DC-DC CONVERTER CIRCUITS

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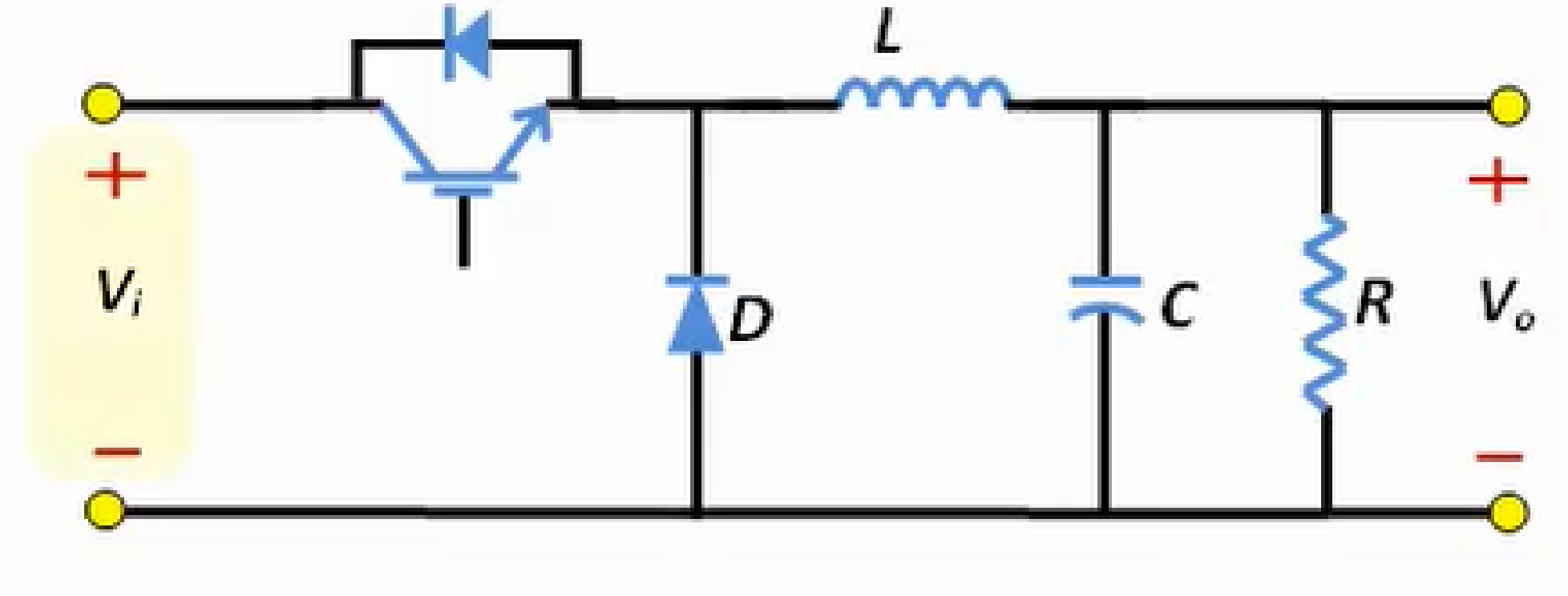
Introduction

- A DC-to-DC converter is an electronic circuit or electromechanical device that converts a direct current (DC) source from one voltage level to another. It is a type of electric power converter. Power levels range from shallow (small batteries) to very high (high-voltage power transmission).
- DC to DC converters are used in portable electronic devices such as cellular phones and laptop computers, primarily supplied with power from batteries. Such electronic devices often contain several sub-circuits, each with a voltage level requirement different from that supplied by the battery or an external supply (sometimes higher or lower than the supply voltage).
- This chapter describes some DC-to-DC converters such as Buck Converter, Boost Converter, and Buck-Boost Converter and Ćuk Converter.

