CHOPPER
DC TO DC CONVERTER

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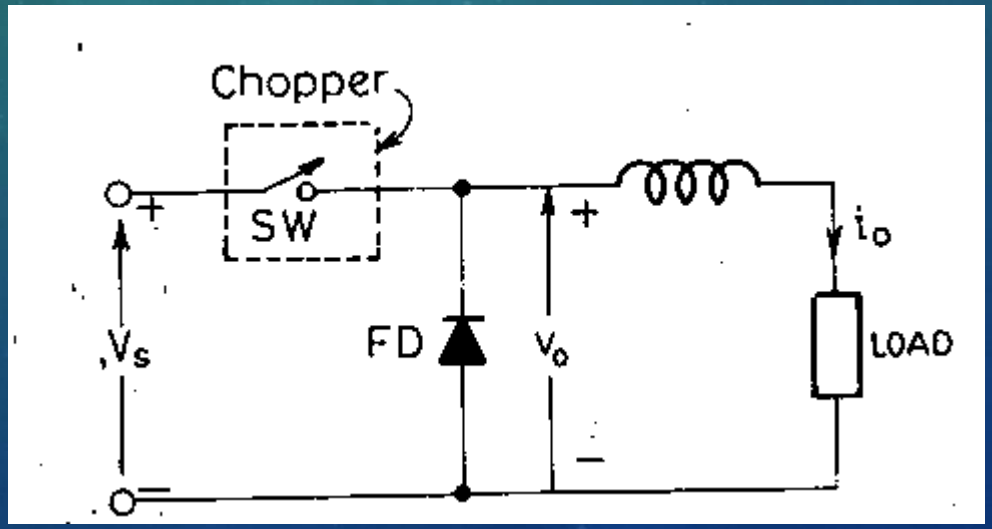
KEY TOPICS TO BE COVERED

- PRINCIPLE OF CHOPPER OPERATION (STEP DOWN CHOPPER)
- CONTROL STRATEGIES
- STEP UP CHOPPERS
- TYPES OF CHOPPER CIRCUITS
  - FIRST QUADRANT –TYPE A CHOPPER
  - SECOND QUADRANT –TYPE B CHOPPER
  - TWO QUADRANT TYPE A CHOPPER –TYPE C CHOPPER
  - TWO QUADRANT TYPE B CHOPPER –TYPE D CHOPPER
  - FOUR QUADRANT CHOPPER –TYPE E CHOPPER

PRINCIPLE OF CHOPPER OPERATION (STEP DOWN CHOPPER)

- A Chopper Is A High Speed On/Off Semiconductor Switch . It Connects Source To Load And Disconnects The Load From Source At A Fast Speed.
- During T_{on} , The Chopper Is On And Load Voltage (V_o) Is Equal To Source Voltage (V_s). The Load Current (I_o) Rises.
- During T_{off} , The Chopper Is Off And Load Current Flows Through The Freewheeling Diode. Load Terminals Are Short Circuited By Fd And Load Voltage (V_o) Is Zero. The Load Current (I_o) Decays.



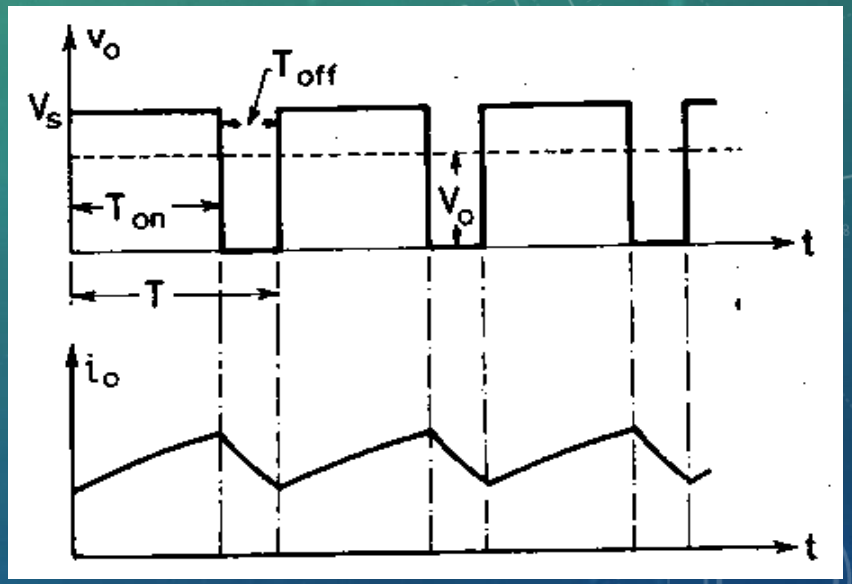
PRINCIPLE OF CHOPPER OPERATION (STEP DOWN CHOPPER)

