EE 303 Energy Systems and Power Electronics

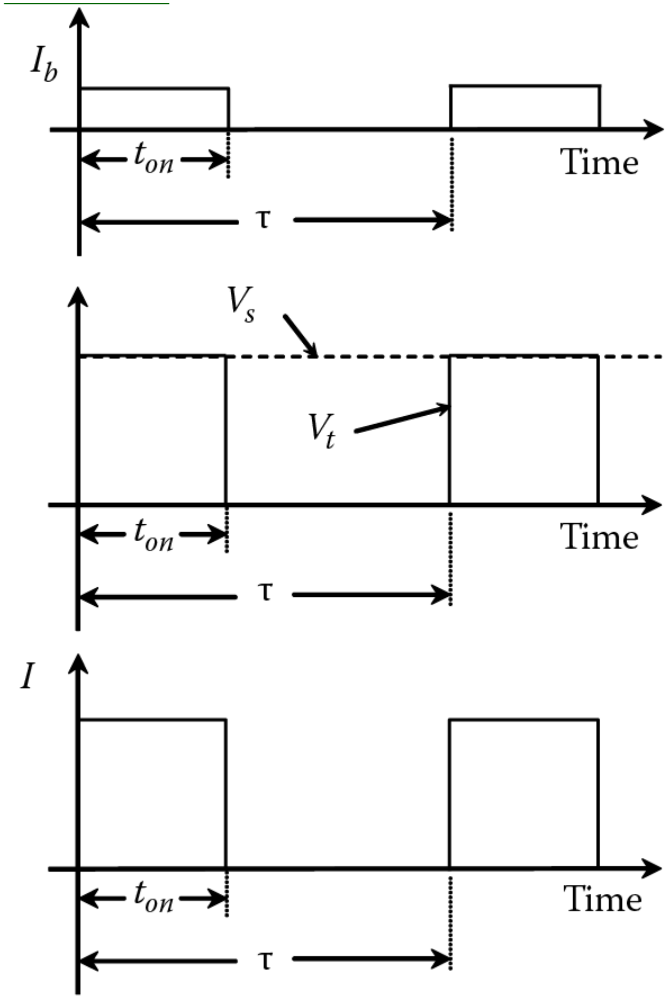
Power Electronics

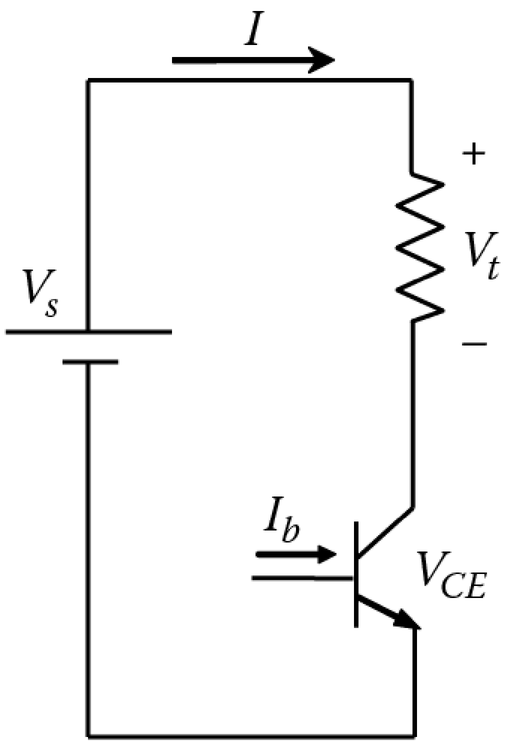
GRA: Prashant Tiwari
Advisor: Dr. Zhaoyu Wang
1113 Coover Hall, Ames, IA
wzy@iastate.edu

DC – DC Converters

- Buck Converter (Step – Down Converter)
- Boost Converter (Step – Up Converter)
- Buck – Boost Converter (Step Up/Down Converter)

