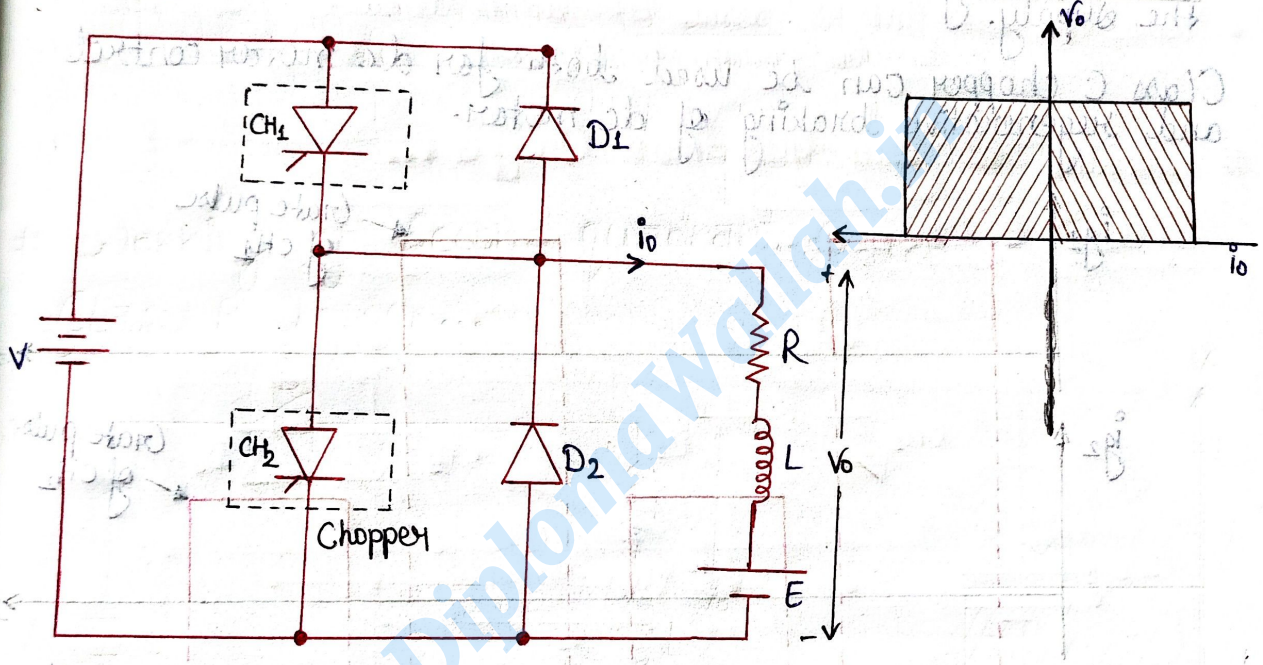
Unit - 5

1) Working of two quadrant Chopper...

Class C Chopper...

- Class C Chopper is a combination of Class A and Class B choppers.
- The figure below shows a class C two quadrant chopper circuit. For first quadrant operation, CH_1 is ON or D_2 conducts and for second quadrant operation, CH_2 is ON or D_1 conducts.



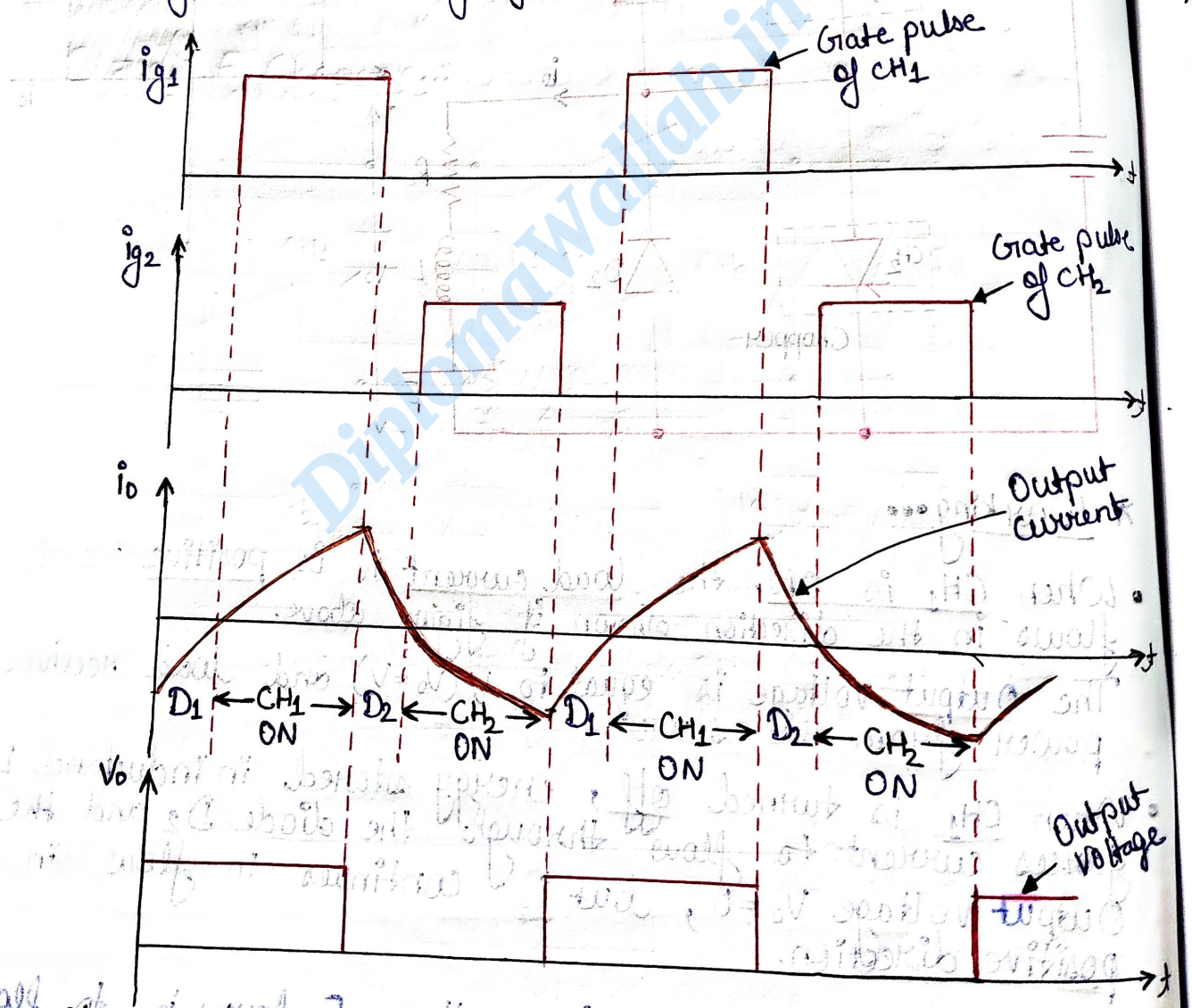
★ Working...

