CHOPPER

By

Dr. Ananyo Bhattacharya
Assistant Professor
EE Department
NIT Jamshedpur

INTRODUCTION

Chopper is a static device.

A variable dc voltage is obtained from a constant dc voltage source.

Also known as dc-to-dc converter.

Widely used for **motor control**.

Also used in **regenerative braking**.

Thyristor converter offers greater efficiency, faster response, lower maintenance, smaller size and smooth control

Definition of Chopper

A chopper is an electronic switch that is used to interrupt one signal under the control of another.

In other words we can say that, a chopper is a kind of switch which allows the power flow in the circuit for a required duration.

Thus, the chopper is also known as a d.c. to d.c converter.

Types of Choppers

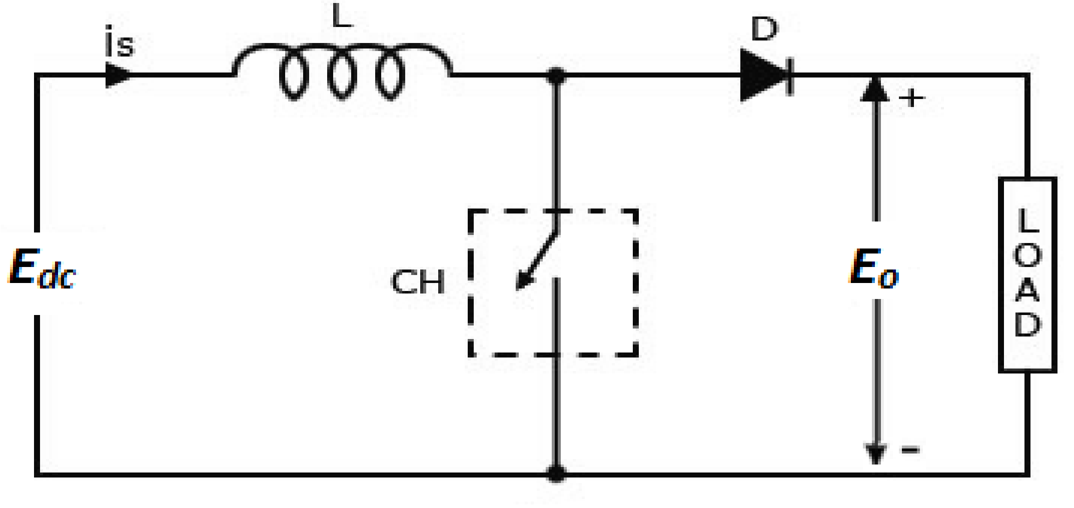
Step-down choppers:

In step down chopper **output voltage is less than input voltage.**

Step-up choppers:

In step up chopper **output voltage is more than input voltage.**

Step-up chopper



Definition :

The chopper can be use to produced higher voltages at the load than the input voltage (i.e., $E_0 \geq E_{dc}$). This is called as Step-up chopper

Working

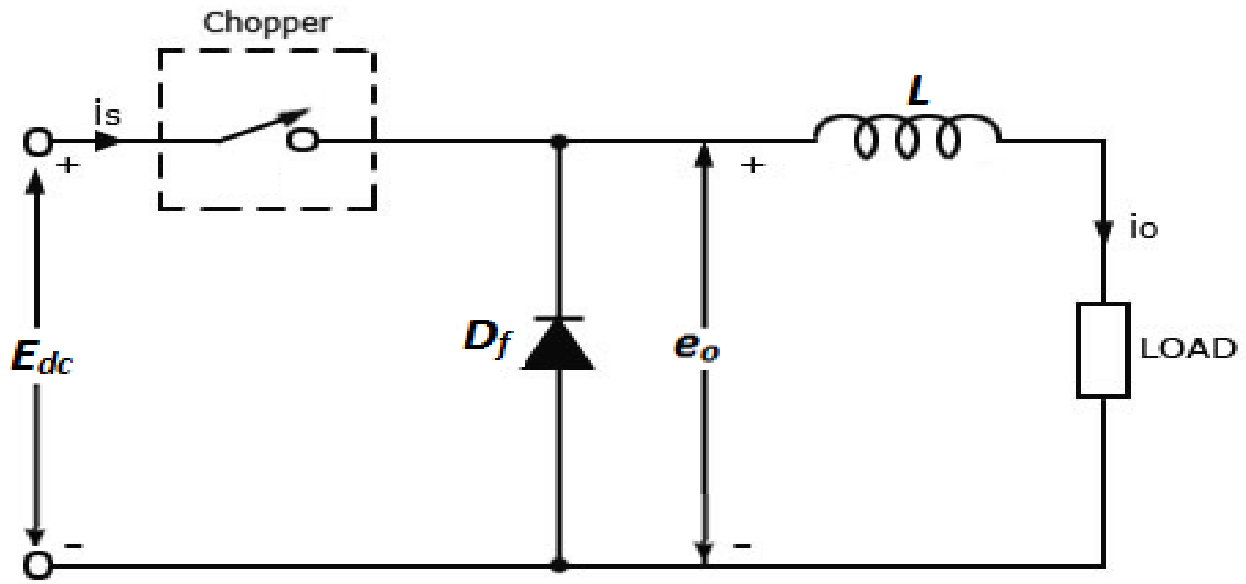
Case 1 : When the chopper is on the current I_L flows through inductor and it stores the energy during on period.

Case 2 : When the chopper is on the inductor force to permit the flow of current through the diode and the load. Therefore the load voltage becomes $E_0 = E_{dc} + E_L$.

$$E_0 = E_{dc} + L. d/dt .(I_L)$$

When the inductor current decreases to zero, the polarity across inductor gets reversed and the process is repeated.

Step-Down chopper



Definition :

When the output voltage is less than the input dc voltage ($E_0 < E_{dc}$) then it is called as Step-down copper.

i.e., $E_0 < E_{dc}$

Working :

Case 1 : During the ON period of chopper the input voltage E_{dc} connected to the load and the inductor stores the energy across it.

Case2 : During the OFF period of chopper the inductor current and load current because of freewheeling diode get short circuited through the load and inductor. Therefore the load voltage is zero during the off period.

The output voltage E_0 is expressed as,

$$E_0 = E_{dc} \times (T_{ON})/(T_{ON} + T_{OFF}) \qquad ...(1)$$

Hence,

$$E_0 = E_{dc} (T_{ON} / T) \qquad ...(2)$$

Here,

$T_{ON} + T_{OFF} = T$ = Chopping Period

T_{ON} = ON period of chopper

T_{OFF} = OFF period of chopper

$\alpha = T_{ON} / T$

The ratio of T_{ON} / T is called as duty cycle and represented as ‘α’.

