Expression for Output Current

During the interval diode 'D' conducts voltage equation is given by

$$V = \frac{L di_O}{dt} + R i_O + E$$

For the initial condition i.e.,

$$i_O(t) = I_{\min} \text{ at } t = 0$$

The solution of the above equation is obtained along similar lines as in step-down chopper with R-L load

$$\therefore \quad i_O(t) = \frac{V-E}{R}\left(1-e^{-\frac{R}{L}t}\right) + I_{\min} e^{-\frac{R}{L}t} \quad 0 < t < t_{OFF}$$

At $t = t_{OFF}$ $\qquad i_{(O)}(t) = I_{\max}$

$$I_{\max} = \frac{V-E}{R}\left(1-e^{-\frac{R}{L}t_{OFF}}\right) + I_{\min} e^{-\frac{R}{L}t_{OFF}}$$

During the interval chopper is ON voltage equation is given by

$$0 = \frac{L di_O}{dt} + R i_O + E$$

Redefining the time origin, at $t = 0 \quad i_O\left(t\right) = I_{\max}$

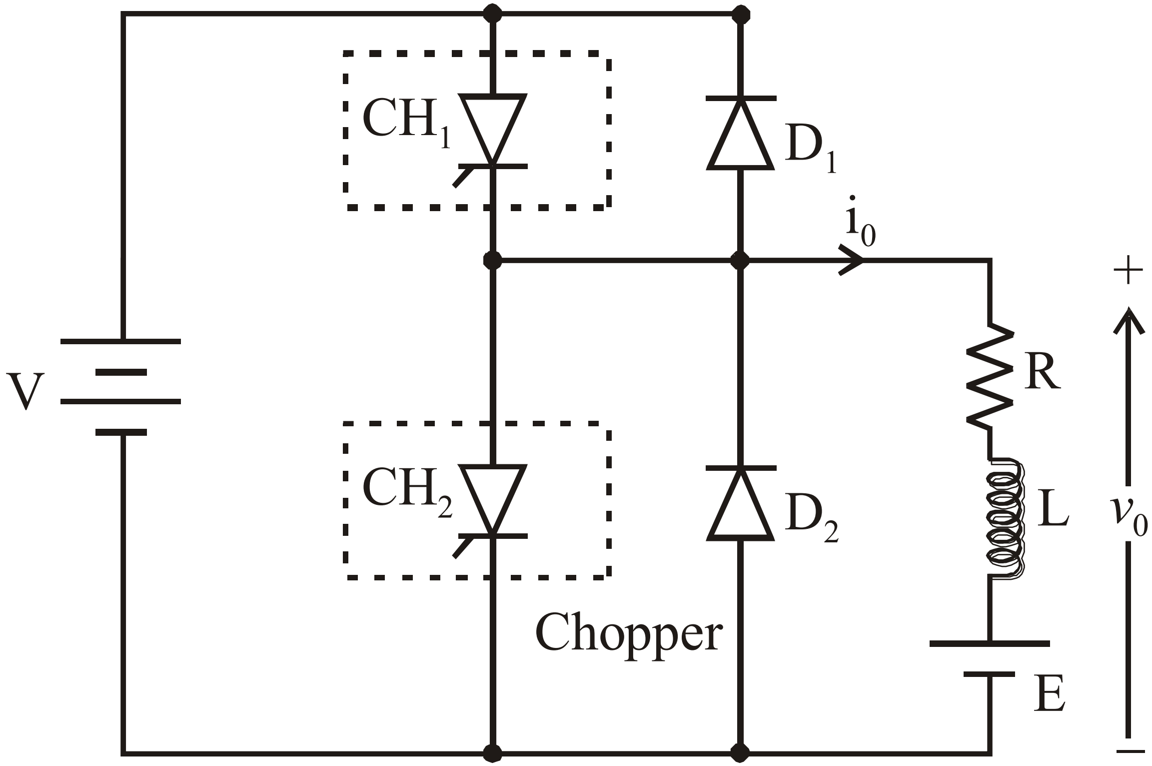
The solution for the stated initial condition is