$$V_0 = \frac{T_{on}}{T_{on} + T_{off}} V_s = \frac{T_{on}}{T} V = \alpha V_s$$

T_{on} = on-time ; T_{off} = off-time

$T = T_{on} + T_{off}$ = chopping period

$$\alpha = \frac{T_{on}}{T} = \text{duty cycle}$$



$$V_0 = f \cdot T_{on} \cdot V_s$$

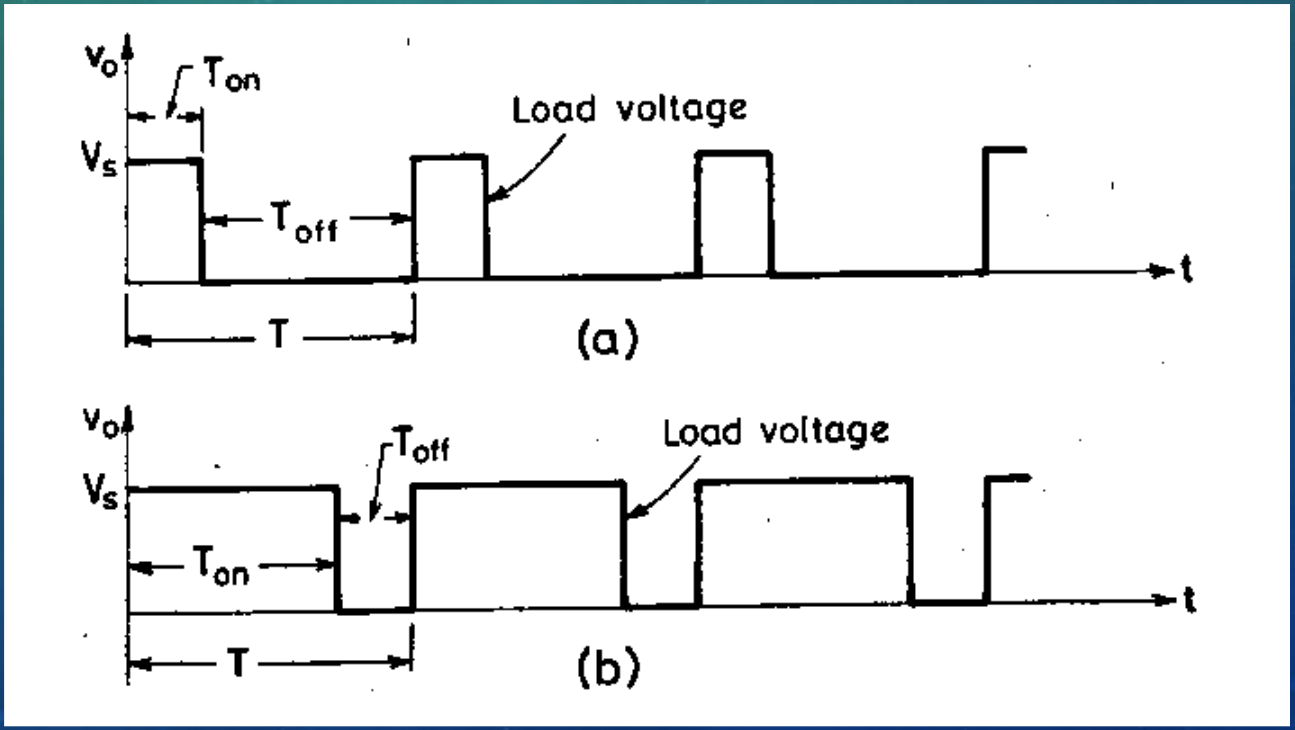
$$f = \frac{1}{T} = \text{chopping frequency}$$