$$E_0 = E_{dc} . \alpha$$

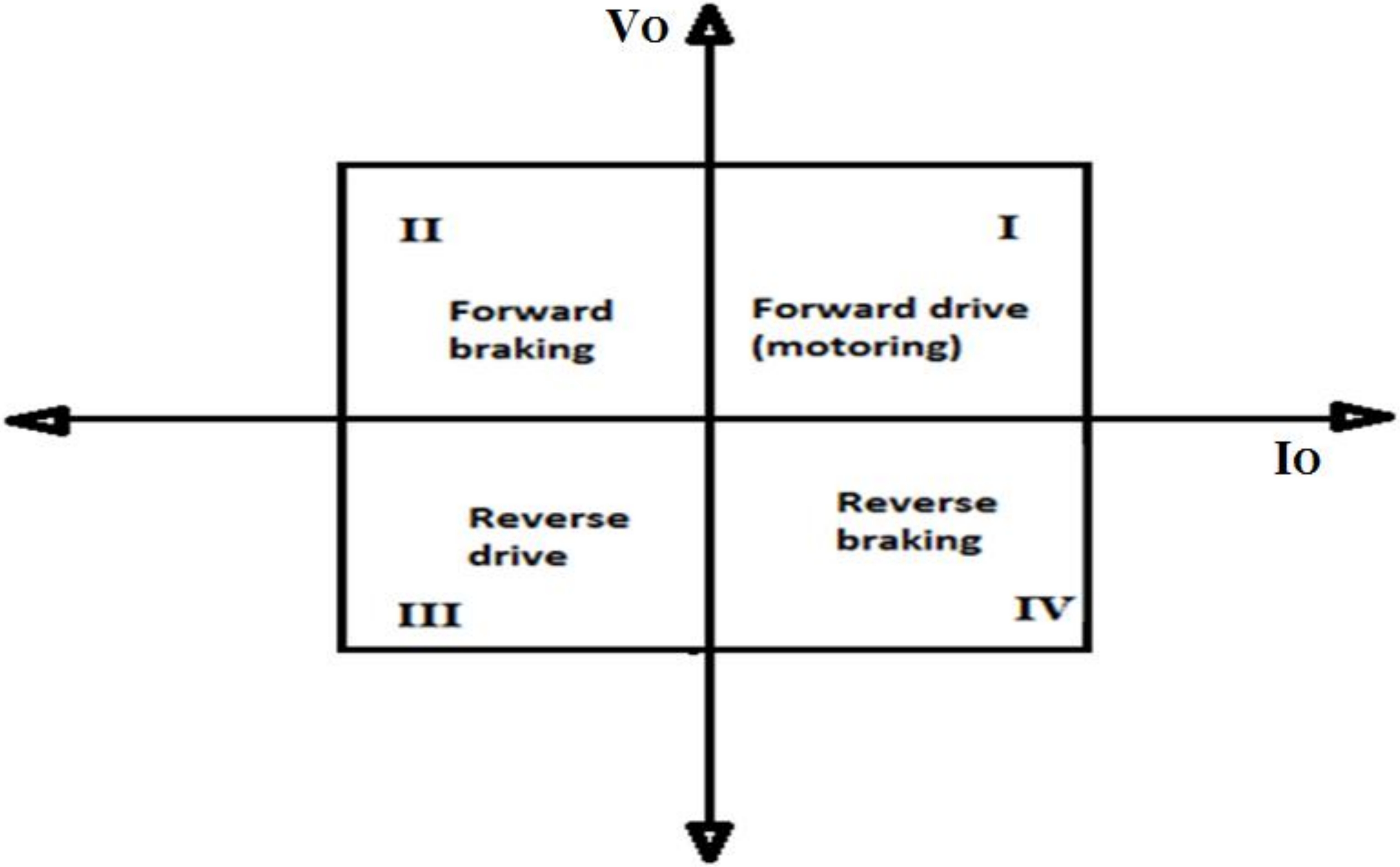
Where,

the chopping frequency control the output voltage.

$$E_0 = E_{dc} . T_{ON} .F$$

Where, $F = 1/T$ = Chopping frequency

Chopper Configuration



Chopper Configuration

- Figure shows the quadrant based chopper classification according to the nature of voltage and current .

- The dc chopper circuit is the combination of all these quadrants , in which the dc motor has to be operated as a load.

In quadrant second and fourth, the direction of energy flow is reversed and the motor is used as a generator rather than drive (motor).

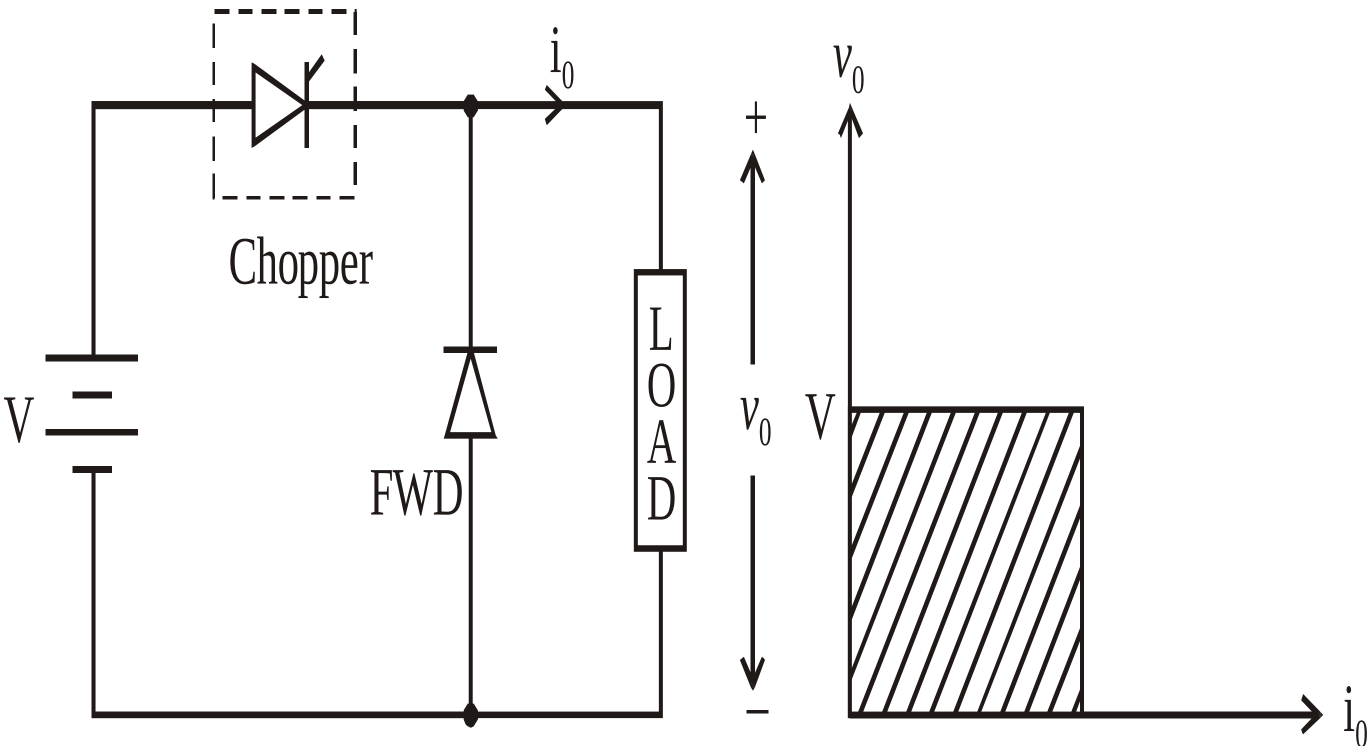
In quadrant first and third , the motor is used as a drive in clockwise and anticlockwise direction respectively.

Classification Of Choppers

Choppers are classified as:

- Class A Chopper
- Class B Chopper
- Class C Chopper
- Class D Chopper
- Class E Chopper

Class A Chopper



Working

When chopper is ON, supply voltage *V* is connected across the load.

When chopper is OFF, $v_O = 0$ and the load current continues to flow in the same direction through the FWD.

The average values of output voltage and current are always positive.

