

Resonant Converters

Resonant converters use a resonant circuit for switching the transistors when they are at the zero current or zero voltage point, this reduces the stress on the switching transistors and the radio interference. We distinguish between ZVS- and ZCS-resonant converters (ZVS: Zero Voltage Switching, ZCS: Zero Current Switching).

To control the output voltage, resonant converters are driven with a constant pulse duration at a variable frequency. The pulse duration is required to be equal to half of the resonant period time for switching at the zero-crossing points of current or voltage.

There are many different types of resonant converters. For example the resonant circuit can be placed at the primary or secondary side of the transformer. Another alternative is that a serial or parallel resonant circuit can be used, depending on whether it is required to turn off the transistor, when the current is zero or the voltage is zero.

The technique of resonant converters is described below giving the ZCS-push-pull resonant converter as an example.

2.4.1 ZCS-Push-Pull Resonant Converter:

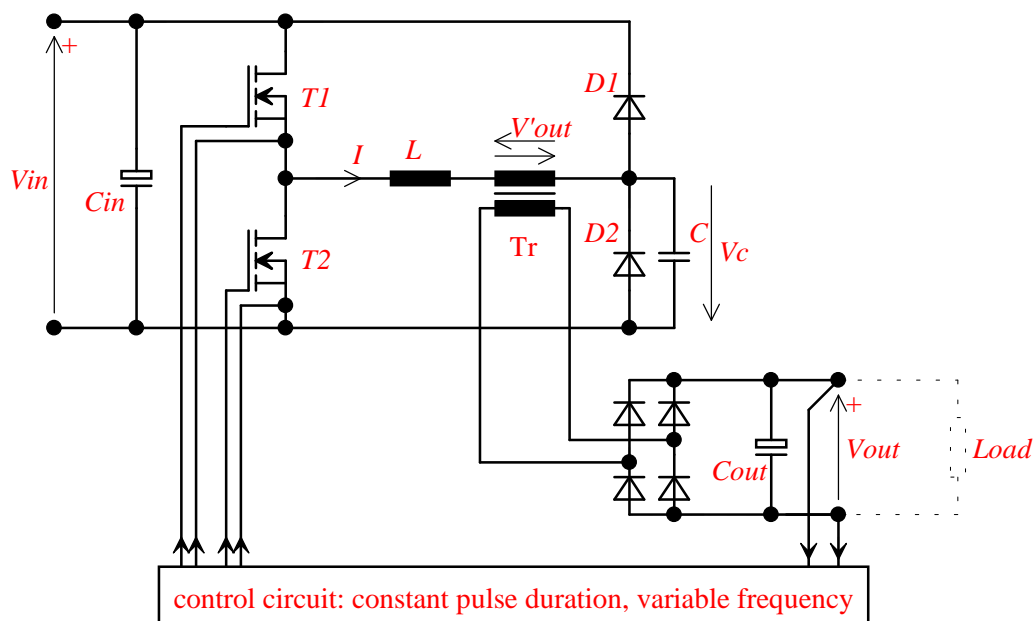


Fig. 2.4.1: The ZCS-push-pull resonant converter

The converter works as follows:

The resonant circuit is formed by L and C . Assume an initial condition of the voltage V_C across C equal to zero. If now the transistor T_1 is turned on, a sinusoidal current half-swing starts through T_1 , L , Tr , C and C_{in} . This half-swing charges the capacitor C from zero to V_{in} . If this first half sinusoidal swing is finished, T_1 can be switched off without losses and after a

short delay T_2 can be switched and a next half sinusoidal swing starts, this discharges C from V_{in} back to zero Volts.

Every half sinusoidal swing transfers a certain amount of energy from the primary to the secondary side of the transformer. The transformer Tr operates on its primary side as a voltage source. For the duration of the current swing through the primary winding, the output voltage V_{out} will be transformed to the primary side: $V'_{out} = V_{out} \frac{N_2}{N_1}$. The energy which is transferred by every half-swing is equal to $W = V'_{out} \cdot \int i(t) dt$. This energy will be transferred twice in each resonant period. This leads to the output power being given by

$P_{out} = W \cdot 2f_{switching}$ ($f_{switching}$: frequency of the converter). Fig. 2.4.2 shows an equivalent circuit for one half-swing.

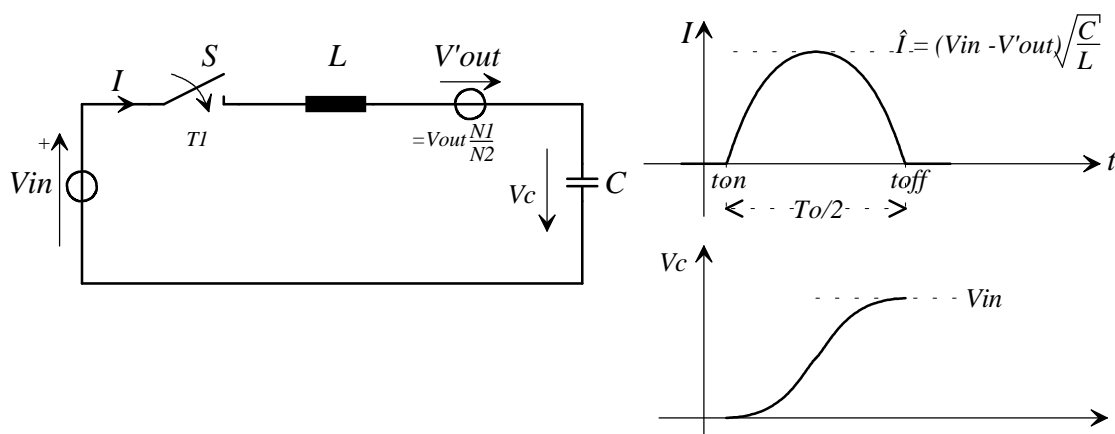


Fig. 2.4.2: Equivalent circuit for one half sinusoidal swing of the ZCS-push-pull resonant converter

