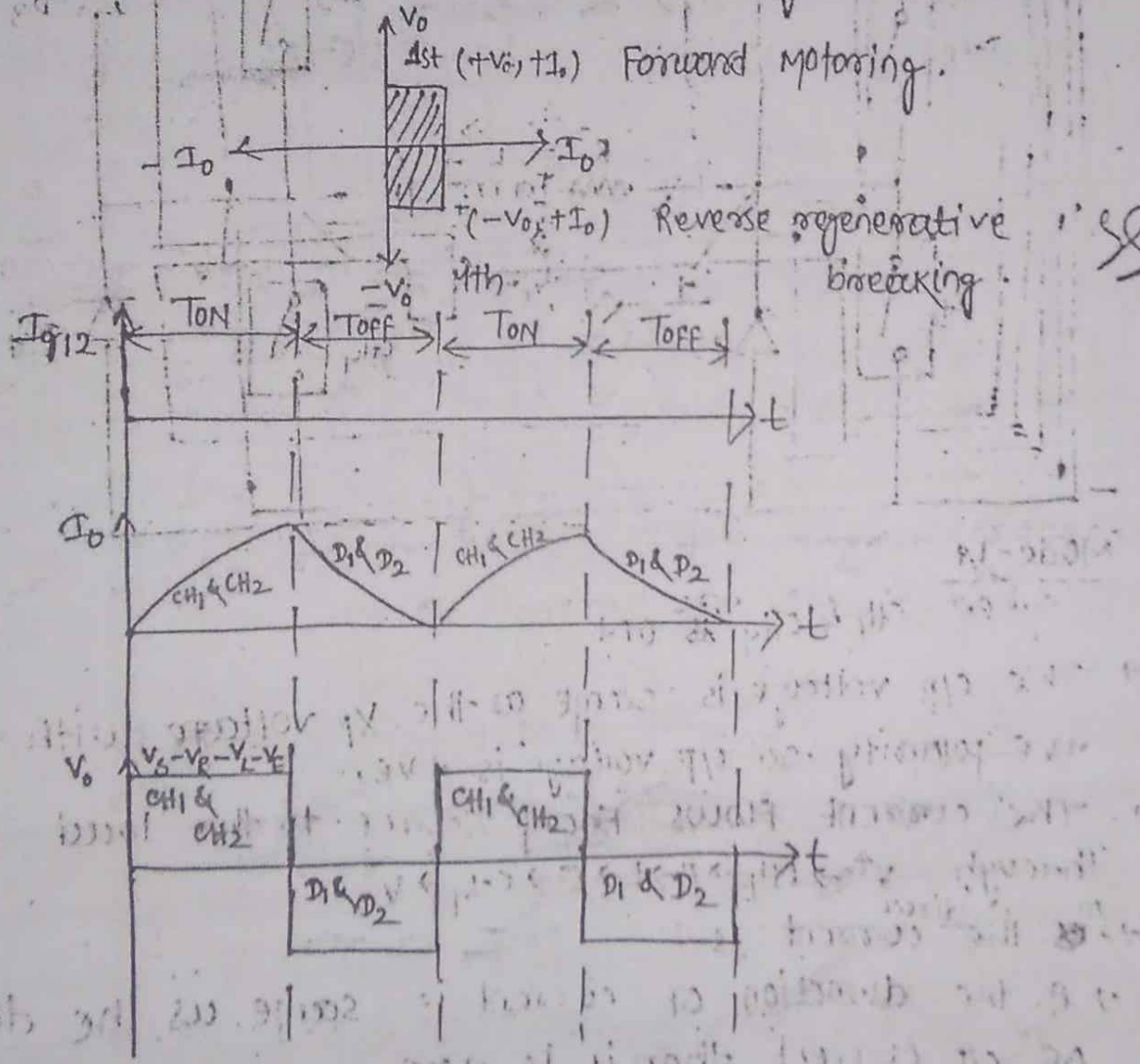
* current starts to flow from the source to the load through $V^+ \rightarrow CH_1 \rightarrow R \rightarrow L \rightarrow E \rightarrow CH_2 \rightarrow V^-$.
* The current charges the inductor.
* As the direction of the current is same as the o/p

current then taken as +ve current.

* the o/p voltage is same as the y/p voltage with +ve polarity.

Mode-2 (Both the chopper CH1 & CH2 will OFF)

* inductor discharges with opposite polarity and Forward biased diode D_1 & D_2.
* Then current Flows From $L^+ \rightarrow E \rightarrow D_1 \rightarrow V \rightarrow D_2 \rightarrow R \rightarrow L^-$.
* Direction of current is same as o/p current then taken as +ve current.
* The voltage appears across the o/p with opposite polarity so it is taken as -ve voltage.



→ This type of chopper are used for Forward Motoring and reverse regenerative breaking.

