UNIT –III
CHOPPER

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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.

Advantages:

- Regeneration
- Smooth acceleration
- Fast dynamic response

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Applications:

- Trolley cars
- Used in electric cars
- Marine Hoists.
- Traction motor control

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Types of choppers:

- Based on Output voltage:
  - Step-Down chopper
  - Step-up chopper
  - Step Down/Up chopper
- Based on direction of Output V & I:
  - Class –A,
  - Class – B
  - Class –C
  - Class –D
  - Class -E

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- Based on Circuit Operation:
  - First quadrant
  - Two quadrant
  - Four quadrant
- Based on Commutation method:
  - Voltage commutation
  - Current commutation
  - Load commutation
  - Impulse commutation

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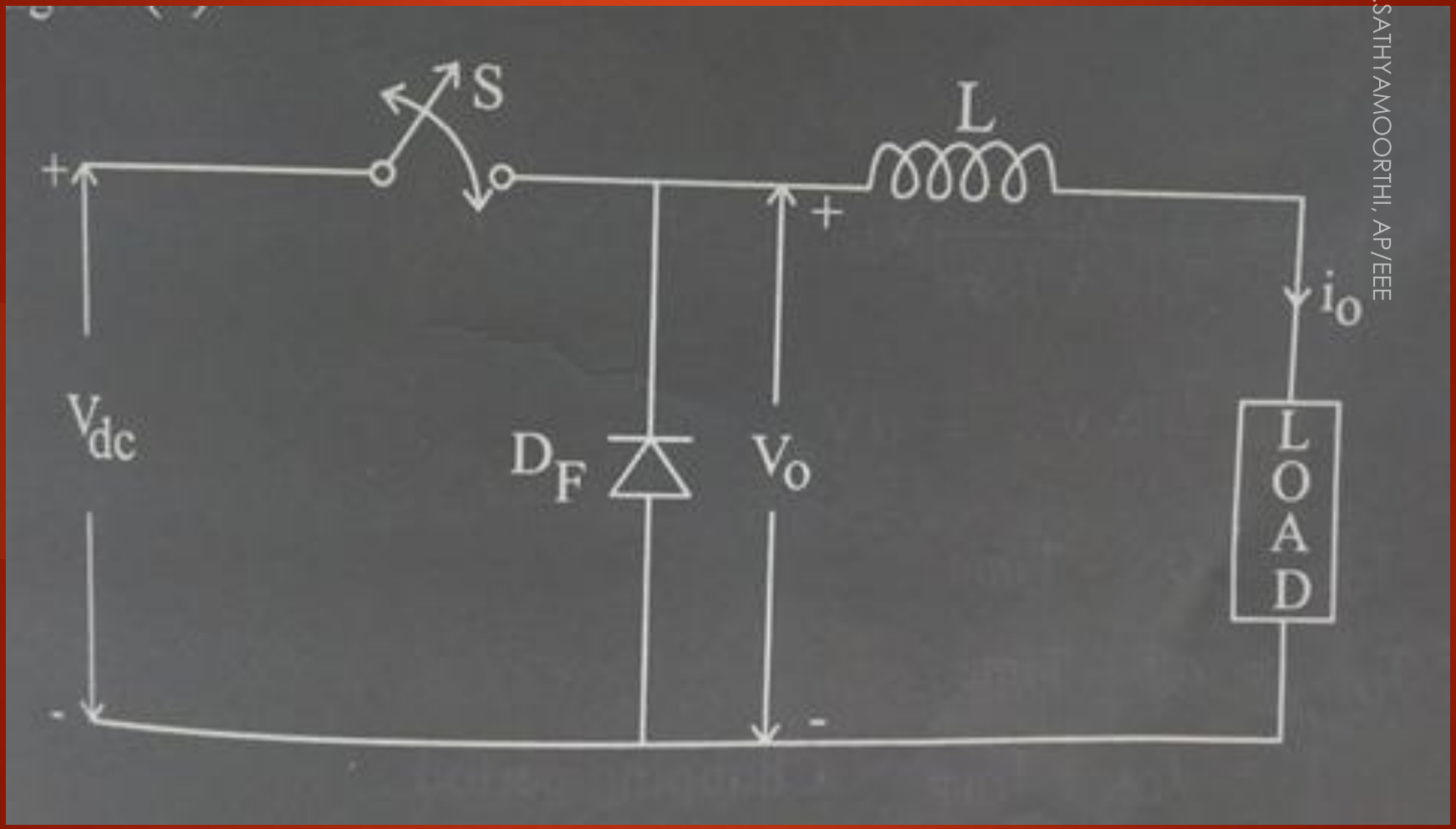
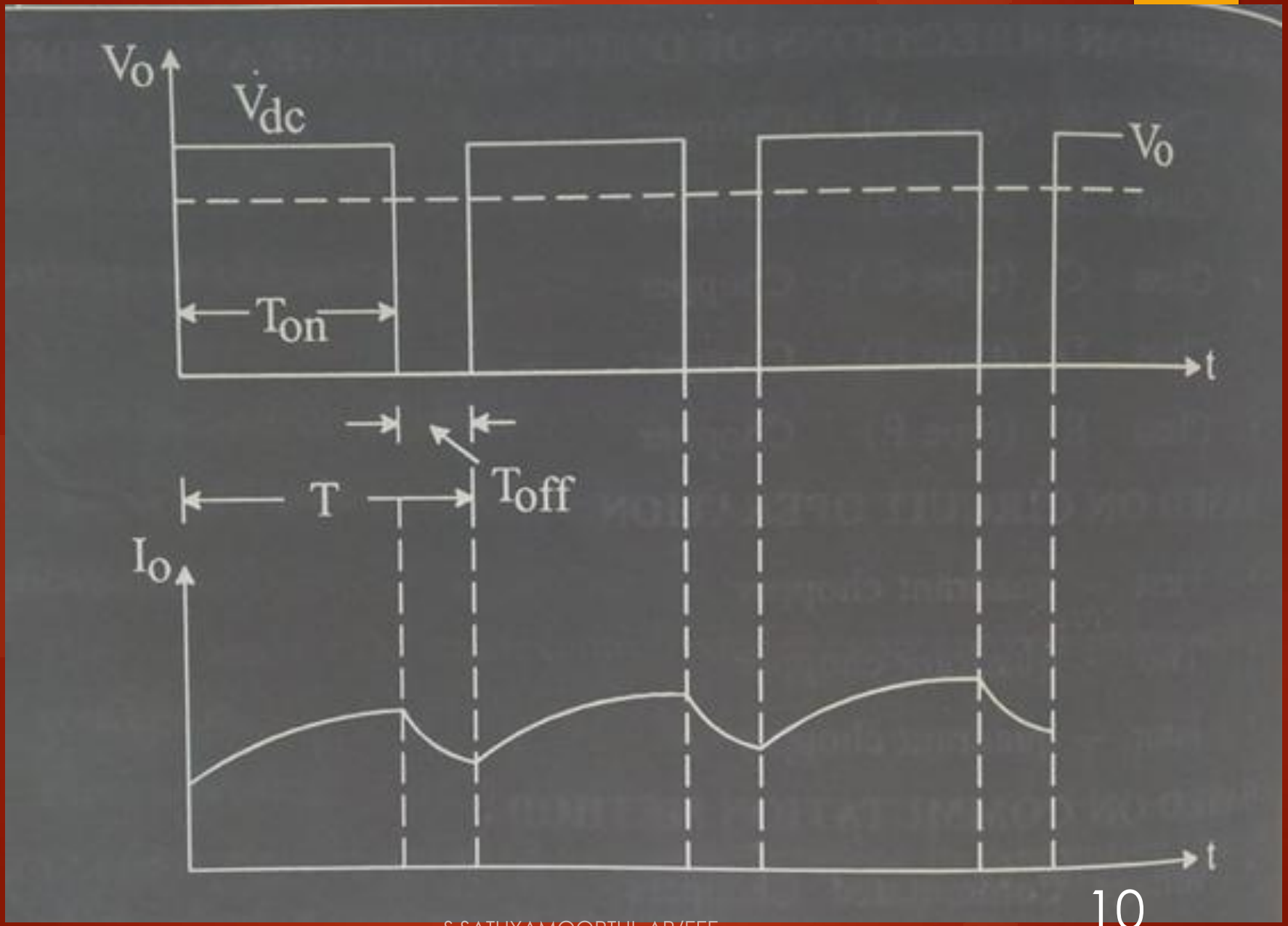
Based on output voltage Choppers:

- 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.

Principle Of Step-down Chopper



- A step-down chopper with resistive load.
- The thyristor in the circuit acts as a switch.
- When thyristor is ON, supply voltage appears across the load
- When thyristor is OFF, the voltage across the load will be zero.


Vo
Vdc
Vo
Ton
t
T
Toff
Io
t

Vdc = Load voltage
Idc = Load Current
T on = Time interval for which SCR conduct ON
T off = Time interval for which SCR is OFF
T = Ton + T off

Average Output Voltage

$$V_{dc} = V\left(\frac{t_{ON}}{t_{ON} + t_{OFF}}\right)$$

$$V_{dc} = V\left(\frac{t_{ON}}{T}\right) = V.d$$

$$but\ \left(\frac{t_{ON}}{t}\right) = d = \text{duty cycle}$$

Average Output Current

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

$$I_{dc} = \frac{V}{R}\left(\frac{t_{ON}}{T}\right) = \frac{V}{R}d$$

RMS value of output voltage

$$V_O = \sqrt{\frac{1}{T}\int_0^{t_{ON}} v_o^2 dt}$$

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But during t_{ON}, $v_o = V$