The resonant frequency is:

$$f_0 = \frac{1}{2\pi\sqrt{LC}}$$

This leads to the minimum on-time of the transistors. The on-time should be a little higher than half of the resonant period time to ensure that the current reduces to zero.

For maximum energy transfer, V'_{out} must be half of V_{in} . This leads to the turns ratio of the transformer:

$$V'_{out} = \frac{1}{2}V_{in} \Rightarrow \frac{N_1}{N_2} = \frac{1}{2} \cdot \frac{V_{in}}{V_{out}}$$

The maximum output power is achieved if one half current swing instantly follows the next.

The transferred energy of each half-swing further depends on the value of C and L . The higher the value of C and the lower the value of L , to maintain a certain resonant frequency, the higher the amount of energy transfer. (see also the peak value of the current in Figs. 2.4.2 and 2.4.3).

For a certain output power P_{out} , considering $V'_{out} = V_{in}/2$, it can be shown that for L and C :

$$\sqrt{\frac{L}{C}} = \frac{\left(\frac{V_{in}}{2}\right)^2 \cdot \frac{2}{\pi} \cdot \frac{f_{Switching}}{f_0}}{P_{out}} \Rightarrow C = \frac{1}{2\pi \cdot \sqrt{\frac{L}{C}} \cdot f_0} \quad \text{und} \quad L = \left(\sqrt{\frac{L}{C}}\right)^2 \cdot C$$

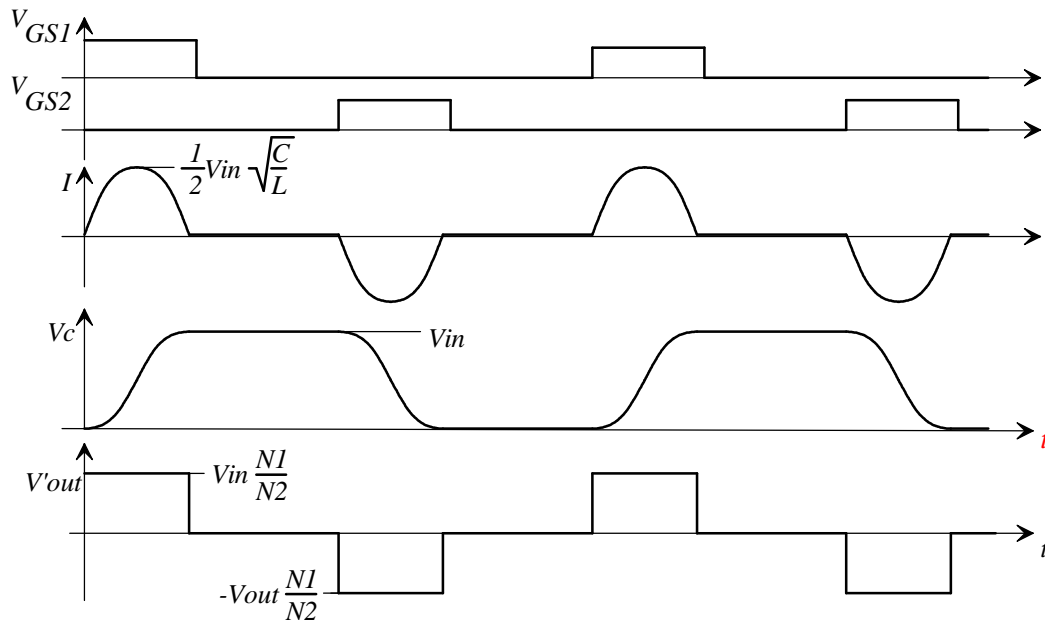


Figure 2.4.3: Voltages and currents at the ZCS-push-pull resonant converter

In addition to the general advantages of resonant converters, having lower switching losses and lower radio interference, this particular resonant converter has two more additional advantages:

- ◆ The ZCS-push-pull resonant converter can regulate several output voltages using one control circuit, as per the flyback converter. This is because several output voltages seem to be parallel connected from the view of the primary side. Due to this the energy always passes to that output, having the lowest voltage value taking into consideration the turns ratio.
- ◆ The ZCS-push-pull resonant converter is no-load and short-circuit proof without any electronic precaution. The output voltage cannot reach more than twice of the nominal value, because then is $V'_{out} = V_{in}$. The current cannot reach more than twice of the nominal output current, because then is $V'_{out} = 0$ and $\hat{I} = V_{in} \sqrt{C/L}$.