Buck Converter – Step Down Converter





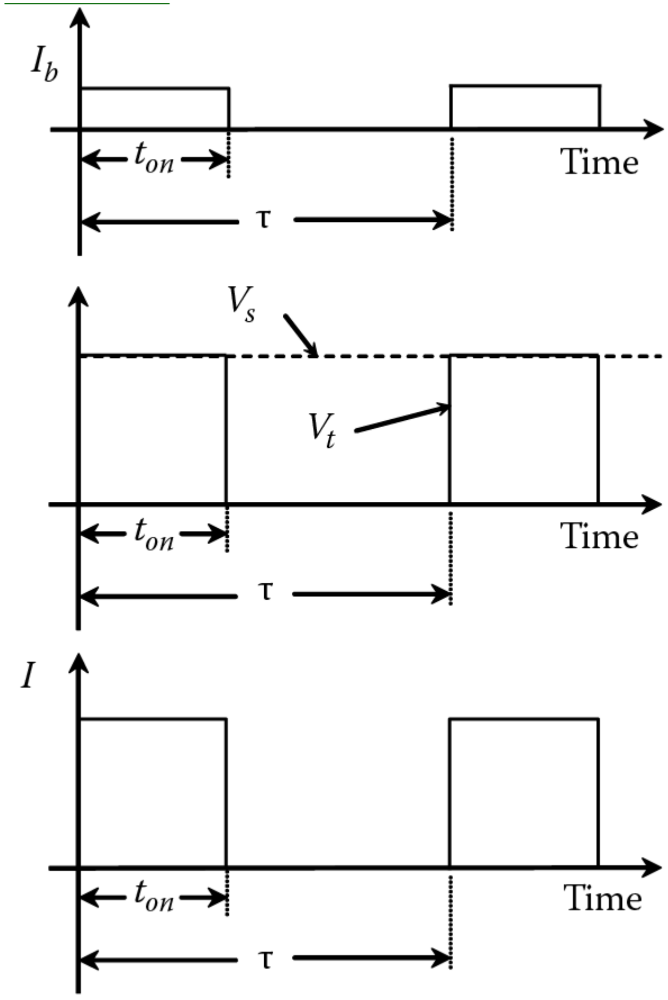
Contd…

$$V_{ave} = \frac{1}{\tau}\int_0^t V_s dt$$

$$= \frac{t_{on}}{\tau} \cdot V_s$$

$$k = \frac{t_{on}}{\tau} = \text{duty ratio}$$

$$V_{ave} = k \cdot V_s$$



Example

The switching frequency of a chopper is 10 KHz, and the source voltage is 40 V. For an average load voltage of 20 V and a load resistance of 10 Ω, compute the following:

1. Duty ratio
2. Average current of the load
3. rms voltage across the load
4. Load power

Example

Solution

1. The duty ratio is

$$K = \frac{V_{\text{ave}}}{V_s} = \frac{20}{40} = 0.5$$

Before we compute the on-time, we need to compute the period:

$$\tau = \frac{1}{f} = \frac{1}{10} = 0.1 \text{ ms}$$

$$t_{\text{on}} = K\tau = 0.5 \times 0.1 = 0.05 \text{ ms}$$

2. The average load current is

$$I_{\text{ave}} = \frac{V_{\text{ave}}}{R} = \frac{20}{10} = 2 \text{ A}$$

3. The rms voltage of the load can be computed using the standard formula for the rms quantity

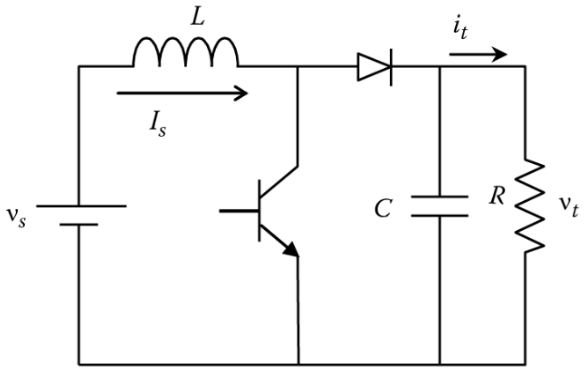
$$V = \sqrt{\frac{1}{\tau}\int_0^{t_{on}} V_s^2 dt} = \sqrt{\frac{V_s^2}{\tau} t_{on}} = V_s\sqrt{\frac{t_{on}}{\tau}} = 28.28 \text{ V}$$

