Exercise 1

The Series load resonant (SLR) DC-DC converter of figure 1 works in discontinuous conduction mode (DCM) at a switching frequency ω_s smaller than the resonant frequency $\omega_0 = 1\sqrt{L_r C_r}$ of the LC-circuit. The switching frequency is set to be $\omega_s < \omega_0/2$.

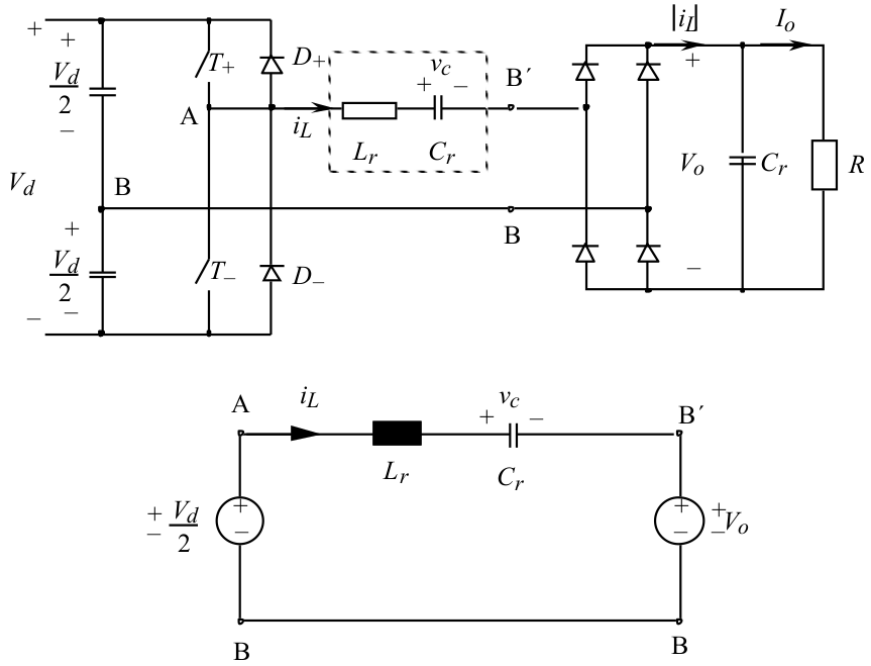

Figure 1: SLR DC-DC converter.

a) Show that the choke maximal current ratio is

$$\frac{I_{L_r,peak}}{I_b} = 1 + 2\frac{V_o}{V_d}, \qquad \text{with } I_b = \frac{V_d}{2Z_0} \text{ and } Z_0 = \sqrt{\frac{L_r}{C_r}} \tag{1}$$

b) Show that the voltage ratio of the peak value over the capacitor C_r is

$$\frac{V_{C_r,peak}}{V_b} = 2 \qquad \text{with } V_b = \frac{V_d}{2} \tag{2}$$

c) Show that the SLR-converter can only work as a voltage step-down.

The instantaneous voltage over C_r and current in the resonant circuit can be expressed as

$$v_{C_r}(t) = V_{in} - (V_{in} - V_{C0})\cos(\omega_0 t) + Z_0 I_{L0}\sin(\omega_0 t) \tag{3}$$

and

$$i_{L_r}(t) = I_{L0}\cos(\omega_0 t) + \frac{V_{in} - V_{C0}}{Z_0}\sin(\omega_0 t) \tag{4}$$

where $V_{AB'}$ is the input voltage of the resonant circuit (figure 2), V_{C0} is the initial voltage over C_r, and I_{L_0} the initial current of L_r.

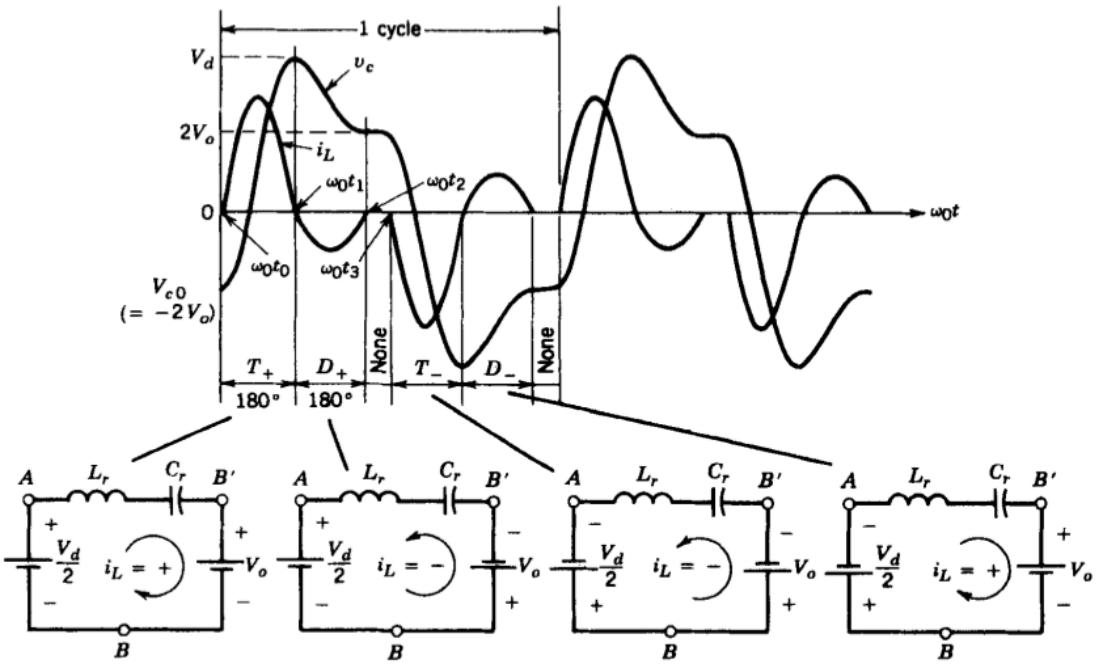

Figure 2: SLR DC-DC converter; discontinuous-conduction mode with $\omega_s < \frac{1}{2}\omega_0$.