- When CH_1 is ON, the load current i_o is positive i.e. i_o flows in the direction shown if figure above. The output voltage is equal to V ($V_o = V$) and 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 $V_o = 0$, but i_o continues to flow in positive direction.
- When CH_2 is triggered, the voltage E forces i_o to flow

in opposite direction through L and CH_2. The output voltage $V_o = 0$.

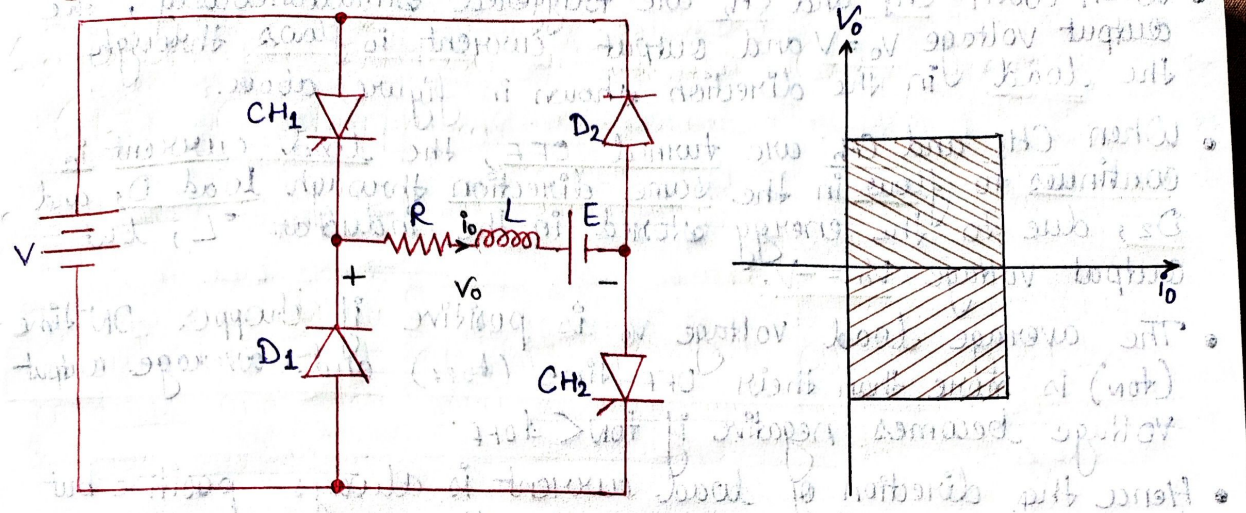
- On turning OFF CH_2, the energy stored in the inductance drives current through diode D_1 and the supply; Output voltage $V_o = V$ the input current becomes negative and power flows from load to source.
- Thus the average output voltage V_o is positive but the average output current i_o can take both positive and negative values.
- Choppers CH_1 and 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.



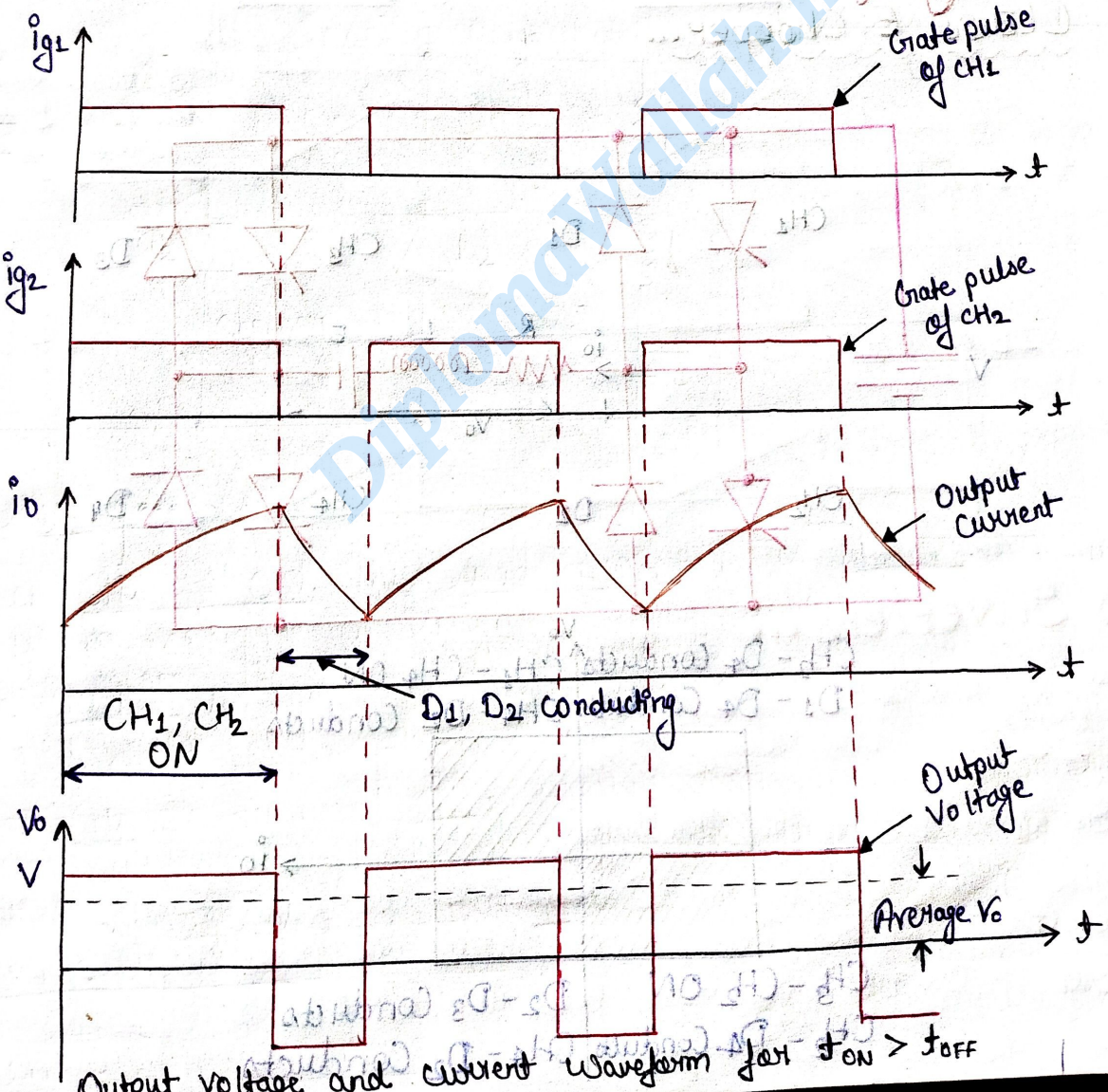
Class C Chopper – Output Voltage and Current Waveform