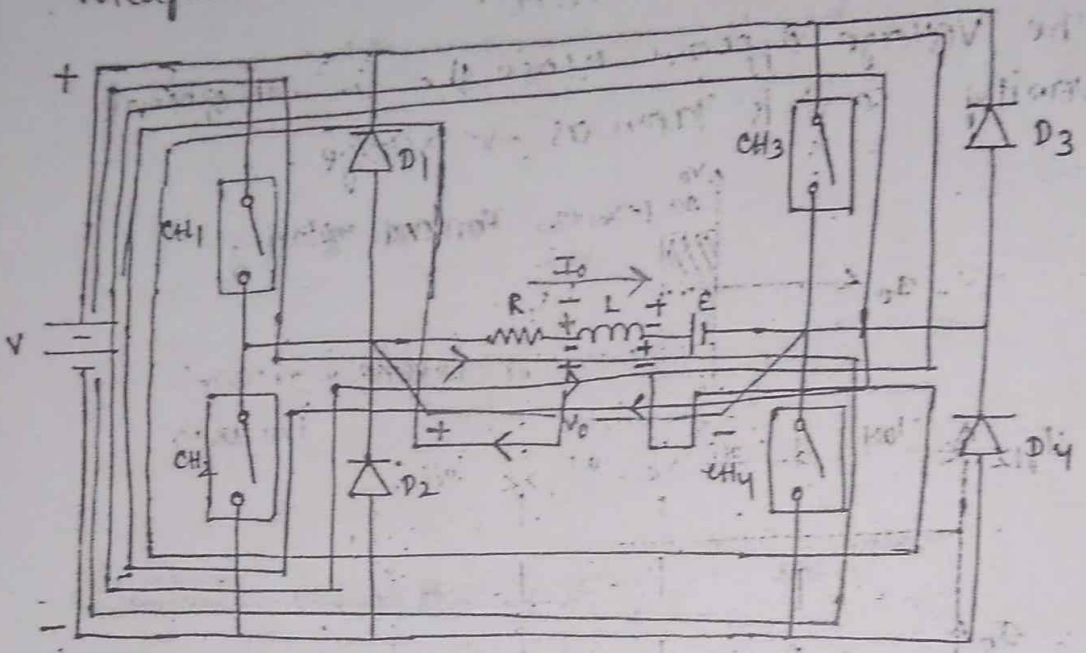
Class-E chopper:-

It is a Four quadrant chopper.

→ It operates on 1st, 2nd, 3rd & 4th quadrant.

→ It is a parallel connection of two class-C chopper.

→ we can't operates CH_1 & CH_2 and CH_3 & CH_4 simultaneously because it will short the source voltage.



Mode-1:

when CH_1 & CH_4 are ON

→ The o/p voltage is same as the i/p voltage with +ve polarity. so o/p voltage is +ve.

→ The current flows from source to the load through $V^+ \rightarrow CH_1 \rightarrow R \rightarrow L \rightarrow E \rightarrow CH_4 \rightarrow V^-$

→ ~~As the direct current is~~ As the direction of current is same as the direction of o/p current then it is +ve.

→ this current charging the inductor

→ ~~There~~ As the voltage & current both are +ve then the operation is in 1st quadrant and the mode of operation is known as forward motoring action.

Mode-2
when CH1 & CH4 are off.
→ Then the inductor will starts to discharge with opposite polarity.
→ Due to this opposite polarity the diode D_2 & D_3 are forward biased.
→ Due to the Forward biased diode a current starts to flow From $L^+ \rightarrow E \rightarrow D_3 \rightarrow V \rightarrow D_2 \rightarrow bR \rightarrow L^-$.
→ As the direction of current is same as the o/p current it is taken as +ve.
→ As the +ve terminal of source is connected to the -ve terminal of o/p and the -ve terminal of source is connected as the +ve terminal of o/p so the o/p voltage is -ve.
→ As the voltage is -ve & the current is +ve it operates on 4th quadrant and the mode of operation is known as reverse regenerative breaking.

Mode-3
when CH2 & CH3 are ON.
→ The +ve terminal of the supply voltage connected across the -ve terminal of o/p voltage and viceversa. so the voltage is taken as -ve voltage.
→ The current is starts to flow From source to load through $V^+ \rightarrow CH_3 \rightarrow E \rightarrow L \rightarrow R \rightarrow CH_2 \rightarrow V^-$.
→ As the direction of current is opposite to the o/p current it is taken as -ve.
→ This reverse current charging the inductor in reverse direction.
→ As the voltage & current both are -ve, it operates on 3rd quadrant and the mode of operation is known as reverse motoring

Mode-4

when CH_2 & CH_3 are OFF

→ The inductor starts to discharge with opposite polarity.

→ This makes the diode D_1 & D_4 forward biased.

→ This forward biased diode makes a current flow

From $L^+ \rightarrow R \rightarrow D_1 \rightarrow V \rightarrow D_4 \rightarrow E \rightarrow L^-$.

→ As the direction of current is opposite to the o/p current then it is taken as -ve. and the inductor get discharged.

→ As the +ve terminal of supply is connected to the +ve and -ve terminal is connected to -ve of the o/p voltage then it is taken as +ve.

→ As the voltage is +ve and current is -ve then it operates in 2nd quadrant and the mode of operation is regenerative breaking.