Buck Converter

- A buck converter (step-down converter) is a DC-to-DC power converter that steps down voltage (while stepping up current) from its input (supply) to its output (load).
- It is a class of switched-mode power supply (SMPS) typically containing at least two semiconductors (a diode and a transistor, although modern buck converters frequently replace the diode with a second transistor used for synchronous rectification) and at least one energy storage element, a capacitor, inductor, or the two in combination.
- To reduce voltage ripple, filters made of capacitors (sometimes in combination with inductors) are normally added to such a converter's output (load-side filter) and input (supply-side filter)

Buck Converter

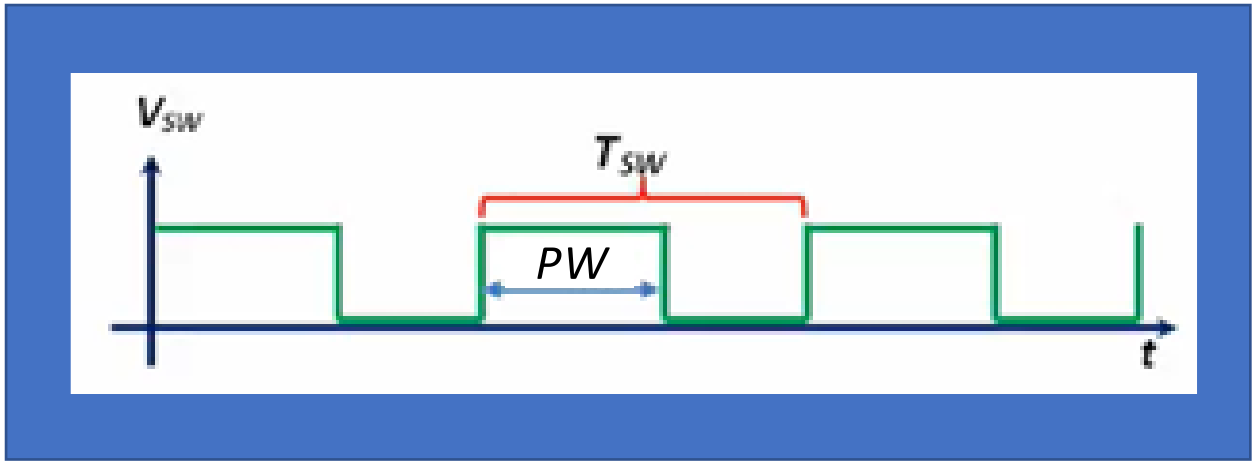


Component of Buck Converter

- The first one is a transistor switch using IGBT (insulated-gate bipolar transistor). So, the trigger switch for this device will be at the gate, however the device will behave as mix between MOSFET and Bipolar Junction Transistor.
- The second component of the circuit is an inductor. The objective of the inductor is to smooth the current.
- Then we have a typical load of converter circuit, which is a capacitor and a resistor that draws current from the circuit.
- The diode is used to guarrantee the current is continues by controlling the duty cycle of the switch. So the switch is controlled by the gate when the voltage of the gate reachs, for example, 10 Volts then the switch becomes close and if it reachs zero, it becomes open.