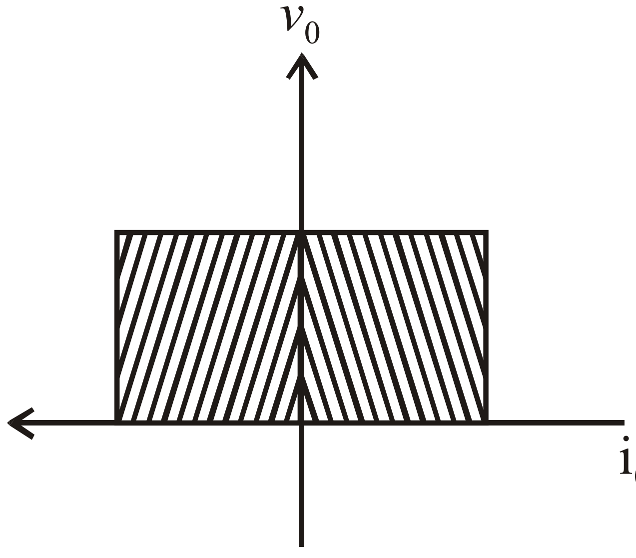
$$i_O\left(t\right) = I_{\max} e^{-\frac{R}{L}t} - \frac{E}{R}\left(1 - e^{-\frac{R}{L}t}\right) \qquad 0 < t < t_{ON}$$

At $t = t_{ON} \qquad i_O\left(t\right) = I_{\min}$

$$\therefore \quad I_{\min} = I_{\max} e^{-\frac{R}{L}t_{ON}} - \frac{E}{R}\left(1 - e^{-\frac{R}{L}t_{ON}}\right)$$