CONTROL STRATEGIES

- TIME RATIO CONTROL
  - CONSTANT FREQUENCY SYSTEM
  - VARIABLE FREQUENCY SYSTEM
- CURRENT LIMIT CONTROL

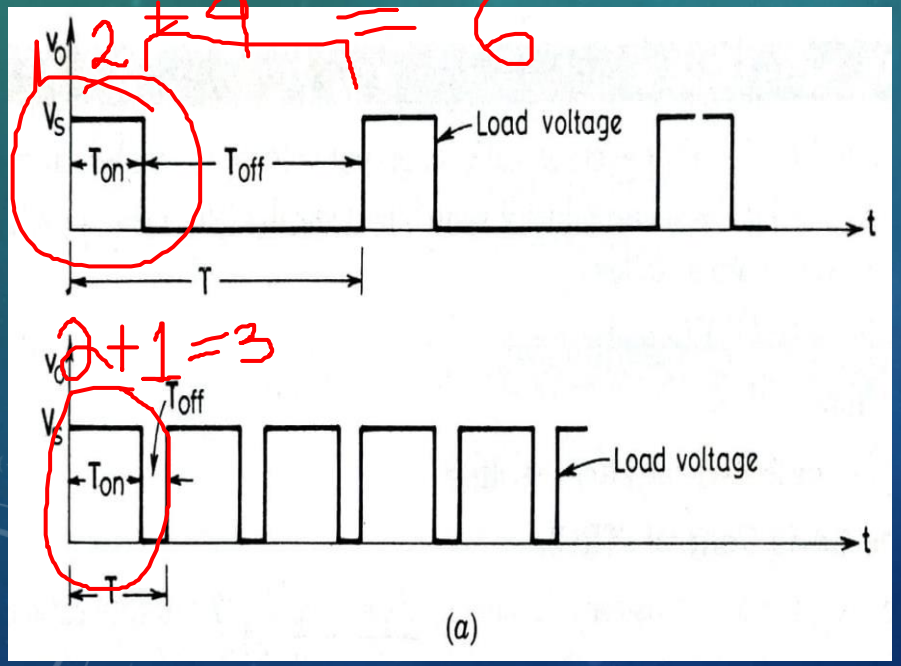
CONSTANT FREQUENCY SYSTEM

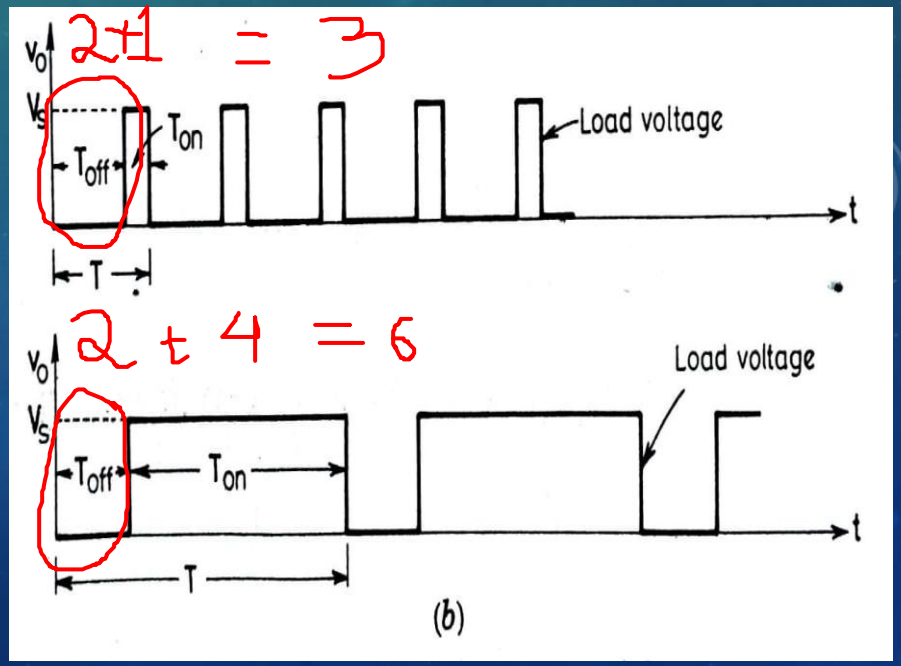
- On Time Is Varied , Chopping Period Remains Same.
- Variation In T_{on} Means Adjustment Of Pulse Width So It Is Called Pulse Width Modulation (PWM).



VARIABLE FREQUENCY SYSTEM

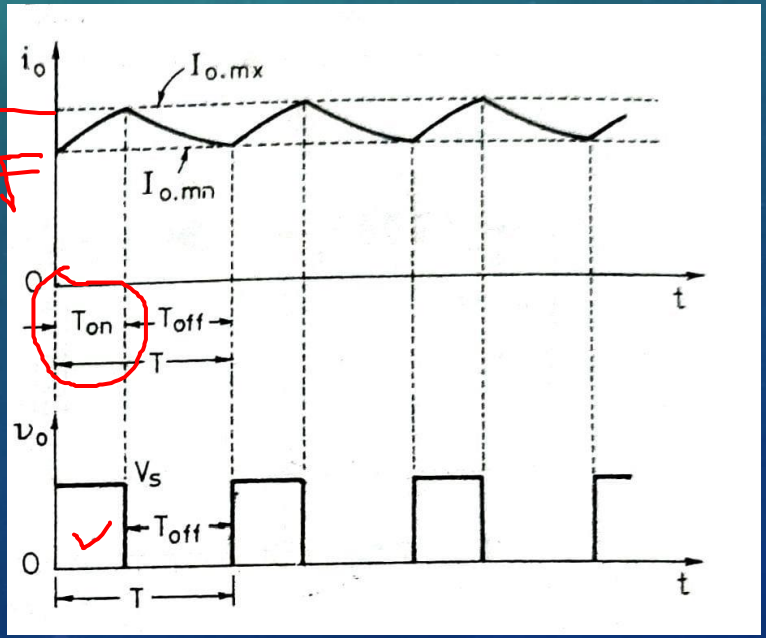
- Chopping Frequency " f " (Or Chopping Period T) is varied and either
  - T_{on} is kept constant or
  - T_{off} is kept constant.





CURRENT LIMIT CONTROL

- When Load Current Reaches The Upper Limit I_{max} , Chopper Is Switched Off.
- When It Falls To Lower Limit I_{min} , Chopper Is Switched On And Load Current Begins To Rise.



STEP UP CHOPPER

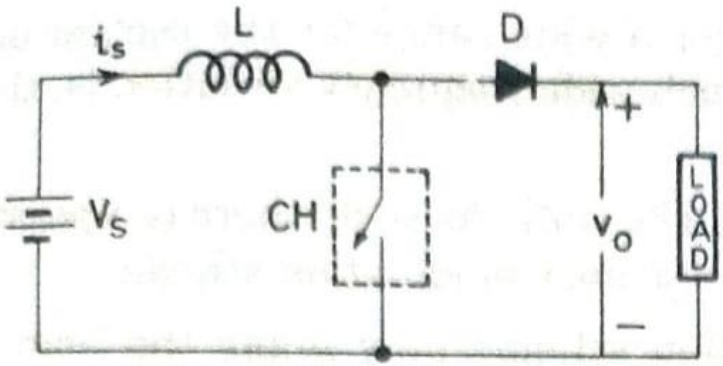
- Average Output Voltage V_o Is Greater Than V_s.

- When The Chopper CH is On , The inductor stores energy.

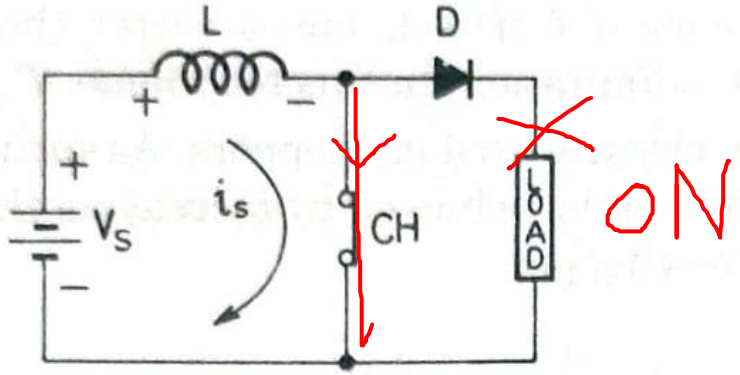
$$V_o = 0\ V$$

- When The Chopper CH is Off , The inductor current cannot die down instantaneously, the current is forced to flow through the load for a time T_{off} .