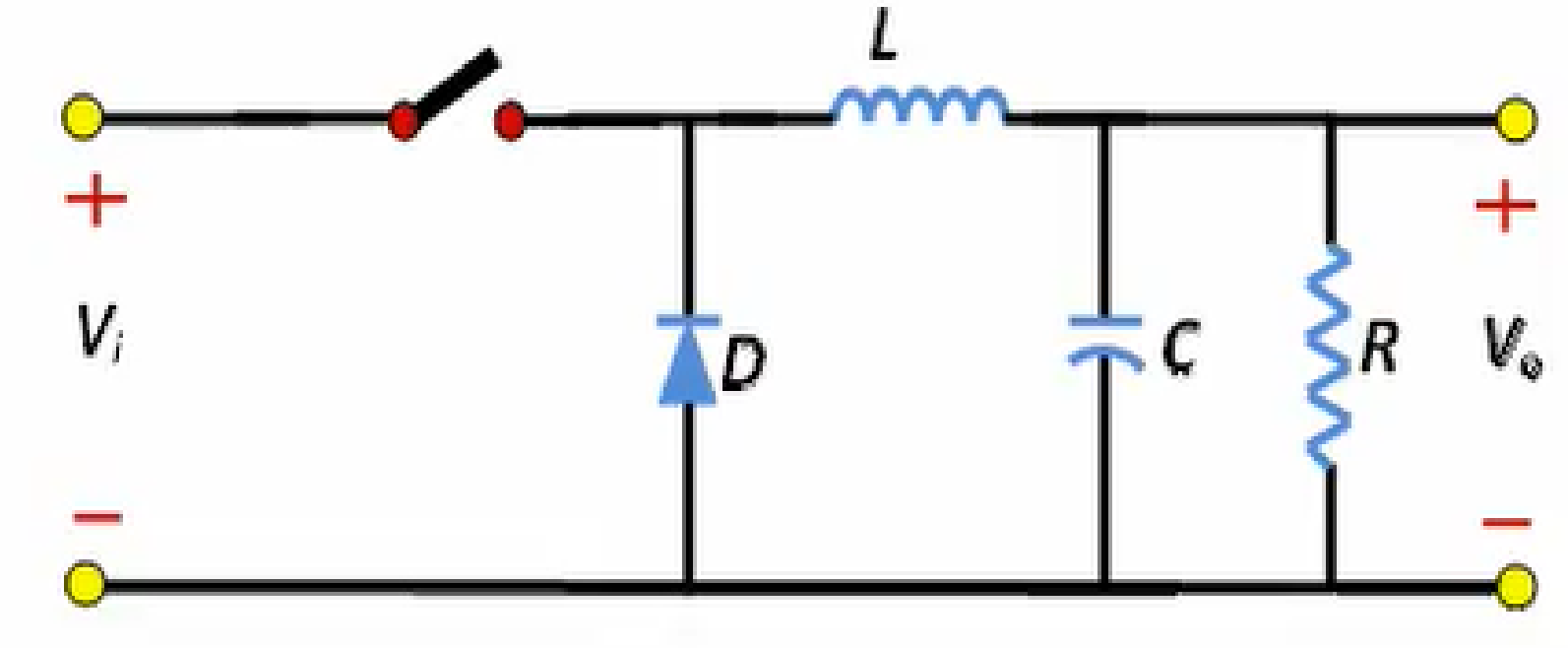
Gate Voltage of Buck Converter

- So the switch is becomes close and open according to time periode given by the controller.
- The duty cycle (*D*) is basically the ratio of the ON time over the total time of the switch. So the ON time (*PW*) is the duty cycle times the time period of the switch.