4. $P = \frac{V^2}{R} = \frac{28.28^2}{10} = 80 \text{ W}$

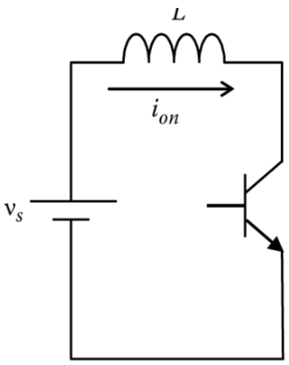
DC – DC Converters

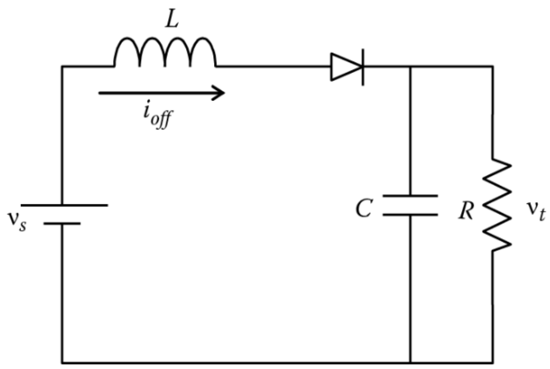
- Buck Converter (Step – Down Converter)
- Boost Converter (Step – Up Converter)
- Buck – Boost Converter (Step Up/Down Converter)

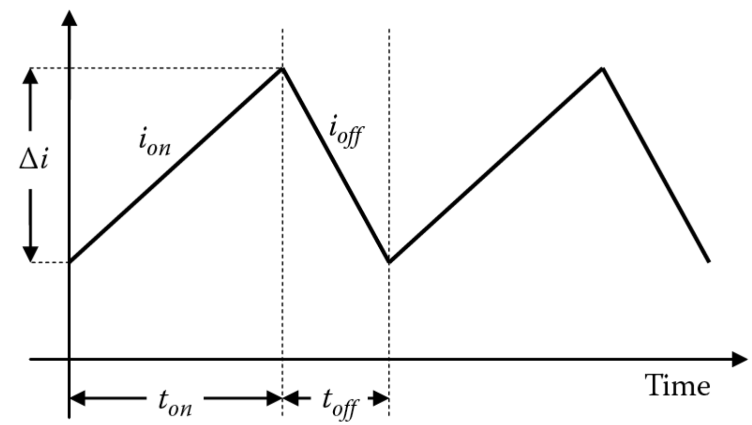
Boost Converter



Filter reduces the voltage ripple







Waveform of boost converter.

Contd...

- When transistor is closed. (t_{on}, i_{on}), charge inductor

$$V_L = L\frac{di_{on}}{dt} = L\frac{\Delta i_{on}}{t_{on}}$$

where Δi_{on} is the change in the current during the period t_{on}. Since the voltage across the inductor is equal to the source voltage when the transistor is closed.

$$V_s = L\frac{\Delta i_{on}}{t_{on}}$$

- When transistor is open. (t_{off}, i_{off}), dicharge inductor

$$V_t = V_s + V_L = V_s + L\frac{di_{off}}{dt} = V_s + L\frac{\Delta i_{off}}{t_{off}}$$

Contd...

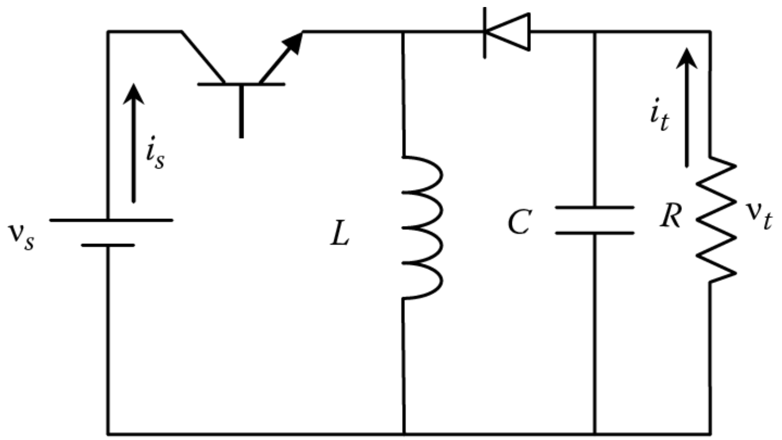
$$V_t = V_s + V_L = V_s + L\frac{di_{off}}{dt} = V_s + L\frac{\Delta i_{off}}{t_{off}}$$