Therefore RMS output voltage

$$V_o = \sqrt{\frac{1}{T}\int_0^{t_{ON}} V^2 dt}$$

$$V_o = \sqrt{\frac{V^2}{T} t_{ON}} = \sqrt{\frac{t_{ON}}{T}}.V$$

$$V_o = \sqrt{d}.V$$

Output power $P_o = V_o I_o$

But $I_o = \frac{V_o}{R}$

$\therefore$ Output power

$$P_o = \frac{V_o^2}{R}$$

$$P_o = \frac{dV^2}{R}$$

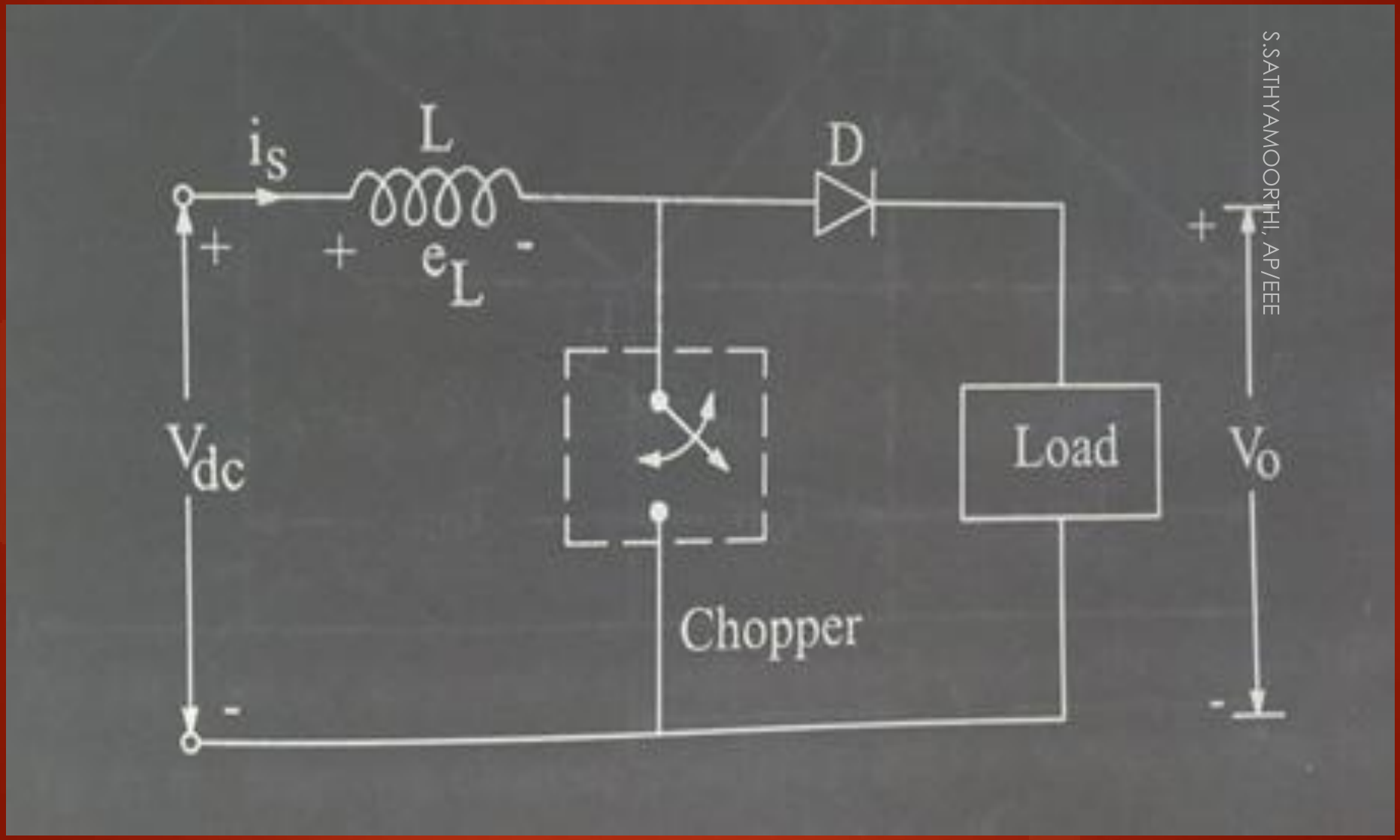
Effective input resistance of chopper

$$R_i = \frac{V}{I_{dc}}$$

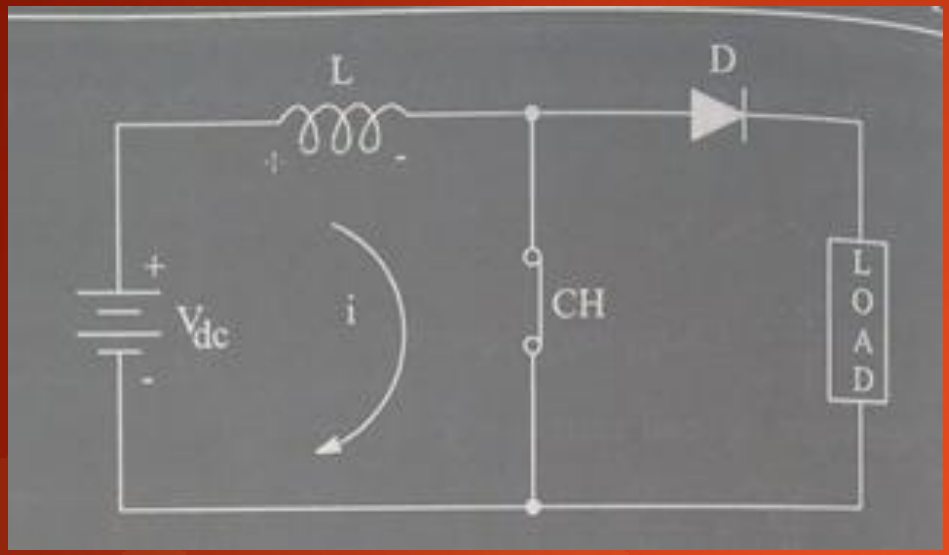
$$R_i = \frac{R}{d}$$

The output voltage can be varied by varying the duty cycle.