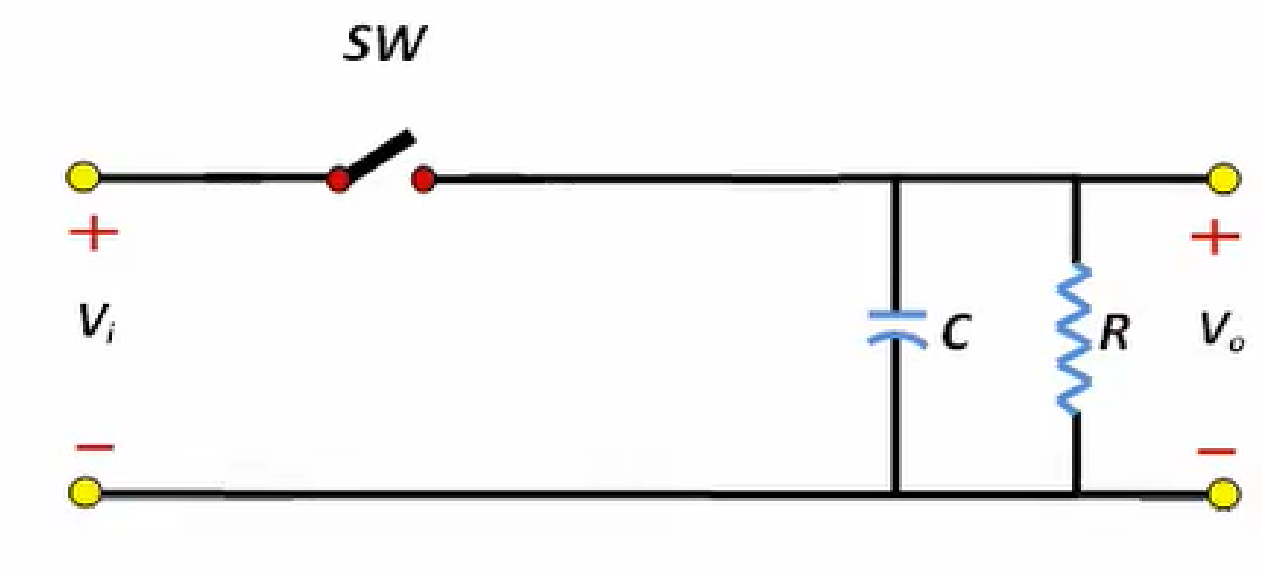
Simplification of Buck Converter

- To simplify the explaination, the IGBT transistor is replaced using a switch



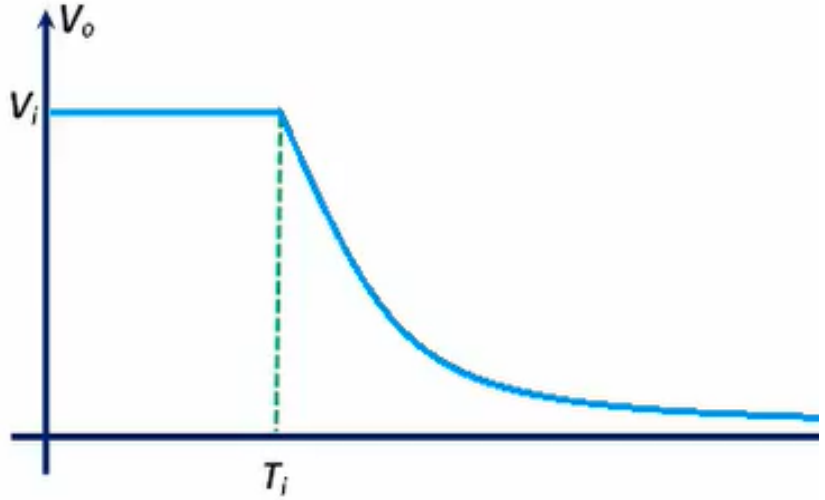
RC Load of Buck Converter

- To analyze the load that consist of RC circuit, we have to remove the inductor and the diode.
- When the switch is close, the current will flows to the load, then the V_o will equal to V_i. When the is open, the capacitor will start to discharge and supply the resistor.



Exponential Decay of Capacitor

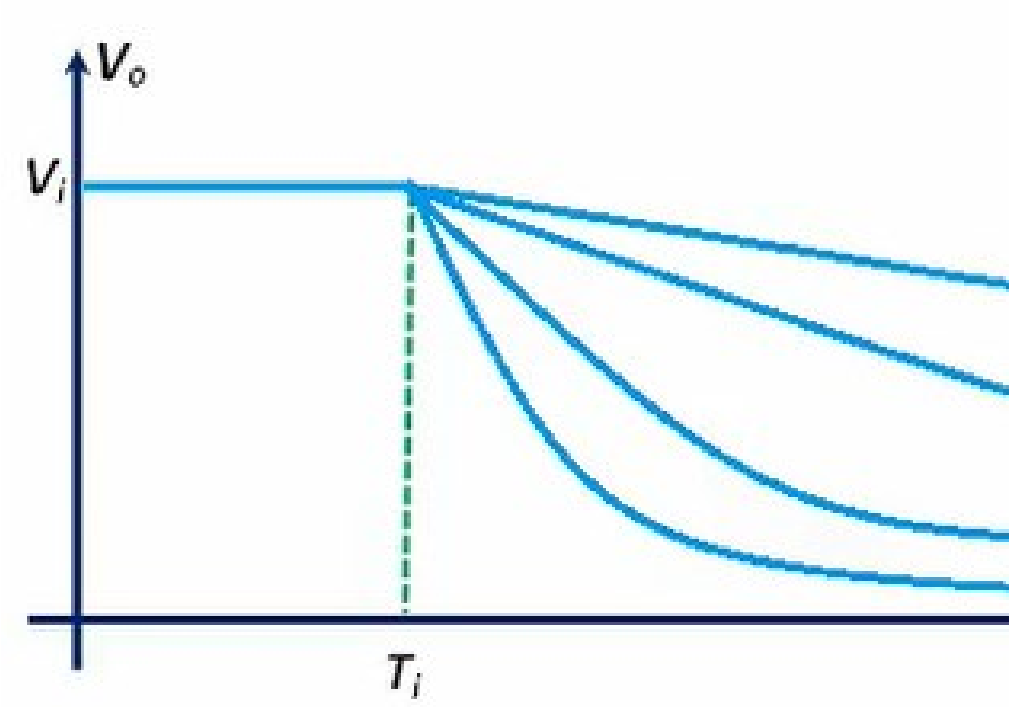
- The capacitor voltage will exponentially decay, when the switch is open.



