Siemens Matsushita Components

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Inductors for distributed power supplies

In modern power electronics, distributed power supply concepts are progressively replacing single-converter topologies. With new core shapes and "high-frequency" ferrite materials from Siemens Matsushita Components, industrial users can now design transformers operating in the kilowatt range and ultra-flat transformers in planar technology.

Developments in distributed power supplies reflect two conflicting trends in ferrite design. On the one hand, the high-power range above 100 kW with switching frequencies up to 100 kHz requires specially designed "oversize" core shapes. On the other, power supplies for laptops, notebooks or high-tech telecommunications applications call for ultra-flat core shapes, often in SMD transformers and chokes for frequencies up to 1 MHz, and in planar technology.

Single-converter concept

In conventional switched-mode power supplies (SMPS), a single converter based on one transformer and possibly with one or more chokes as outputs must satisfy all design requirements relating to voltage and current characteristics, EMC and cost. The drive and control circuitry is geared to the needs of a single converter for the entire power supply. Requirements such as isolation, dielectric strength, and high voltage and current stability at the outputs have a major impact on design costs.

Distributed functions

The concept of distributed power, on the other hand, is based on the premise that power supplies can meet these requirements with greater efficiency and at lower cost if their functions are split between one large main converter and several small DC/DC converters to supply the various output units. The versatility of this power supply concept is illustrated by the wide range of applications in which it is employed:

- telecommunications, e.g. in ISDN networks, power supply networks and uninterruptible power supplies (UPS),
- portable computer equipment, e.g. laptops, notebooks and palmtops,
- automotive electrical systems, especially in electric cars.

Such distributed power supplies can cover a wide range from several watts to more than 100 kW.

Centralization demands compromises

The single-converter concept attempts to satisfy all internal and external power supply requirements in one unit. So requirements such as

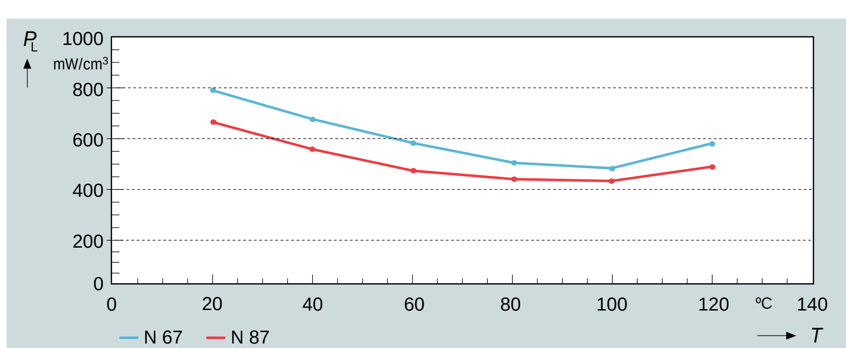
- several stabilized outputs,
- sinusoidal system reaction,
- network isolation
- high dielectric strength,
- high voltage transforming ratios,
- high efficiency and
- low cost

can usually only be met by making compromises in transformer design. This often results in costly solutions, because complicated winding structures, special coil formers and insulation increase the cost of inductive components. New EMC regulations calling for extra chokes, capacitors or shielding measures are another important factor in SMPS design.

Benefits of distribution

The distributed power supply concept splits up the functions of the single-converter topology among different stages of several converters. At first sight, this solution seems expensive because control circuits,

Fig. 1 Comparison of power losses in materials N67 and N87 at 100 kHz/200 mT



chokes and capacitors must be provided for each converter. But a detailed analysis reveals a host of technical benefits which make the distributed concept competitive in terms of cost as well. The reduced requirements for each converter mean reduced electrical specifications for the components in turn, so that low-cost standard components will generally suffice.

Circuit concept

In the distributed power supply concept, a main converter transforms the AC or DC voltage from the line supply to an internal DC voltage, which fluctuates within defined limits. The requirements for network isolation, sinusoidal system reaction and primary interference suppression are generally met as well, because the circuit dispenses with several stable outputs. A not too small fluctuation of the DC voltage on the secondary side and AC ripple can be tolerated; these effects must in any case be compensated for, albeit in reduced form, in the converters of the following stages.

Main converter

The main converter – the interface between the power supply network and the outside world – uses the largest ferrite cores and chokes because it must handle the total power required by the network. Typical switching frequencies are in the range up to 100 kHz, especially if very large core shapes are used in the kilowatt range. Examples are the ER 180 core with a diameter of 180 mm, the PM 114 (the PM 140 is in preparation) and U93 cores, usually made of the N27 ferrite material. Higher transformer outputs up to 100 kW can be obtained with materials N67 or N87 **(Fig. 1).** These high-power ferrite materials have very low hysteresis losses and highly reduced eddy current losses thanks to their higher specific resistance.