Class D Chopper...



Class D two quadrant chopper circuit.

★ Waveform...



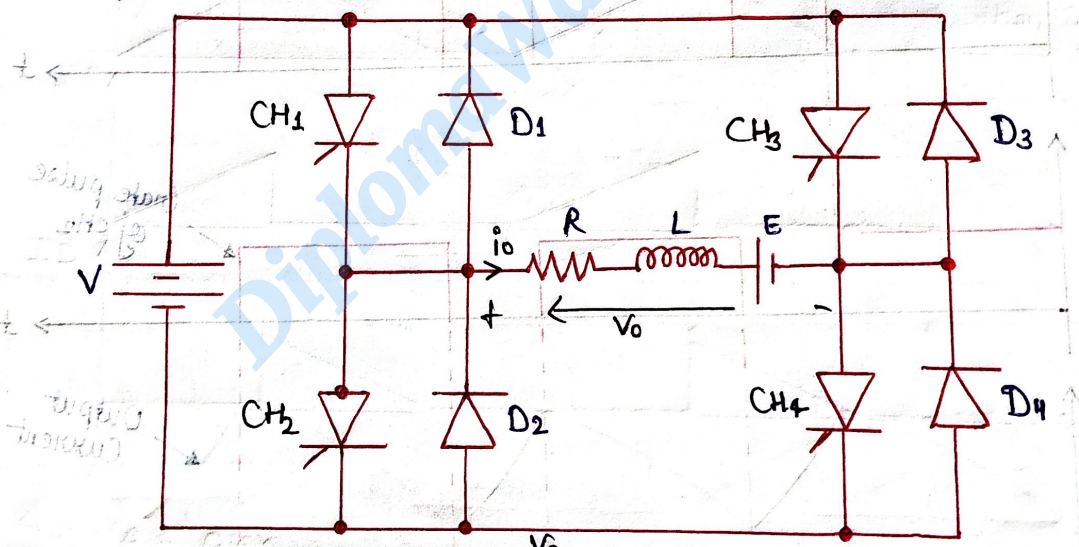
Output voltage and current waveform for $t_{ON} > t_{OFF}$

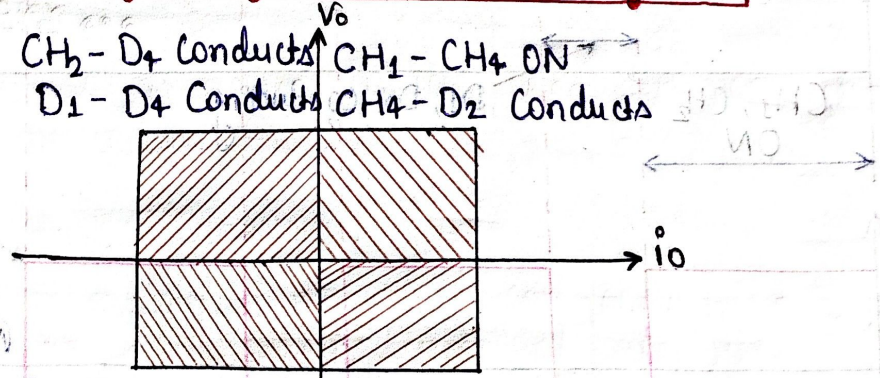
★ Working...

- When both CH_1 and CH_2 are triggered simultaneously, the output voltage $V_o = V$ and output current i_o flows through the load in the direction shown in figure above.
- When CH_1 and CH_2 are turned OFF, the load current i_o continues to flow in the same direction through load D_1 and D_2, due to the energy stored in the inductor 'L', but output voltage $V_o = -V$.
- The average load voltage V_o is positive if chopper ON-time (t_{ON}) is more than their OFF-time (t_{OFF}) and 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.

Working of four quadrant Chopper...

Class E Chopper...