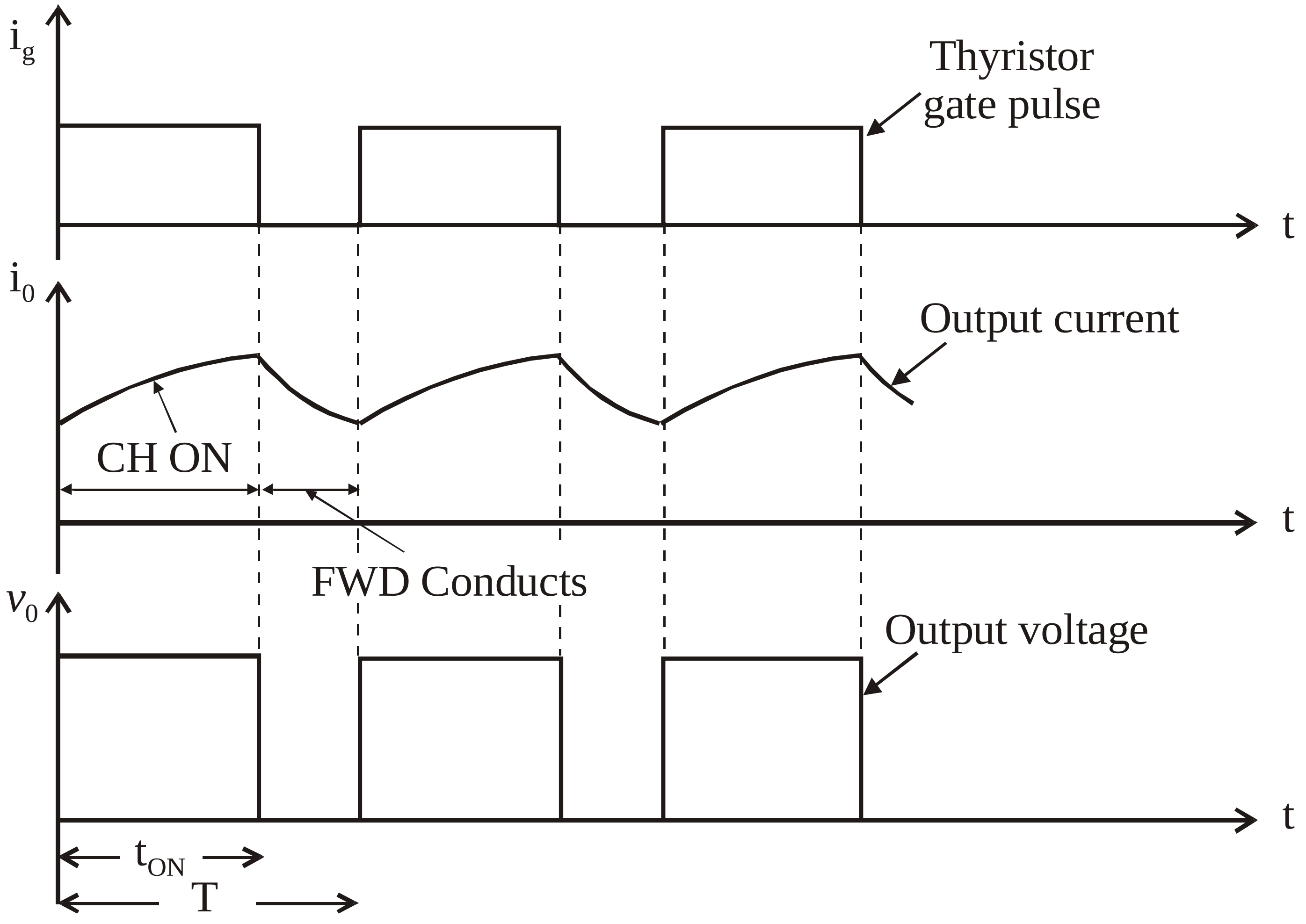
Class A Chopper is a first quadrant chopper

Class A Chopper is a step-down chopper in which power always flows form source to load.

It is used to control the speed of dc motor.

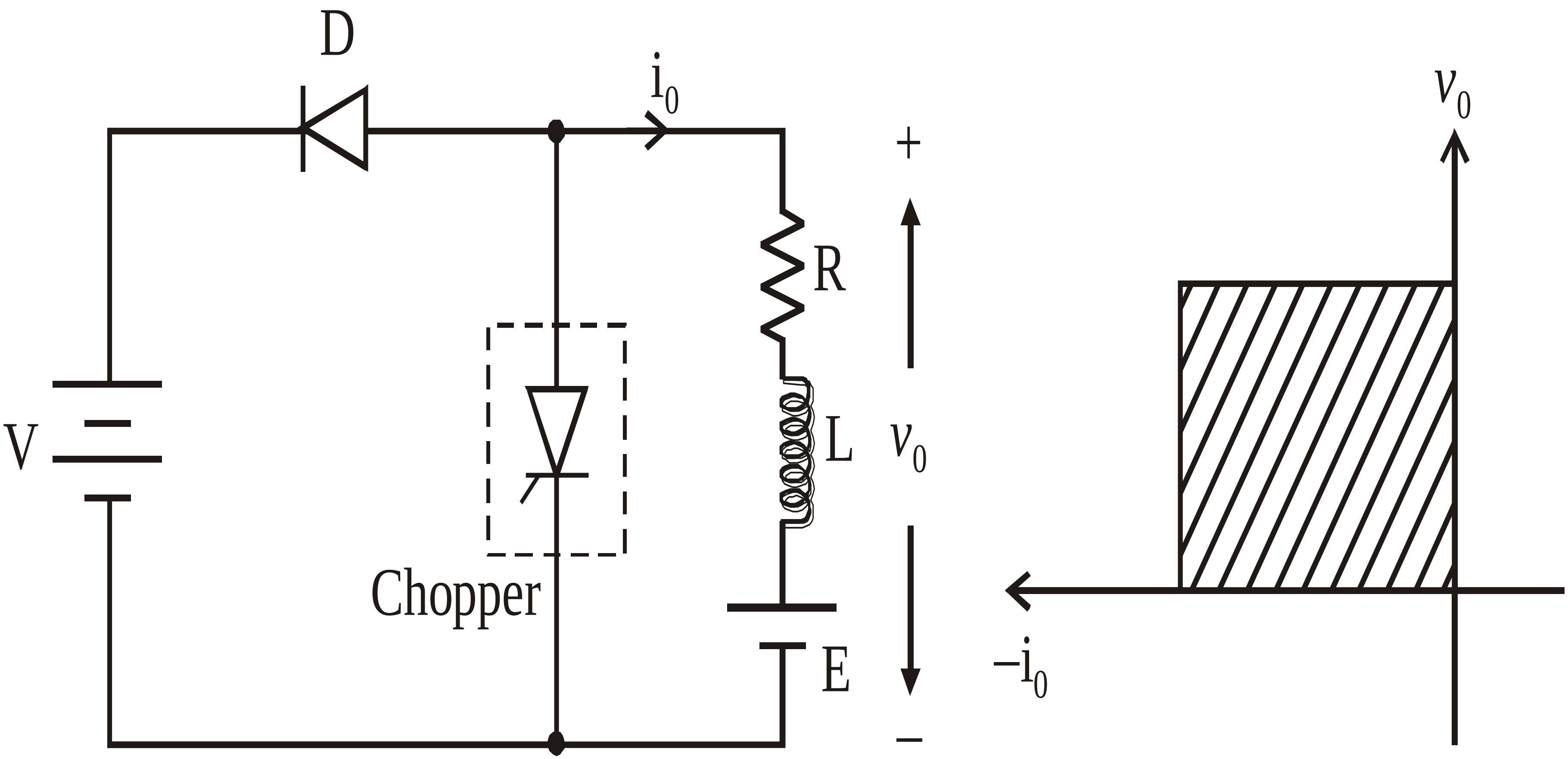
The output current equations obtained in step down chopper with *R*-*L* load can be used to study the performance of Class A Chopper.

