Maximizing power handling in HEVs and EVs with power magnetics

By Abdelkader Birch

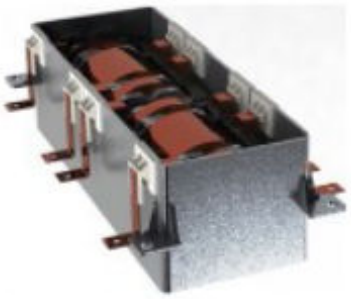

Fig. 1: Premo's 22kW 2x (1/2 Lr + Transformer 11kW +1/2 Lr).

In Electric Vehicles (EVs) and Plug-in Hybrid Electric Vehicles (PHEVs), the most common electronic architectures for On-Board Charger (OBC) converters with a power range of 1,8kW to more than 22kW are resonant converters like LLC topologies. The LLC topology converter includes a resonant cell (resonant capacitor + resonant choke) and a power transformer. Figure 1 shows a Premo kit box that includes all the magnetics components needed to operate the two stages of a 22 kW on-board charger:

- 2 x (½ resonant choke + 11kW transformer + ½ resonant choke) = 22kW

This kit box includes optimized molded integrated magnetics that can be implemented directly in the converter of our customers developing 22kW OBCs. The AECQ200-qualified unit optimized for an on-board charger applications integrates split resonant chokes and deliver optimum power density, efficiency and performance. With a footprint of just 213x73mm and only 67mm high, this magnetic component kit has a power density of 19.5kW/dm3. Its thermal transfer is maximized by a heat conductive aluminium casting.

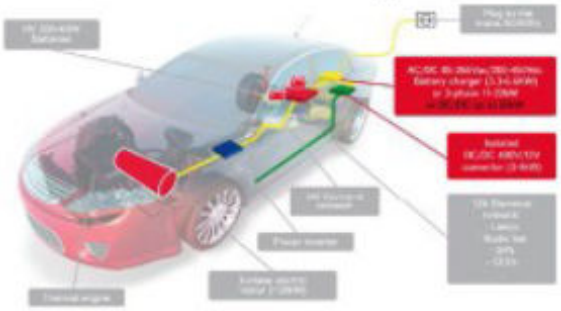

Fig. 2: Typical car electrical system: Plug-in Hybrid System.

Typically, the electrical system of EV/Plug-in HEV involves three types of converters: an On-Board Charger taking the mains to the HV battery, a DC/DC converter connecting the HV battery to a low voltage 12V battery / 12V network and a traction converter providing power from the HV battery to the engine.

The most common electronic topologies for these converters include an LLC topology for the On-Board Charger, an ZVS topology for the DC/DC converter and a power inverter for the traction converter.

DC/DC converter: ZVS topology

DC/DC converters in automotive applications typically deliver 12VDC to supply the 12V network. The ZVS topology (Zero Voltage Switching) is required to reduce, losses, heating and reliability issues in these converters.

Abdelkader Birch is R&D engineer at Premo – www.grupopremo.com

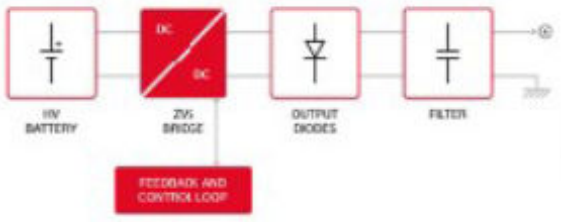

Fig. 3: Block diagram of a typical ZVS topology

A ZVS topology is more suitable for a DC-DC application (400V to 12V) because the output voltage must be adjusted only slightly in the range 10.5V to 15.5V. This enables the global effective turn ratio not to fluctuate significantly.

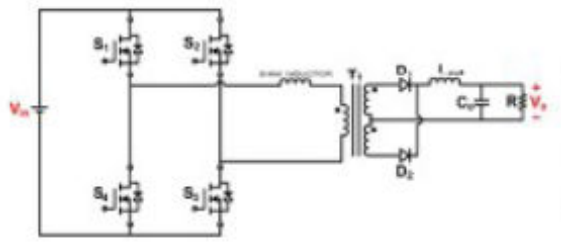

Fig. 4: typical structure of DCDC converter with a ZVS topology

In these topologies, an input "SHIM inductor" is often needed to achieve the phase-shift function. Premo suggests smart magnetic solutions without any additional SHIM inductor component. The leakage inductance of the transformer can be used to implement the necessary input serial inductance. However, that must be managed carefully because the leakage inductance is a "parasitic" parameter naturally intrinsic in the transformer. This value depends mainly on the winding structure. Physically, we can say that this is the result of a poor coupling between primary and secondary windings. The method consists of considering different winding structures.

Thanks to a finite element analysis software – like Maxwell – electromagnetic simulations can be performed to investigate different winding structures for a specific leakage inductance. This will provide the required input inductance value without adding a choke.

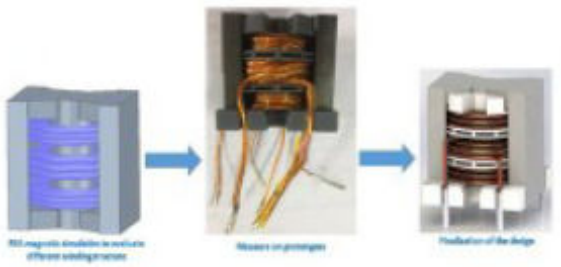

Fig. 5: Development stages of the integrated transformer

OBC: LLC topology

An LLC topology is more suitable for OBC applications (400V to 400V) since the output voltage should be adapted according to the battery charging voltage range (270V to 470V). The resonant cell allows the level of voltage to be adjusted with the switching frequency. Efficiencies up to 98% can be achieved with LLC resonant converters when integrated magnetics are used. Resonant converters have been around for a long time. However, power electronics for automotive HEV/EV is boosting demand as there is an absolute need to improve efficiency.

The typical structure of a resonant converter LLC topology is shown in figure 6.