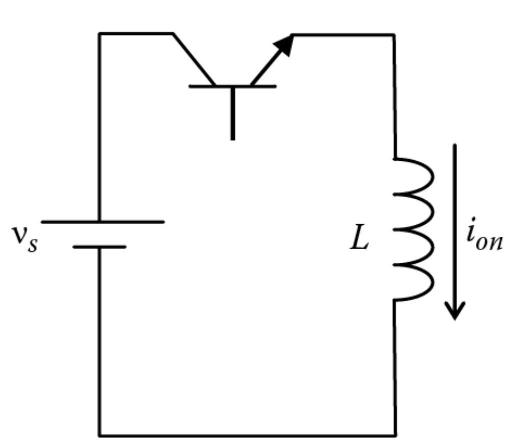
$$V_t = V_s + V_s\frac{t_{on}}{\Delta i_{on}} \cdot \frac{\Delta i_{off}}{t_{off}}$$

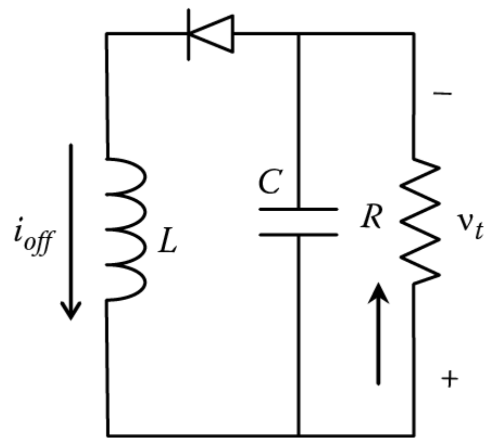
$$\Delta i_{on} = \Delta i_{off}$$

$$V_t = V_s + V_s\frac{t_{on}}{t_{off}} = V_s(1 + \frac{t_{on}}{t_{off}})$$

Buck – Boost Converter







Contd…

- When transistor is closed. (t_{on}, i_{on})

$$V_L = L\frac{di_{on}}{dt} = L\frac{\Delta i_{on}}{t_{on}}$$

$$V_s = V_L = L\frac{\Delta i_{on}}{t_{on}}$$

- When transistor is open. (t_{off}, i_{off})

$$V_L = \frac{\Delta i_{off}}{t_{off}} \longrightarrow V_t = V_L = L\frac{\Delta i_{off}}{t_{off}}$$

$$V_t = V_s\frac{t_{on}}{\Delta i_{on}} \cdot \frac{\Delta i_{off}}{t_{off}} \quad (\Delta i_{on} = \Delta i_{off}) \longrightarrow V_t = V_s\frac{t_{on}}{t_{off}}$$

Example

A buck–boost converter with an input voltage of 20 V is used to regulate the voltage across a 10 Ω load. The switching frequency of the transistor is 5 kHz. Compute the following:

- On-time of the transistor to maintain the output voltage at 10 V

Example

A buck–boost converter with an input voltage of 20 V is used to regulate the voltage across a 10 Ω load. The switching frequency of the transistor is 5 kHz. Compute the following:

- On-time of the transistor to maintain the output voltage at 10 V

Solution,

The period can be computed from the switching frequency f

- $\tau = \frac{1}{f} = \frac{1}{5} = 0.2$ ms
- $V_t = V_s \frac{t_{on}}{\Delta i_{on}}$

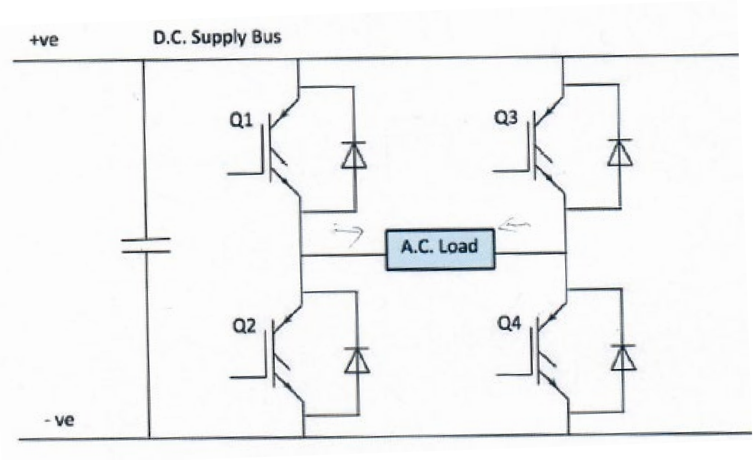
$$\frac{t_{on}}{t_{off}} = \frac{V_t}{V_s} = \frac{10}{20} = 0.5$$