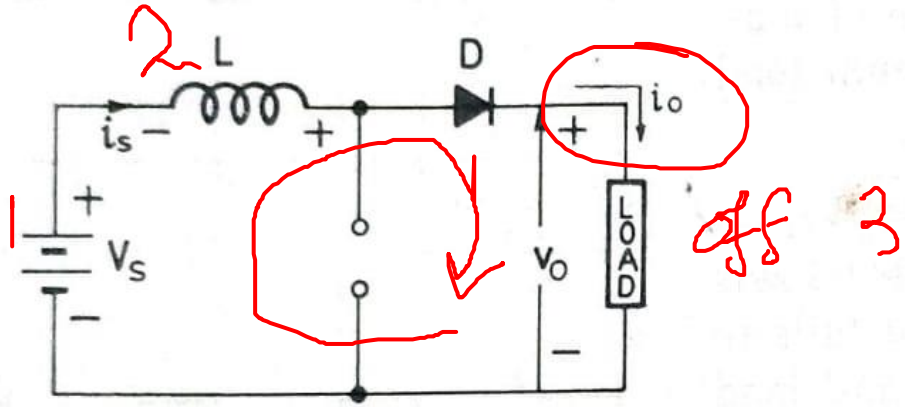
$$V_o = V_s + L(di/dt)$$

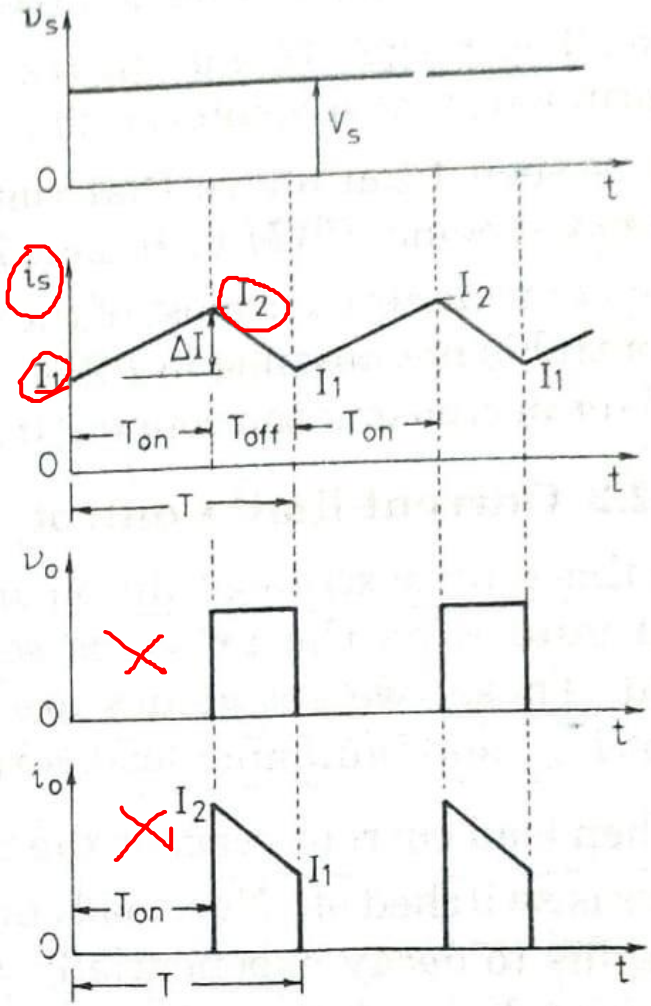

i_s
L
D
V_S
CH
v_o
LOAD
+
–

(a)


L
D
+
–
V_S
i_s
CH
LOAD
ON

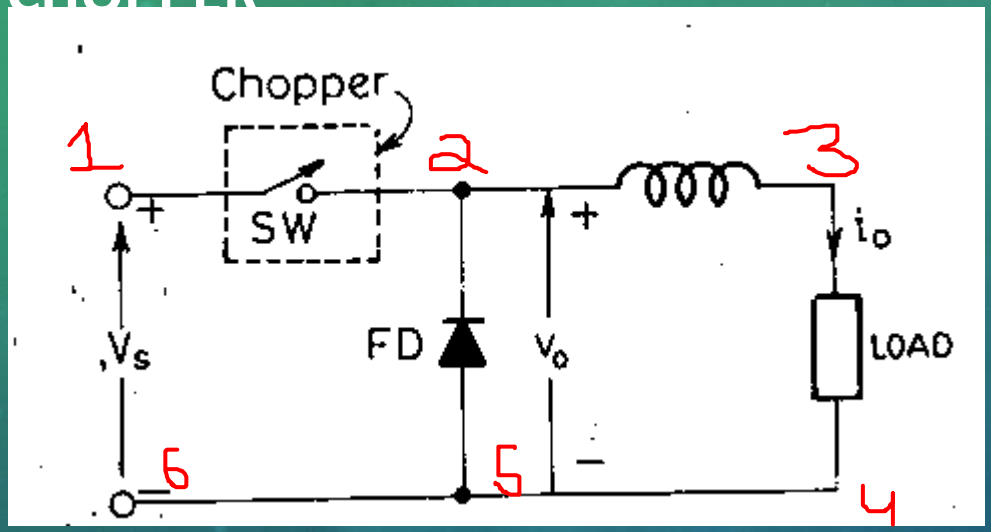
(b)