Class C Chopper

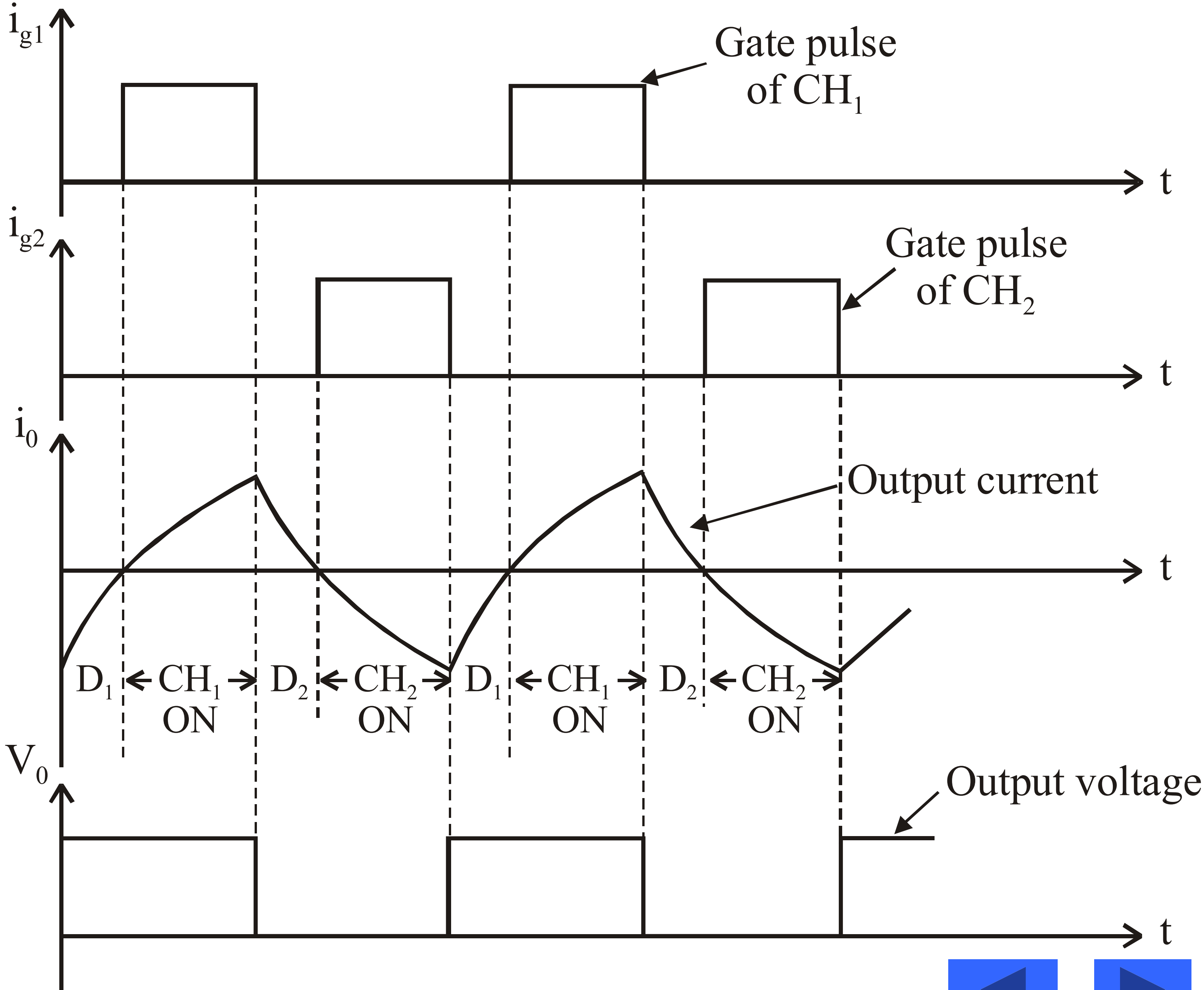




- *Class C Chopper* is a combination of *Class A* and *Class B Choppers*.
- For first quadrant operation, CH_1 is ON or D_2 conducts.
- For second quadrant operation, CH_2 is ON or D_1 conducts.
- When CH_1 is ON, the load current is positive.
- The output voltage is equal to '*V*' & the load receives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