$CH_2 - D_4$ Conducts	$CH_1 - CH_4$ ON
$D_1 - D_4$ Conducts	$CH_4 - D_2$ Conducts

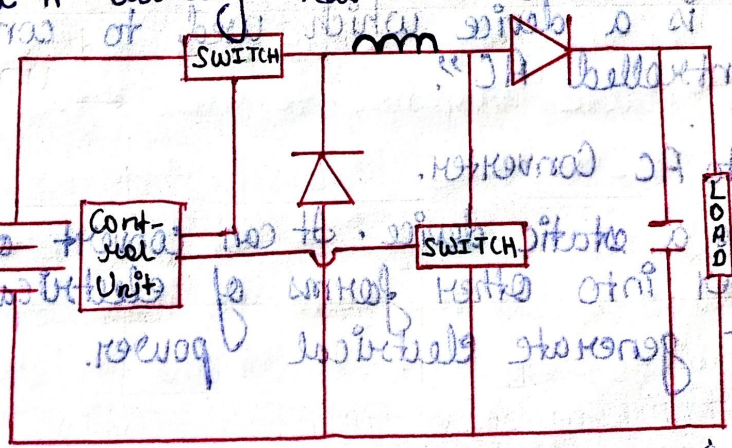
$CH_3 - CH_2$ ON	$D_2 - D_3$ Conducts
$CH_2 - D_4$ Conducts	$CH_4 - D_2$ Conducts

★ Working ...

- The figure above shows a class E 4 quadrant chopper circuit. When CH_1 and CH_4 are triggered, output current i_o flows in positive direction through CH_1 and CH_4, 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_3 and D_2 in the same direction, but output voltage $V_o = -V$.
  Therefore the chopper operates in the fourth quadrant. For fourth quadrant operation the direction of battery must be reversed.
- When CH_2 and CH_3 are triggered, the load current i_o flows in opposite direction and 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 through 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.

Buck and boost Converters ...

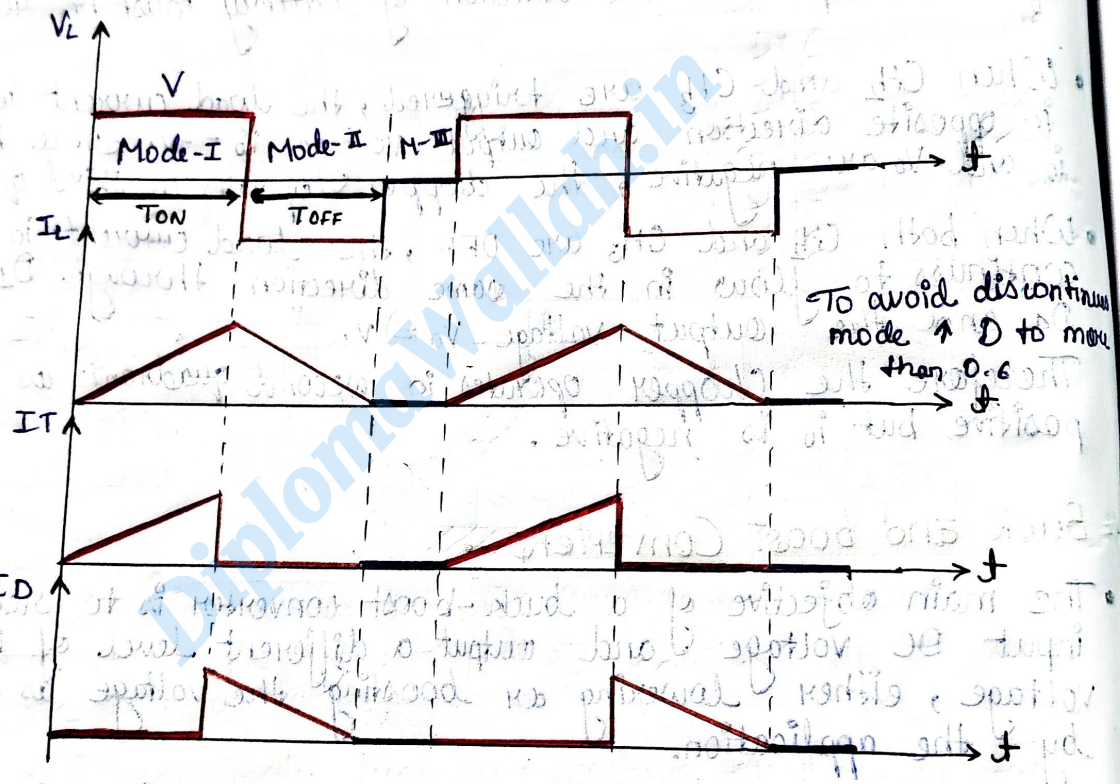
- The main objective of a buck-boost converter is to receive an input DC voltage and output a different level of DC voltage, either lowering or boosting the voltage as required by the application.
- The design of a buck-boost converter is similar to a buck converter and boost converter, except that it is in a single circuit and it usually has an added control unit.



[Non-isolated type converter]

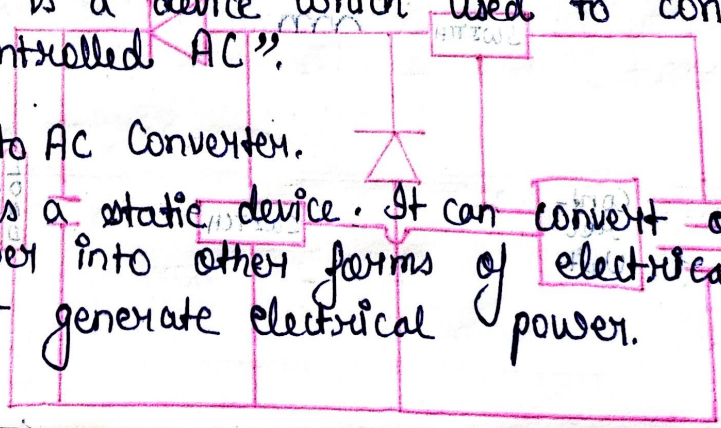
[Inverting Regulator]

Mode-I	Mode-II	Mode-III
→ Switch T is ON. → Inductor stores energy. → Diode D is OFF. → Voltage across inductor is V.	→ Switch is OFF. → Inductor realeses its energy. → Diode D is ON. → Capacitor C_2 charges by lower plate (+ve).	→ D-OFF, T-OFF → Now capacitor voltage appears at output → Output voltage is -ve → So buck-boost regulator is inverting regulator.



2.) Inverters...