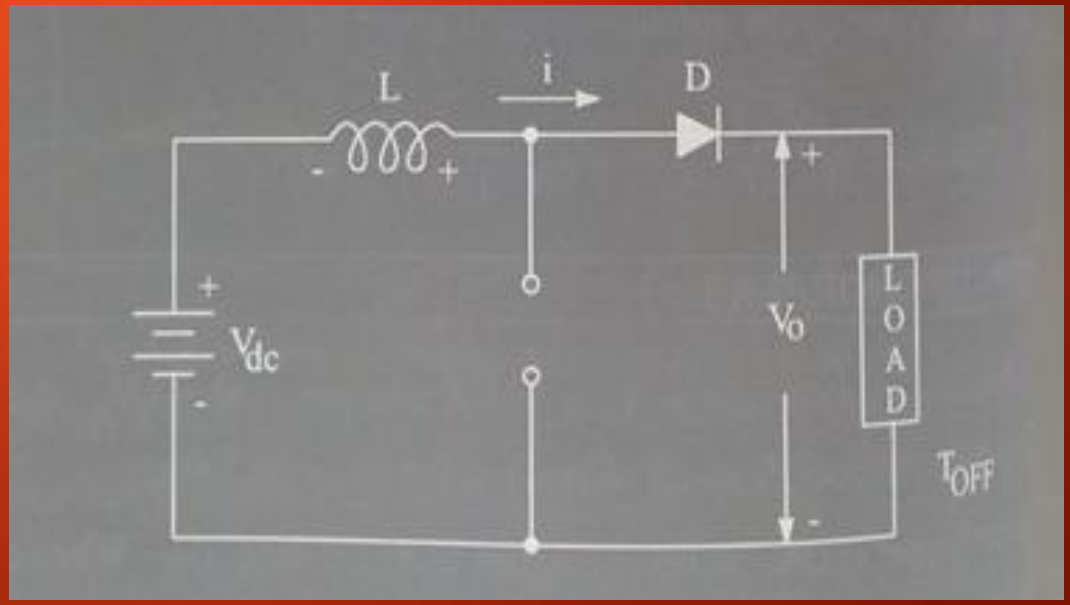
Step-Up Chopper

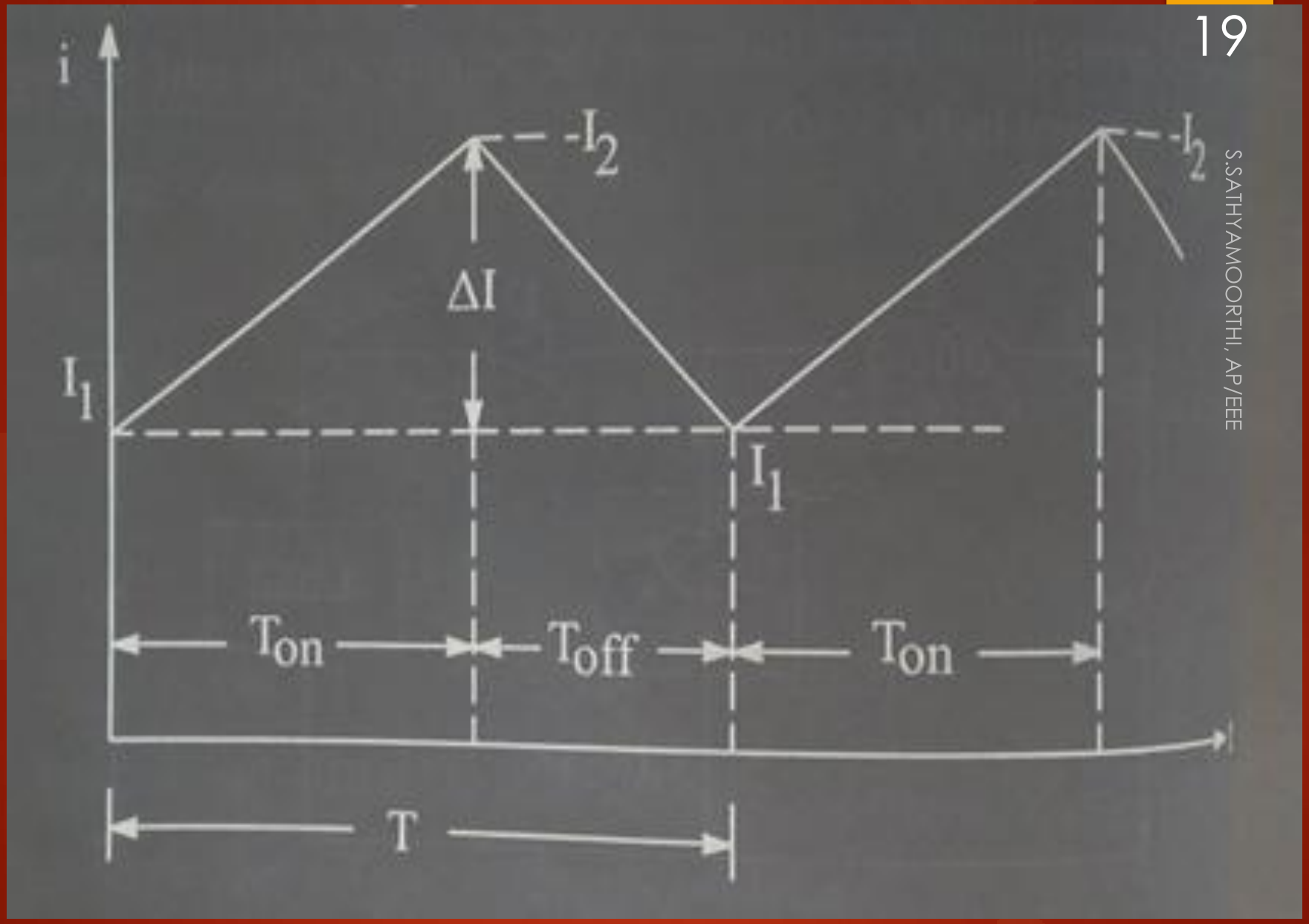


Ton Condition



Toff Condition

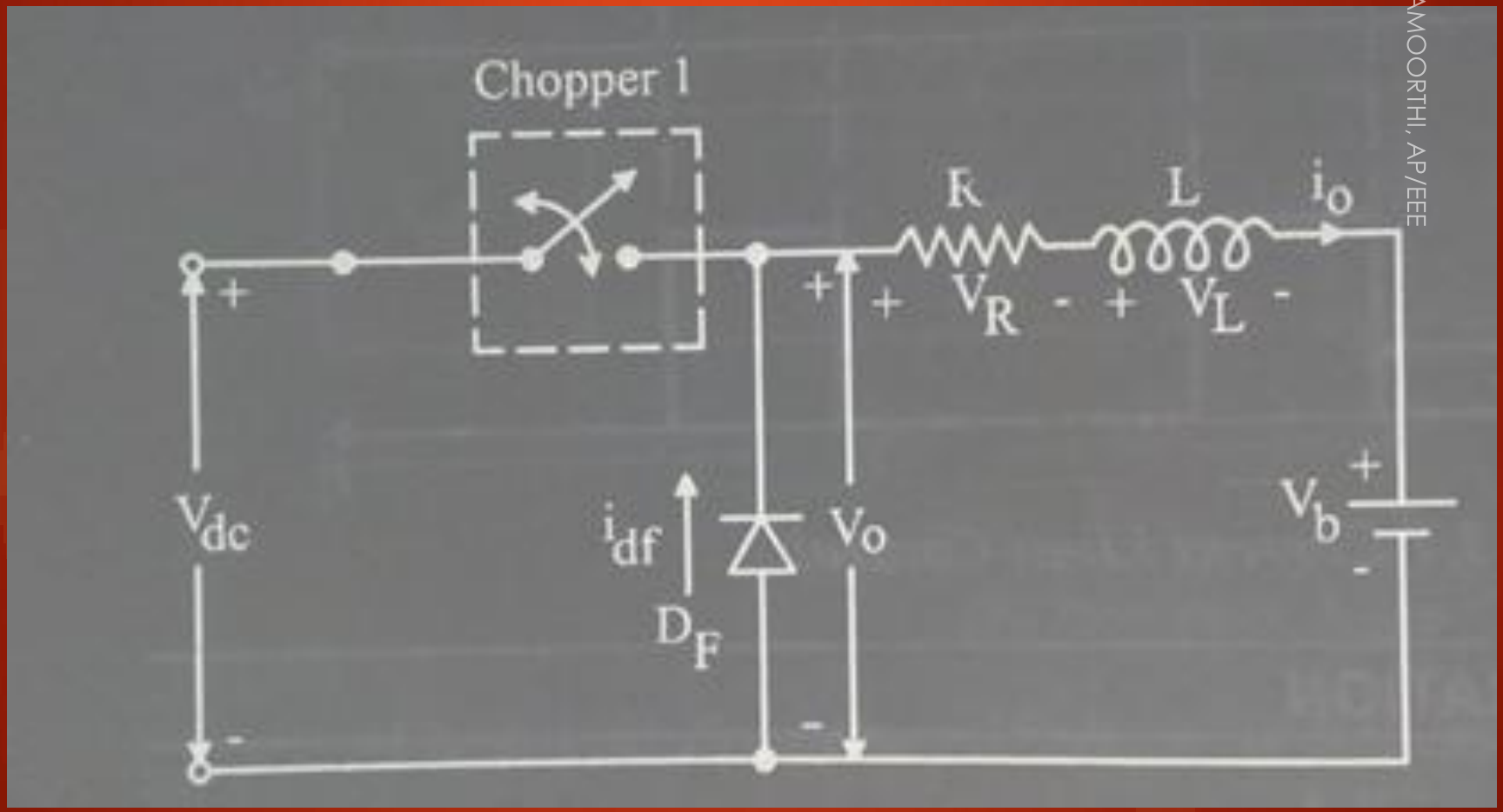


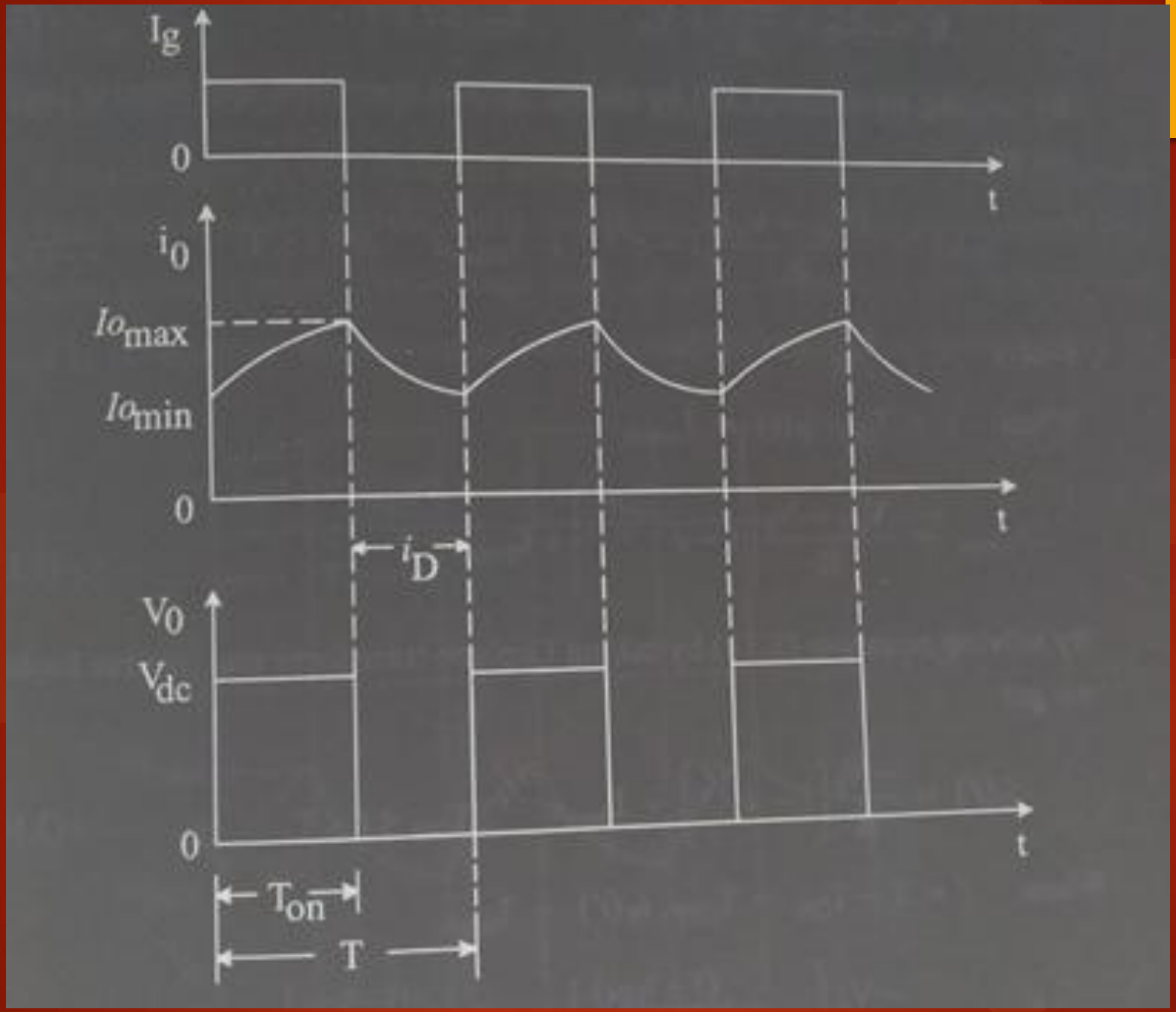

i
I_2
I_2
ΔI
I_1
I_1
T_{on}
T_{off}
T_{on}
T

CHOOPER CONFIGURATION

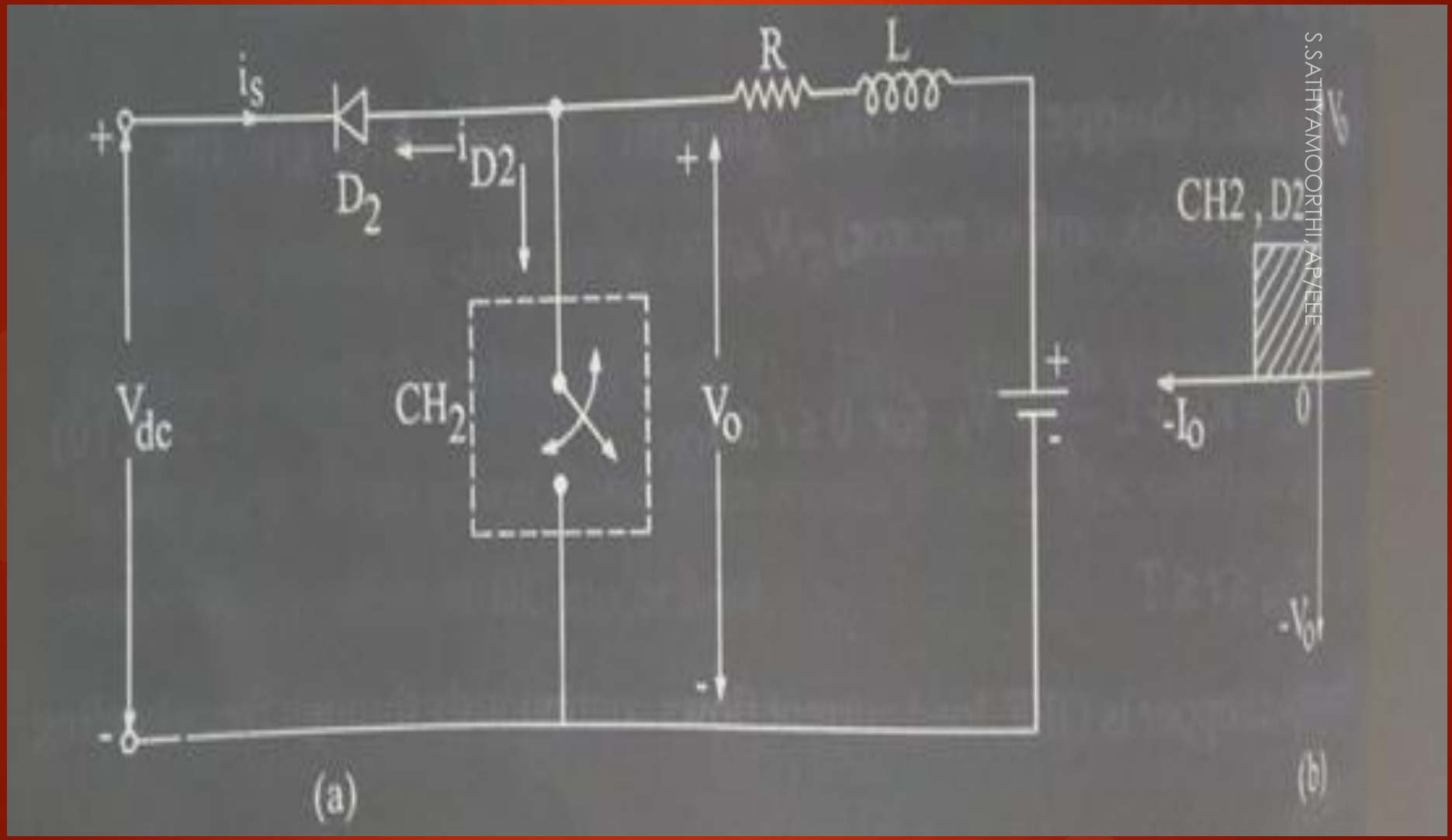
One Quadrant Operation:

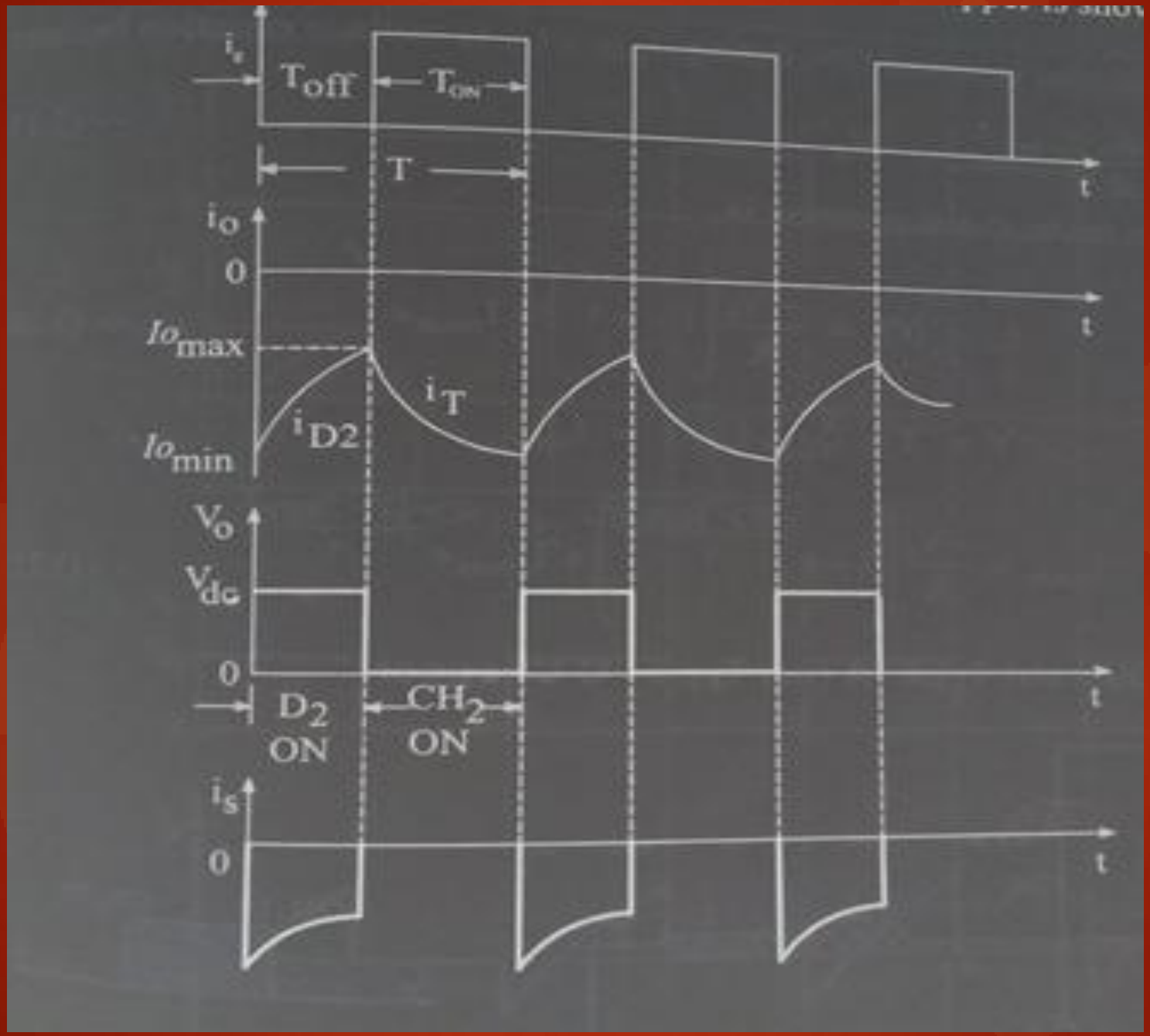
First Quadrant Operation:




Ig
0
t
i0
Iomax
Iomin
0
t
iD
V0
Vdc
0
t
Ton
T

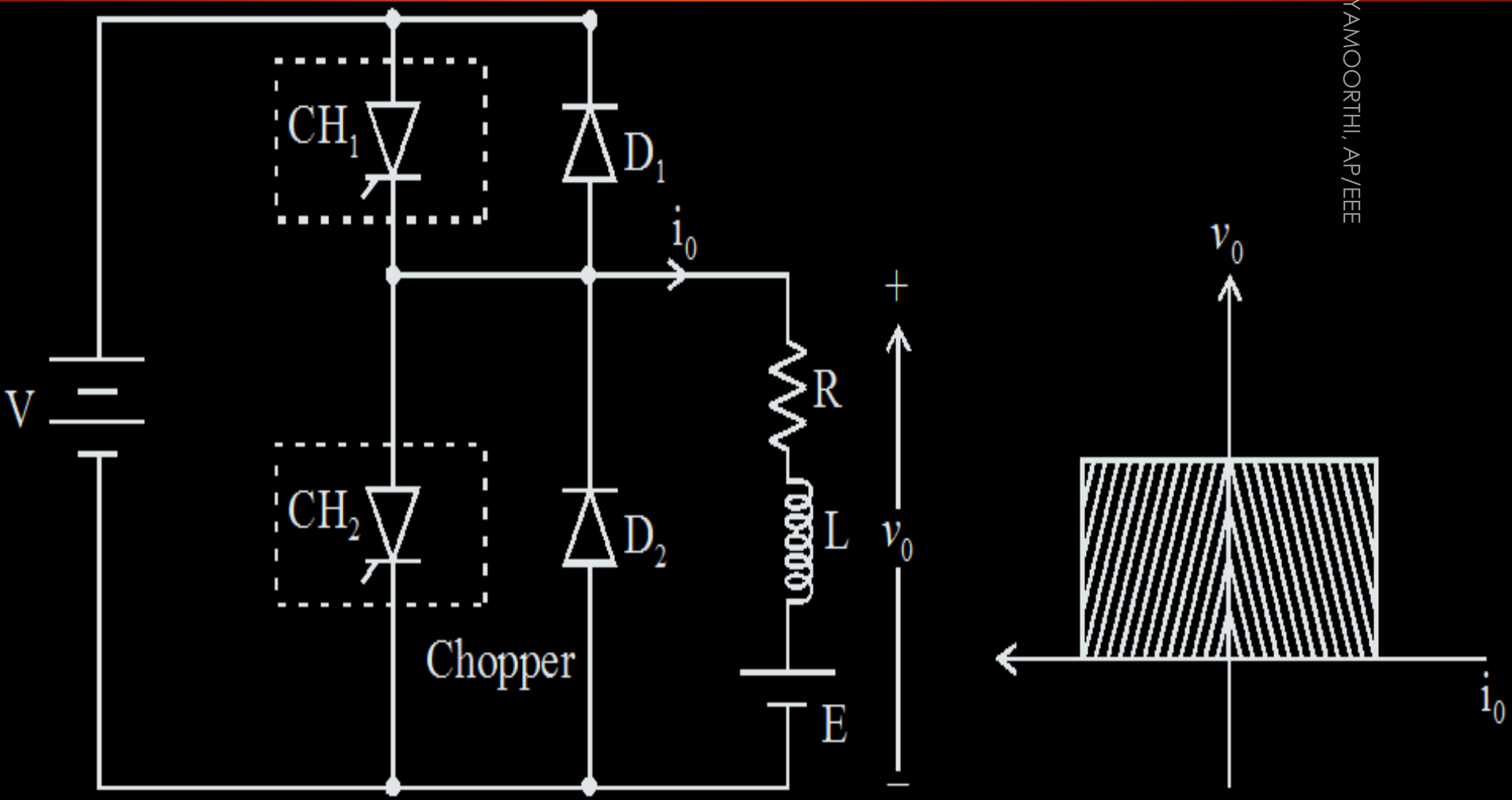
Second Quadrant Operation:




i_g
T_{off}
T_{ON}
T
t
i_o
0
Io_{max}
i_T
i_{D2}
Io_{min}
V_o
V_{dc}
0
D_2 ON
CH_2 ON
i_s
0

Two Quadrant Operation:

One & Two Quadrant Operation: Class C Chopper:



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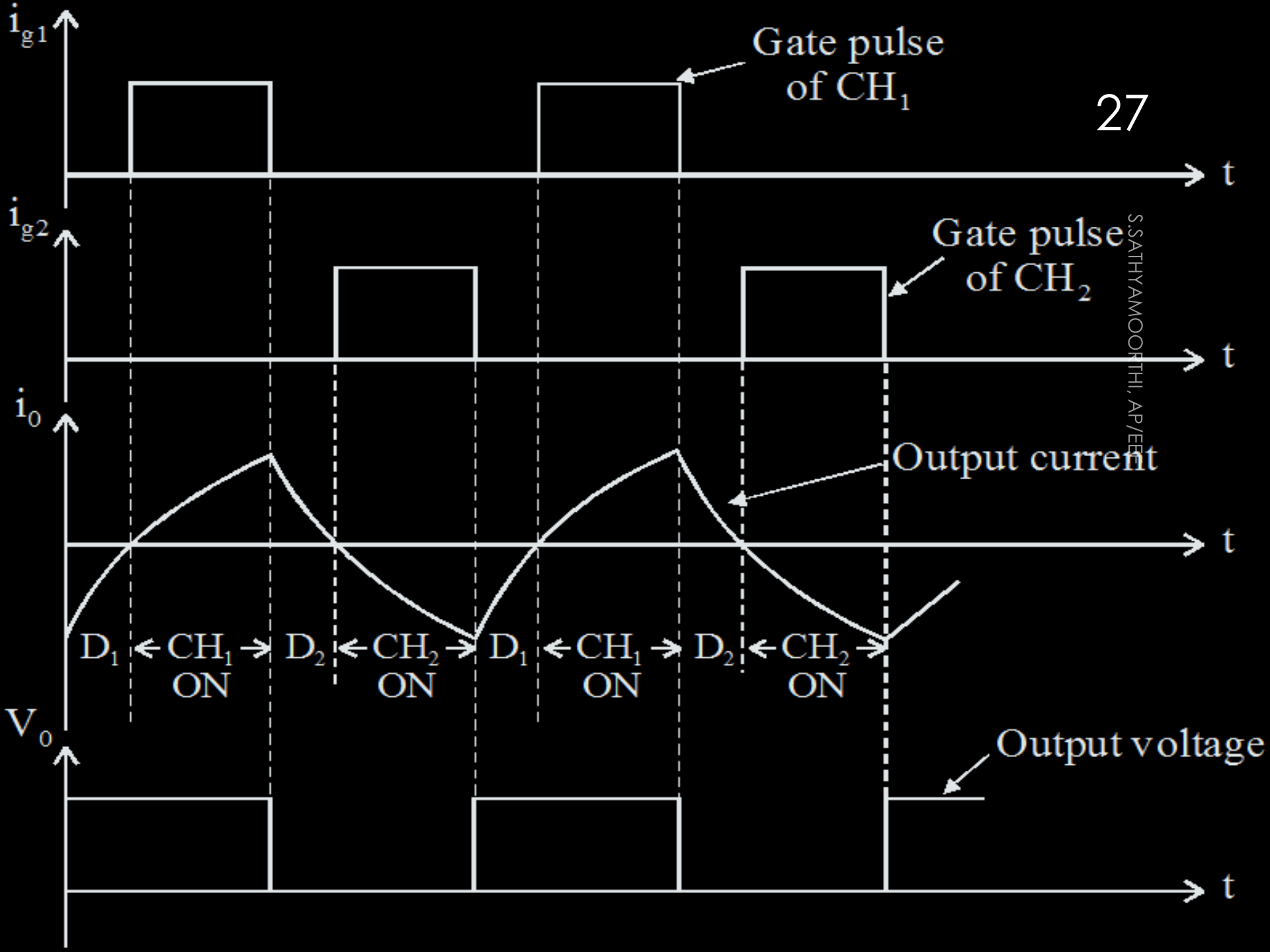
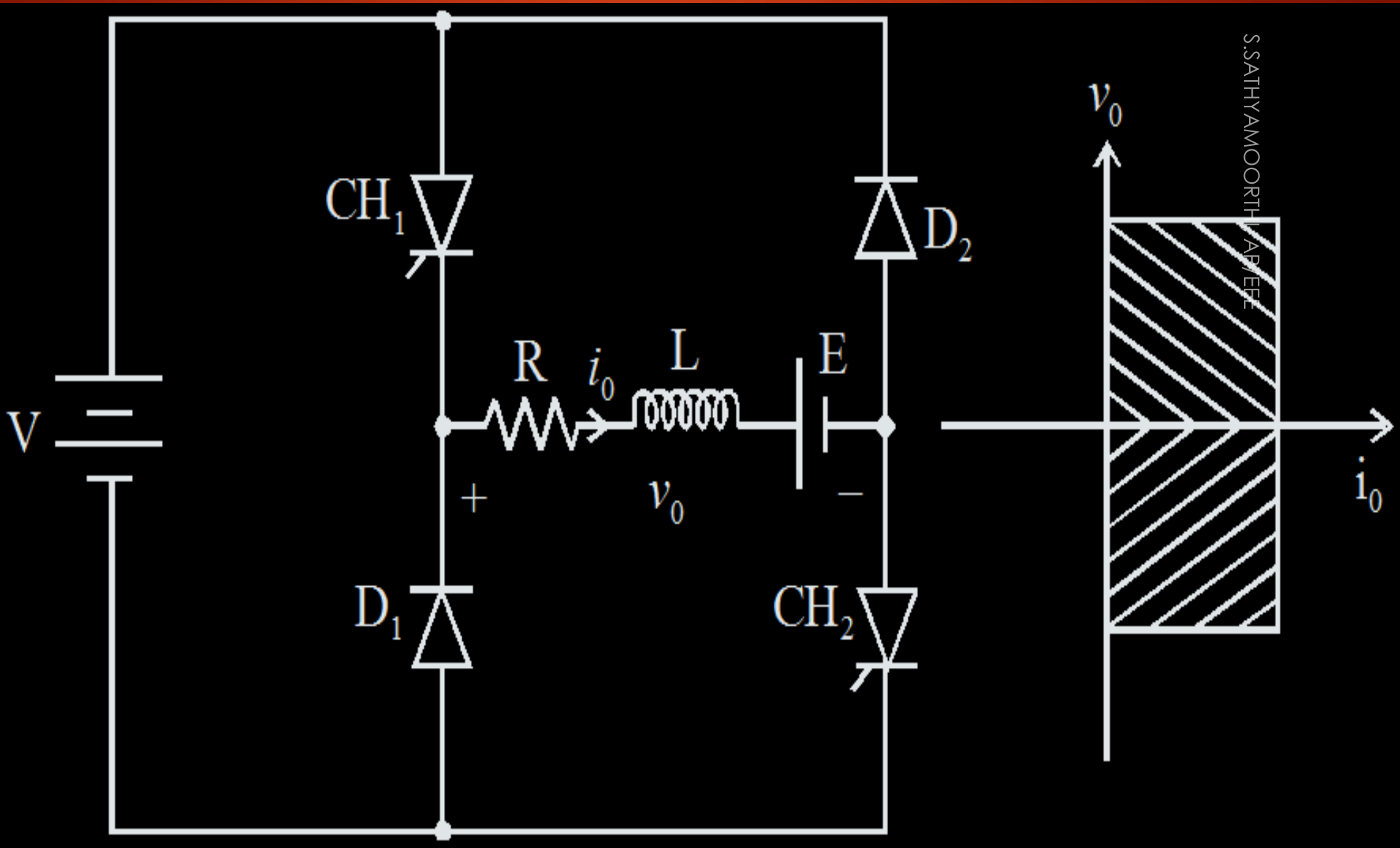
- *Class C Chopper* is a combination of *Class A* and *Class B Choppers*.
- For first quadrant operation, CH_1 is ON or D_2 conducts.
- For second quadrant operation, CH_2 is ON or D_1 conducts.
- When CH_1 is ON, the load current is positive.
- The output voltage is equal to '*V*' & the load receives 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.

