Resonant power supply

The inductive components

ITACOIL collaborates with electronic designers in the design of inductive parts in order to contribute to the attainment of the best results in LLC resonant SMPS projects.

The need for high performance power supply systems for LED lighting and, in general, the increasingly greater request for energy efficiency, both regarding running costs and compliance with recent Standards, has brought about a revaluation of the LLC series resonant topology. (SRC).

All the main manufacturers of active components currently available on the SMPS market have included efficient chips in their product catalogues. With an effectively contained degree of circuit complexity, they allow the realisation of power supplies with 90-96% efficiency, (which can be improved further using synchronous rectifiers instead of output diodes) and reduced EMI/EMC problems in comparison to other topologies thanks to the "Zero Voltage Switching" and to the substantially sinusoidal high frequency currents.

The operating principle is based on the characteristic gain curve of the resonant tank" (*Fig. 1*), which allows to change the gain by a moderate variation of the switching frequency, thus resulting in an effective regulation of output voltage or current in relation to load and input voltage changes.

The resonant "tank" is a set of two inductive elements and one capacitor (LLC). Even if the use of three different components, i.e. a discrete inductor, a conventional transformer and a capacitor is technically possible, poor results would be obtained on all fronts: cost, size and energy efficiency.

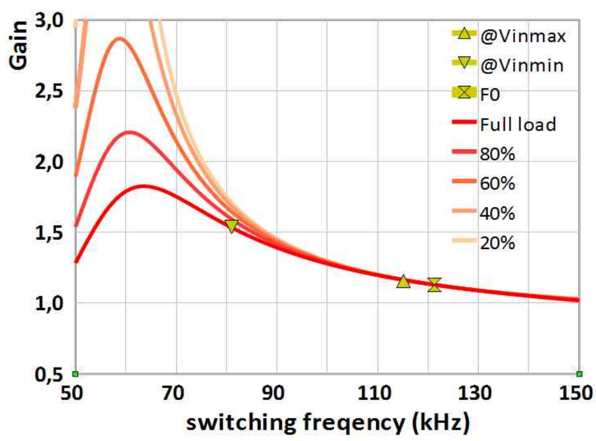

Fig. 1 – Inductance current wave form of a Transition Mode PFC (simulation from ITACOIL software)

The use of an integrated transformer is much more convenient, which has specific features and integrates resonant inductance as described below.

To give an idea of the advantages, if a 150 W integrated transformer is well-dimensioned it can have dimensions of less than 28x29x23 mm, with costs that are obviously more competitive with respect to solutions with discrete inductance (*Fig. 2*).

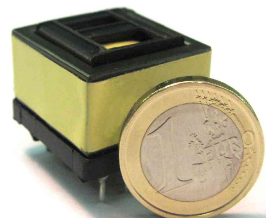

Fig. 2 - 150W integrated transformer

It is therefore evident that the only reason that can lead to this solution is the design difficulty of a coherent tank.

While the designs of the largest manufacturers of electronic equipment generally show a correct structuring of the integrated transformer and other inductive components, mid-sized or small manufacturers - even if all SMPS manufacturers enjoy the same technology advantages in relation to active and passive components - very often do not have the same benefits in regards to fundamental components, such as the integrated transformer and PFC stage inductor, given the specificity of the inductive components and the limitation of resources destined to the project.

The integrated transformer

The transformers designed especially for this type of use, i.e. the so-called "integrated resonant transformers", make use of leakage inductance, which normally represents an undesirable parasitic effect, instead of a discrete inductor, integrating two of the three resonant tank elements in just one inductive component.

As well as convenience in terms of costs and dimensions, it must also be highlighted that the magnetic flux of the leakage inductance goes substantially through free air, thus eliminating every problem linked to saturation of the core, which must be kept in mind 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 bring about approximations that can be more or less accepted in many specifications, these are not acceptable in high-efficiency applications. In fact, in this case, a few more lost Watts - sometimes a fraction of a Watt - can have a significant effect on the power supplier's overall efficiency; it can easily compromise the careful choices made during the design of the converter.

Optimal efficiency for inductive components can only be 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 efficiency point can be identified through the ad hoc definition of the losses depending on the induction value (*Fig. 3*).

In the specific case of integrated transformers, there are a number of restrictions which require close co-operation with the inductive components manufacturer during the electronic design.