Production of very large core shapes, especially with high-frequency, high-power ferrite materials, has been made possible by 3D finite-element-method simulation programs. The mechanical and thermal stress parameters for pressing and sintering can thus be optimized so that even “oversize” core shapes can be manufactured without cracks. Applications for these core shapes include automotive electronics (electric cars), uninterruptible power supplies, power

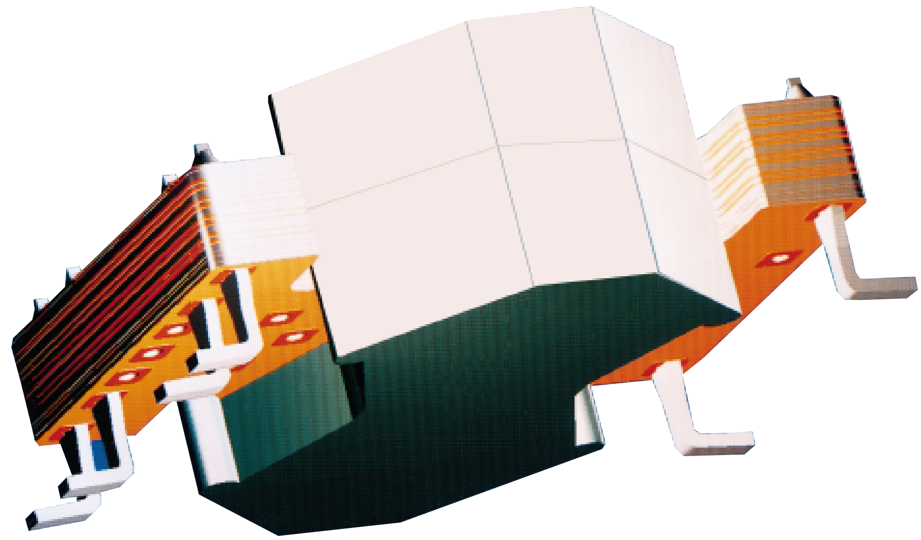


Fig. 2 Planar inductor design

supply networks for electronic switching systems in telecommunications, and solar energy systems.

The inductors of the main converter are either wound with a standard winding technique or assembled with water-cooled copper pipes for the very high-power applications. Special coil formers generally make high isolation voltages possible.

Small converters

The small converters make up the second stage of the distributed power concept, but further DC/DC converters can, of course, be added. On the primary side, design measures for EMC and sinusoidal system reaction can be kept to a minimum. Fluctuation of the input voltage is relatively small and well defined by the main converter. These DC/DC converters can therefore be designed for optimum power efficiency and output stability. In many applications, only one special output voltage is required. In resonant converters in particular, smaller and smaller components can be implemented with rising switching frequencies. Thanks to “soft” switching, in which current and voltage never reach their maximum simultaneously, transistor losses are significantly reduced and overheating of the entire converter is avoided.

The transformers and chokes of the small converters mainly use ferrite cores which are as small and flat as possible to fit the compact dimensions of laptops and notebooks, for example. The switching frequencies for this power range (a few watts up to about 150 W) are generally high, so the flux distribution in the core must be as homogeneous as possible. Transformers and chokes based on EFD cores designed with 3D FEM tools are ideal for this application. Very efficient transformers for high switching frequencies up to 1 MHz can be built with core sizes of 10, 15, 20, 25 and 30 mm (standard products). These not only have a homogeneous flux distribution, but the offset position of the center leg and the position of the outer legs keep leakage fields under control. Transformers and chokes with EFD 10 and EFD 15 cores have been developed as SMDs for this type of application.

For the combined requirement of low voltages, e.g. logic levels of 3.3/5 V, high currents (up to 20 A), high switching frequencies and a total installed height of less than 10 mm, the low-profile rectangular module (RM) cores are an excellent design basis. These cores are derived from the standard RM cores, for which Siemens Matsushita Components can point to years of manufacturing know-how. Low-profile RM cores combine optimum power density per unit of volume with good shielding properties and SMD design for automatic placement (tested up to the RM 10 low-profile version).

