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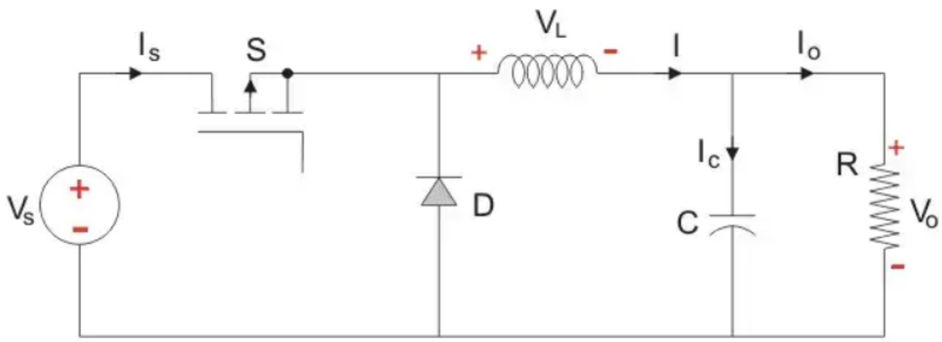
EE3035 GRID INTEGRATING TECHNIQUES AND CHALLENGES

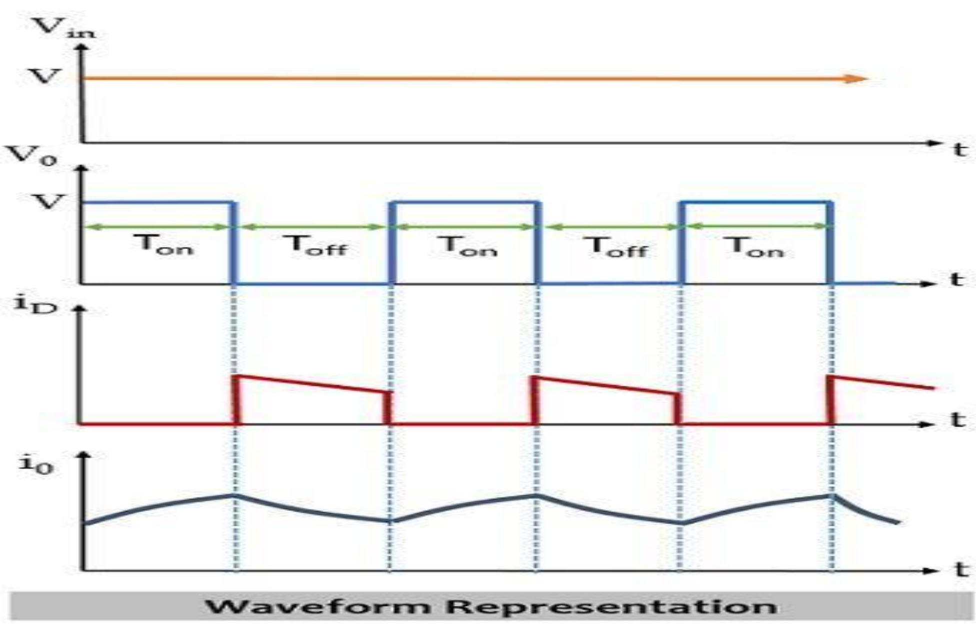
Unit III

Buck Converter

DC-DC converters, often called **Choppers**, include the **Buck converter**, which steps down a higher input DC voltage to a lower specified output voltage.

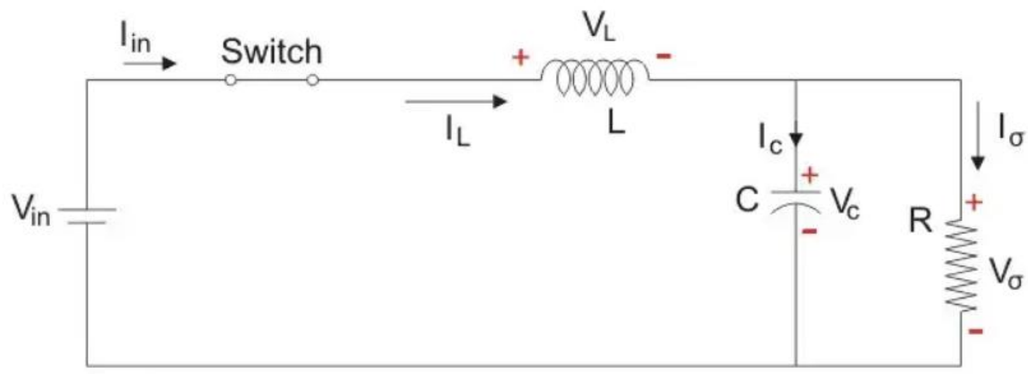
A typical Buck converter is shown below.





The **Buck converter** has two modes of operation. The first mode is when the switch is on and conducting.

