1 Boost Converter

The boost converter which is shown in Figure 1 supplies an amplifier with a rated voltage of 60 V. For this exercise steady-state operation is assumed.

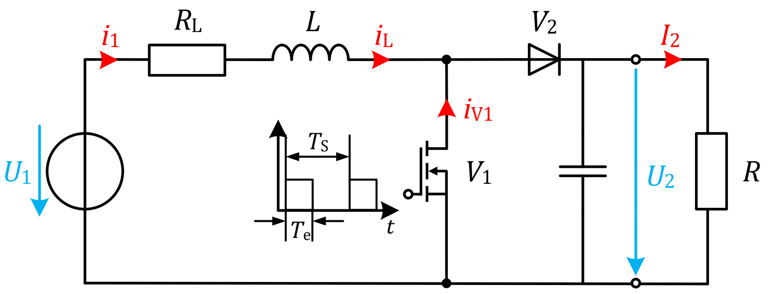

Figure 1: Boost converter topology

The specification of the boost converter is given below:

Input Voltage:	$U_1 = 12$ V	Minimal Output Power:	$P_{\text{outmin}} = 10$ W
Output Voltage:	$U_2 = 60$ V	Output Voltage Ripple:	$\Delta u_2 = 120$ mV
Output Current:	$I_2 = 2$ A	Switching Frequency:	$f_s = 100$ kHz

First, all losses of the boost converter including the resistance of the inductor are neglected.

1. Derive the duty cycle , which leads to the specified output voltage.

2. Determine the mean input current $\bar{i}_L$.

3. Define a suitable inductivity for the coil L, so that the boost converter is operating in continuous conduction mode for the minimum output power given in the specification above. Determine the maximal switch-off current $\hat{i}_{V1}$ of the transistor V_1 for the rated output current $I_2 = 2$ A.

4. Calculate a suitable capacity , using the output voltage ripple given in the specification. Determine the current stress of the capacitor $I_{C,RMS}$.

For the following points an ideal smoothed input current and a ripple-free output voltage are assumed.

5. From now on, the influences of the resistor R_L are considered. Derive the efficiency η and voltage ratio U_2/U_1 of the boost converter, in dependence on the duty cycle D and the resistance ratio $\alpha = R_L/R$. Sketch both values η and U_2/U_1 over the duty cycle D and give comments. Calculate D under consideration of $R_L = 0.2\ \Omega$.

6. Calculate the efficiency η of the boost converter for an output current of 2 A and a coil resistance of $R_L = 0.2\ \Omega$.

7. In addition, consider the conduction losses of the diode V_2 and transistor V_1. Assume an equivalent resistance of $R_\mathrm{F} = 5\ \mathrm{m\Omega}$ and voltage of $U_\mathrm{TH} = 1\ \mathrm{V}$ for the diode and an equivalent resistance of $R_\mathrm{DSon} = 30\ \mathrm{m\Omega}$ for the transistor. Determine the required duty cycle when the conduction losses are considered. Discuss the deviation to the ideal case.

8. Beside the conduction losses also switching losses need to be considered in reality. In this part the switching losses of a fast diode are compared to a normal silicon diode. Figure 2 illustrates the current and voltage waveforms during a turn-off event of a fast diode.

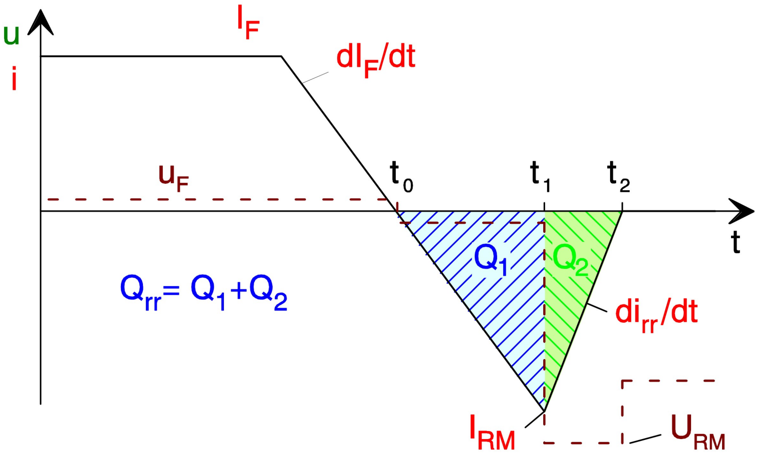

Figure 2: Turn-off behavior of a fast silicon diode

Determine the turn-off switching losses of

a) a fast diode with a
   i. commutation inductivity loop (comprising the loop with $V_1 - V_2 - C$ switches on) of $L_\mathrm{K} = 500\ \mathrm{nH}$
   ii. peak reverse recovery current of $I_\mathrm{RM} = 4\ \mathrm{A}$
   iii. reverse recovery time of $t_\mathrm{rr} = t_2 - t_0 = 46.6\ \mathrm{ns}$
b) a normal silicon diode with $Q_\mathrm{rr} = 16\ \mathrm{\mu C}$ and $\frac{\mathrm{d}i_\mathrm{rr}}{\mathrm{d}t} = 40\ \frac{\mathrm{A}}{\mathrm{\mu s}}$

9. In this part a malfunction is assumed. The diode V_2 is disconnected. Starting from an input current of $i_1 = 0\ A$ the transistor V_1 is switched on for a duration of $T_\mathrm{e} = 10\ \mathrm{\mu s}$. For this calculation the resistor R_L and the forward voltage of the transistor V_1 can be neglected. The transistor V_1 is protected against overvoltage by a Z-diode having a Zener-voltage of $U_\mathrm{Z} = 84\ \mathrm{V}$. Determine with $L = 40\ \mathrm{\mu H}$ the waveform of the current $i_\mathrm{L}(t)$. Calculate the period of time necessary for the current to reach $i_\mathrm{L} = 0\ \mathrm{A}$. State the energy which is stored in the coil when the switch is turned off. Determine the energy which is transformed to heat by the Zener diode.