$$V_o = V_i e^{-\frac{(t-T_1)}{RC}}$$

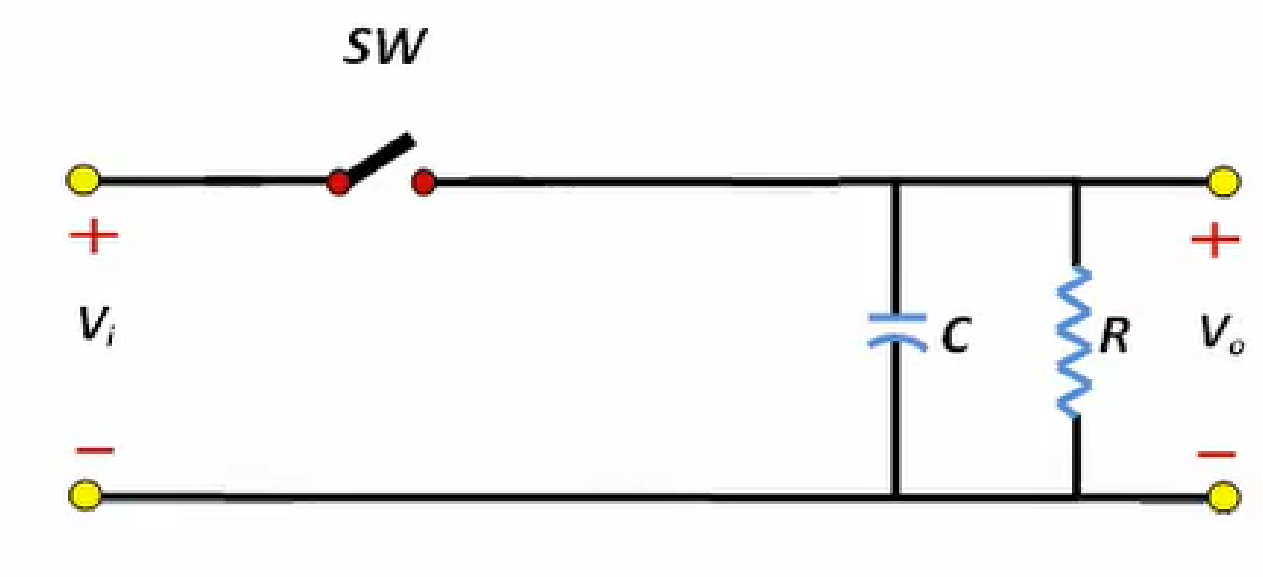
Effect of Time Constant of RC Circuit

- The increases of capacitor value will increases the time constant of the RC circuit. So the decay of capacitor voltage will take a longer time.