Exercise 2

In the figure, a ZCS (Zero current switch) DC-DC converter is represented.

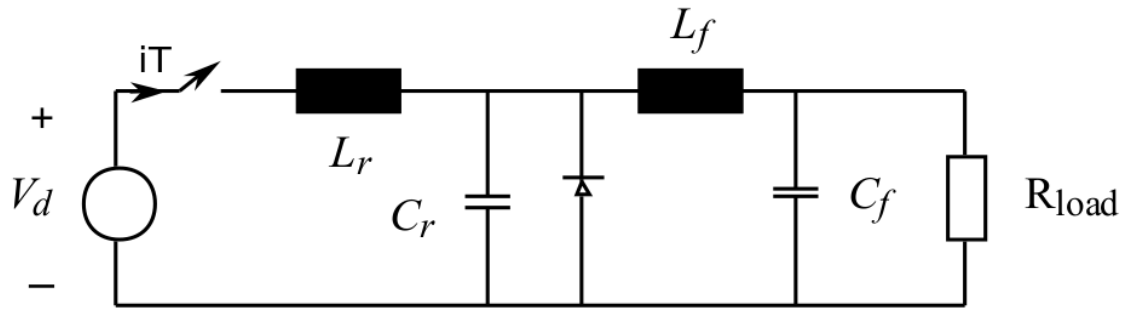

Figure 3: ZCS resonant switch DC-DC converter.

The characteristics of the circuit are as follow:
-the resonance frequency $f_0 = 1$MHz
-The characteristic impedance $Z_0 = 10\Omega$
-the input voltage is $V_d = 15$V
-the output voltage is $V_o = 10$V
-the output power $P_o = 10$W

Obtain the instantaneous current $i_T(t)$ and voltage $u_{C_r}(t)$ over the capacitor C_r, and the time intervals $t1 - t0, t_1' - t_1, t_1'' - t_1, t_2 - t_1, t_3 - t_2, t_3 - t_4$. Calculate the maximal and minimal value of $i_T(t)$ and $u_{C_r}(t)$. What is the switching frequency f_s?

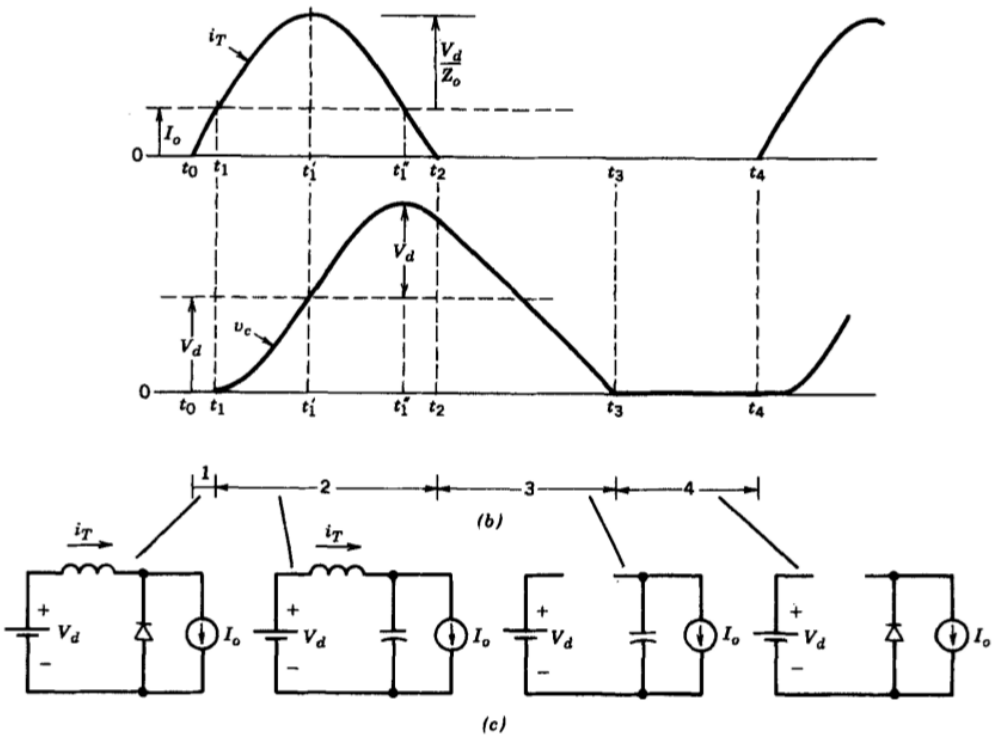

Figure 4: ZCS resonant-switch DC-DC converter waveforms.

The resonant circuit with a parallel load has the following equations: the current in the choke L_r is

$$i_{L_r}(t) = I_o + (I_{L0} - I_o)\cos(\omega_0 t) + \frac{V_d - V_{C0}}{Z_0}\sin(\omega_0 t) \tag{5}$$

and the voltage over the capacitor C_r

$$v_{C_r}(t) = V_d - (V_d - V_{C0})\cos(\omega_0 t) + Z_0(I_{L0} - I_o)\sin(\omega_0 t) \tag{6}$$

The initial values are V_{C0} for the capacitor C_r and I_{L0} for the inductance L_r.