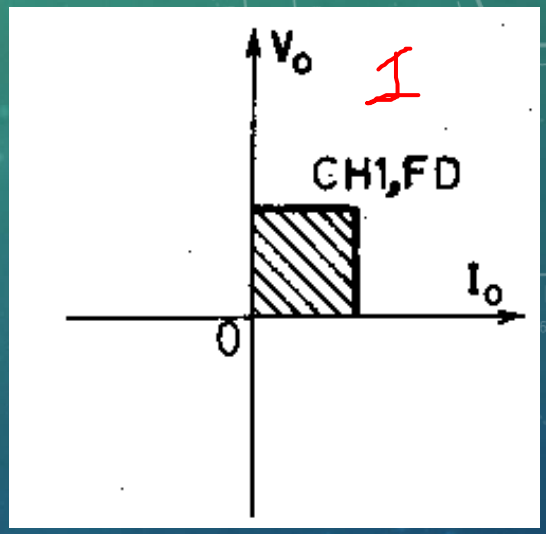

2
L
D
i_s
i_o
V_S
v_o
LOAD
1
off
3


v_s
V_s
0
t
i_s
I_2
I_1
ΔI
T_{on}
T_{off}
T
v_o
i_o

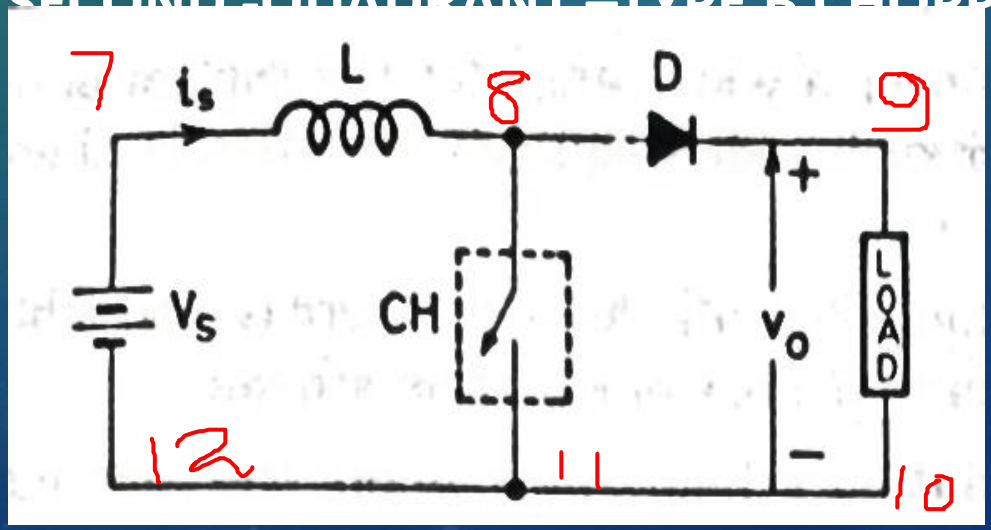
TYPES OF CHOPPER CIRCUITS

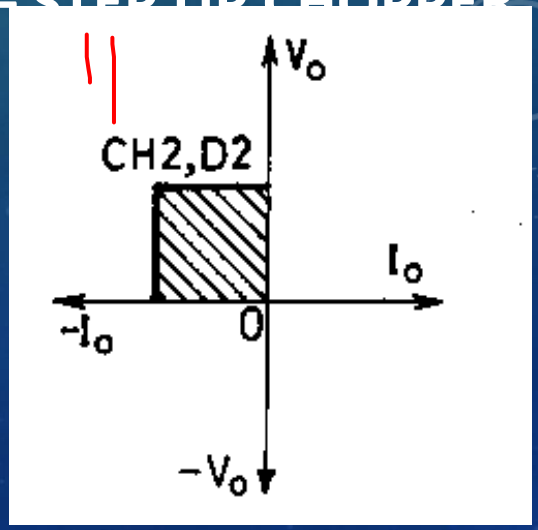
FIRST-QUADRANT –TYPE A CHOPPER – STEP DOWN CHOPPER



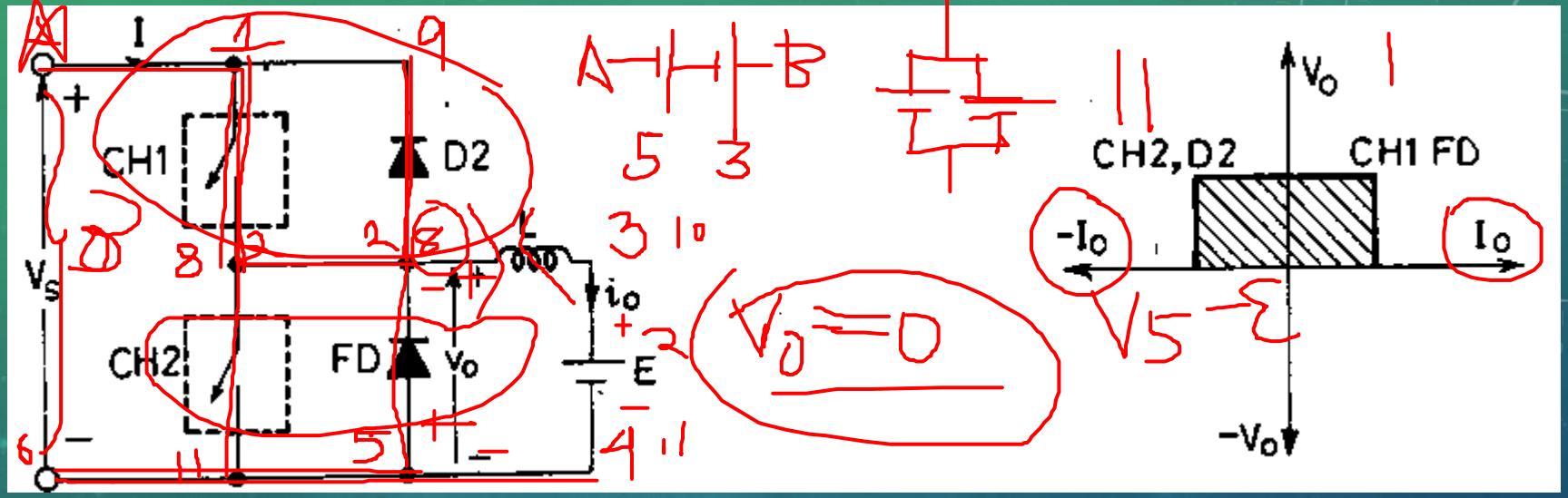


SECOND -QUADRANT –TYPE B CHOPPER– STEP UP CHOPPER



