Siemens Matsushita Components

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Planar multilayer technology for telecom DC/DC modules:

Maximum power in a minimum of space

Thanks to innovative inductive components in planar multilayer technology, Siemens Matsushita Components and the Siemens Public Communication Networks Group have together succeeded in developing a new series of hybrid DC/DC power supply modules for telecom applications based on advanced circuit design principles.

Conventional power supplies for telecom applications are based on uninterruptible, battery-buffered DC voltages of 48 or 60 V. The logic levels required, e.g. 3.3 or 5 V, are then provided by distributed DC/DC converters. One such converter with a typical output of 100 to 200 W and a clock frequency of about 100 kHz supplies a system segment comprising several system modules.

Advances in IC packaging density have made it possible to reduce the entire module frame to its smallest autonomous functional unit: a single module. To provide redundancy and ensure independent operation, a module of this kind requires an autonomous on-board power supply. DC/DC converters for this function must not only have a low profile and high power density, but also meet the following standard telecom requirements:

- extremely low electromagnetic interference,
- high operational reliability, and
- long service life.

To obtain the low-profile design required, the switching frequency must be significantly increased, because this is the only way of substantially reducing the height of the critical components. Surface mount devices (SMDs), optimized cooling techniques and state-of-the-art manufacturing technologies are likewise essential to space-saving design.

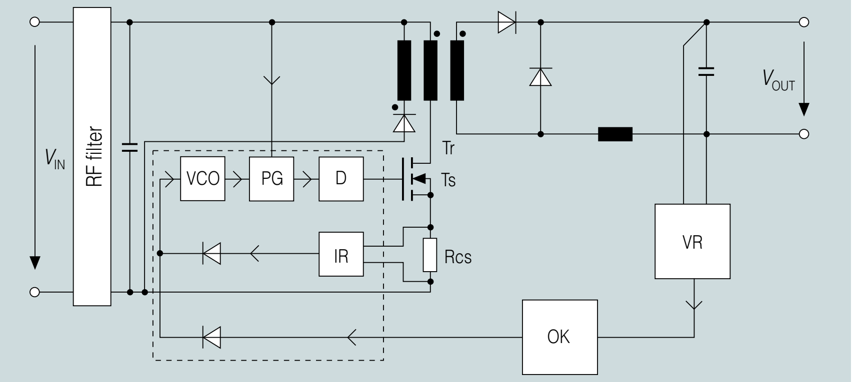
Hybrid modules combine benefits of resonance technology and PWM

The basic issue facing the designers of the new generation of DC/DC converters was to select the technology and components most appropriate to the application. But neither resonance converter technology based on sinuosoidal signals (for which extensive development work has been done worldwide in the targeted frequency range from 500 kHz to 1 MHz) nor PWM topologies based on square-wave signals could meet the design goals by themselves [1]. As **Fig. 1** shows, the optimum solution was obtained by combining the advantages of the two technologies:

● Frequency modulation based on quasi-resonance technology is used for regulation and control at high switching frequencies of 700 kHz.

● Low switching losses in the forward converter are guaranteed by careful selection of power components with very low parasitic

Fig. 1 The new generation of DC/DC converters represents a synthesis of resonance converter technology and PWM topologies based on square waves



D	Driver	Tr	Power transformer
IR	Current controller	Ts	Switching transistor
OK	Optocoupler	VCO	Voltage-controlled oscillator
PG	Pulse generator		
R_{cs}	Current sense resistor	VR	Voltage controller

inductances and capacitances, and by transistors with short switching times of less than 50 ns.

The power transformer with its extremely low leakage inductance is a key component for low-loss energy conversion.

New generation of DC/DC hybrids

DC/DC converters based on the circuit topology described [2] were designed in ceramic multilayer technology for the 5 W to 60 W power range (**Table 1**). Modified versions with reduced power are also available for a logic voltage of 3.3 V.

Converter efficiencies better than 80% are attained at a maximum frequency of 700 kHz. The exacting requirements of telecommunications systems are met with an output tolerance of ±3% and a residual voltage ripple of less than 1%.

With a low insertion height of 8.3 to 17.5 mm, the new converters can be used even in the most densely packed system card frames. Their flat open design facilitates heat dissipation by forced convection. The modules offer only minimum resistance to the air current between them, satisfying the requirement of an air flow rate of 1 m/s. Thanks to the optional flat heat sink on the underside of the substrate, the modules can also be used with free convection under extreme temperature conditions. Despite stringent RF interference suppression requirements (class B), no extra EMC components are needed by the on-board assembly, nor is a metal casing required for electromagnetic shielding.