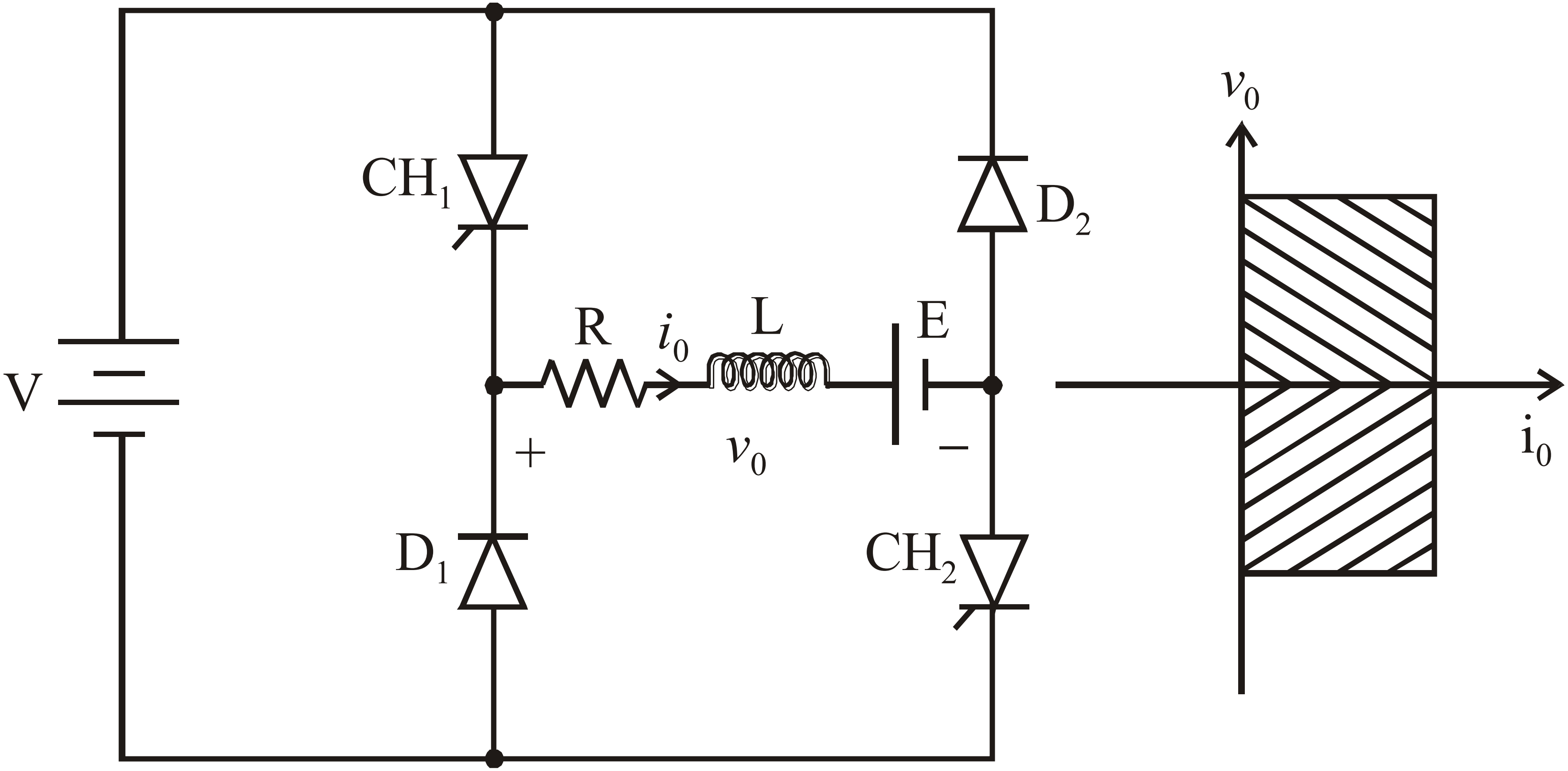
- Current continues to flow in positive direction.
- When CH_2 is triggered, the voltage E forces current to flow in opposite direction through L and CH_2 .
- The output voltage is zero.
- On turning OFF CH_2 , the energy stored in the inductance drives current through diode D_1 and the supply
- Output 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.



