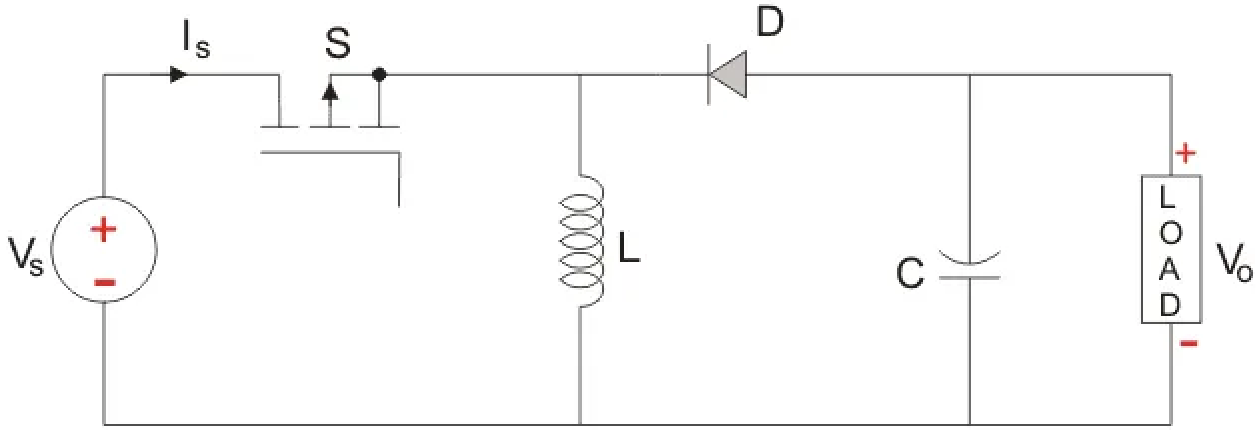
Background

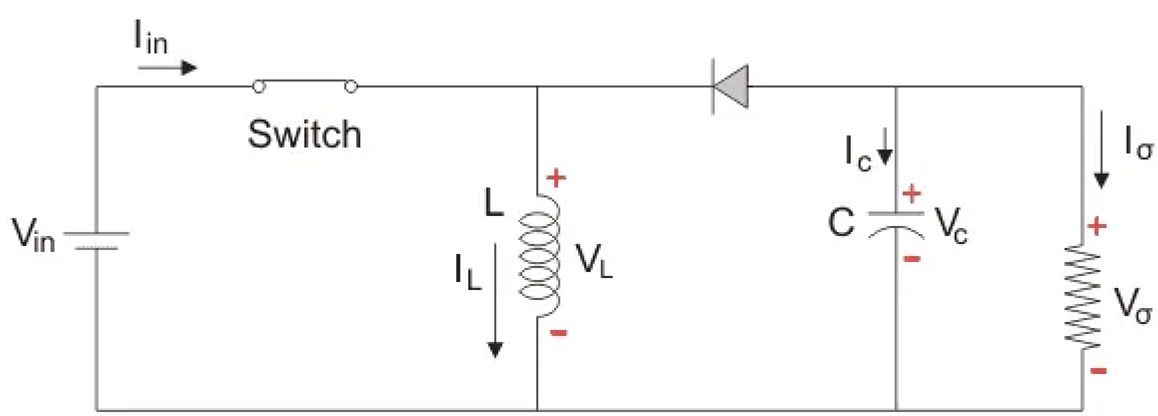
The buck–boost converter is a type of DC-to-DC converter (also known as a *chopper*) that has an output *voltage* magnitude that is either greater than or less than the input voltage magnitude. It is used to "step up" the *DC voltage*, similar to a *transformer* for AC circuits.

A typical Buck-Boost converter is shown below:



A typical Buck-Boost converter has two modes of operation:

Mode I : Switch is ON, Diode is OFF



The Switch is ON and therefore represents a short circuit ideally offering zero *resistance* to the flow of *current* so when the switch is ON all the current will flow through the switch and the inductor and back to the DC input source.

The *inductor* stores charge during the time the switch is ON and when the solid state switch is OFF the polarity of the Inductor reverses so that current flows through the load and through the *diode* and back to the inductor. So the direction of current through the inductor remains the same.