State-of-the-art techniques, such as passive and active laser trimming, are used in the manufacture of the ceramic multilayer series. Key components specially developed for this application include not only the control ICs, but also a new generation of planar multilayer inductors, such as transformers and storage chokes.

Planar multilayer inductors ensure high power density

Particularly high performance is required from the inductive components used in this circuit topology. High output currents of about 1 A for the 5 W module to 12 A for the 60 W module must be obtained in conjunction with low output voltages and an overall component height not exceeding 10 mm. Low leakage inductance, low coupling capacitances and very low ohmic resistances must be ensured in the manufacture of these components with high reproducibility. To avoid excessive heat generation, power dissipation in the ferrite core and the winding must be kept as low as possible. On the mechanical side, perfect reflow solderability for surface mounting, coplanarity of less than 0.1 mm and high long-term mechanical stability. deserve special mention.

For the 5 W and 15 W modules, standard winding components based on ER 11 and low-profile RM5 (rectangular module) cores made of materials N49 and N87 (chokes) were used. However, the demand that the wire thickness be linked to the SMD coplanarity requirement and the winding factor required proved difficult to meet in terms of production technology.

The 30/60 W modules could not be produced with standard winding technology because either the wire cross-sections required for the currents would not fit in the winding space or the wire cross-sections possible could no longer handle the currents required. The skin effect in 700 kHz transformers plays a critical role in this context. It proved impossible to balance the coplanarity requirement with the thick wires that had to be wound in gull-wing technology.

Planar technology was the obvious alternative. Here the wire winding is replaced either by stacks made up of punched copper parts, capton insulation film and simple circuit boards, or by a pure multilayer winding. Basically, both technologies satisfy the electrical requirements.

In terms of production technology and mechanical tolerance, only planar multilayer components can satisfy the stringent requirements for the modules. The cemented stack made up of different materials has different coefficients of expansion, so that at best only the soldered-on SMD terminals no longer have a coplanarity of less than 0.1 mm. As a rule, however, the mechanical stresses are so high that the structure of the entire stack is destroyed or the surrounding planar E-core is ruptured. The shape of the latter likewise makes it unsuitable for reflow soldering [3].

The design of the low-profile RM planar multilayer inductor makes use of high-tech methods [4]. Multilayer circuit boards of FR4 material have high mechanical