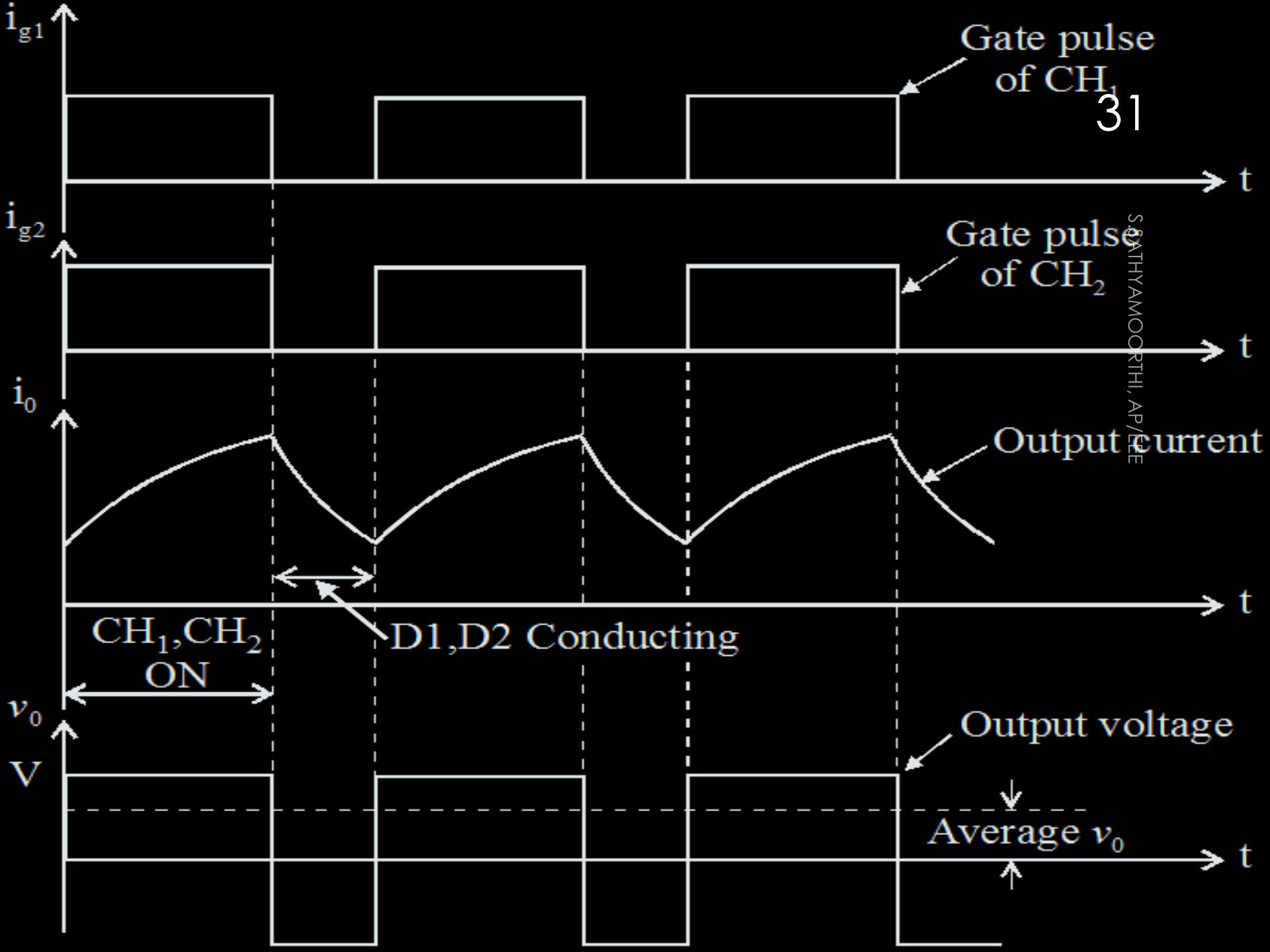


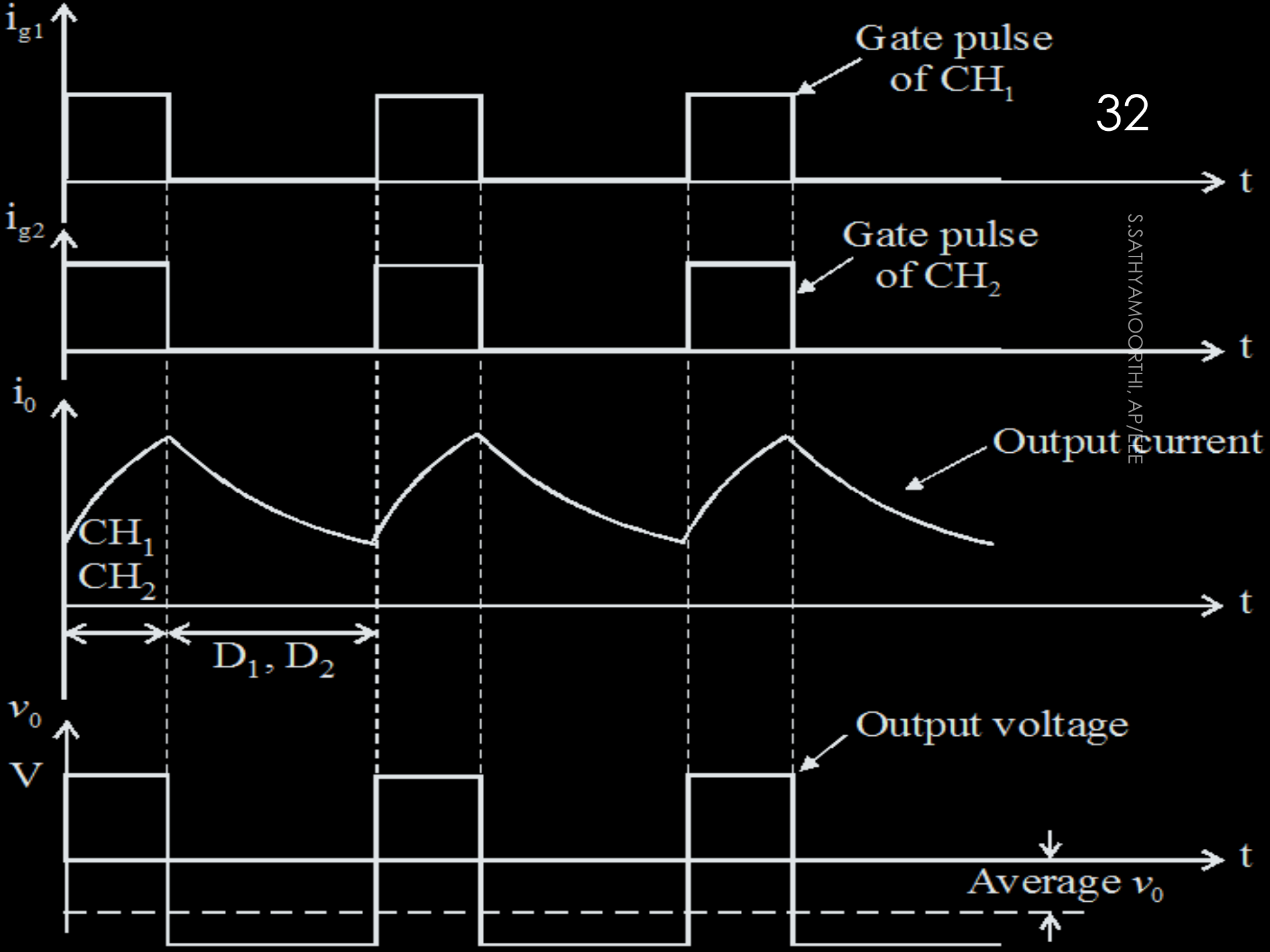
Class D Chopper



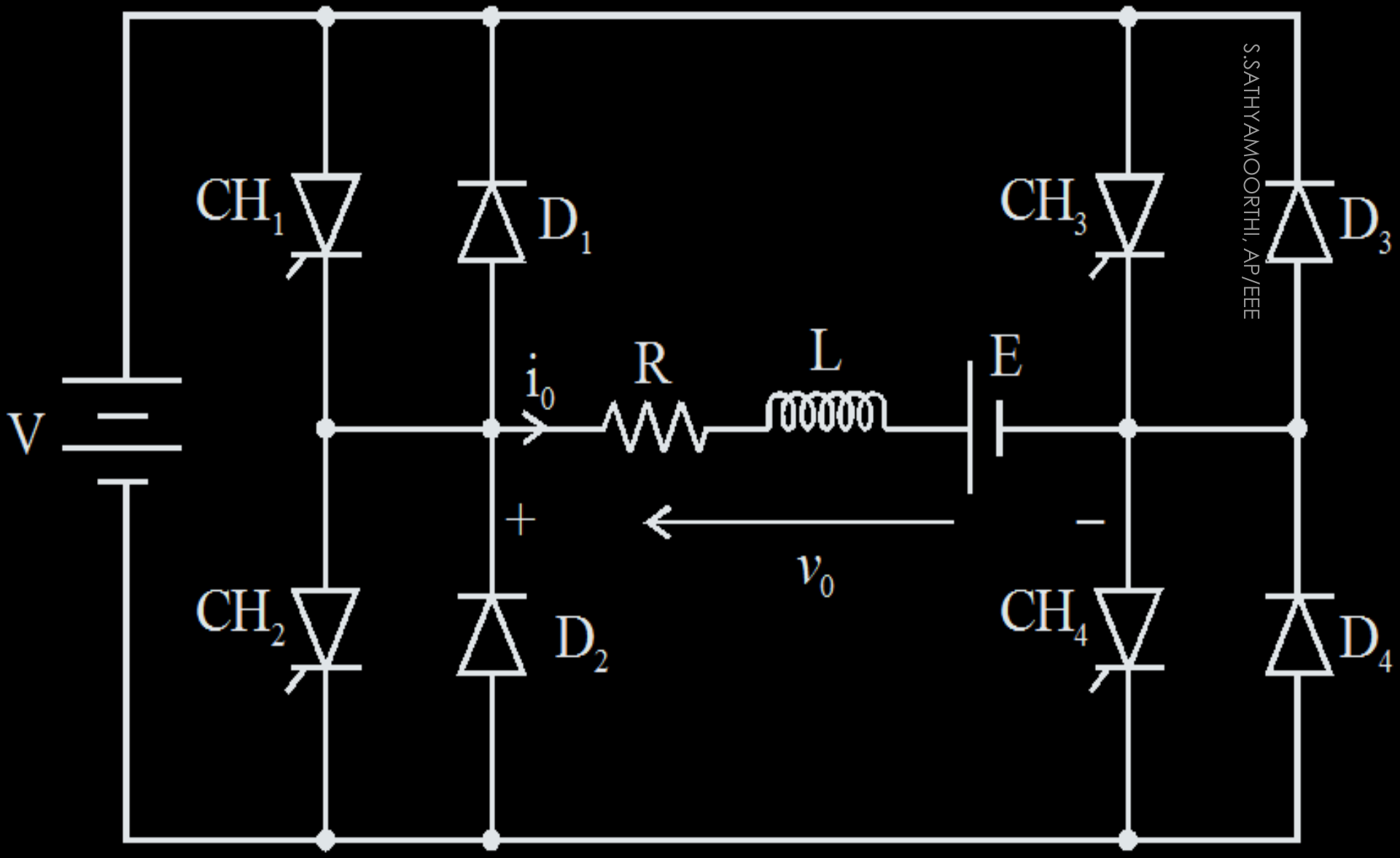
- Class D is a two quadrant chopper.
- When both CH_1 and CH_2 are triggered simultaneously, the output voltage $v_O = V$ and output current flows through the load.
- When CH_1 and CH_2 are turned OFF, the load current continues to flow in the same direction through load, D_1 and D_2 , due to the energy stored in the inductor L.
- Output voltage $v_O = - V$.

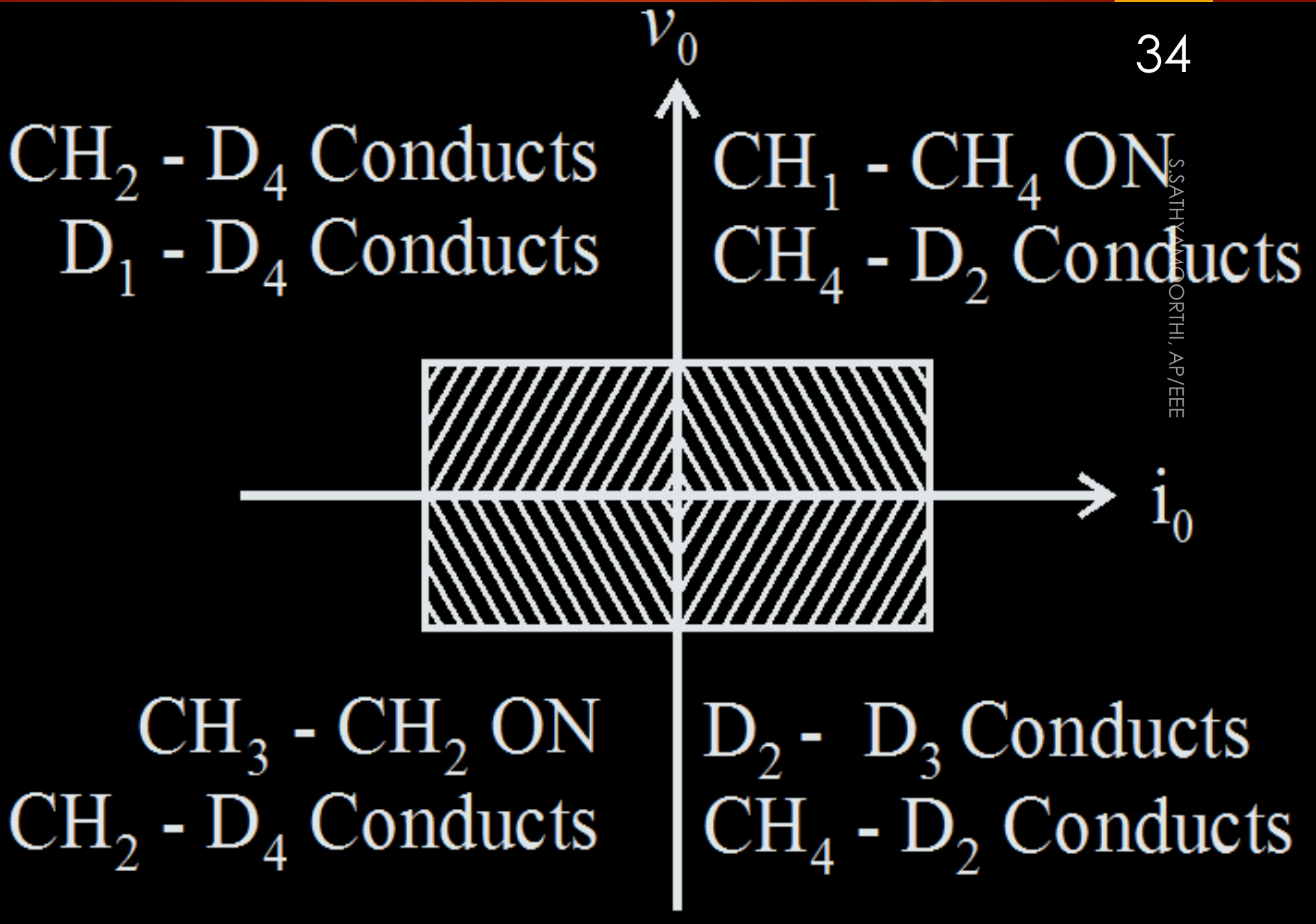
- Average load voltage is positive if chopper ON time is more than the OFF time
- Average output voltage becomes negative if $t_{ON} < t_{OFF}$.
- Hence the direction of load current is always positive but load voltage can be positive or negative.