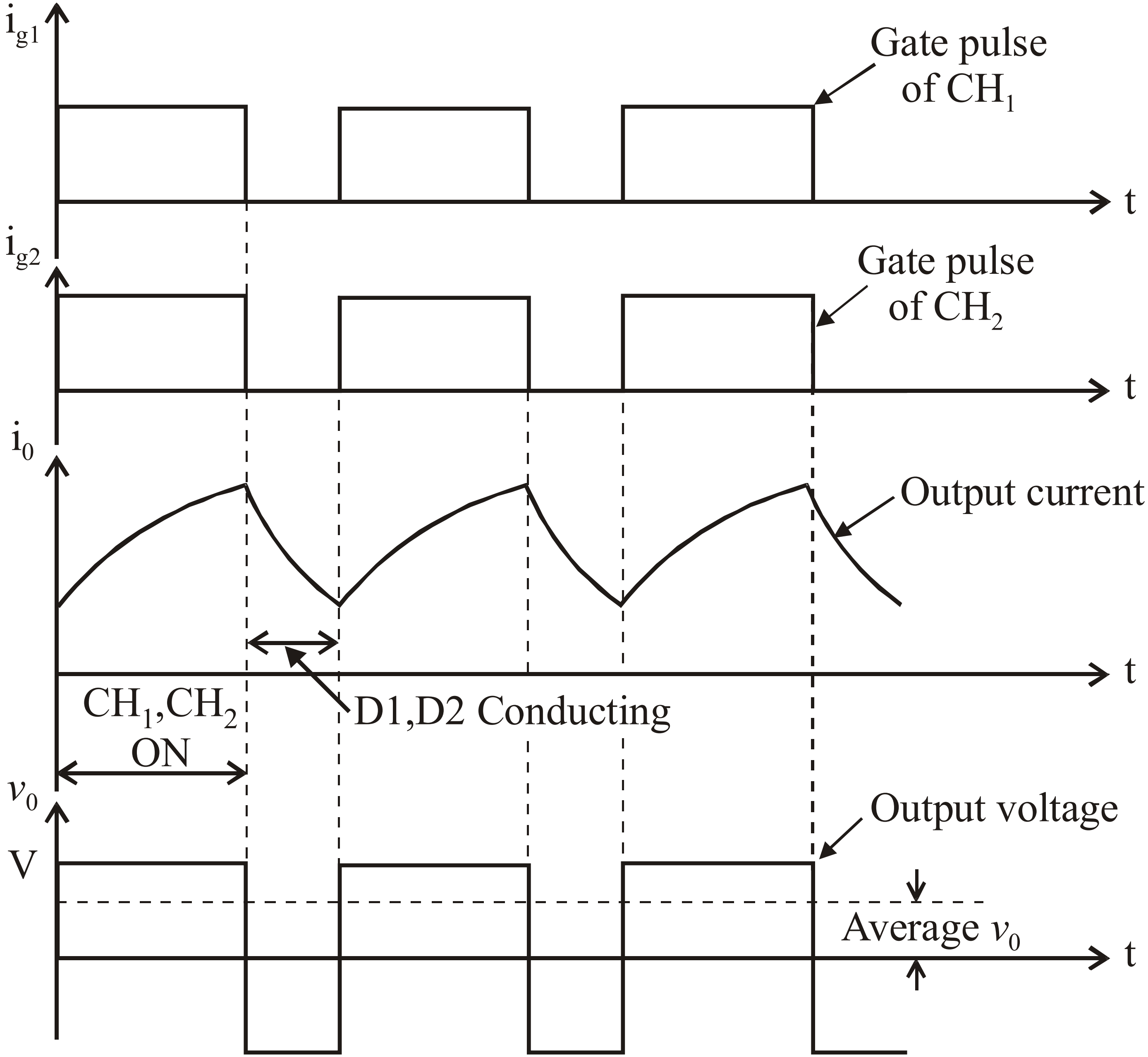
i_{g1}
Gate pulse of CH_1
t
i_{g2}
Gate pulse of CH_2
t
i_0
Output current
t
D_1
CH_1 ON
D_2
CH_2 ON
D_1
CH_1 ON
D_2
CH_2 ON
V_0
Output voltage
t