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:

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

- Switching frequency,

$$f_s = \frac{1}{T}$$

- Duty Cycle,

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

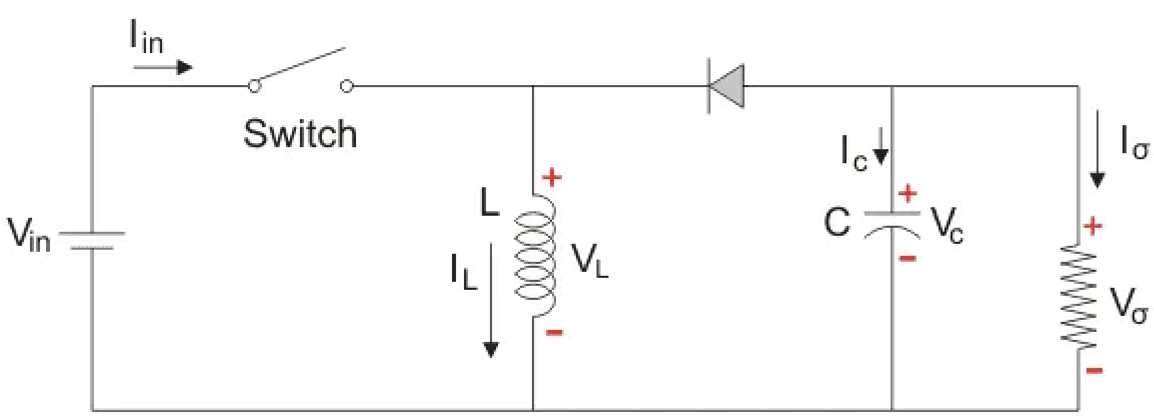
Analysis:

$$V_{in} = V_L$$

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

$$\frac{di}{dt} = \frac{\Delta i_L}{\Delta t} = \frac{\Delta i_L}{DT} = \frac{V_{in}}{L}$$

Mode II : Switch is OFF, Diode is ON



In this mode the polarity of the inductor is reversed and 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* in the same direction through the load and also step-up the output *voltage* as the inductor is now also acting as a source in conjunction with the input source.

Analysis

$$V_L = V_0$$

$$V_L = L\frac{di_L}{dt} = V_0$$

$$\frac{di_L}{dt} = \frac{\Delta i_L}{\Delta t} = \frac{\Delta i_L}{(1-D)T} = \frac{V_0}{V_L}$$

Net change of the inductor current over any one complete cycle is zero:

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

$$\left(\frac{V_0}{L}\right)(1-D)T + \left(\frac{V_in}{L}\right)DT = 0$$

$$\frac{V_o}{V_{in}} = \frac{-D}{1-D}$$

Since we are only interested in magnitude and not the polarity of voltages, we can write

$$\left|\frac{V_0}{V_{in}}\right| = \frac{D}{1-D}$$

Solution:

Given:

$$V_{in} = 40V$$

$$10V \leq V_0 \leq 80V$$

$$T_{ON} = 0.1ms$$

We know from earlier section:

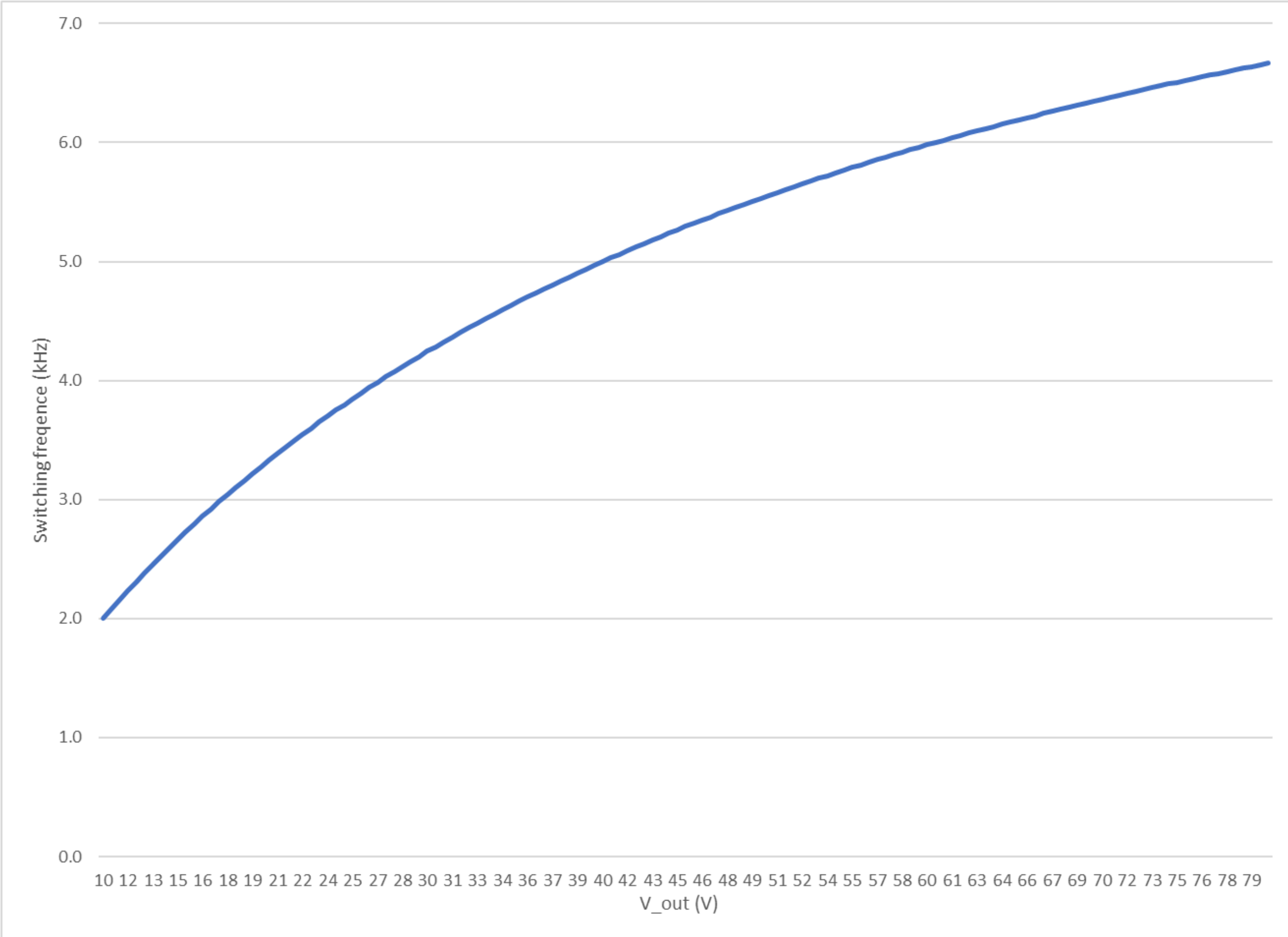
$$\left|\frac{V_0}{V_{in}}\right| = \frac{D}{1-D}$$

$$\implies D = \frac{|V_0|}{|V_{in}| + |V_0|}$$

$$D = \frac{T_{ON}}{T} = T_{ON} * f_s = \frac{|V_0|}{|V_{in}| + |V_0|}$$

$$\implies f_s = \left(\frac{|V_0|}{|V_{in}| + |V_0|}\right)\frac{1}{T_{ON}}$$

A quick graph of f_s vs V_0 shows that f_s is monotonically increasing wrt V_0.
Hence we can calculate the range of f_s by simply calculating the upper and lower bounds of V_0.



$$(f_s)_{min} = \left(\frac{|V_0|_{min}}{|V_{in}| + |V_0|_{min}} \right) \frac{1}{T_{ON}} = 2\ kHz$$

$$(f_s)_{max} = \left(\frac{|V_0|_{max}}{|V_{in}| + |V_0|_{max}} \right) \frac{1}{T_{ON}} = 6.67\ kHz$$

$$\implies 2\ kHz \leq f_s \leq 6.67\ kHz$$

Reference:

- *Buck-Boost Converter: What is it? (Formula and Circuit Diagram) | Electrical4U*