$$t_{off} + t_{on} = \tau$$

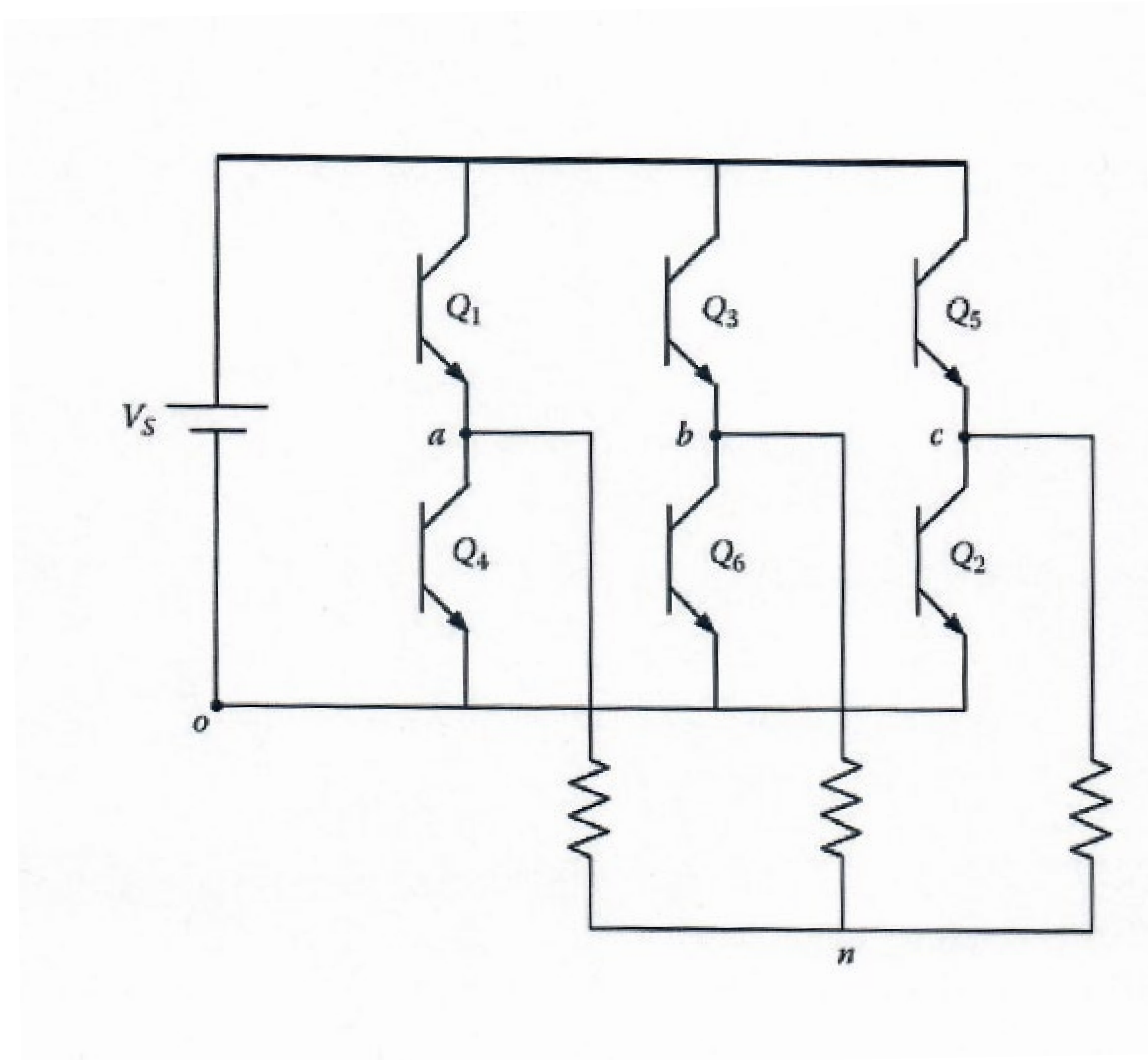
$$t_{on} = 0.0667\ ms$$

DC-AC Inverter (H- Bridge Circuit)