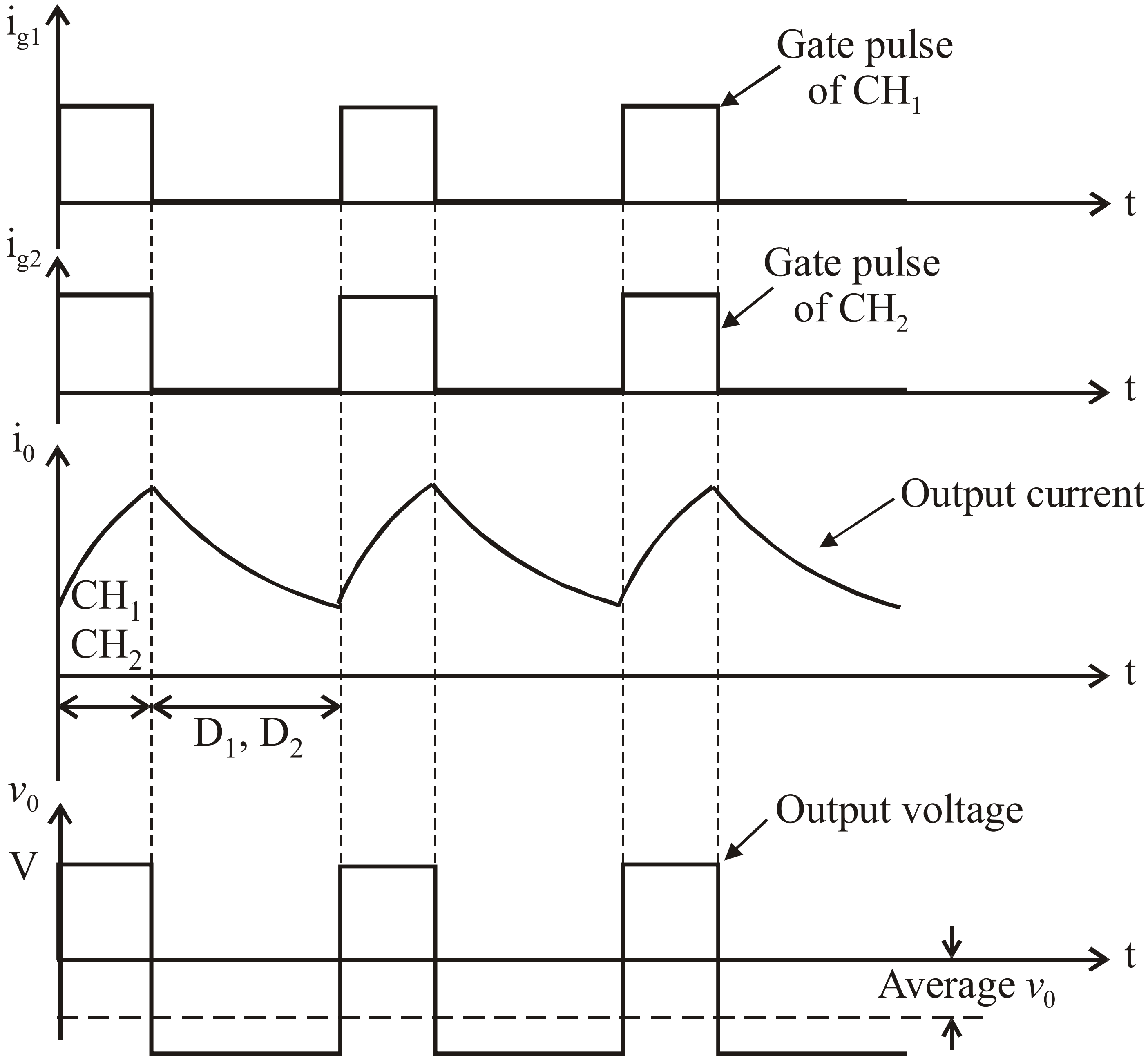
Class D Chopper



- 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 $v_O = - V$.