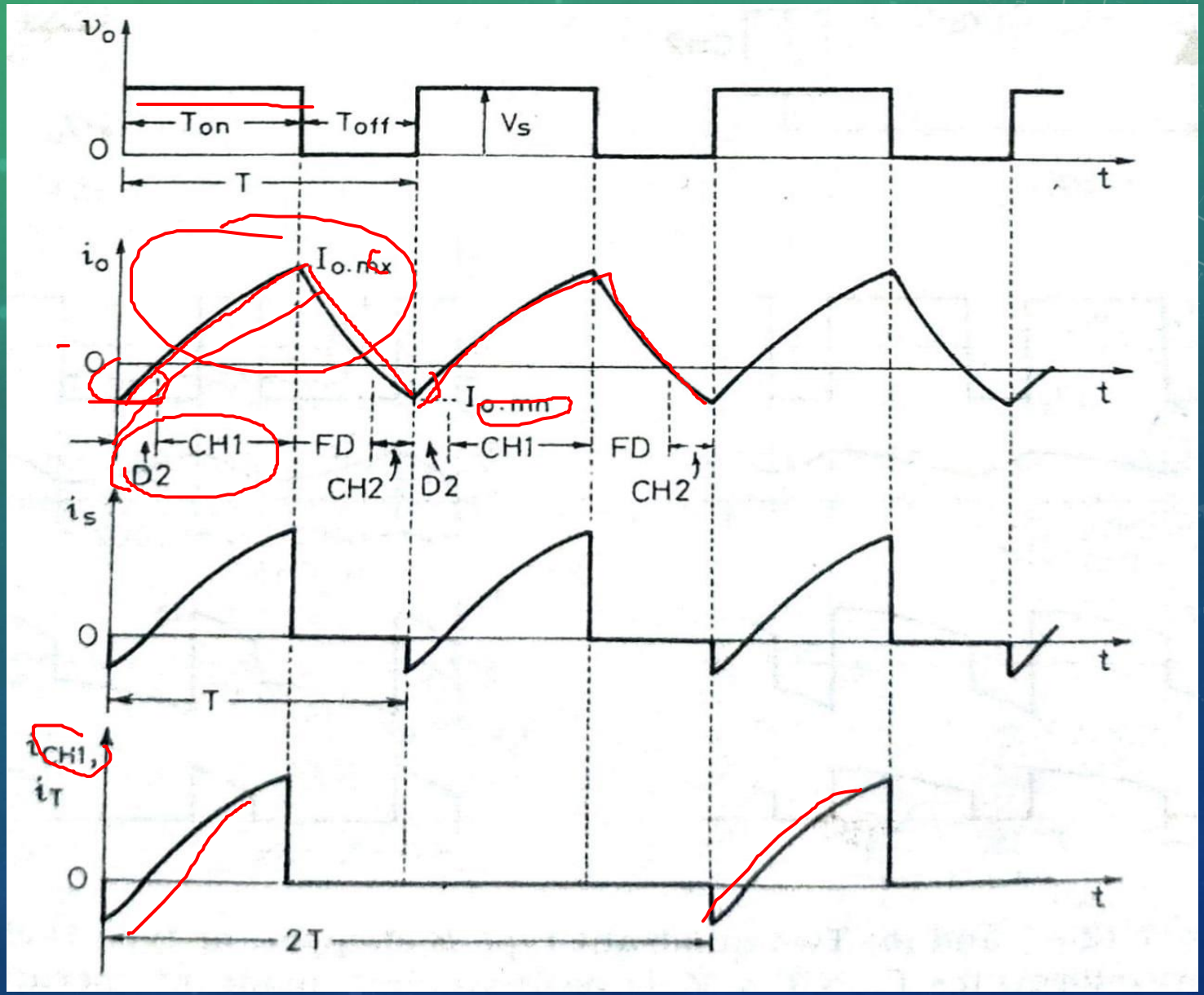


TWO QUADRANT TYPE A CHOPPER – TYPE C CHOPPER



- OUTPUT VOLTAGE V_O IS ALWAYS POSITIVE BECAUSE OF FREEWHEELING DIODE ACROSS THE LOAD.
- CURRENT LIMIT CONTROL IS USED.
- WHEN D2 CONDUCTS OR CH1 IS ON, LOAD VOLTAGE $V_O = V_S$ (T_{ON})
- WHEN FD CONDUCTS OR CH2 IS ON, LOAD VOLTAGE $V_O = 0$ V (T_{OFF})

