2 Circuit topologies

2.1 Buck (step-down) converters

The input voltage of the buck converter, also known as step-down converter, is always higher or very close to the output voltage (Fig. 2.1). There are designs with fixed or variable output voltage whose minimum or maximum values depend on different design parameters, e.g. the internal reference.
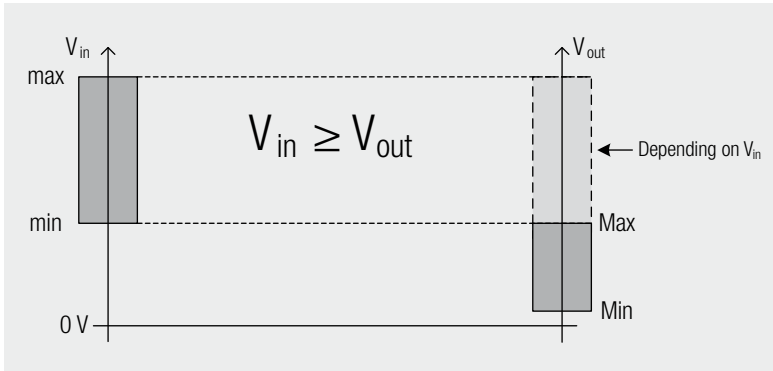
Buck (step-down) converters

Fig. 2.1: Schematic relationship between input and output voltage

The buck converter is the simplest converter of all switching regulators and the circuit topology is very often used to supply power to processors that require a low voltage and high current. As long as the difference between the input and output voltage is not too high, a very good efficiency of up to 95% can be achieved. The low number of components necessary allows for easy design-in, particularly as numerous regulators and controllers from different manufacturers are already available on the component market.

An electrical isolation between the input and output is not possible and the buck converter can only generate one output voltage.
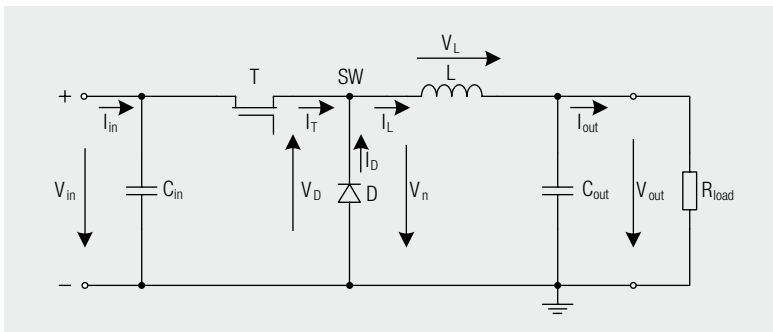

Fig. 2.2: Schematic buck converter

2 Circuit topologies

2.1 Buck (step-down) converters

Figure 2.2 shows the basic circuit of a buck converter, including the branch currents/voltages. The voltage from the switch node (SW) to ground is termed as V_n. The switch (S) (also see Chapter 1.3) has been replaced with a switching transistor (T) (bipolar, FET, MOSFET). This can be part of an IC or may also be a separate component.

At the switch node between the transistor (T), diode (D) and inductor (L), depending on the circuit state: transistor closed/diode blocks or transistor open/diode conducting, the voltage changes between the value of V_{in} and ground potential minus diode forward voltage (0V-V_D) see Fig 2.3.

In the stationary state, the mean value of the output voltage is as follows:

$$V_{out} = V_{in} \cdot \frac{t_{on}}{t_{on} + t_{off}} = V_{in} \cdot D \qquad (2.1)$$

As the duty cycle D can only take on values between zero and one, the output voltage is always lower than or equal to the input voltage.

If the transistor (T) is closed, the diode (D) is reverse biased and blocks. The current I_L then flows through the inductor (L) to the output capacitor (C_{out}) and to the connected load (R_{load}).

At the end of the switch-on time, the inductor current has the following value:

$$I_{L\,on} = \frac{(V_{in} - V_{out}) \cdot t_{on}}{L} \qquad (2.2)$$

At the end of the On-time t_{on}, the switching transistor opens controlled by the internal control circuit (controller IC). There is reversal of the voltage at the inductor and across the diode. The diode is now polarized in the forward direction and the output capacitance continues to be charged with the energy stored in the inductor. The current in the inductor drops and at the end of the switch-off time the inductor current has attained the following value:

$$I_{L\,off} = \frac{(V_{out} - V_D) \cdot t_{off}}{L} \qquad (2.3)$$

The controller IC starts the next switching cycle by again closing the switch and the process or functional sequence starts anew.

The mean value inductor current of the buck converter corresponds to the output current I_{out}. The maximum current of the inductance $I_{L\,max}$ is given in the continuous mode with the following relationship:

$$I_{L\,max} = I_{out} + \frac{V_{out} \cdot \left(1 - \dfrac{V_{out}}{V_{in}}\right)}{2 \cdot f_{sw} \cdot L} \tag{2.4}$$

The voltage and current waveforms of a continuous mode buck converter are as follows (Fig. 2.3):

Continuous mode