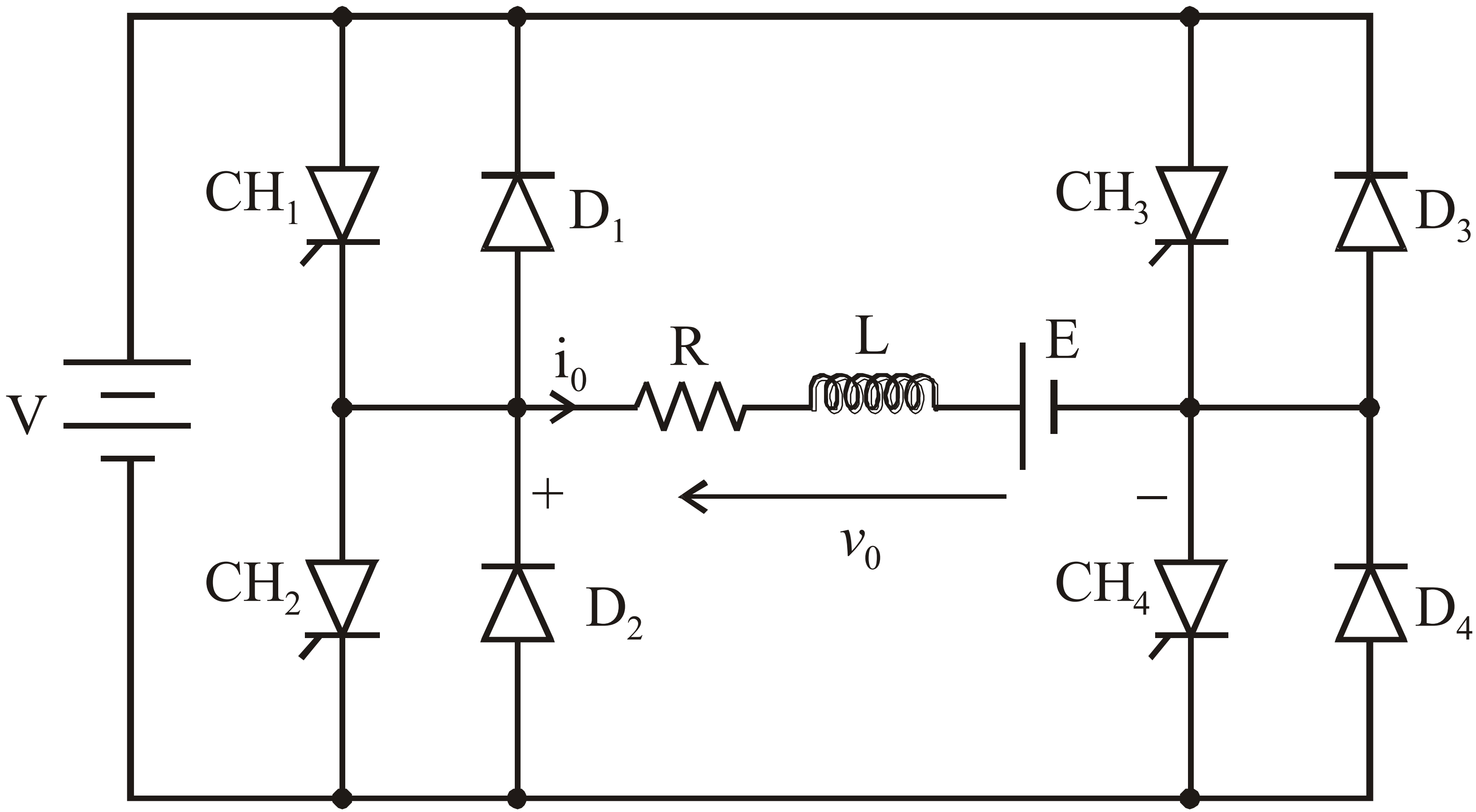
- Average load voltage is positive if chopper ON time is more than the OFF time
- Average output voltage becomes negative if $t_{ON} < t_{OFF}$.
- Hence the direction of load current is always positive but load voltage can be positive or negative.