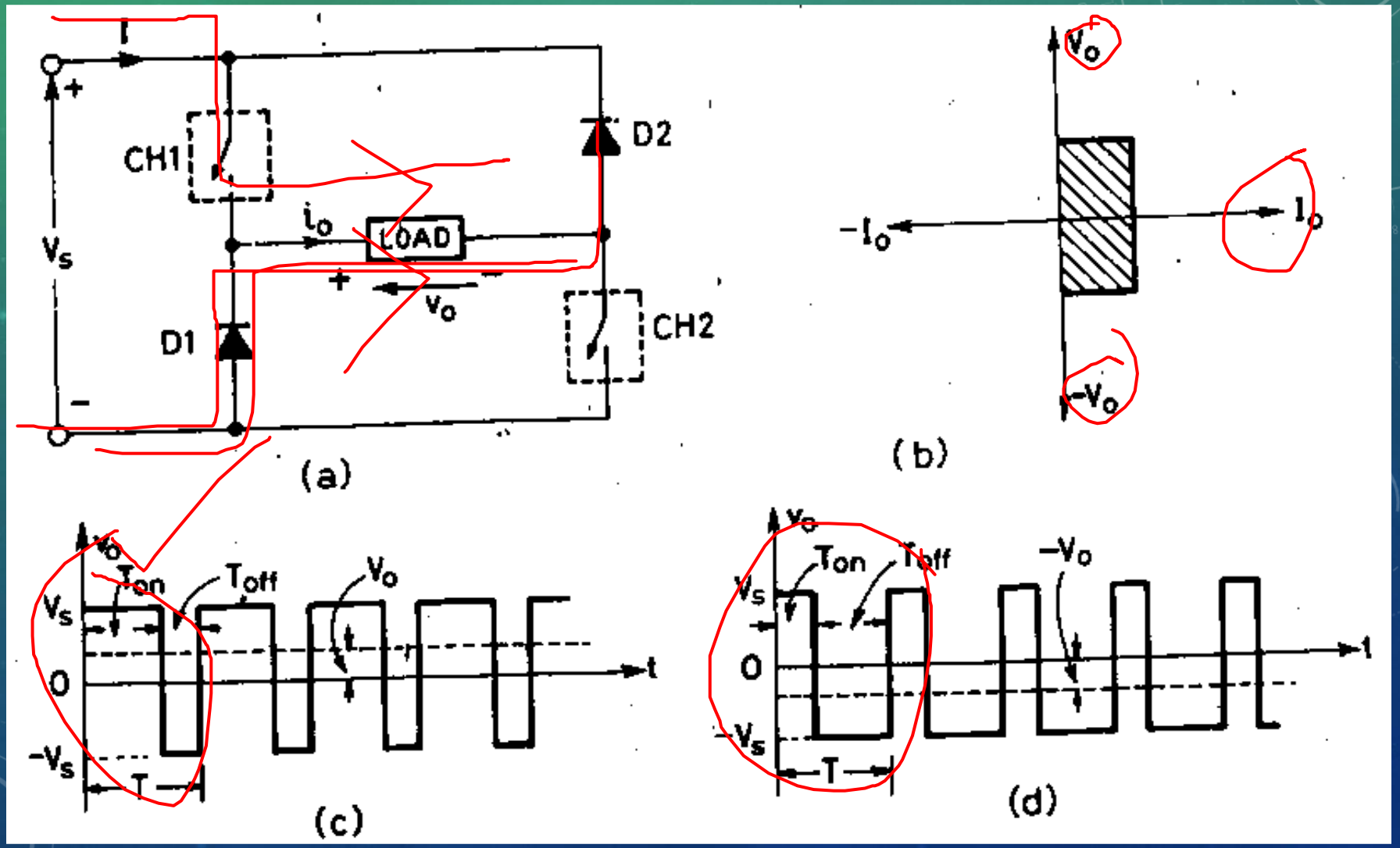
TWO QUADRANT TYPE A CHOPPER – TYPE C CHOPPER



TWO QUADRANT TYPE B CHOPPER – TYPE D CHOPPER

- When both the choppers CH1 and CH2 are on , $V_o = V_s$
- When both the choppers CH1 and CH2 are off and the diodes D1 and D2 are on , $V_o = -V_s$
- If T_{on} is greater than T_{off} , then the Average Output voltage V_o will be positive
- If T_{on} is less than T_{off} , then the Average Output voltage V_o will be negative
- Average Output Voltage (V_o can be positive or negative) but I_o is always positive.
- So the chopper works in two quadrants i.e. First and Fourth

TWO QUADRANT TYPE B CHOPPER – TYPE D CHOPPER



FOUR QUADRANT CHOPPER –TYPE E CHOPPER

- **First Quadrant:**
  - CH4 is kept on , CH3 is kept off and CH1 operated , When CH1, CH4 on then $V_o = V_s$.
  - When CH1 is off, positive current freewheels through CH4 , D2 .
  - V_o and I_o both are positive , So operates in First quadrant .

