Single Transistor Forward Converter

The **single transistor forward converter** belongs to the primary switched converter family since there is isolation between input and output. It is suitable for output powers up to 1kW. The single transistor forward converter is also called a *single ended forward converter*.

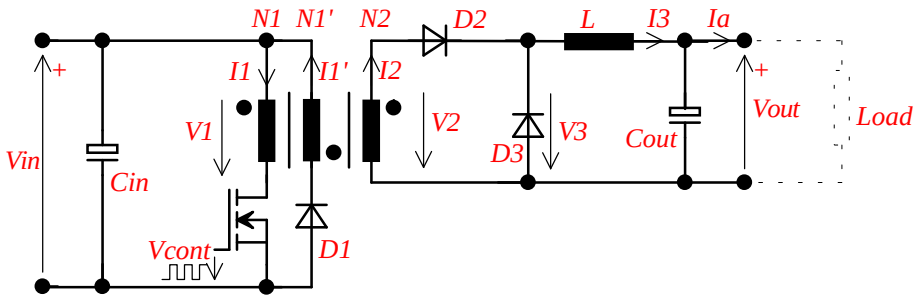

Figure 2.2.1: Single transistor forward converter

The forward converter transfers the energy during the on-time of the transistor. During this time the voltage V_1 is equal to the input voltage. The winding N_2 is in the same direction as N_1. When the transistor is on voltage V_2 at N_2 is given by $V_2 = V_{in}\frac{N_2}{N_1}$. The voltage V_2 drives the current I_2 through the diode D_2 which during this time is equal to I_3 through L which charges the output capacitor C_{out}.

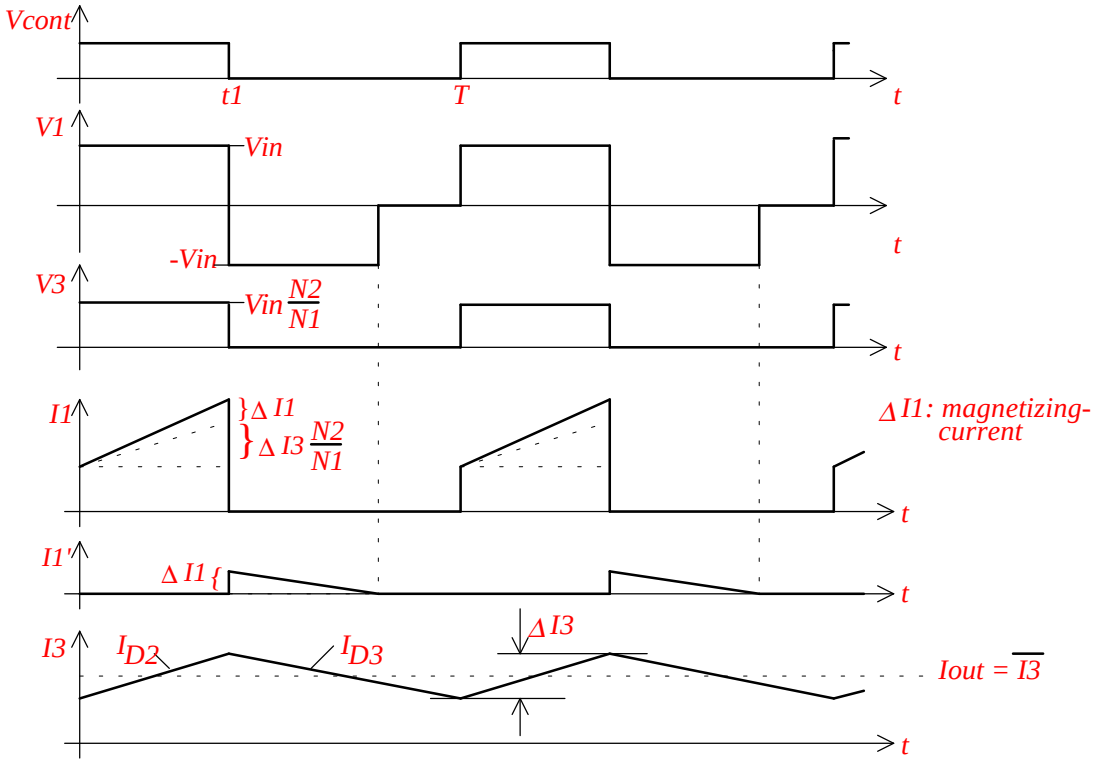

Fig. 2.2.2: voltages and currents at the single transistor forward converter

During the off-time of the transitor, N_1 and N_2 are without current. The inductor L drawes its current through the diode D_3. The value of the voltage V_3 is equal to zero (neglecting the forward voltage drop of D_3).