Waveforms



i_g
Thyristor gate pulse
t
i_0
Output current
CH ON
t
FWD Conducts
v_0
Output voltage
t
t_{ON}
T

Class B Chopper



When chopper is ON, *E* drives a current through *L* and R in a direction opposite to that shown in figure.

During the ON period of the chopper, the inductance *L* stores energy.

When Chopper is OFF, diode *D* conducts, and part of the energy stored in inductor *L* is returned to the supply.

Average output voltage is positive.

Average output current is negative.

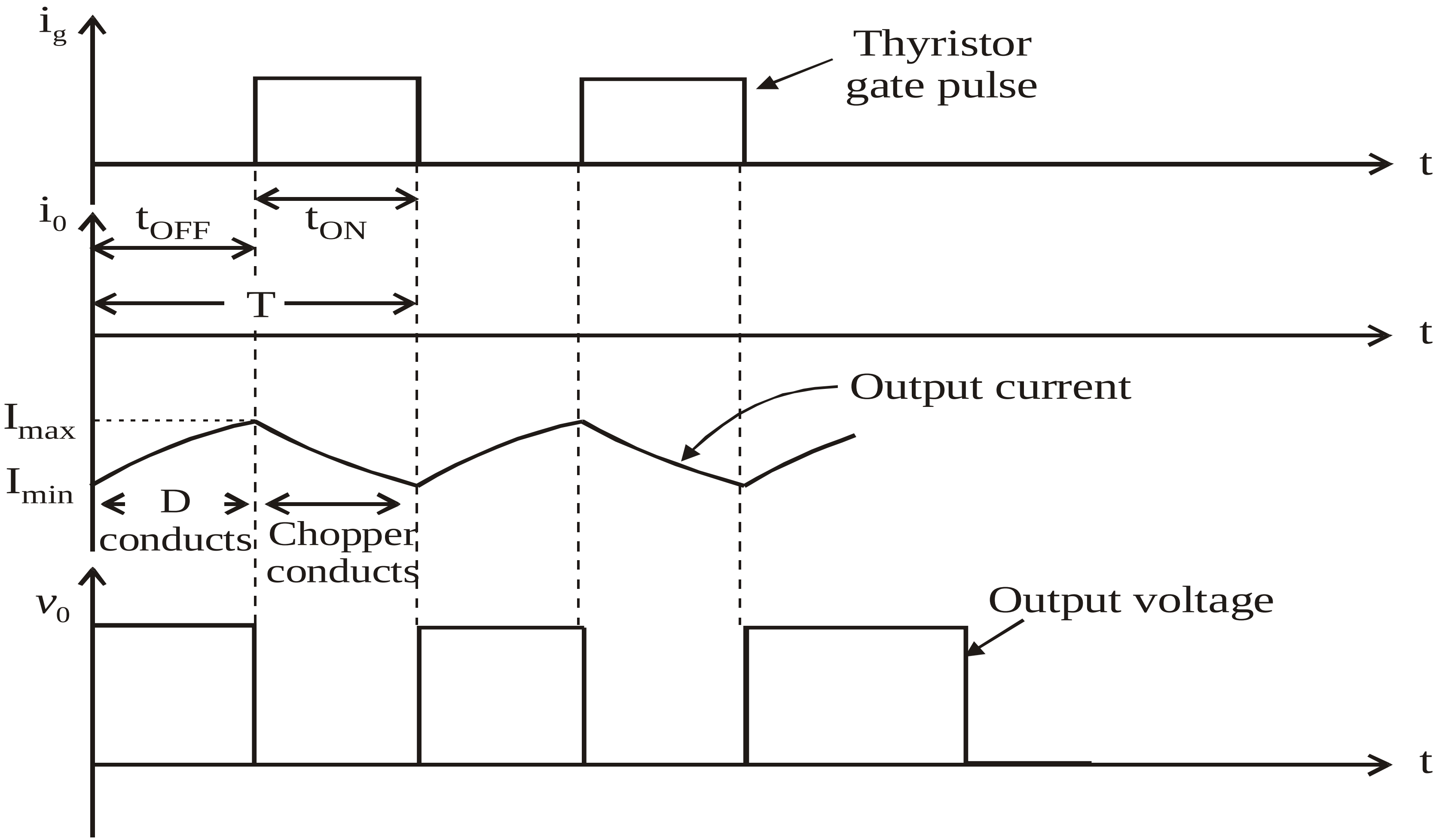
Therefore Class B Chopper operates in second quadrant.

In this chopper, power flows from load to source.

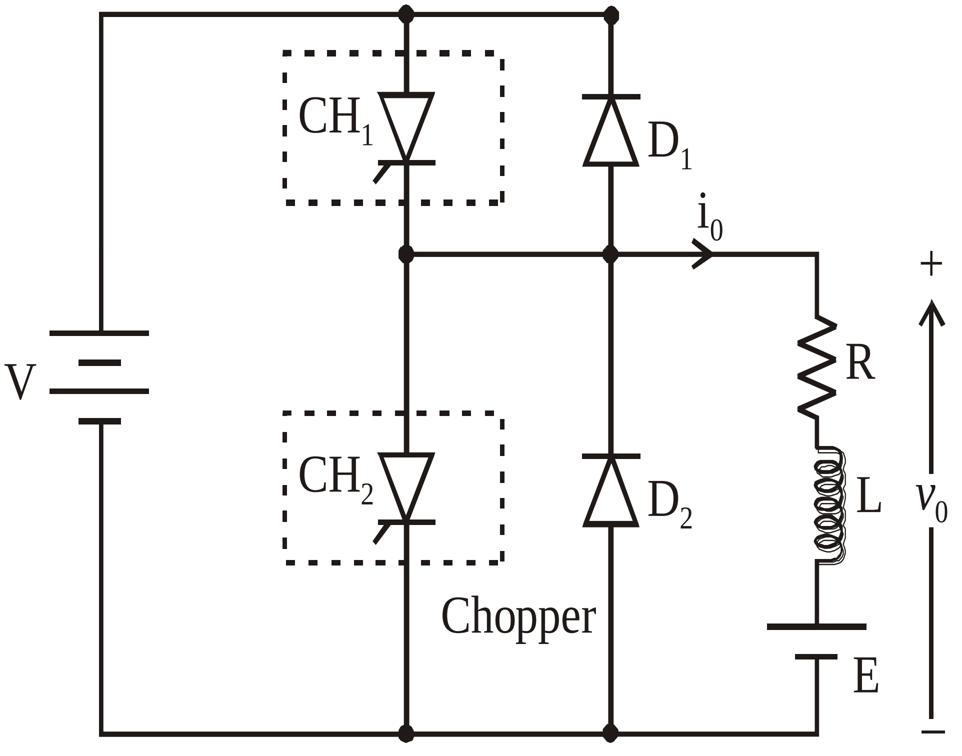
Class B Chopper is used for regenerative braking of dc motor.

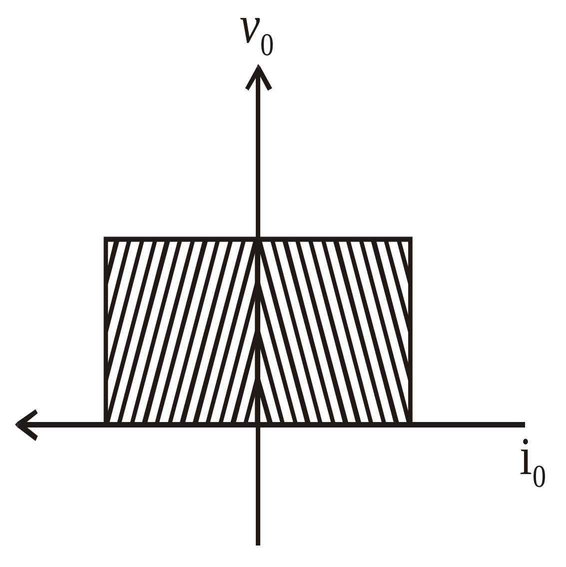
Class B Chopper is a step-up chopper.