- "An inverter is a device which used to convert fixed DC into controlled AC".
- It is a DC to AC Converter.
- The inverter is a static device. It can convert one form of electrical power into other forms of electrical power. But it cannot generate electrical power.



- The inverter takes DC power from the batteries and converts into AC power at the time of the power failure.
- A power inverter used in the power system network to convert bulk DC power to AC power i.e. It used at the receiving end of HVDC transmission lines. This inverter is known as a grid-tie inverter.
- Force commutation are used in inverter.
- IGBT, MOSFET, GTO are the most commonly used switches in inverter.

Who invent the Inverter?....

- Before the inverter was invented, a motor-generator set and rotary converter were used to convert DC power into AC power.
- The engineering term inverter was first introduced by David Prince titled "The Inverter" in 1925.
- Prince defined the inverter as the inverse of a rectifier.

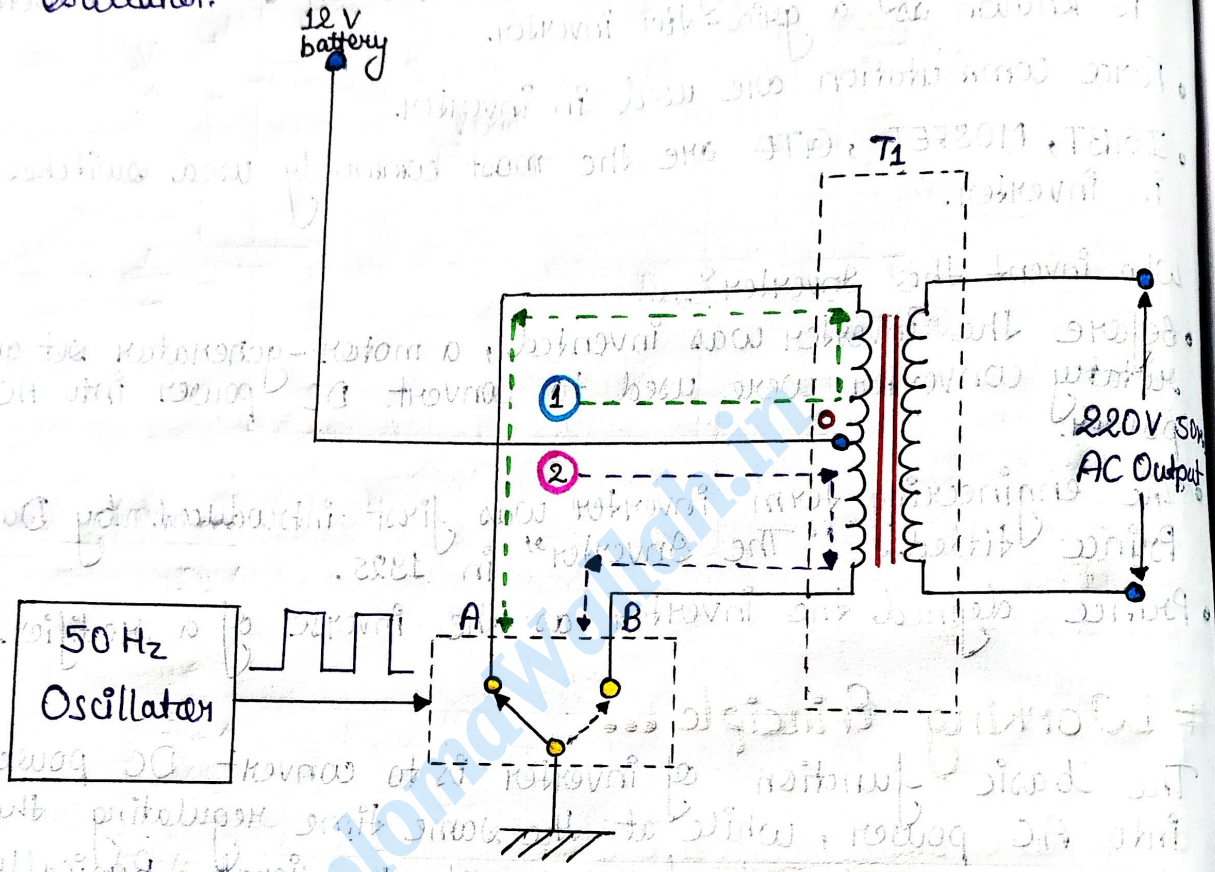
Working Principle ...

The basic function of inverter is to convert DC power into AC power, while at the same time regulating the voltage, current and frequency of the signal. Basically, Inverter is a kind of oscillator.

- Transistors are the key components of inverter, which convert DC power into AC power.
- IGBT, MOSFET are the most commonly used switches in inverter.
- How many numbers of switches we use depends on the type of inverter?
- The transistor is used to change the steady voltage and one-way current flow of DC to the constantly changing voltage and oscillating current of AC.
- The key feature of the transistor in the generation of AC power is that it can rapidly switched on or off.

★ Working...

Here we see in the circuit diagram, here we use 12 V battery, one transformer (Primary winding of transformer is center tapped), one two-way switch and 50 Hz oscillator.



- Here 12V battery generate DC supply and inverter will change it into, AC supply of 220V, 50Hz to use to operate any appliances.
- The 12V DC supply from the positive terminal of the battery comes to the primary winding of transformer which is center tapped.
- The two ends of the primary winding of transformer (A and B point) are connected to the two-ways switch to the ground.
- If the switch connects to A point of the primary winding the current flows from the battery into upper half of primary winding (o) through A contact of the switch to the ground.

- If switch turn from A point into B point. This time the current number 1 stops flowing. Then, the current 2 flows to the ground through 0 and connect B of the switch.
- We know that transformers work on the principle of Electromagnetic induction. When current flow in primary winding EMF induced and a current will be induced into the secondary winding of transformer.
- Which it causes AC voltage 220V 50Hz. Now, the voltage is use to be supplied to the various types of electrical equipment that operate in 220 volts AC supply.

Types of Inverter...

Inverters are classified into two main categories—

Voltage Source Inverter (VSI)...