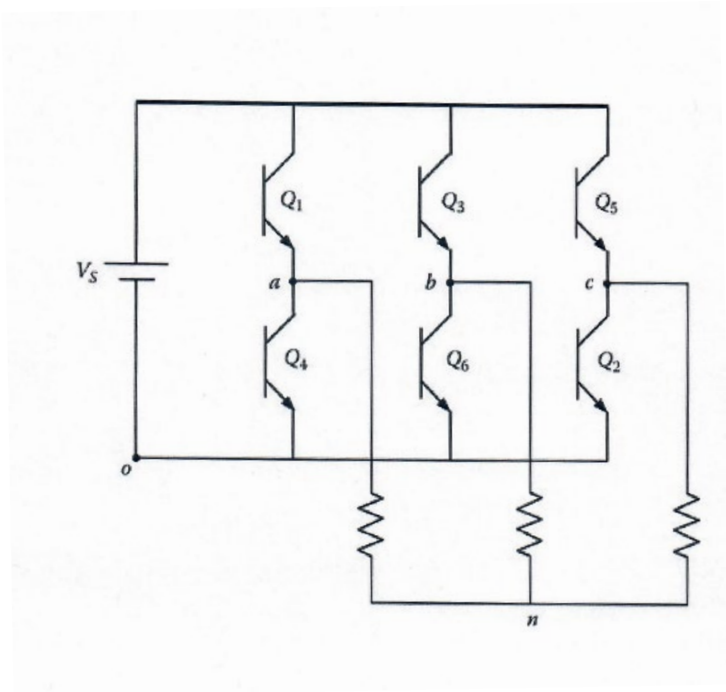
- Most of the inverter consists of simple H-Bridge arrangement. The circuit is an implementation of a single-phase H-Bridge circuit using Insulated Gate Bipolar Transistors (IGBT).
- The IGBT act as a switch in the above circuit.
- When a signal is applied to the gate, they turn on and when the signal is removed, they turn off. By closing Q1 and Q4, a positive DC supply is applied to the load.
- The Q3, and $Q3$ will result in a negative DC supply across the load.
- Then the control circuits are used to generate the necessary gate signals to produce the required PWM waveform.
- It is necessary to avoid short circuits. This happens by closing both Q1 and $Q2$ at the same time. To avoid this, it is necessary to turn off one set of IGBT before turning on the next.
- The Diodes provide a necessary path for inductive current in order to limit potential voltage build-up during the transition period. The capacitor provides smoothing to even out any variation in the DC supply.