Waveforms


i_g
Thyristor gate pulse
t
i_0
t_{OFF}
t_{ON}
T
t
Output current
I_{max}
I_{min}
D conducts
Chopper conducts
v_0
Output voltage
t

Class C Chopper





Class C Chopper is a combination of Class A and Class B Choppers.

For first quadrant operation, CH_1 is ON or D_2 conducts.

For second quadrant operation, CH_2 is ON or D_1 conducts.

When CH_1 is ON, the load current is positive.

The output voltage is equal to *'V'* & the load receives power from the source.

When CH_1 is turned OFF, energy stored in inductance L forces current to flow through the diode D_2 and the output voltage is zero.

Current continues to flow in positive direction.

When CH_2 is triggered, the voltage E forces current to flow in opposite direction through L and CH_2 .

The output voltage is zero.

On turning OFF CH_2 , the energy stored in the inductance drives current through diode D_1 and the supply.

Output voltage is V, the input current becomes negative and power flows from load to source.

Average output voltage is positive

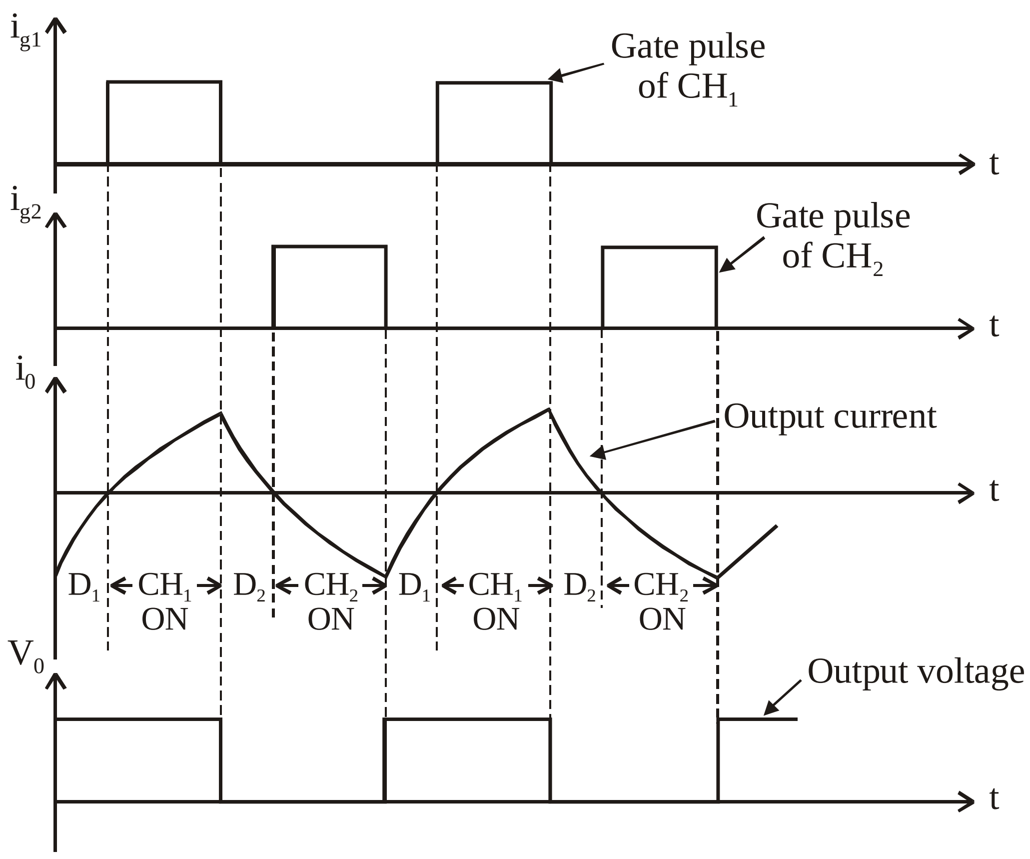
Average output current can take both positive and negative values.

Choppers CH_1 & CH_2 should not be turned ON simultaneously as it would result in short circuiting the supply.

Class C Chopper can be used both for dc motor control and regenerative braking of dc motor.

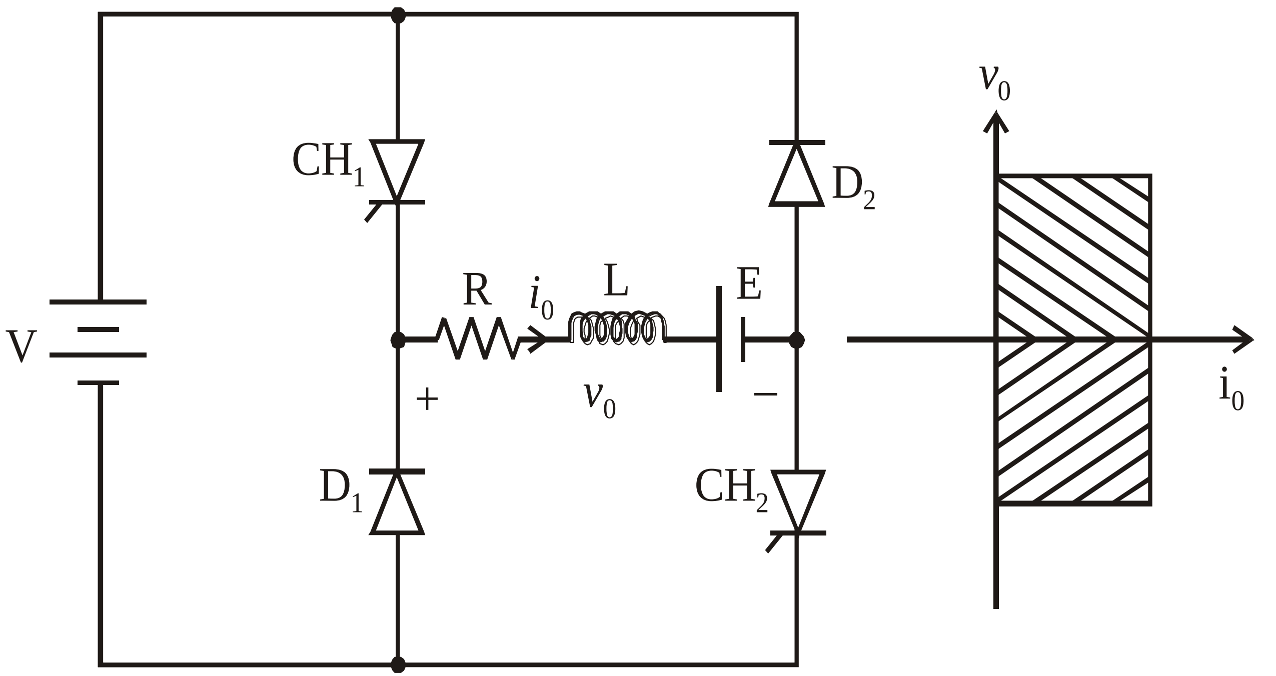
Class C Chopper can be used as a step-up or step-down chopper.

Waveforms



i_{g1}
Gate pulse of CH_1
t
i_{g2}
Gate pulse of CH_2
t
i_0
Output current
t
D_1 CH_1 ON D_2 CH_2 ON D_1 CH_1 ON D_2 CH_2 ON
V_0
Output voltage
t

Class D Chopper



Class D is a two quadrant chopper.