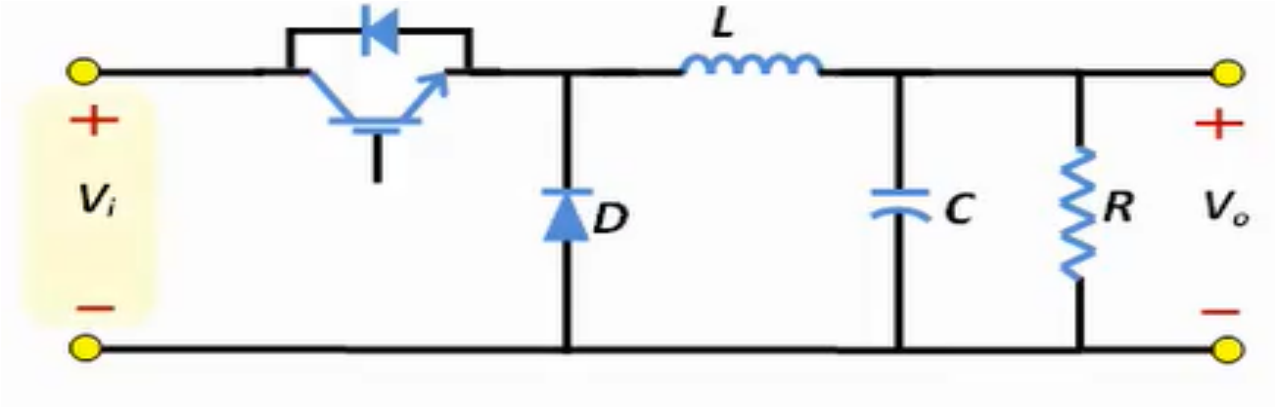
Effect of Time Constant of RC Circuit

- The advantage of using very high frequency to trigger the switch ON and OFF is we don't need to have a very large capacitor. The voltage will not dramatically drop with a small capacitor. As the gate switching in very high frequency, it will produce output voltage with a small ripple due to the discharge and the charge of capacitor.



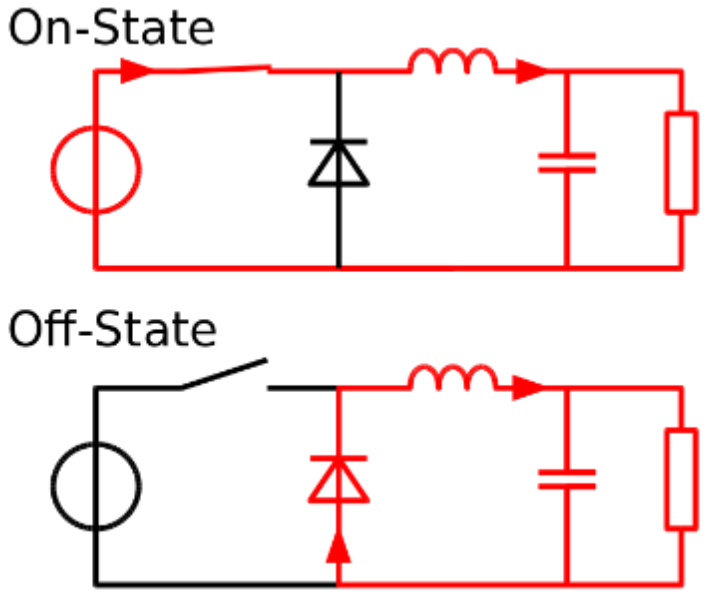
Effect of Time Constant of RC Circuit

- The inductor will smooth the current because the inductor will act as a storage energy. So when the switch is close, the inductor will absorb that energy, but when the switch is open, the inducor will suplly the capacitor that stored energy. So the inductor will act as a buffer that will absorb the voltage difference between V_i and V_o. It will smooth the current.



On-State and Off-State of Buck Converter

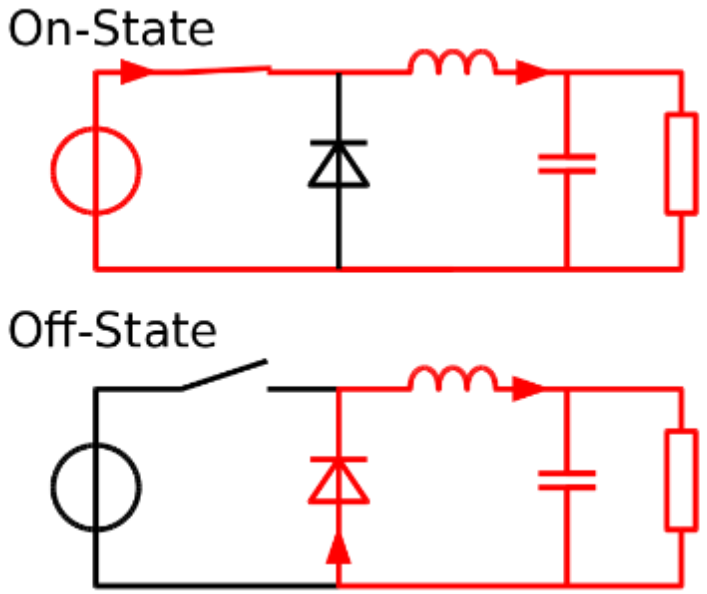
- When the switch pictured above is closed (top of figure), the voltage across the inductor is $V_L=V_i-V_o$. The current through the inductor rises linearly (in approximation, so long as the voltage drop is almost constant). As the diode is reverse-biased by the voltage source V_i, no current flows through it.