During the off-time of the transistor, the magnetic flux of the transformer has to reduce to zero. The core is demagnetized with N_1' via D_1 to V_{in}. N_1' has the same number of turns as N_1 therefore the demagnetization needs an equal time intervall as the on-time. For this reason the minimum off-time has to be as long as the on-time. This causes a maximum duty cycle t_1/T of 0.5 for the single transistor forward converter.

During the off-time, the voltage at N_1' is equal to the input voltage V_{in}. This voltage will be transformed back to the primary winding N_1 and for V_1 follows: $V_1 = -V_{in}$. Due to this the drain source voltage steps up to $V_{DS} \geq 2V_{in}$ when the transistor is turned off.

In comparison to the transformer of the flyback converter the transformer in this forward converter is a "normal" transformer. Its job is not to store energy but to transfer energy. For this reason the core has no air gap.

- The breakdown voltage of the transistor has to be $V_{DS} > 2V_{in}$.
- The windings N_1 and N_1' must be closely coupled. However a snubber circuit as shown in Fig. 2.1.3, chapter 2.1. "flyback converter" is necessary.
- In comparison to the flyback converter, the forward converter can only have one regulated output voltage.
- The maximum duty cycle is $\frac{t_1}{T} = 0.5$.

Design of the single transistor forward converter:

The output voltage V_{out} is equal to average of V_3. The maximum duty cycle is 0.5.This leads to (see also Chap. 1.1: "buck converter"):

$$\boxed{V_{out} = V_{in} \cdot \frac{N_2}{N_1} \cdot \frac{t_1}{T}}$$

For the turns ratio follows:

$$\boxed{\frac{N_2}{N_1} = 2 \cdot \frac{V_{out}}{V_{in}} \quad \text{and} \quad N_1 = N_1'}$$

For further calculation of the transformer see Chapter 5: "Inductors and high frequency transformers"

To calculate L the method used for the buck converter is appropriate. Initially the current ripple ΔI_3 of the inductor current I_3 has to be selected. A value for it is 20% of the output current is normally acceptable: $\Delta I_3 \approx 0,2 \cdot I_{out}$. Assuming a maximum duty cycle of 0.5, this leads to:

$$L = \frac{V_{out} \cdot T/2}{\Delta I_3}$$

The value of C_{out} depends on the acceptable voltage ripple ΔV_{out} of the output voltage. This voltage ripple is mainly determined by the impedance $Z_{\max}$ of the output capacitor C_{out}:

$$\Delta V_{out} \approx \Delta I_L \cdot Z_{\max}$$

$Z_{\max}$ can be verified from the datasheet of C_{out}.

The input capacitor C_{in} for 230V/50Hz-mains should be:

$$C_{in} \approx 1\frac{\mu F}{W} \cdot P_{in}$$

2.2.1 Two-Transistor forward converter:

The **two-transistor forward converter** is a variant of the single transistor forward converter.

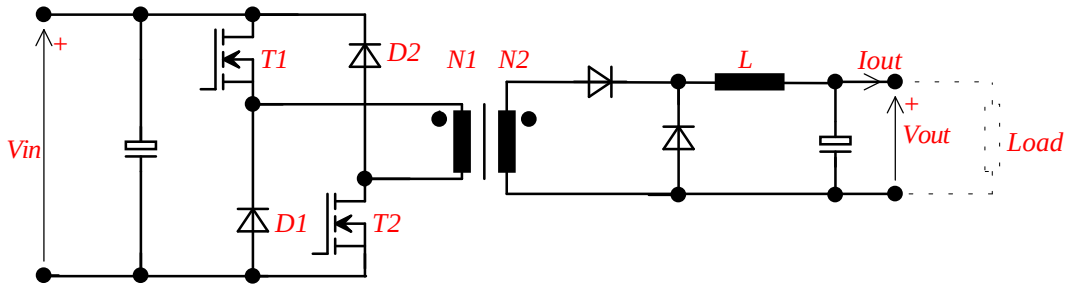

Fig. 2.2.3: two-transistor forward converter

The transistors T_1 and T_2 are switching at the same time. During the on-time of the transistors, the voltage at the primary winding is equal to the input voltage V_{in}. During the off-time of the transistors the transformer will be demagnetized via the diodes D_1 and D_2 into the input voltage V_{in}. In comparison to the single transistor forward converter this converter has the advantage that its transistors only have to block the input voltage and the winding N_1' is not required. In addition to this the coupling of the transformer windings is no longer critical. These advantages make this converter type suitable for significantly higher output powers compared to the single transistor converter.

The calculation of the components is equivalent to the single transistor forward converter.

- For the two transistor forward converter the breakdown voltage of the transistors is only required to be $V_{DS} = V_{in}$.

- The two transistor forward converter can be used for powers up to a few kWs. It is a simple converter, which is not critical in regard to its physical design and its electrical operation.