When both CH_1 and CH_2 are triggered simultaneously, the output voltage $v_O = V$ and output current flows through the load.

When CH_1 and CH_2 are turned OFF, the load current continues to flow in the same direction through load, D_1 and D_2 , due to the energy stored in the inductor L.

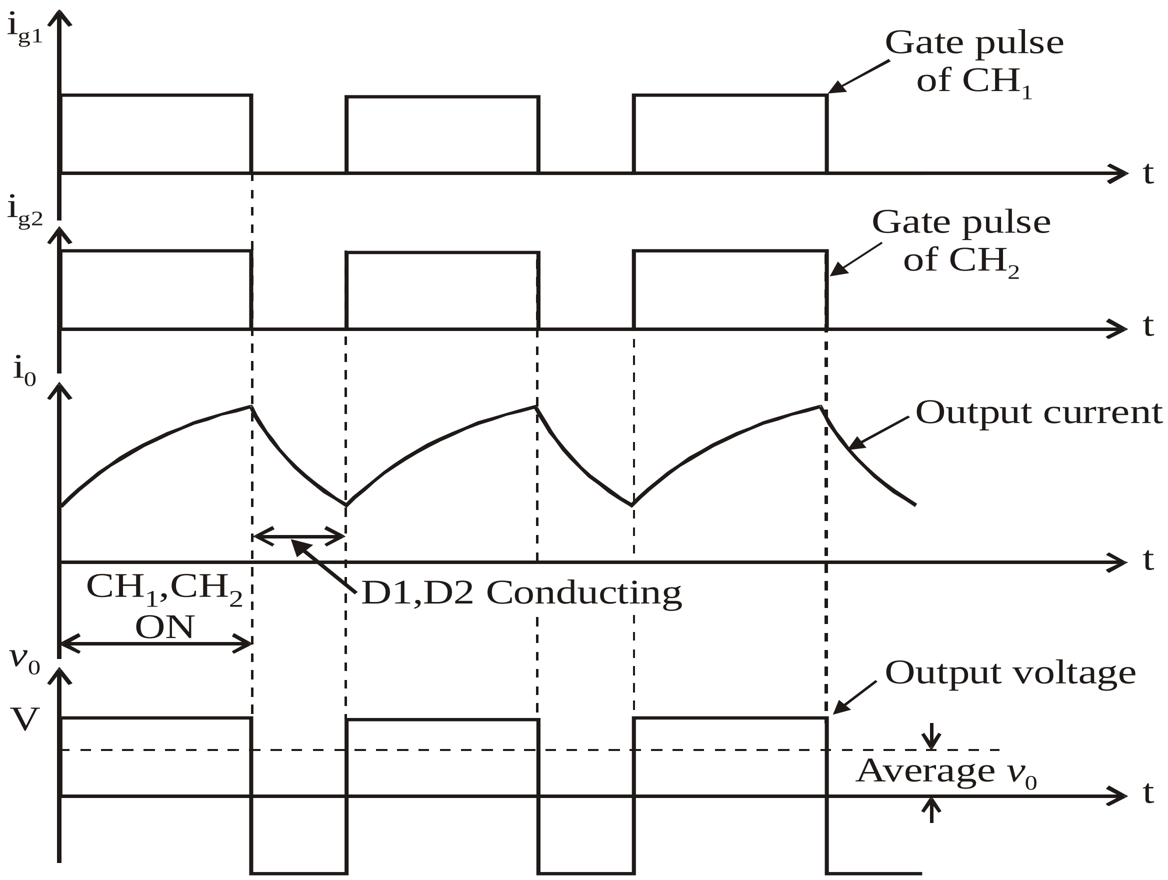
Output voltage $v_O = - V$.

Average load voltage is positive if chopper ON time is more than the OFF time

Average output voltage becomes negative if $t_{ON} < t_{OFF}$

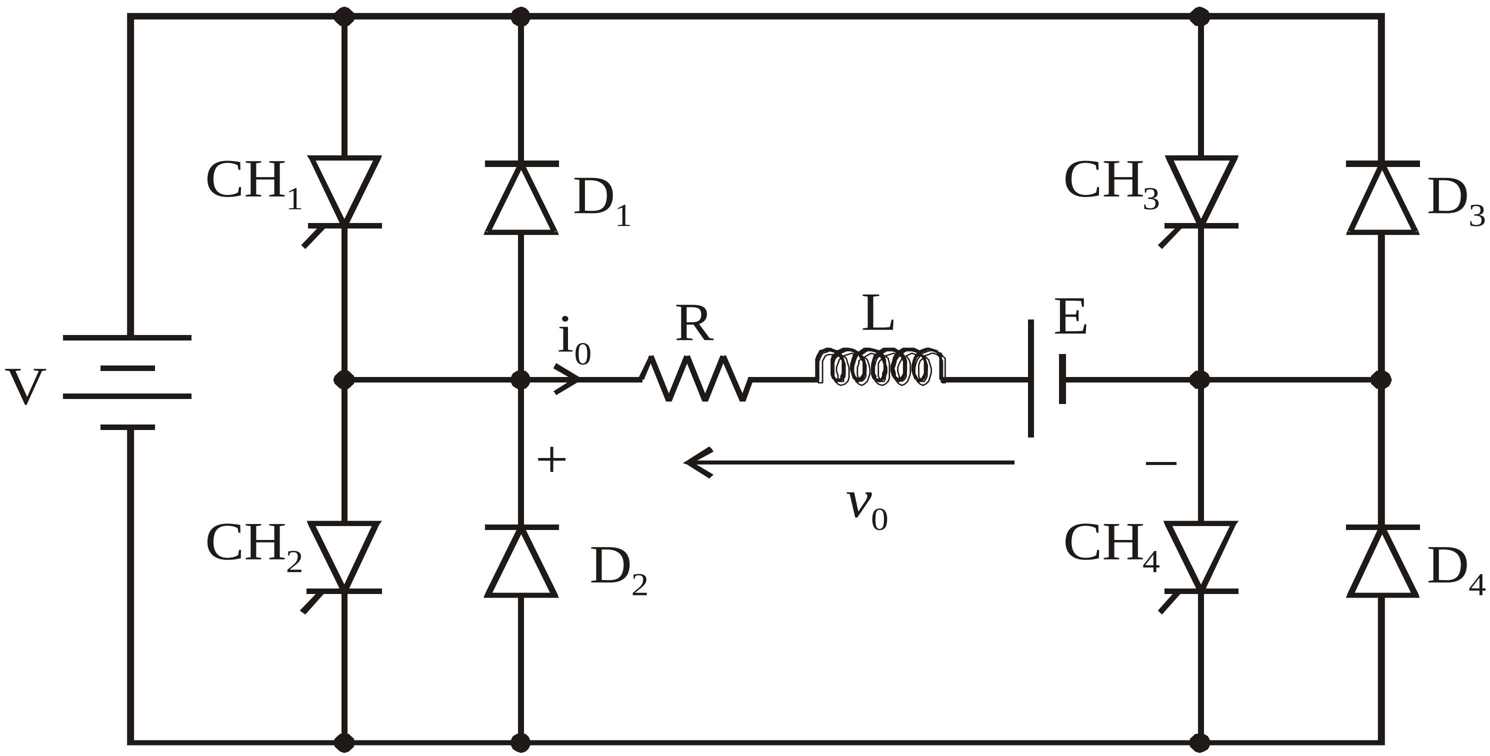
Hence the direction of load current is always positive but load voltage can be positive or negative.