The requirements mentioned cannot always be satisfied by low-profile RM cores using

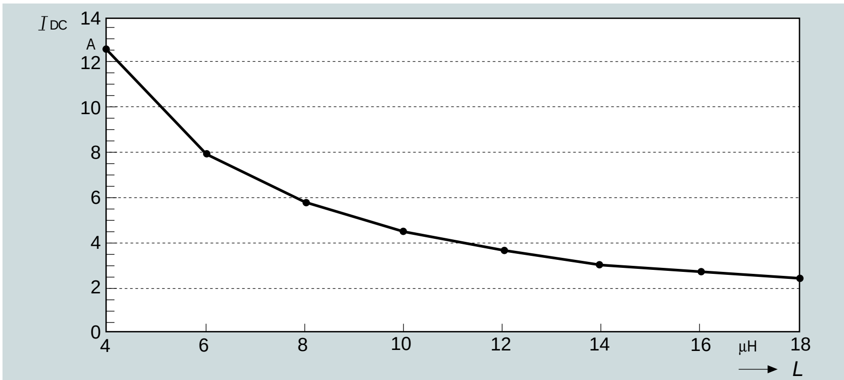


Fig. 3 Current and inductance in a low-profile RM 7 choke of material N87

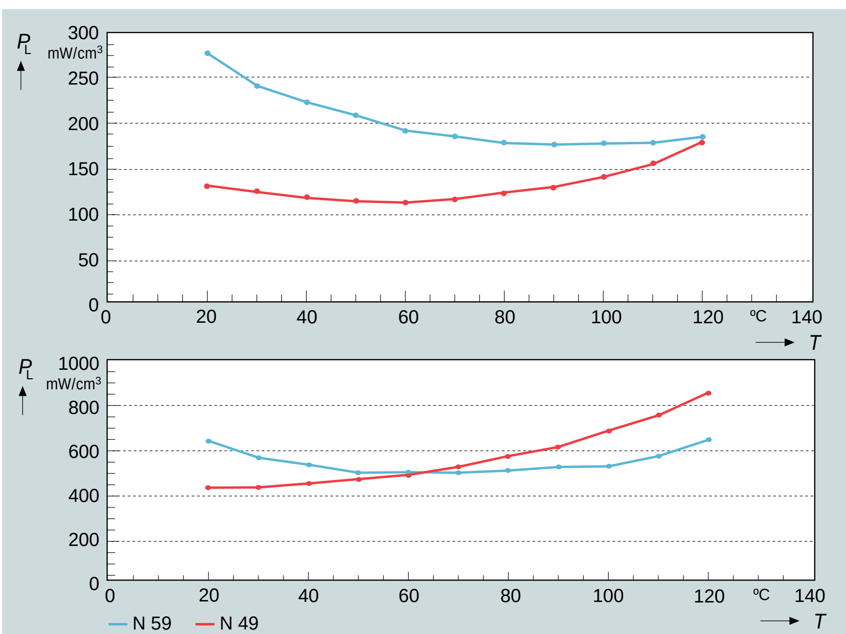


Fig. 4 Comparison of power losses in materials N49 and N59 at 500 kHz/50 mT (top) and 1 MHz/50 mT (bottom)

standard winding techniques. The conventional wire winding is replaced either by punched copper plates combined with windings printed on a PC board and separated by capton insulation film **(Fig. 2),** or by a multilayer PC board.

Planar multilayer inductors are the first components in planar technology which can satisfy the demands of high-tech applications in telecommunications and be produced in volume at reasonable prices. Two designs have been developed. The first, based on a low-profile RM 7 core of N49 material, can handle up to 50 W and 10 A (inductance 5 mH) at 700 kHz **(Fig. 3).** The second design, based on the low-profile RM 10 core, can transmit up to 120 W at the same frequency.

The main benefits of the multilayer design in mechanical terms are:

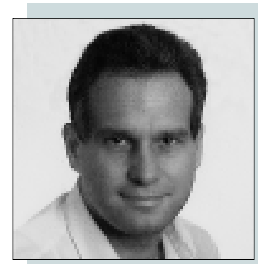
- high mechanical stability, because the core is not glued, but clamped in place,
- coplanarity of 0.1 mm for SMD applications, and
- unrestricted suitability for reflow soldering.

Flexible windings are another planar technology that deserves mention. These are windings printed on a plastic film, insulated by further films and stacked to form the complete winding assembly. They are assembled manually.

Two ferrite materials can be used for high-power applications in the frequency range up to 500 kHz. These are materials N67 (rated up to 300 kHz) and N87, which also gives excellent performance in planar chokes at 750 kHz. For the 700 kHz range, material N49 is particularly suitable. A comparison with the genuine “megahertz” material N59 **(Fig. 4)** shows how the use of purer raw materials combined with new powder and sintering techniques has paved the way to high-power ferrite inductors.

Prospects

New core shapes and ferrite materials have been developed by Siemens Matsushita Components in response to the trend toward switching frequencies above 500 kHz in SMPS. Development of planar multilayer inductors opens up enormous design opportunities, especially for (quasi) resonant circuits. Advances in materials have thus brought the megahertz range with reach, and as new applications emerge, the experience gained with planar inductors will fuel progress in transformer design. □



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