The voltage source inverter has stiff DC source voltage that is the DC voltage has limited or zero impedance at the inverter input terminals.

Current Source Inverter (CSI)...

A current source inverter is supplied with a variable current from a DC source that has high impedance. The resulting current waves are not influenced by the load.

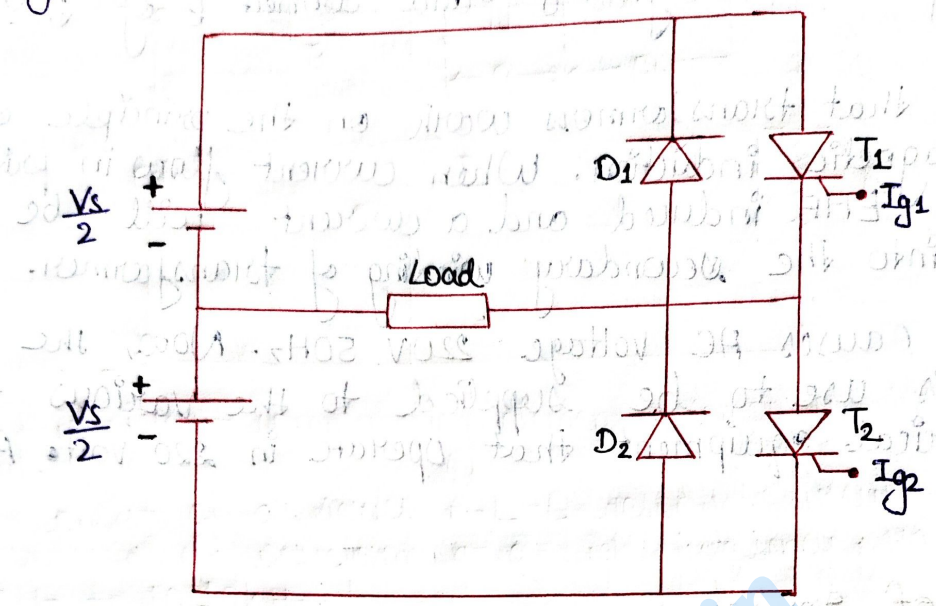
★ Single phase Inverter —

There are two types of single phase inverters — full bridge inverter and half bridge inverter:-

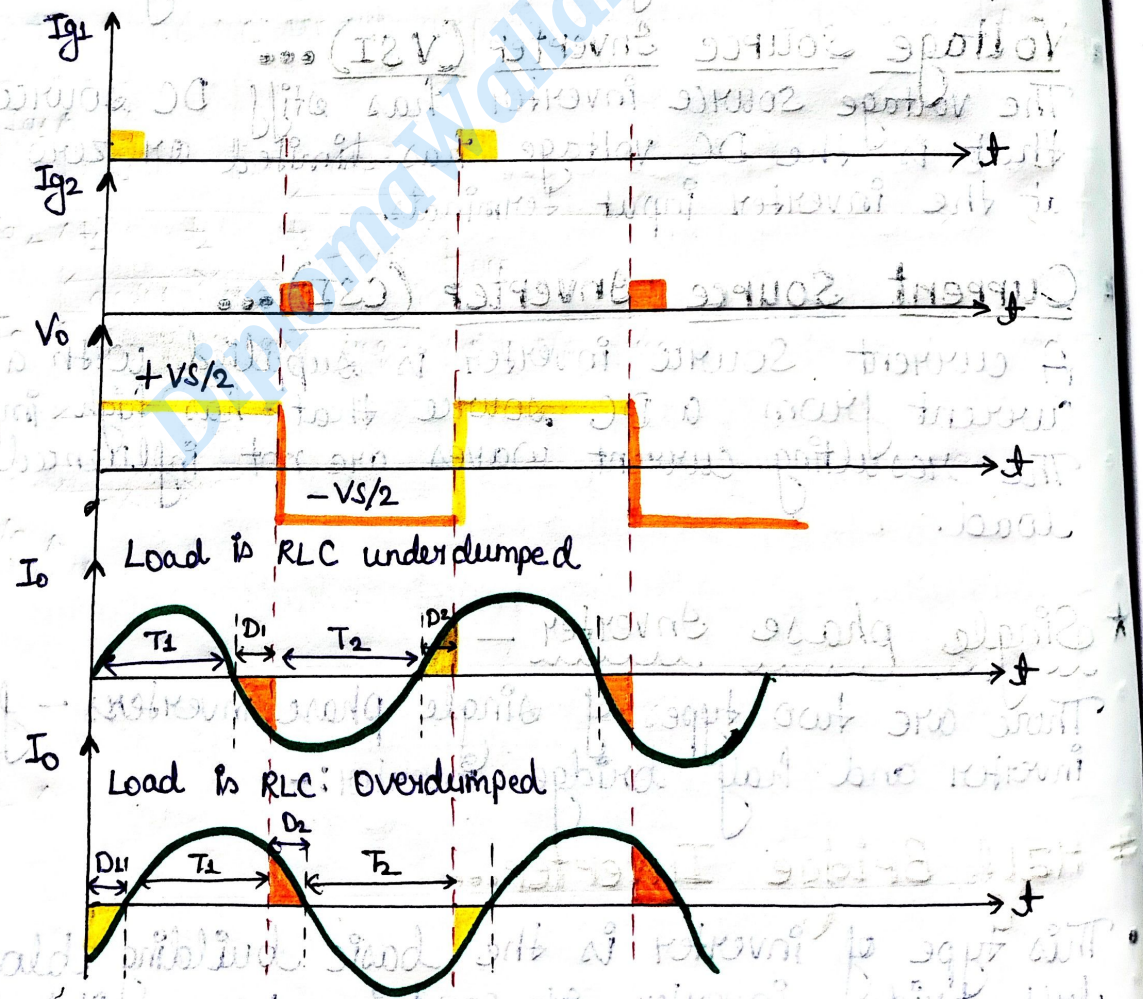
Half Bridge Inverter...

- This type of inverter is the basic building block of a full bridge inverter. It contains two switches and each of its capacitors has a voltage output equal to $\frac{V_{dc}}{2}$.