Mode I : Switch is ON, Diode is OFF



The voltage across the capacitance in steady state is equal to the output voltage.

Let us say the switch is on for a time T_{ON} and is off for a time T_{OFF}. We define the time period, T, as

$T = T_{ON} + T_{OFF}$

and the switching frequency,

$$f_{switching} = \frac{1}{T}$$

Let us now define another term, the duty cycle,

$$D = \frac{T_{ON}}{T}$$

Let us analyse the Buck converter in steady state operation for this modeusing KVL.

$$\therefore V_{in} = V_L + V_o$$

$$\therefore V_L = L\frac{di_L}{dt} = V_{in} - V_o$$

$$\frac{di_L}{dt} = \frac{\Delta i_L}{\Delta t} = \frac{\Delta i_L}{DT} = \frac{V_{in} - V_o}{L}$$

Since the switch is closed for a time $T_{ON} = DT$ we can say that $\Delta t = DT$.

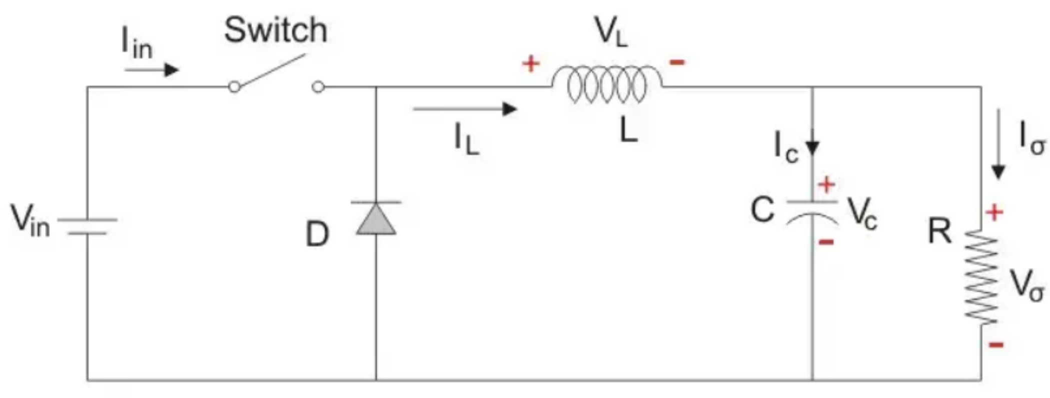
$$(\Delta i_L)_{closed} = \left(\frac{V_{in} - V_o}{L}\right) DT$$

While performing the analysis of the Buck converter, we have to keep in mind that

1. The inductor current is continuous and, this is made possible by selecting an appropriate value of L.
2. The inductor current in steady state rises from a value with a positive slope to a maximum value during the ON state and then drops back down to the initial value witha negative slope. Therefore the net change of the inductor current over anyone complete cycle is zero.

Mode II: Switch is OFF, Diode is ON

Here, the energy stored in the inductor is released and is ultimately dissipated in the load resistance, and this helps to maintain the flow of current through the load. But for analysis we keep the original conventions to analyse the circuit using KVL.



Let us now analyse the **Buck converter** in steady state operation for Mode II using KVL.

$$\therefore 0 = V_L + V_o$$

$$\therefore V_L = L\frac{di_L}{dt} = -V_o$$

$$\frac{di_L}{dt} = \frac{\Delta i_L}{\Delta t} = \frac{\Delta i_L}{(1-D)T} = \frac{-V_o}{L}$$

Since the switch is open for a time

$T_{OFF} = T - T_{ON} = T - DT = (1-D)T$

we can say that $\Delta t = (1- D)T$.

$$(\Delta i_L)_{open} = \left(\frac{-V_o}{L}\right)(1-D)T$$

It is already established that the net change of the inductor current over anyone complete cycle is zero.

$$\therefore (\Delta i_L)_{closed} + (\Delta i_L)_{open} = 0$$

$$\left(\frac{V_{in} - V_o}{L}\right)DT + \left(\frac{-V_o}{L}\right)(1-D)T = 0$$

$$\frac{V_o}{V_{in}} = D$$

A circuit of a Buck converter and its waveforms is shown below.

The inductance, L, is 20mH and the C is 100μF, and the resistive load is 5Ω. The switching frequency is 1 kHz. The input voltage is 100V DC, and the duty cycle is 0.5.

The duty cycle (D) varies between 0 and 1. If D = 1, the output voltage would theoretically be infinite, which isn't possible. In practice, a duty cycle above 0.7 can cause instability in the Boost converter. Below is a circuit diagram of a Boost converter with an inductance (L) of 20mH, capacitance (C) of 100μF, a 20Ω resistive load, a 1 kHz switching frequency, a 100V DC input, and a duty cycle of 0.5.