The definition of the best parameters of a resonant tank cannot be made without considering the restrictions linked to the structural elements of each transformer, firstly the curve

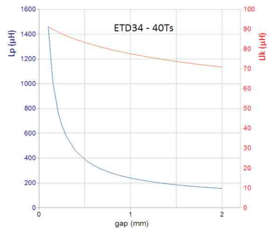

Fig. 3 – Leakage/ inductance relationship

showing the relationship between inductance and leakage inductance (*Fig. 4*).
Without this dialogue, at best, you will be forced to work with an inappropriate inductance value, which can result in very bad energy and cost efficiency.
The most critical issue in the design of these transformers is the realistic calculation of winding losses, without which any design optimisation becomes unfeasible.
During this calculation, the eddy current loss resulting from the "proximity effect", should be considered as well as the "*skin effect*", a recognised phenomenon that is easy to manage. These calculations become even more complex in the presence of litz wire windings (multistrand), whose use is inevitable given the typical working frequencies in the order of 100 KHz and over.
These critical aspects along with other minor issues often lead to transformers with poor efficiency from an economical, energy and dimensional point of view.

PFC inductor

The presence of the active PFC stage at the input of the high performance SMPS is almost mandatory. There are also some critical design considerations relating to this component, especially for some of the most used types.
The most popular type of PFC adopted for power levels up to 200-300 W is the "*Transition Mode*" (sometimes also named "Critical Mode" or "Boundary mode"), where the usual core loss calculation methods cannot be used due to the complexity of the current waveform.
In fact, even with constant load the current has a particular wave shape, substantially triangular but with continuously variable frequency and amplitude, depending on the instantaneous input voltage value [|sen (Vin_{RMS})|] (*Fig. 5*).
This increases possible errors in the loss calculations, making the use of advanced calculation methods necessary.
It must be taken into consideration that the loss curves published by the manufacturers of magnetic cores refer to sinusoidal waveforms as well as specific frequencies and temperatures and therefore are not directly applicable.
The calculation problems for losses in the windings mentioned above in relation to the integrated transformers also exist for this component. Therefore, optimal design requires the access to specific resources and tools, normally not available to electronic design teams.

A feasible solution

From a general supply chain point of view, the manufacturer of inductive components should take charge of the design, in order to generate evident scale benefits, with the purpose of a fruitful collaboration.
The investments required in order to generate the necessary specific skills, to implement sophisticated calculation tools and to build moulds for bobbins and specific accessories, adequate both in terms of performance and safety (isolation, creepage, dimensions, etc. that allow to exclude many problems during type-approval tests, also in demanding sectors such as that regarding electromedical devices) can be more easily sustained by the supplier of inductive components.
ITACOIL has acted in this respect, investing in recent years in order to give customers the opportunity to realise their projects with really small design efforts.
With the resonant tank already correctly designed, according to all the requirements and structural restrictions of the integrated transformer, the design of this type of converter becomes objectively easy also for designers who approach this topology for the first time. The use of standard integrated transformers found in the catalogue allows to easily solve most of the needs in the LED lighting, home appliances, home automation, information technology sectors and many others, but the highly qualified technical support and rapid sampling enable the same benefits even where a custom product is required.


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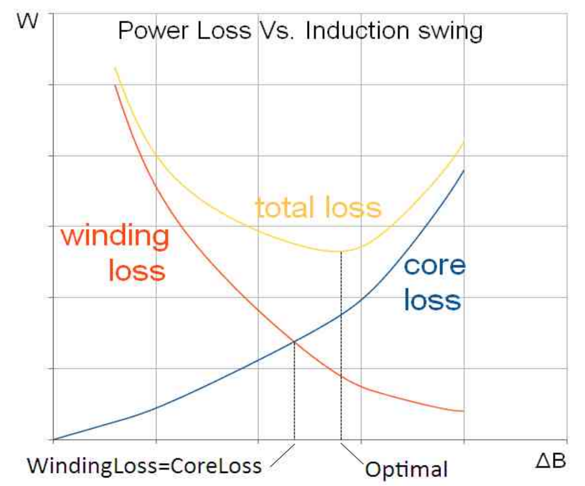

Fig. 4 – Losses in an inductive component depending on induction value

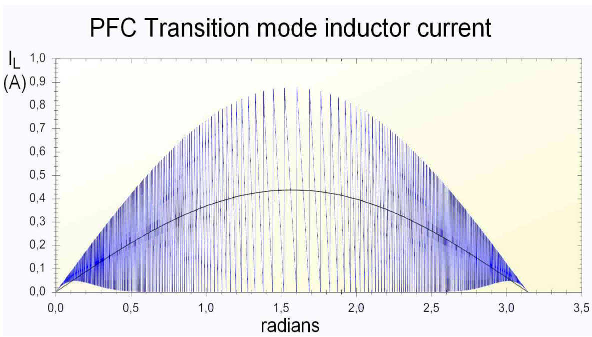

Fig. 5 – Inductance current wave form of a Transition Mode PFC (simulation from ITACOIL software)