Class E Chopper

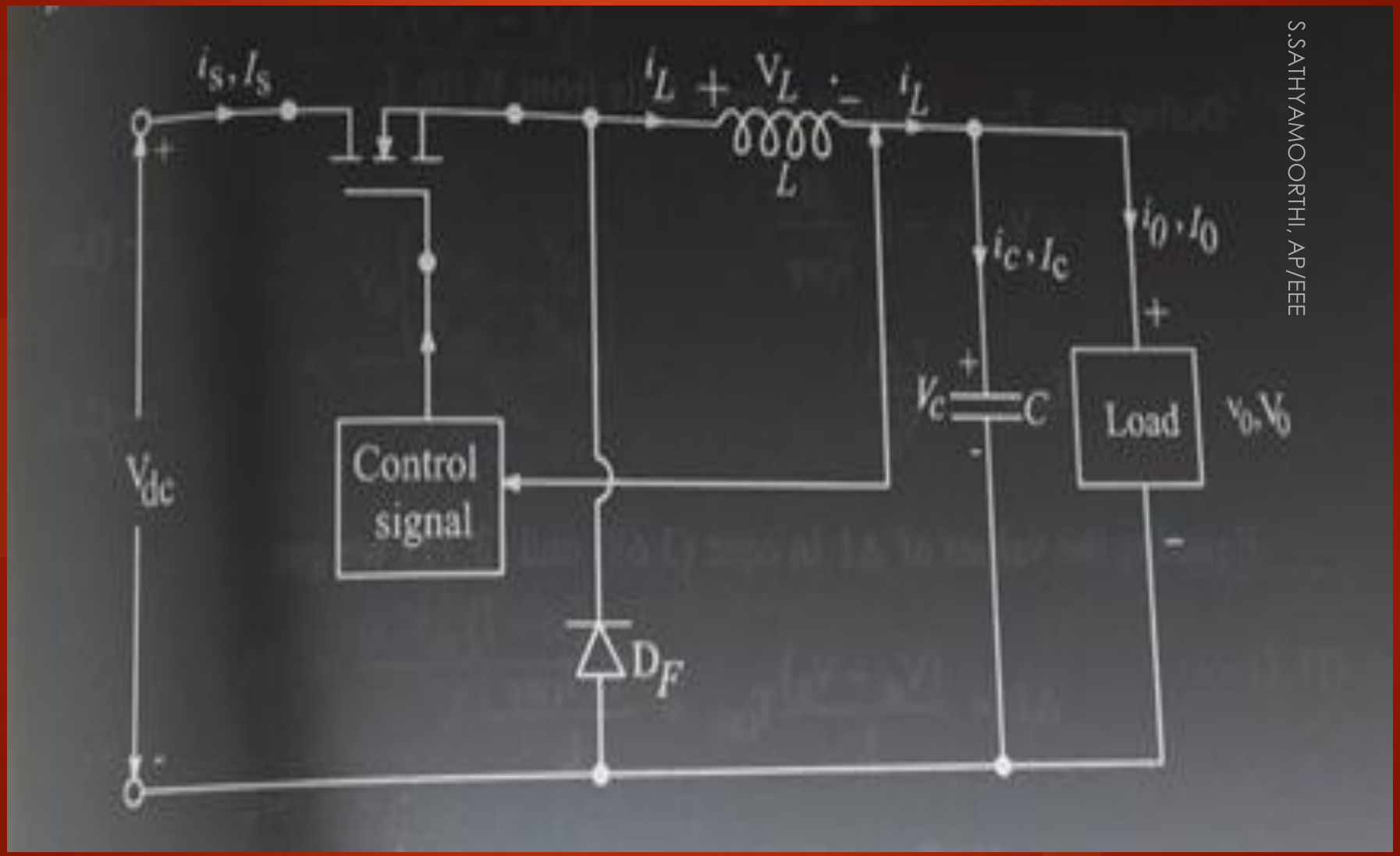


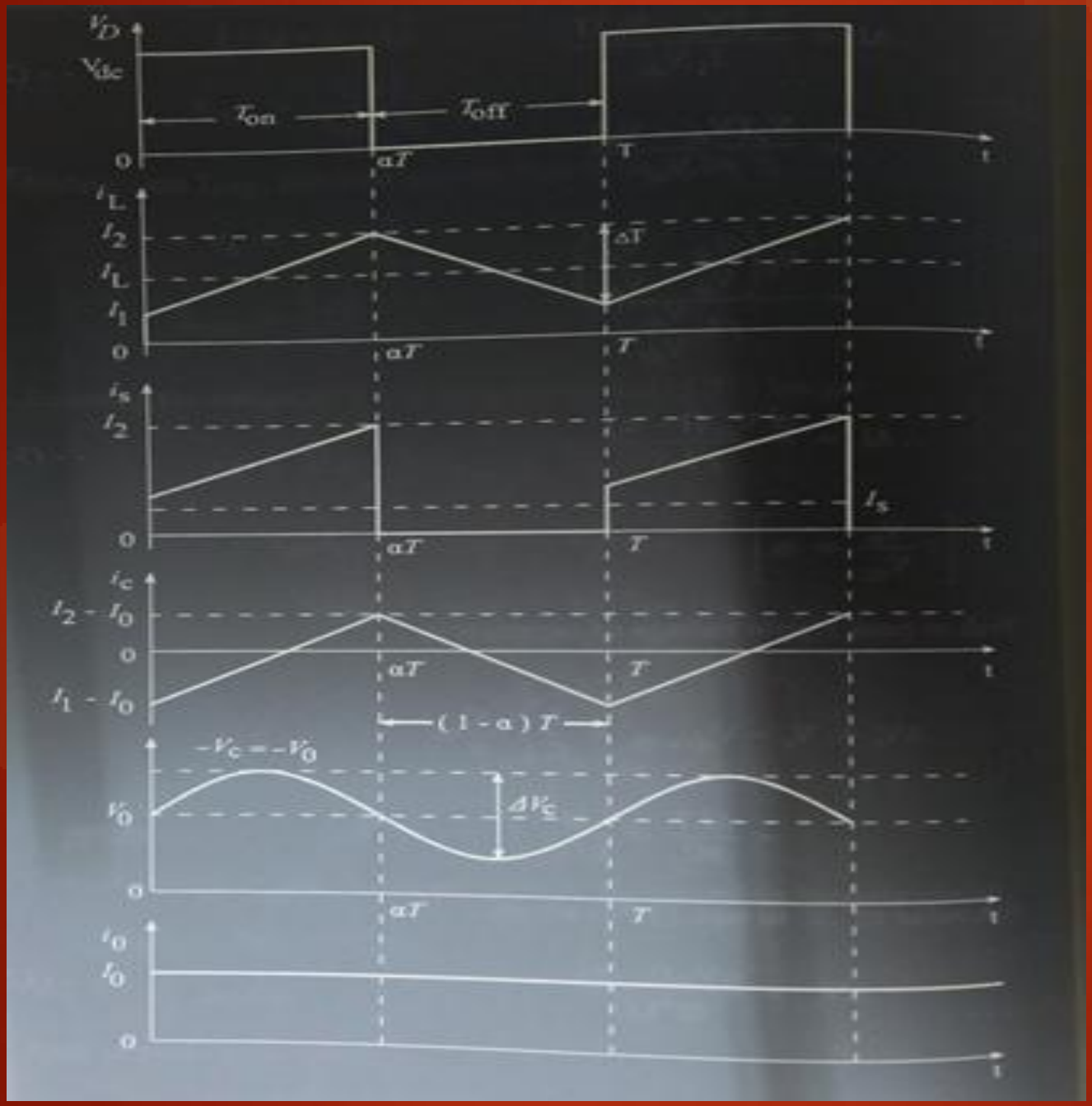


Fly Back Converter:

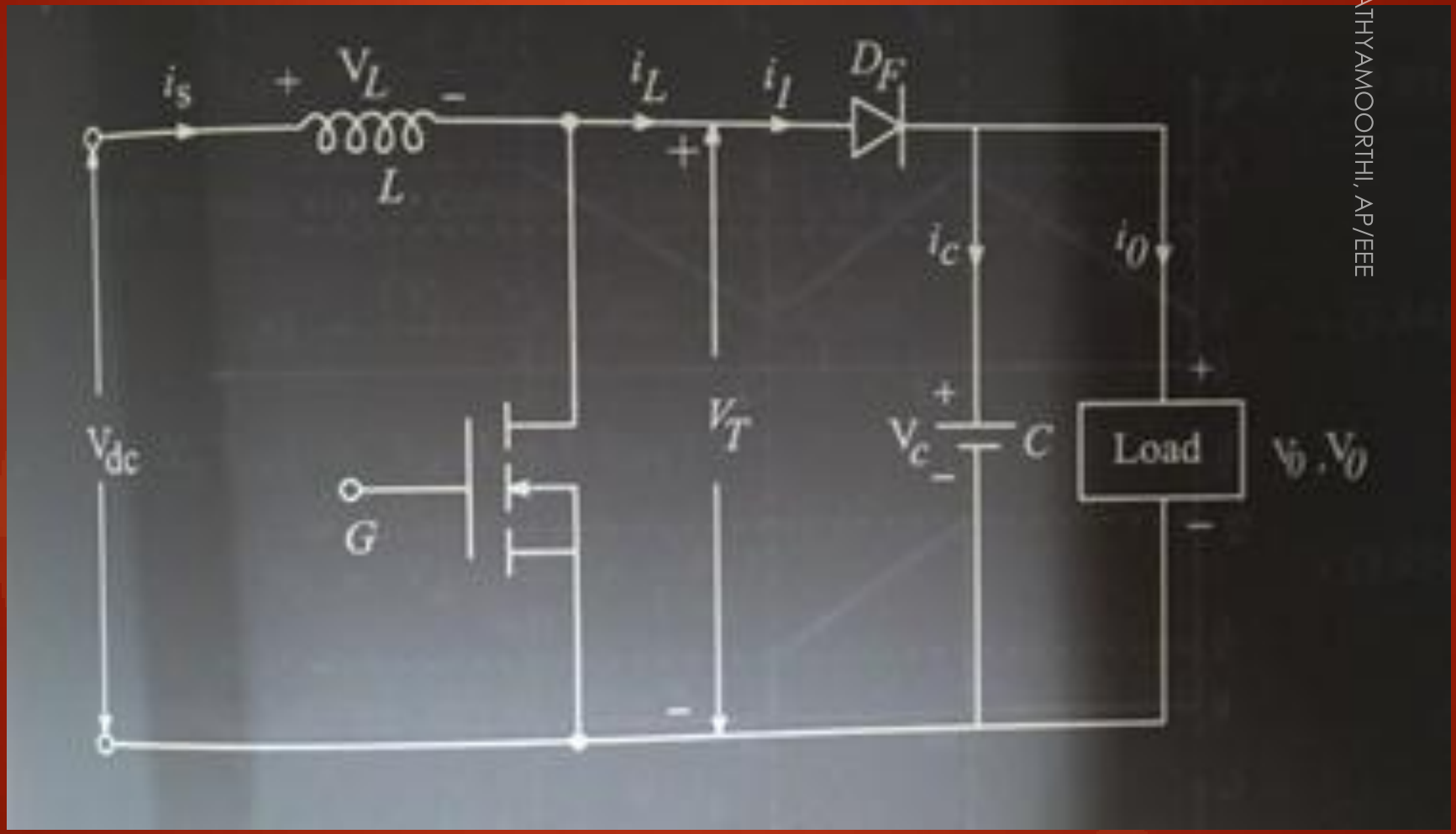
- Buck Converter (Step-Down)
- Boost Converter (Step-Up)
- Buck-Boost Converter
- Cuk Converter

Buck Converter:




V_D
V_{dc}
T_{on}
T_{off}
0
αT
T
t
i_L
I_2
I_L
I_1
ΔI
i_s
I_s
i_c
$I_2 - I_0$
$I_1 - I_0$
$(1-\alpha)T$
$-V_c = -V_0$
V_0
ΔV_c
i_0
I_0

Boost Converter:



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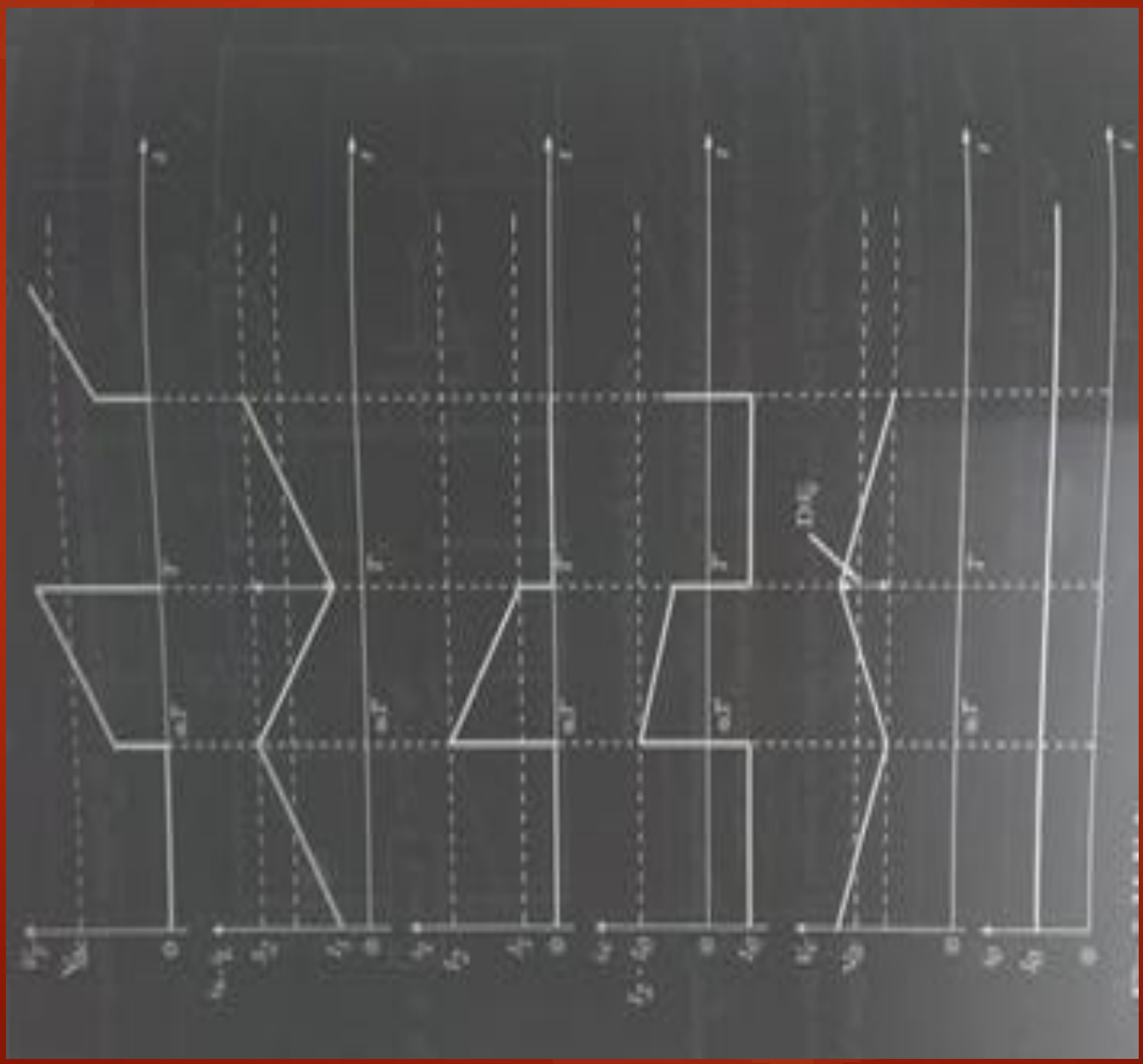
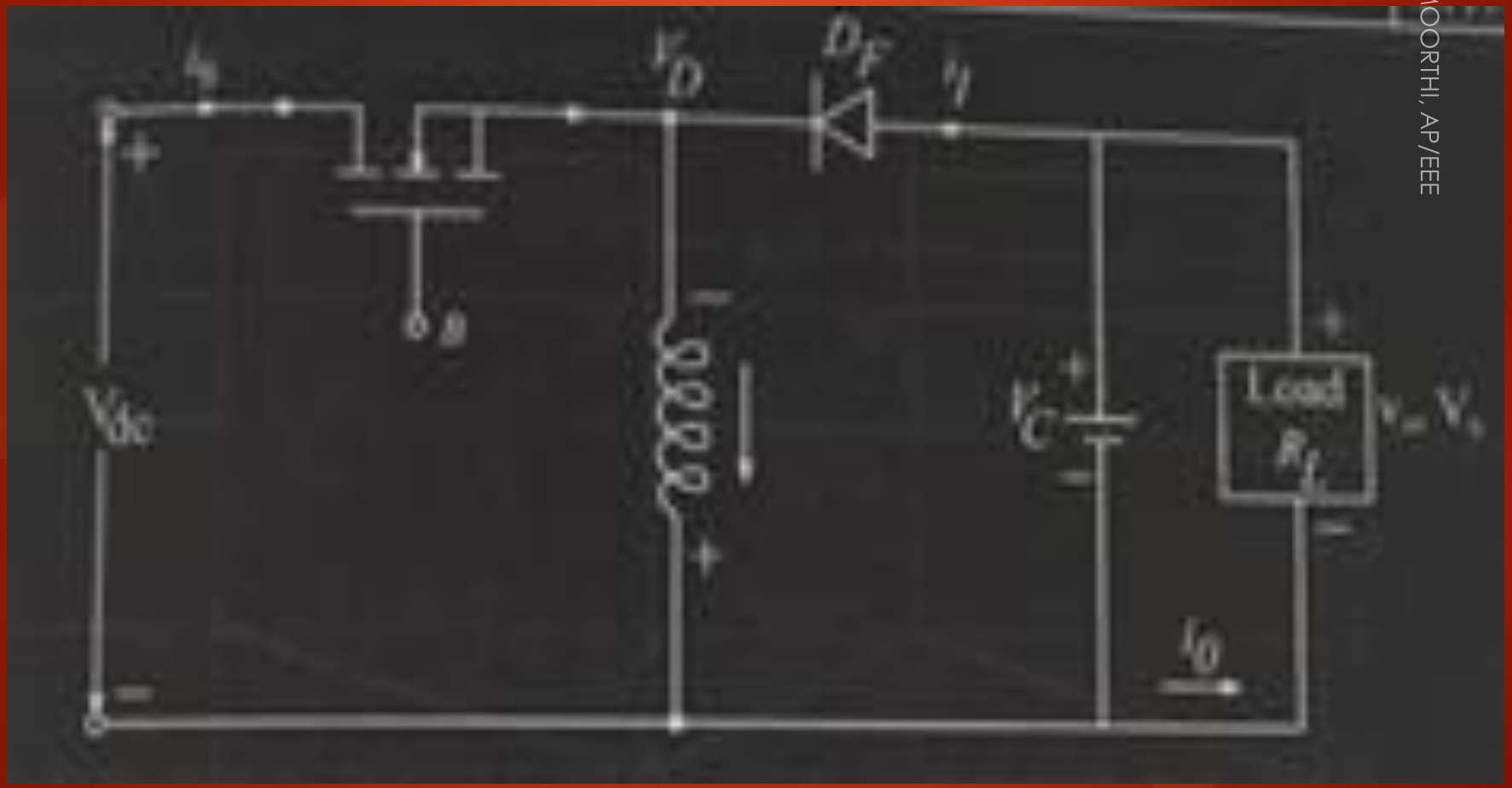
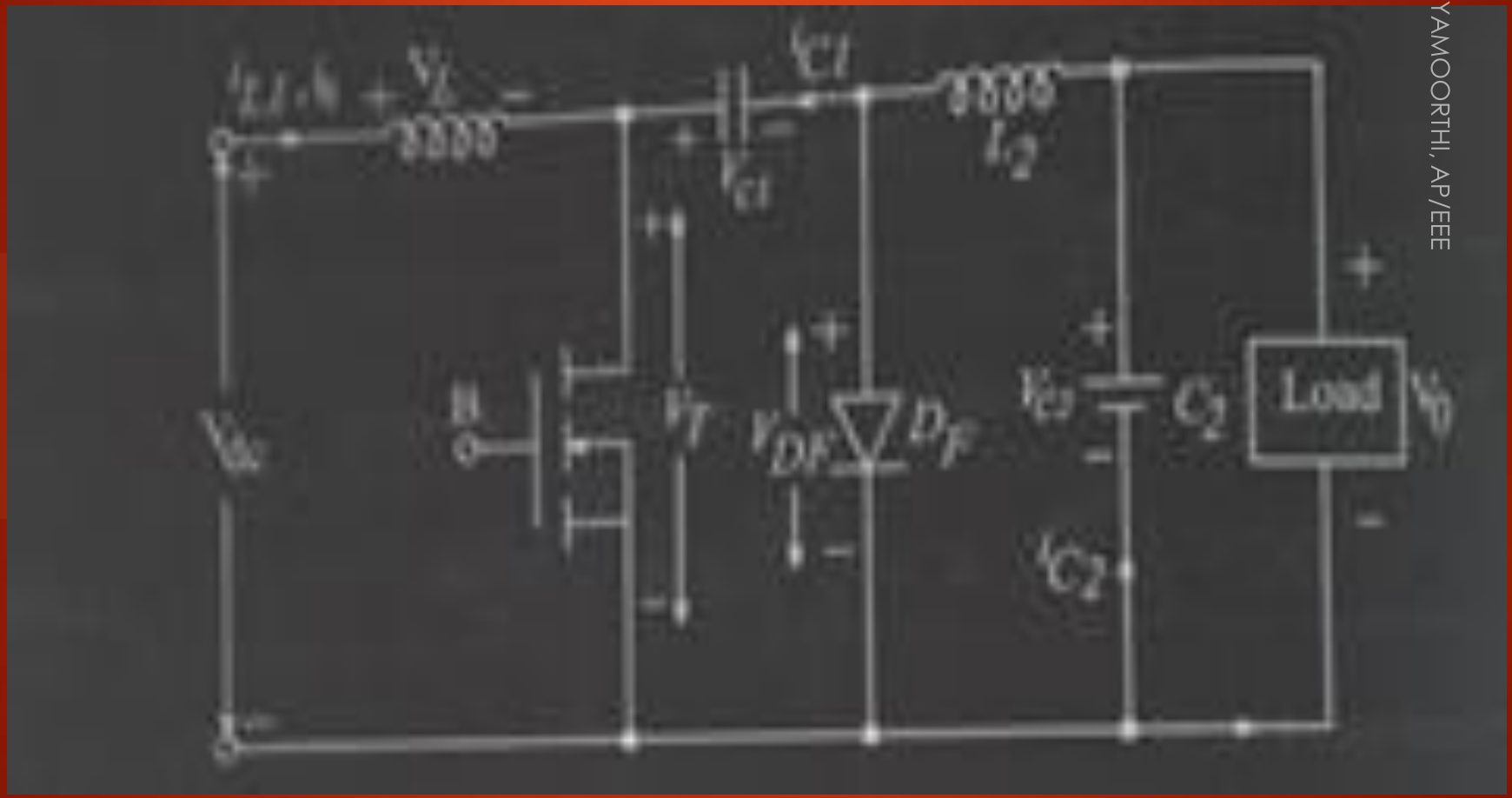


Buck- Boost Converter



Cuk Converter:



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