In addition, the switches complement each other, that is, if one is switched ON the other one goes OFF.



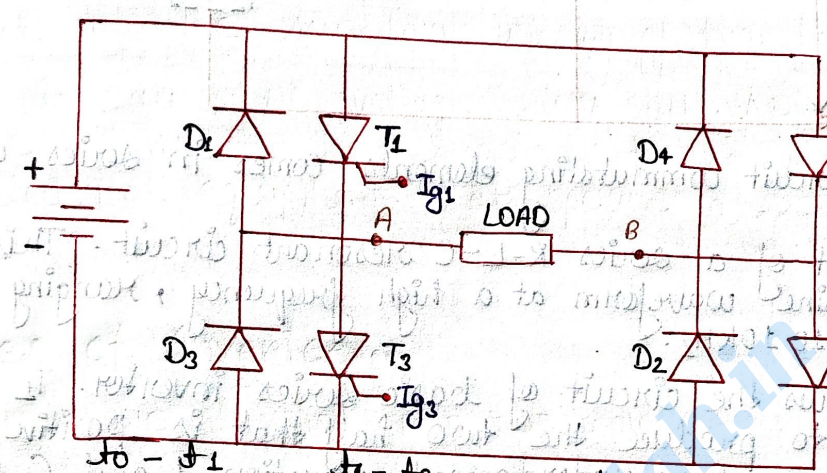
★ Waveform ...



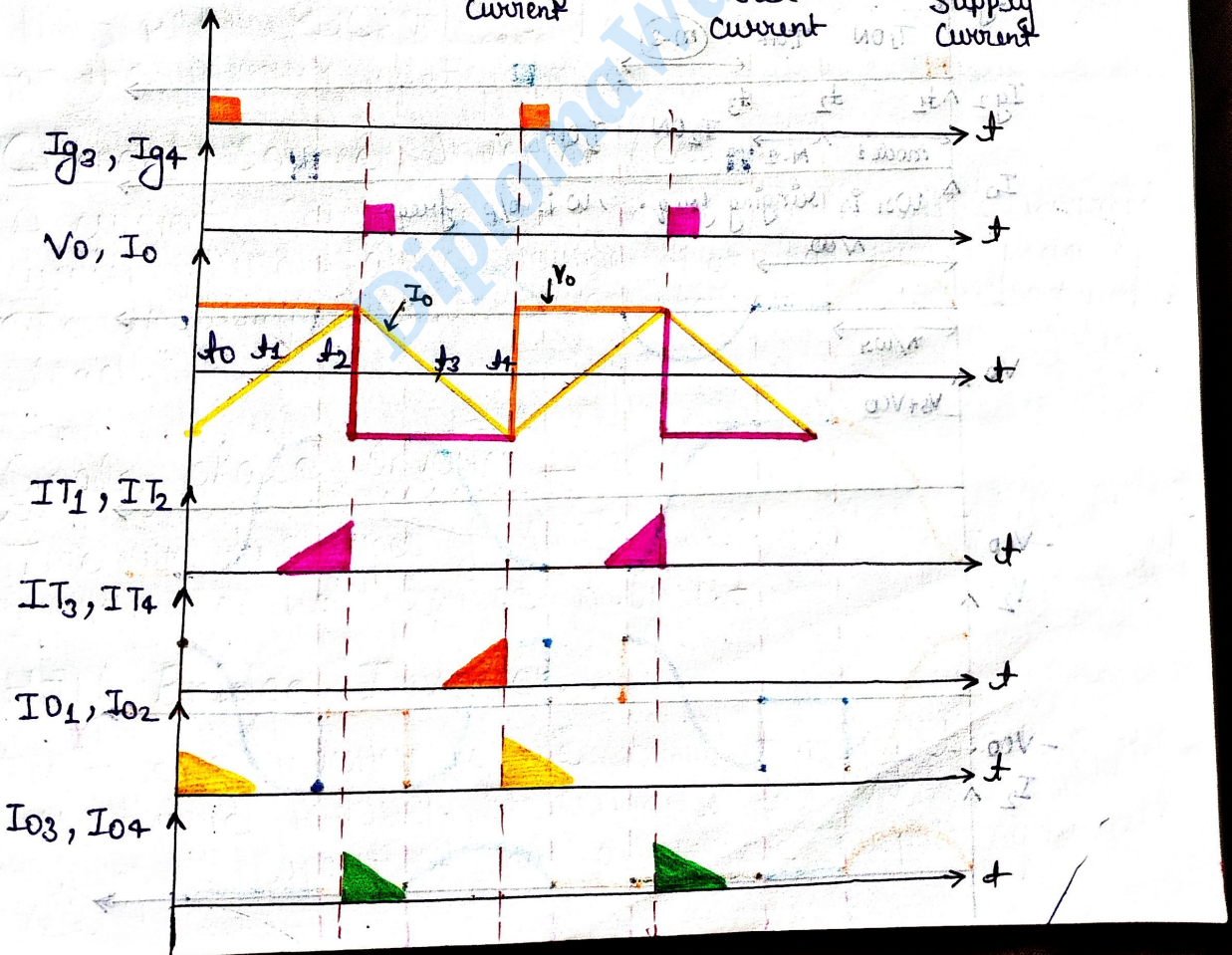
3.) Full Bridge Inverter...

This inverter circuit converts DC to AC. It achieves this by closing and opening the switches in the right sequence.