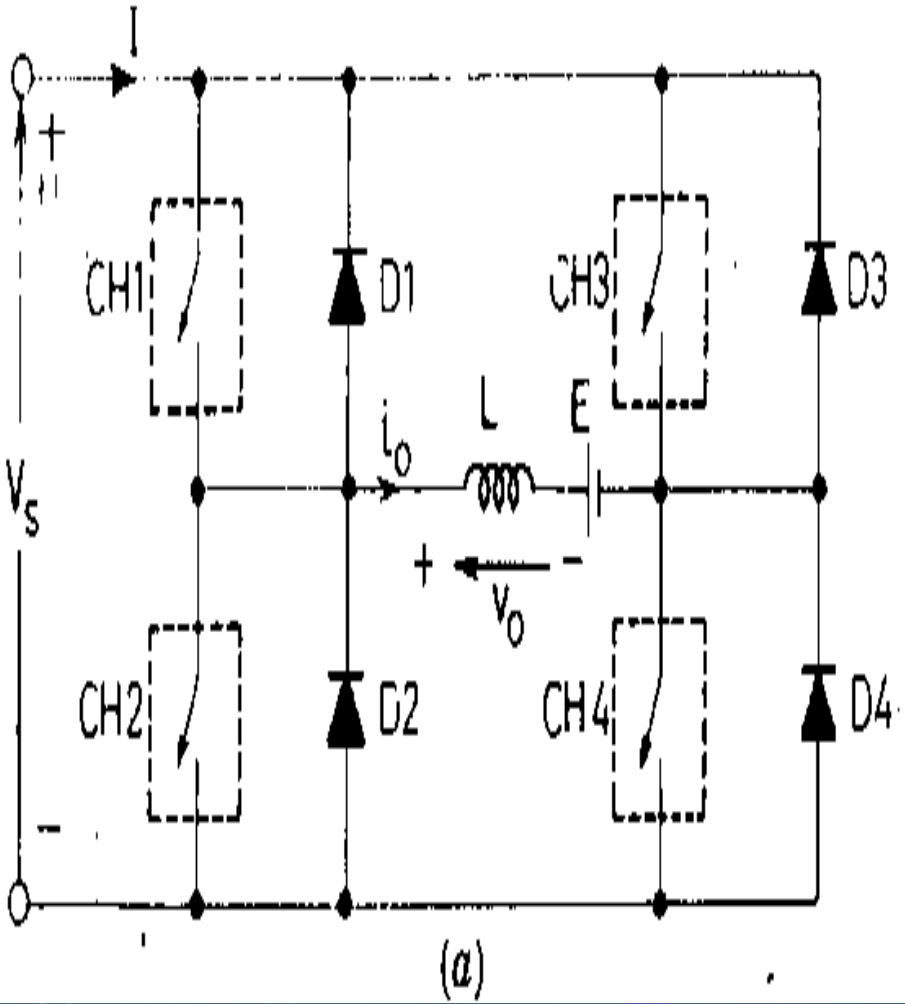
- **Second Quadrant:**
  - CH1 , CH3 and CH4 are off and CH2 is operated .
  - With CH2 on , reverse current flows through L , CH2 , D4 , E and the inductor stores energy .
  - When CH2 is off , current is feedback to source through D1 and D4 .
  - As the output voltage is greater than source voltage so the current flows from load to source and I_o is negative. But voltage V_o is always positive , so operates in second quadrant .

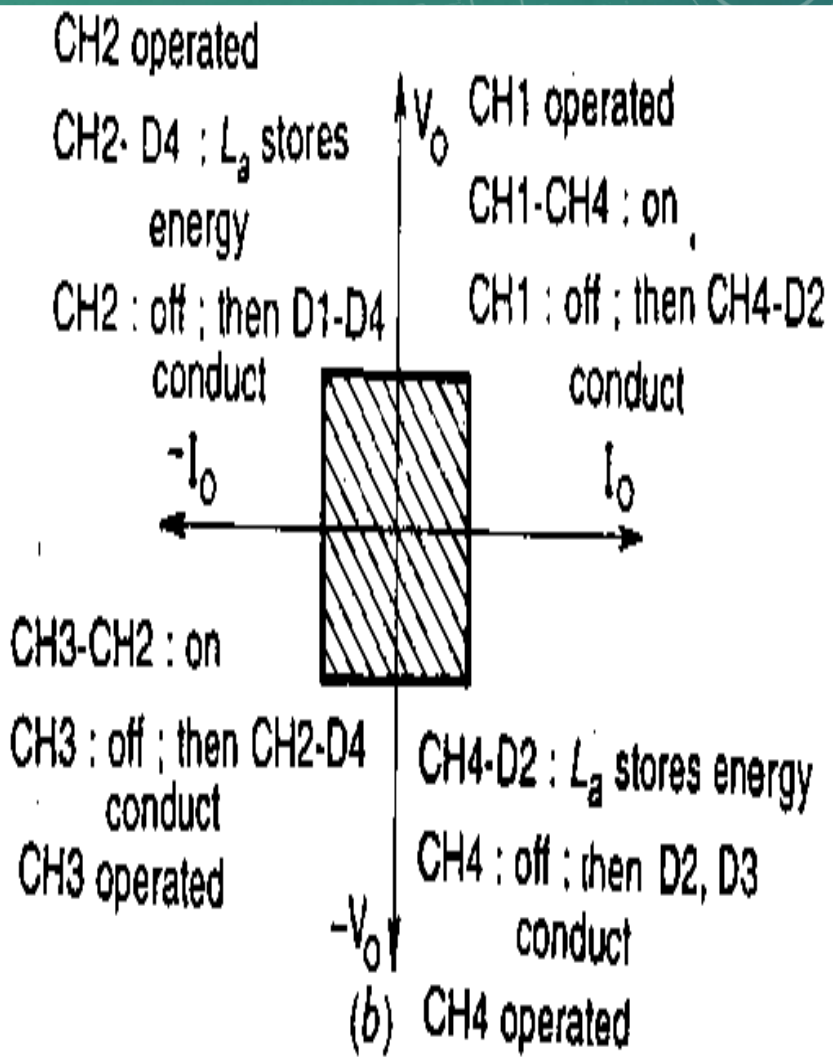
FOUR QUADRANT CHOPPER –TYPE E CHOPPER

- **Third Quadrant:**
  - CH1 is kept on , CH2 is kept off and CH3 operated , When CH2, CH3 on then $V_o = -V_s$.
  - When CH3 is off, negative current freewheels through CH2 , D4 .
  - V_o and I_o both are negative , So operates in Third quadrant .

- **Fourth Quadrant:**
  - CH1 , CH2 and CH3 are off and CH4 is operated .
  - With CH4 on , reverse current flows through L , CH4 , D2 , E and the inductor stores energy .
  - When CH4 is off , current is feedback to source through D2 and D3 .
  - As the output voltage is greater than source voltage so the current flows from load to source and V_o is negative. But Current I_o is always positive , so operates in fourth quadrant .

FOUR QUADRANT CHOPPER –TYPE E CHOPPER





THANK YOU