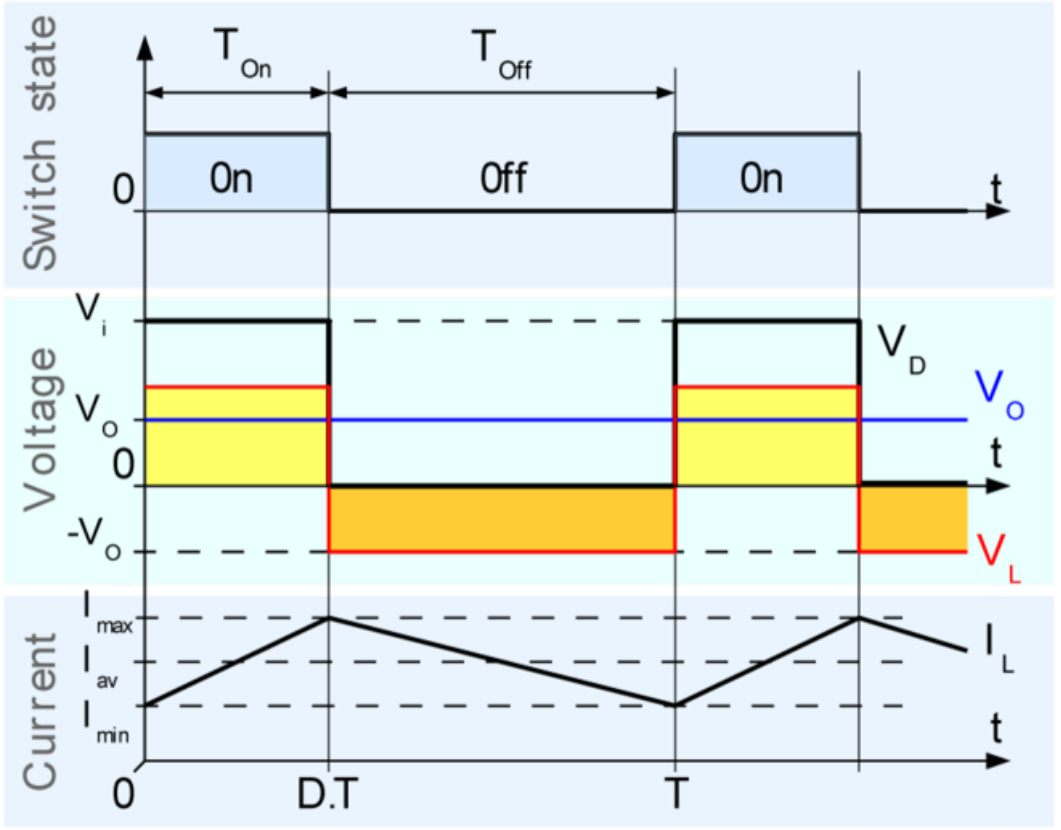
On-State and Off-State of Buck Converter

- The output voltage of the converter varies linearly with the duty cycle for a given input voltage. As the duty cycle, *D*, is equal to the ratio between *PW* and the period *T*, it cannot be more than 1. Therefore, $V_o \leq V_i$. This is why this converter is referred to as *step-down converter*.

$$D = \frac{V_o}{V_i}$$



Voltage and current



Voltage and current with time in an ideal buck converter operating in continuous mode.

References

- DC-to-DC , https://en.wikipedia.org/wiki/DC-to-DC_converter.
- Buck Converter, https://en.wikipedia.org/wiki/Buck_converter.
- Boost Converter, https://en.wikipedia.org/wiki/Boost_converter.
- Buck-Boost Converter, https://en.wikipedia.org/wiki/Buck-boost_converter.