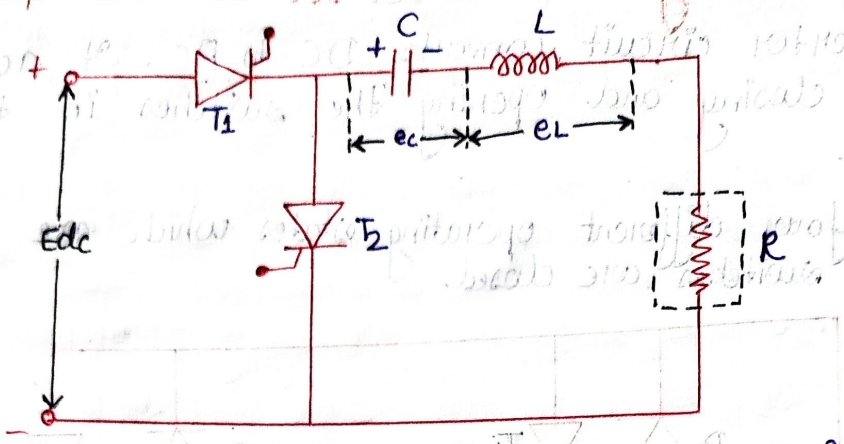
It has four different operating states which are based on which switches are closed.



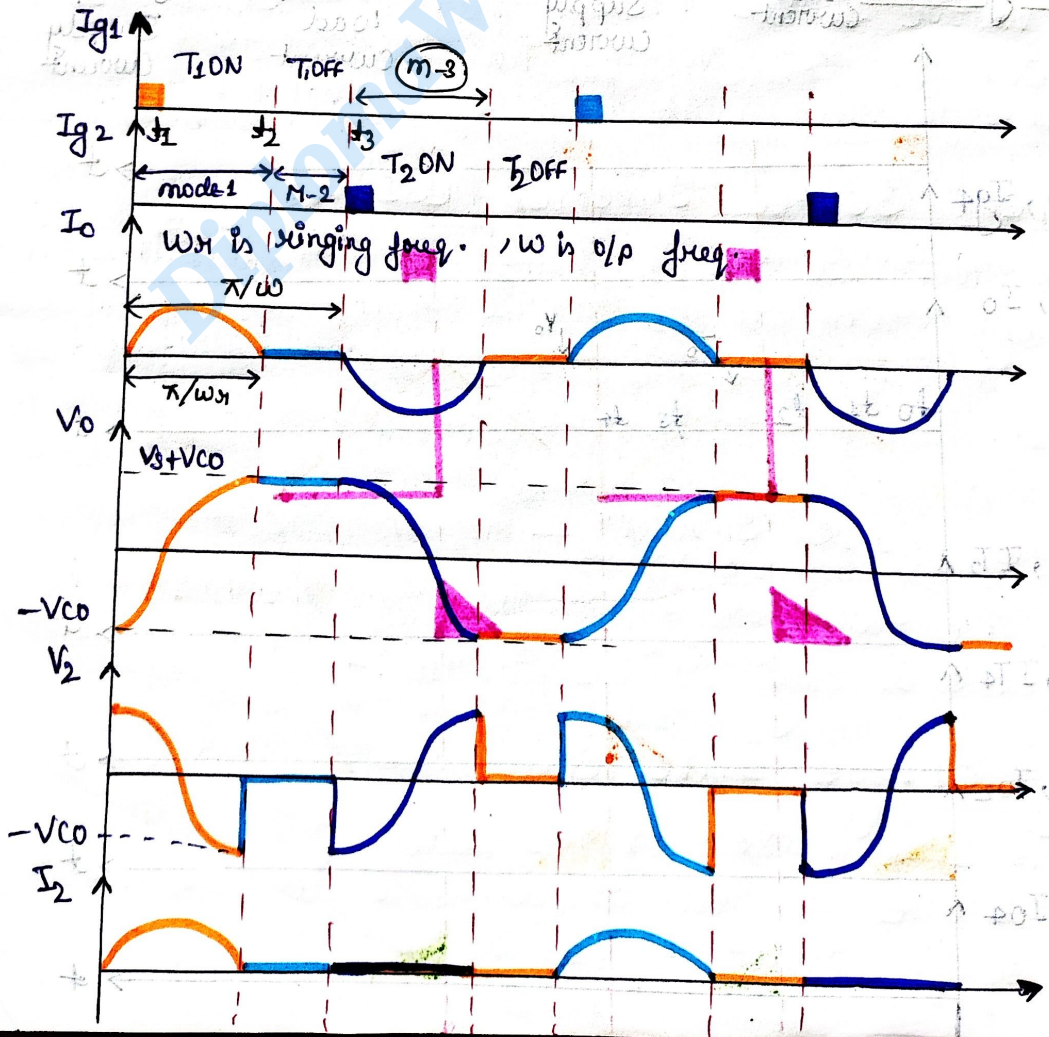
★ Waveform... $t_0 - t_1$ D_1 & D_2 Load current | $t_1 - t_2$ T_1 & T_2 Supply current | $t_2 - t_3$ D_3 & D_4 Load current | $t_3 - t_4$ T_3 & T_4 Supply current



Series Inverter ...



- In this circuit commutating elements comes in series with the load.
- This consist of a series R-L-C resonant circuit. This provides sine waveform at a high frequency, ranging from 200Hz to 10 10kHz.
- Figure shows the circuit of basic series inverter. T_1 and T_2 are used to produce the two half that is positive and negative to produce underdamped operation. L and C should be choosen.



★ Working...

- When a DC voltage Edc is applied to the circuit and thyristor T_1 is triggered it starts conducting.
- Resulting some current to flow through the R-L-C series circuit.
- Capacitor C gets charged up to voltage Ec.
- When the current reaches its peak-value, the voltage across the capacitor is approximately the supply voltage Edc.
- After this, the current starts decreasing but the capacitor retains the higest voltage [Edc + Ec].
- SCR T_1 is automatically turned-off because the current flowing through it becomes zero.
- During this mode, the load current remains at zero for sufficient time [T_{OFF}]. Therefore, both the thyristors T_1 and T_2 are off. During this period capacitance voltage will be held constant.
- Since the positive polarity of the capacitor C appears on the anode of SCR T_2, it is in conducting mode.
- When SCR T_2 starts conducting, capacitor C gets discharged through it. Thus, the current through the load flows in the opposite direction forming the negative alteration. This current builds up to the negative maximum and then decreases to zero. Capacitor voltage reverses to some value depending upon the value of R, L and C.

Again after some time delay [T_{OFF}] SCR T_1 is triggered and cycles are repeated.