WAVEFORMS

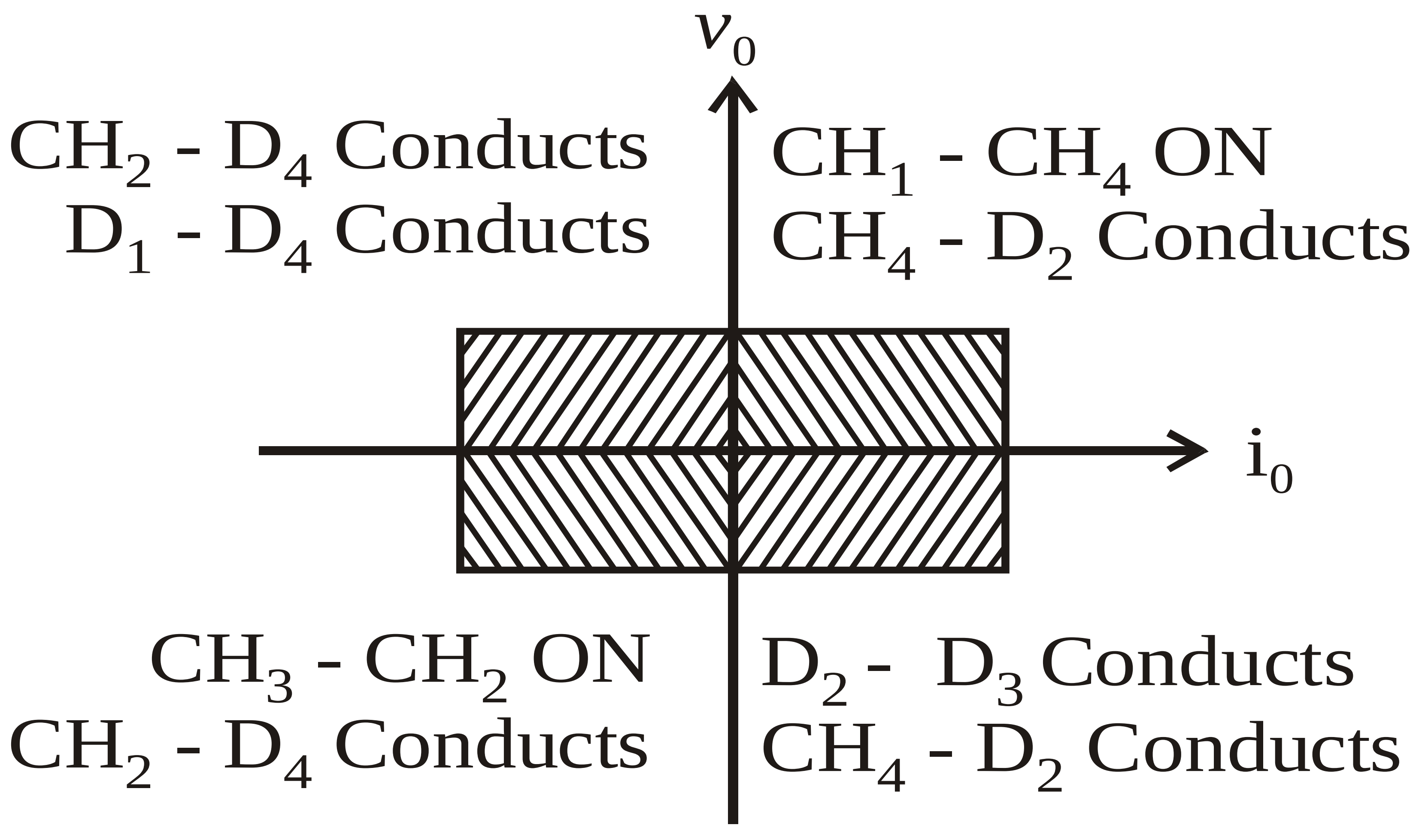


i_{g1}
Gate pulse of CH_1
t
i_{g2}
Gate pulse of CH_2
t
i_0
Output current
t
CH_1,CH_2 ON
D1,D2 Conducting
v_0
V
Output voltage
Average v_0
t

Class E Chopper



Four Quadrant Operation



Class E is a four quadrant chopper

When CH_1 and CH_4 are triggered, output current i_O flows in positive direction through CH_1 and CH_4, and with output voltage $v_O = V$.

This gives the first quadrant operation.

When both CH_1 and CH_4 are OFF, the energy stored in the inductor L drives i_O through D_2 and D_3 in the same direction, but output voltage $v_O = -V$.

Therefore the chopper operates in the fourth quadrant.

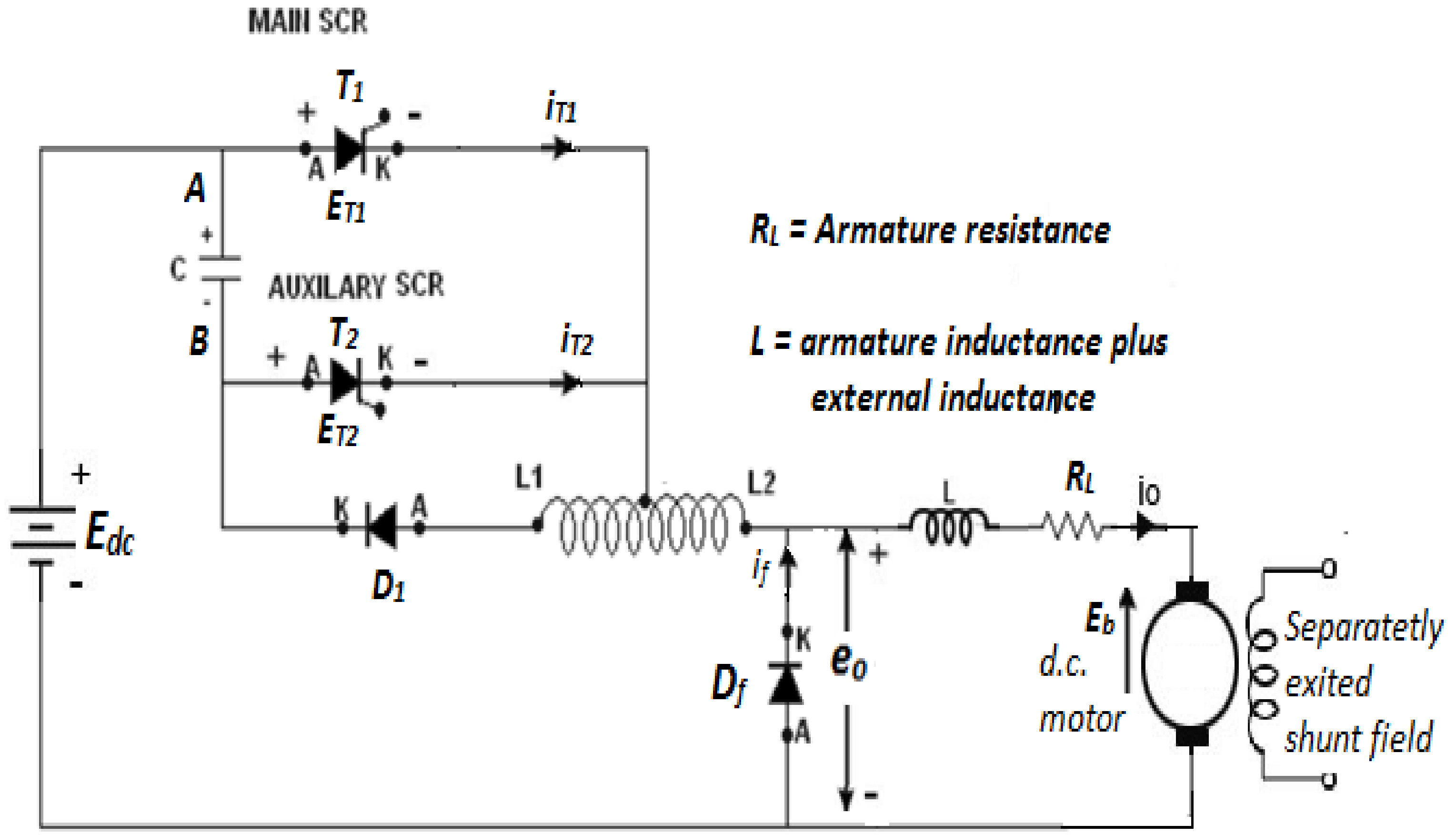
When CH_2 and CH_3 are triggered, the load current i_O flows in opposite direction & output voltage $v_O = -V$.

