Resonant power supply

the magnetic components "feel neglected"

In order to contribute to the best possible results for the SMPS projects, ITACOIL srl collaborates with electronic designers in the design of the magnetic parts.

The evolution of the European directives regarding energy efficiency, together with the demand for high performance power supply in various sectors (primarily the sectors of LED lighting, solar energy and information technology), in recent years have brought about a revaluation of the series resonant topology (SRC), which offers several advantages as described below.
All the main manufacturers of the active components currently available on the SMPS market have included efficient chips in their product catalogues which, with an effectively contained degree of circuit complexity, provide for the realization of power supplies with 90-95% efficiency. What's more, thanks to "Zero Voltage Switching" and to the substantially sinusoidal high frequency currents, these chips also offer reduced EMI / EMC problems in comparison to other topologies.
While the projects of the largest electronic equipment manufacturers generally employ proper structuring for the magnetic components, manufacturers who do not have "six-figure" quantities, despite making use of the same active and passive component technologies in general, do not offer the same benefits with regards to the magnetic components, including fundamental components such as integrated transformers and PFC inductors. This is due to the necessary degree of customisation and the reduced amount of resources which can be allocated to the power supply's design.

The integrated transformer

By using leakage inductance (which normally represents an undesirable parasitic effect) instead of a discrete inductor, two of the three elements of the LLC resonant tank upon which the resonant converter's functionality is based, can be combined within a single magnetic component.
While the convenience of this integration in terms of cost and space is evident, it should also be noted that the magnetic flux of leakage inductance takes place substantially in the air, thereby virtually eliminating problems of core saturation, which must be kept in mind when using a discrete inductor.
In order to achieve good results, the design structure and details must be skilfully managed so as to obtain the required leakage inductance, in relation to all the other design parameters, under conditions of minimal loss.
While, in other situations, the use of empirical experience and simple generic calculating methods provides for approximations which are more or less acceptable for many specifications, in high-efficiency applications a few more lost Watts -sometimes only a fraction of a Watt- can have a significant effect on the power supply's overall efficiency, thereby frustrating the cautious choices made for this purpose in relation to the other passive and active components.
Optimal efficiency for magnetic components can only achieved by surpassing a number of simplified design methodologies, such as the equal division of the loss target between the core and the copper.
Literature and experience teach us that the best point of efficiency can be identified through the accurate computation of the losses based on the induction value [fig.1].

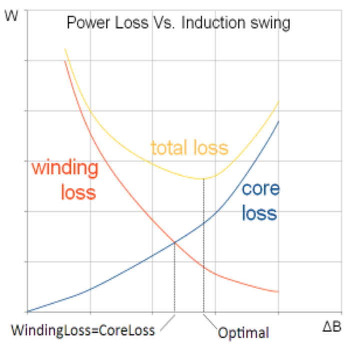

Fig.1 – Example of losses in a magnetic component based on the induction value.

In the specific case of integrated transformers, there are a number of constraints which require close cooperation with the magnetic components' manufacturer during the electronic design.
In fact, the ratio primary inductance (Lp) and leakage inductance (Llk) in a defined transformer structure is fixed at a defined primary turn number [fig.2].
For this reason, lack of dialogue with the designer, to establish targeted improvements for certain parameters, will at best result in less than perfect induction values and therefore extremely poor energy or economic efficiency.

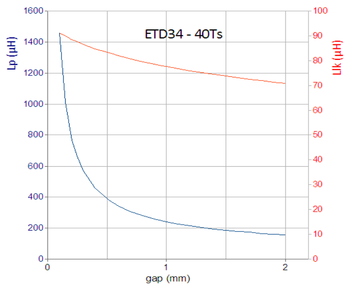

Fig.2 – Example of the relationship between primary inductance and leakage inductance

Increased scrutiny in the design of the transformers described above allows for the realistic calculation of loss, without which every design optimisation would be rendered impracticable.
This calculation must keep in mind the eddy current loss resulting from the "proximity effect" and must assume a relevant complexity in the presence of litz (multistrand) wire windings, whose use is inevitable given the typical working frequencies around 100 KHz and above.
While, in other situations, a structure with interleaved windings can be utilised to reduce eddy current leakage, in this case these cannot be used due to the need for consistent leakage inductance values.
Contrary to a popular belief which limits the purpose of the interleaved structure to the reduction of leakage inductance only, in reality it also provides for a reduction in peak magneto-motive force between the winding layers, resulting in a substantial reduction in "proximity effect" leakage.
These critical aspects often lead to the development of transformers with extremely limited efficiency, from the point of view of both energy and economics.

PFC inductance

The presence of the active PFC stage at the input of the high performance SMPS is almost mandatory. This component too, above all for certain largely utilised typologies, requires a number of critical design considerations.

The most utilised PFC typology for power levels of up to 200-300W is the "Transition Mode" (sometimes also named “Critical Mode”), in which the regular core leakage calculation methods cannot be used due to the complexity of the current waveform.

In fact, even with constant load the current has continuously variable frequency and amplitude, based on the instantaneous mains voltage value [|sen(Vin_{RMS})|] [fig.3].

This increases the possibilities for error in loss calculation, rendering it necessary to use advanced calculation methodologies that keep in mind the power loss curves published by the core's manufacturers, which are referred to sinusoidal waveforms and therefore cannot be applied directly.

It is therefore necessary to use advanced calculation methodologies that consider the particular application.

Considering that the above cited winding loss issues are also present in this component, an optimal design will require access to specific tools and resources which are not available to many purely electronic design teams.

A feasible solution

From a general supply chain point of view, the manufacturer of the magnetic components should take charge of the design in order to generate evident economies of scale in the scope of a fruitful collaboration.

In fact, the investments required in order to generate the necessary specific skills and implement sophisticated calculation tools, as well as to build moulds for specific windings and accessories which are adequate in terms of both performance and safety (insulation, creepage, clearance, etc.), can be more easily sustained by suppliers of magnetic components.

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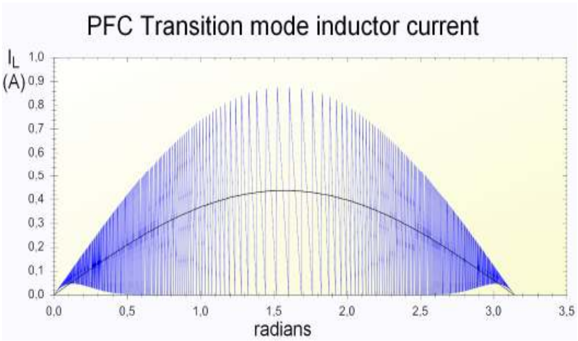

Fig.3 – The inductor current waveform of a Transition Mode PFC (simulation performed by ITACOIL proprietary software)