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

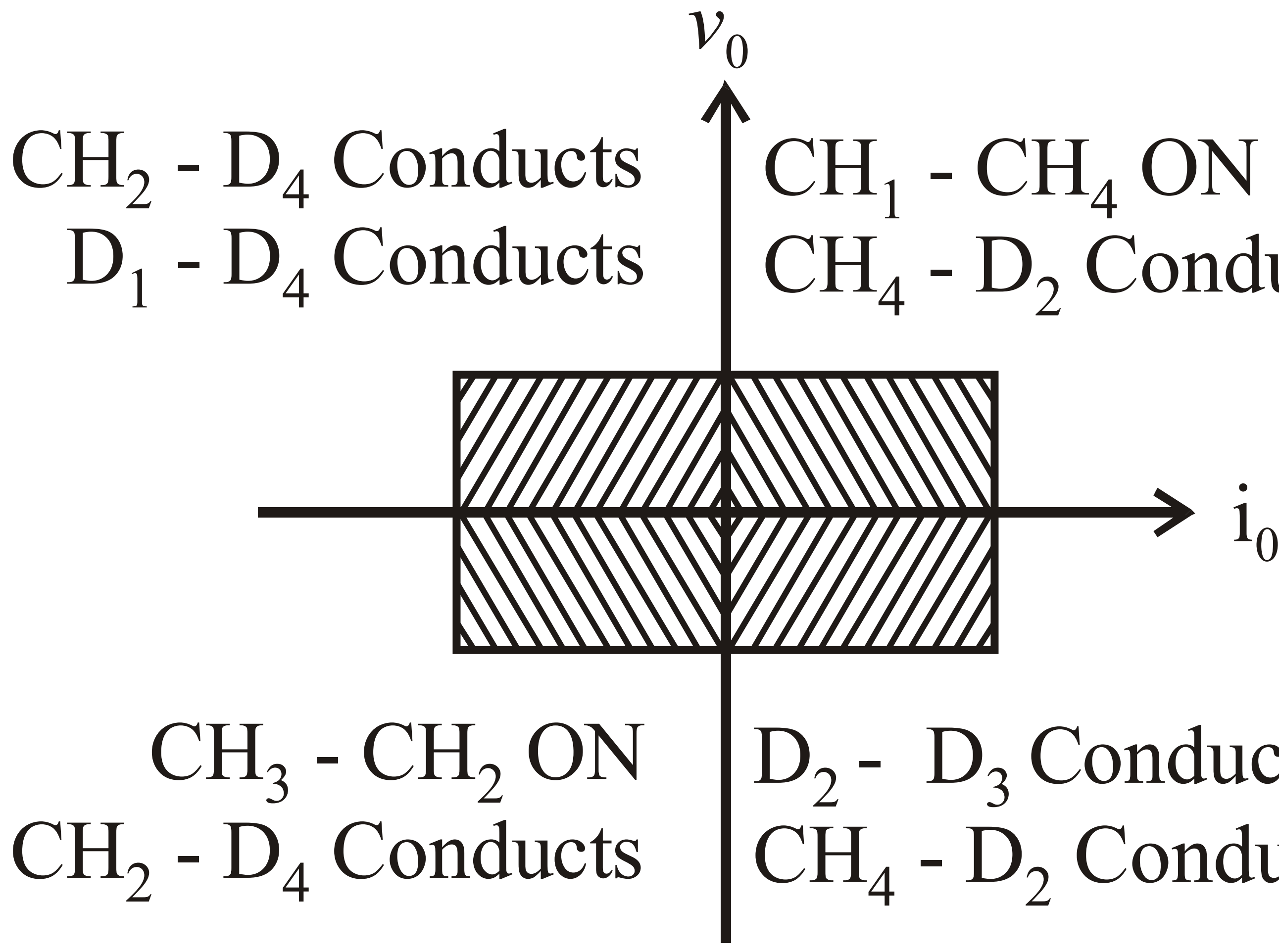


i_{g1}
Gate pulse of CH_1
t
i_{g2}
Gate pulse of CH_2
t
i_0
Output current
CH_1
CH_2
t
D_1, D_2
v_0
V
Output voltage
t
Average v_0

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.

Effect Of Source & Load Inductance

- The source inductance should be as small as possible to limit the transient voltage.
- Also source inductance may cause commutation problem for the chopper.
- Usually an input filter is used to overcome the problem of source inductance.

- The load ripple current is inversely proportional to load inductance and chopping frequency.
- Peak load current depends on load inductance.
- To limit the load ripple current, a smoothing inductor is connected in series with the load.