Since both i_O and v_O are negative, the chopper operates in third quadrant.

- When both CH_2 and CH_3 are OFF, the load current i_O continues to flow in the same direction D_1 and D_4 and the output voltage $v_O = V$.

- Therefore the chopper operates in second quadrant as v_O is positive but i_O is negative.

Jones Chopper



Freewheeling Diode d.c. motor Drive using Jones Chopper

Working :

- Figure shows the basic power circuit of Jones chopper. This chopper circuit is an example of Class D commutation. In this circuit, SCR T_1 is the main thyristor , whereas SCR T_2 , capacitor C , D_2 , and autotransformer (T) forms the commutating circuit for the main thyristor T_1 .

- Therefore , the special features of this circuit is the tapped autotransformer T through a portion of which the load current flows. Here , L_1 and L_2 are closely coupled so that the capacitor always gets sufficient to turn off the main SCR $T_{1.}$

- If the main thyristor T_1 is on for a long period , then the motor will reach the maximum steady-state speed determined by the battery voltage , the motor and the mechanical load characteristics. If thyristor T_1 is off , the motor will not rotate. Now , if thyristor T_1 is alternatively on and off in a cyclic manner , the motor will rotate at some speed between maximum and zero.

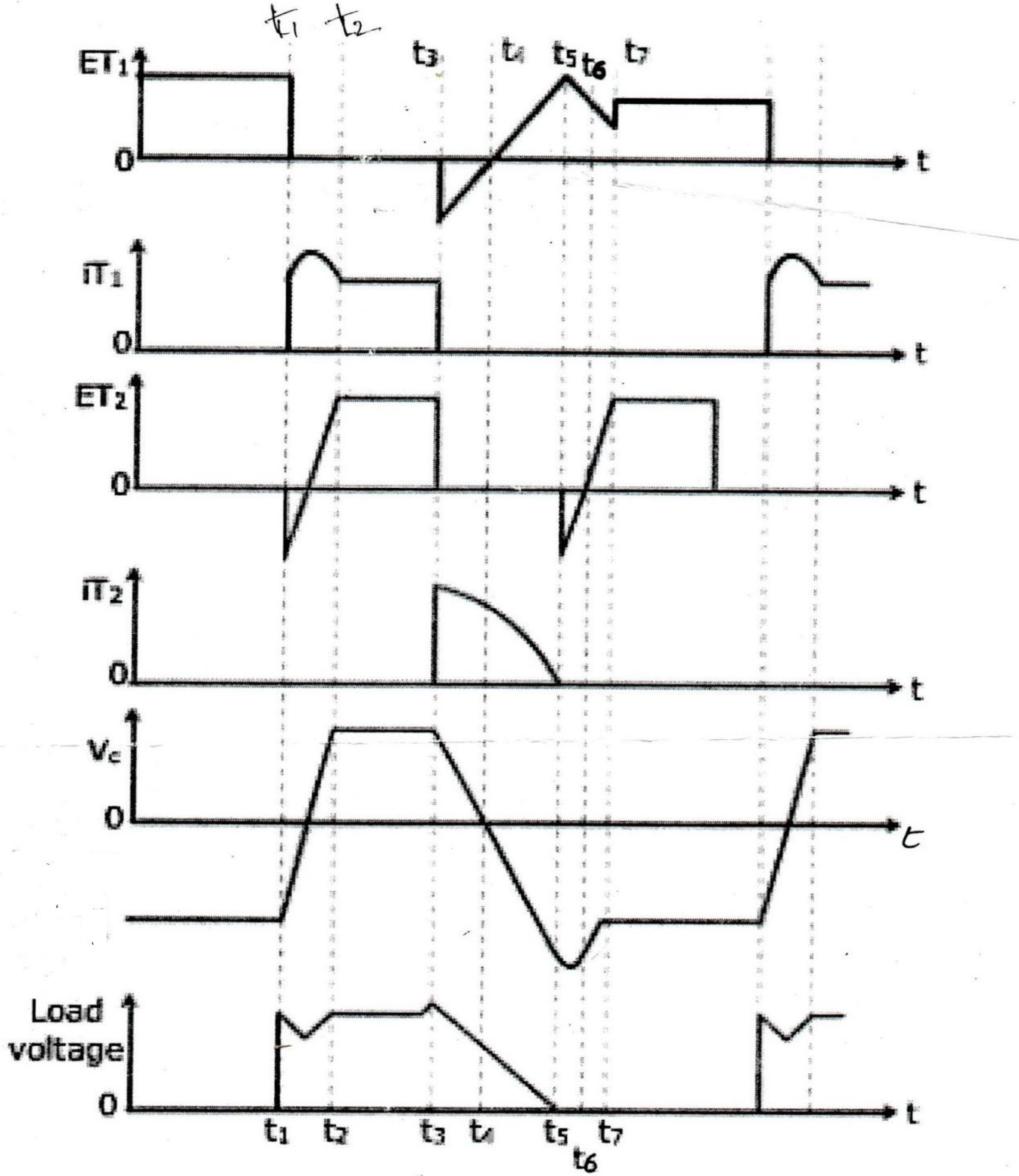
- Let us assume that initially capacitor C is charged to a voltage E_{dc} with the polarity shown in figure . As shown in fig. , SCR T_1 is triggered at time $t = t_1$, current flows through the path $C_A – T_1 – L_2 – C_B$ and capacitor C charges to opposite polarity , i.e. Plate B positive and plate A negative.

- However , diode D_1 represents further oscillation of the resonating L_2 C circuit. Hence capacitor C retains its charge until SCR T_2 is triggered. The capacitor voltage waveform are drawn at bottom plate B of capacitor.

- Now , at time $t = t_3$, SCR T_2 is triggered. Current flow through the path C_B – T_2 – T_1 – C_A . Therefore, discharge of capacitor C reverse biases SCR T_1 and turns it off. The capacitor again charges up with plate A positive and SCR T_2 turns off because the current through it falls below the holding current value when capacitor C is recharged.

The cycle repeats when SCR T_1 is again triggered. The use of autotransformer insures that whenever current is delivered from dc source to the load , a voltage is included in L_2 in the correct polarity for changing the commutating capacitor to a voltage higher than E_{dc} . Thus , the autotransformer measurably enhances the reliability of the circuit.

At t_5 , the bottom plate (B) of capacitor C reaches a peak value. Since at t_5 , the capacitor is charged to a voltage greater than E_{dc} , diode D_1 is again forward biased . Capacitor C now discharges to a value lower than E_{dc} . The time duration t_3 to t_4 is the circuit turn off time presented to SCR T_1.



t1 t2
t3 t4 t5 t6 t7
ET1
0
t
iT1
0
t
ET2
0
t
iT2
0
t
Vc
0
t
Load voltage
0
t
t1 t2 t3 t4 t5 t7
t6