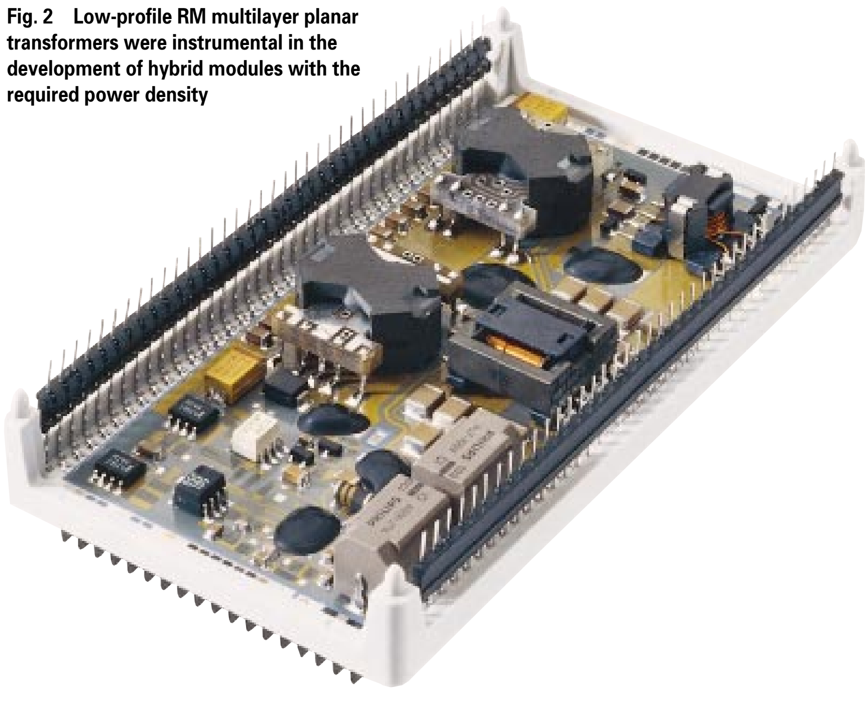
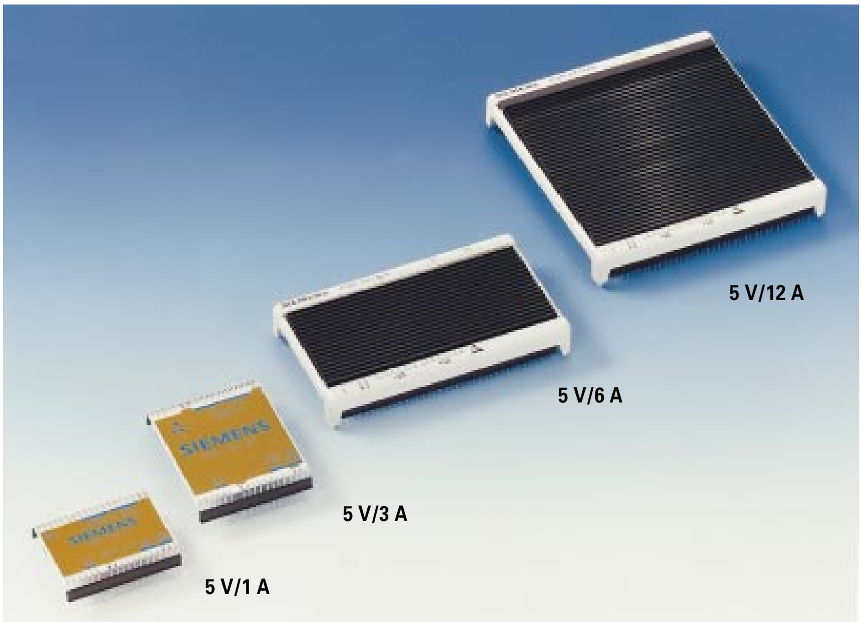


Fig. 2 Low-profile RM multilayer planar transformers were instrumental in the development of hybrid modules with the required power density



Type	5 V/1 A	5 V/3 A	5 V/6 A	5 V/12 A
Dimensions in mm	50.8 × 37.6 × 8.3	57.6 × 47.8 × 9.7	107.1 × 59.6 × 12.5	109.6 × 107.1 × 17.5
Weight	17 g	22 g	100 g	250 g
Efficiency	82 %	82 %	83 %	84 %
Input voltage range	37.5 to 80 V			
RF interference suppression at input	Class B			
Output voltage tolerance	±3 %			
Output ripple (peak-to-peak)	≤50 mV			
Temperature range	−40 to +70 °C at air flow rate of 1 m/s			
MTBF	≥2,000,000 h			
Service life	≥220,000 h			

Table 1 The hybrid DC/DC modules cover the current range from 1 to 12 A at 5 V

stability and can easily be reflow-soldered. Siemens Matsushita Components has many years of experience in manufacturing low-profile RM cores from RF power materials N49 and N687. These are finely pressed standard RM cores whose electrical, mechanical and thermal properties match the full range of functions required. Compared with planar E-core solutions, the circular shape of the windings and their compact design result in even lower leakage fields and lower ohmic resistances. Openings in the windings also ensure good heat dissipation.

Thanks to their transparent design, low-profile RM multilayer planar transformers are suitable for automatic assembly with a minimum of cemented parts. That also means that at the end of their useful life, modules can easily be disassembled and fully recycled – an environmentally friendly solution. Narrow production tolerances can be maintained, so that their electrical performance increases the efficiency of the high-frequency forward converter circuit.

The key technical data of the low-profile RM7 transformer for the 5 V/6 A hybrid module (**Fig. 2**) are:

- primary copper resistance $R_{\text{cu prim}}$ of 48 mΩ
- secondary copper resistance $R_{\text{cu sec}}$ of 5 to 50 mΩ (application-specific)
- primary inductance $L_{\text{o prim}}$ of 69.3 μH
- copper and iron losses $P_{\text{v cu+fe}}$ of 0.45 W (at 700 kHz/20 °C excess temperature/natural convection).

Both the DC/DC converter and the RM multilayer planar inductors are high-tech products that open up new dimensions in performance. Because they satisfy the exacting requirements of telecommunications technology, they are ideal for many other applications. ☐

References

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