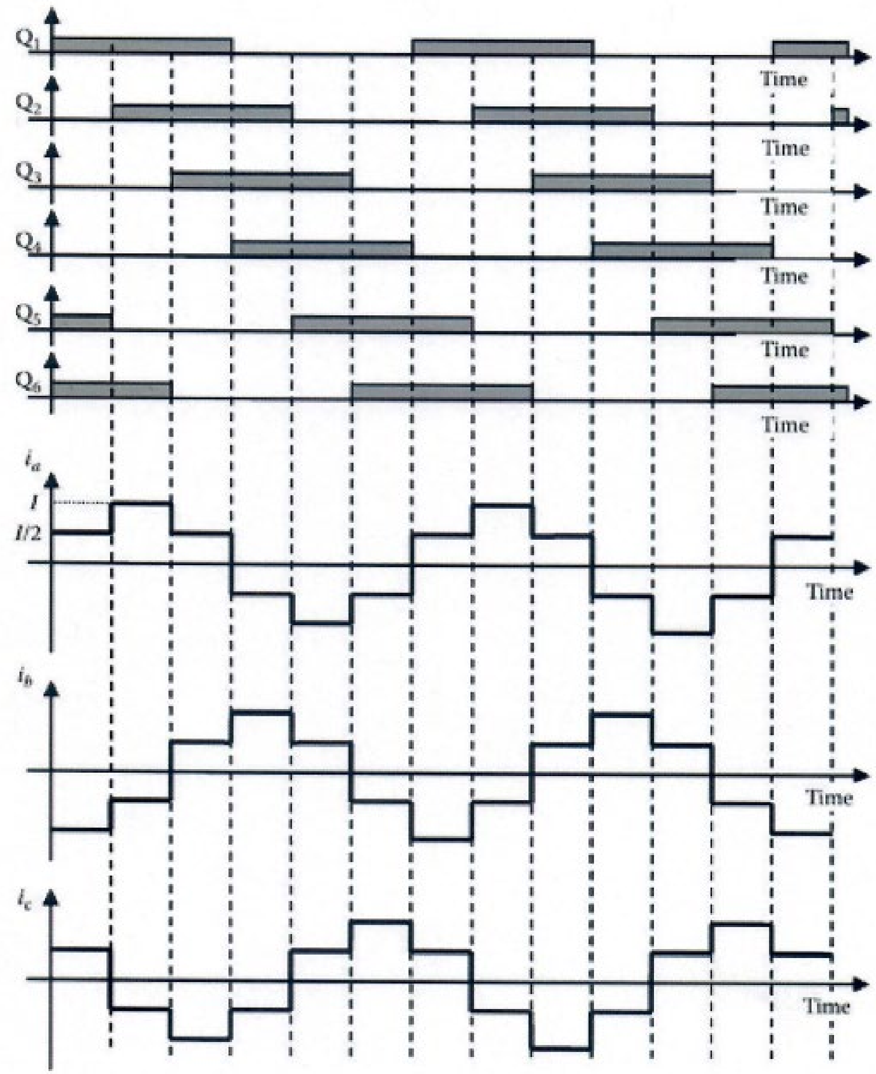


Contd…

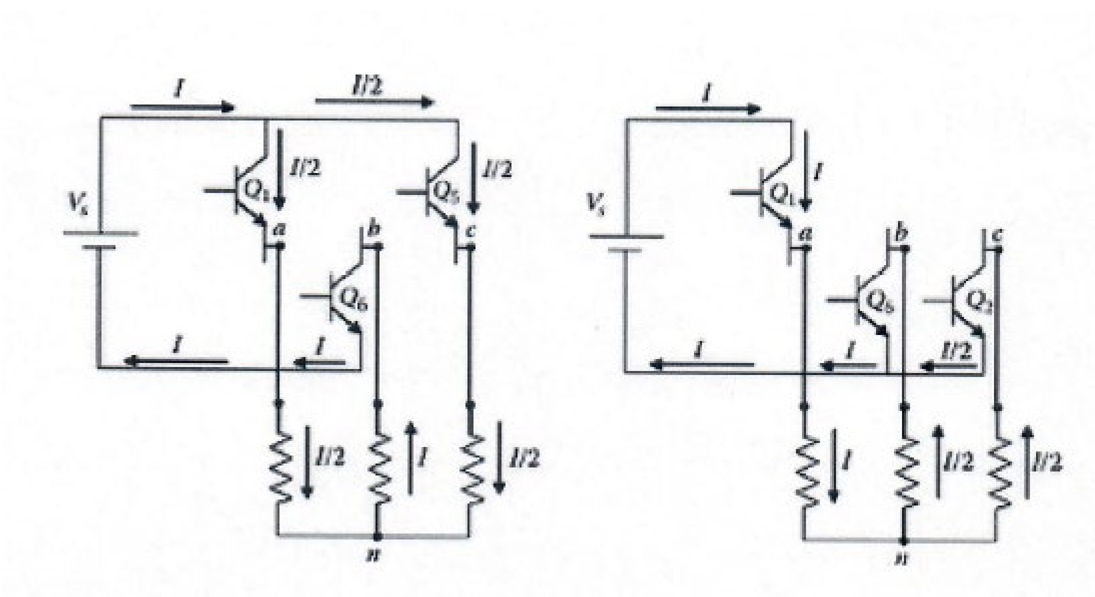


Contd...


Q1
Q3
Q5
V_S
a
b
c
Q4
Q6
Q2
o
n


Q1
Q2
Q3
Q4
Q5
Q6
Time
Time
Time
Time
Time
Time
i_a
I
I/2
Time
i_b
Time
i_c
Time

Contd…



Thank You!