The "MPCG" of Large-Current Choke Coils Using the Low-Loss Metallic Magnetic Material "Senntix"

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Abstract

Recently, the decrease in voltage and the increase in the current demand of mobile notebook PCs have led to more importance being placed on improving the power loss characteristic. In order to meet this trend, NEC TOKIN has developed the MPCG series of integrally molded choke coils that feature improved power conversion efficiency by the use of a low-loss magnetic core material called "Senntix." The series achieves a high-current energization capability and a significant reduction in core loss. It incorporates a flat rectangular conductor coil that is wound edge-wise and is fabricated with "Senntix" in a one-piece construction format. It is likely that the power load to the power supply system of electronic equipment will continue to increase in the future. We therefore intend to expand the product lineup and enhance the specifications of the MPCG series and to position them as optimum solutions for electronic equipment energy saving countermeasures by suppressing the amount of heat generated and improving their power integrity.

Keywords

metallic glass, low loss, one-piece construction, inductor, choke coil, DC/DC converter

1. Introduction

The performance and functionality of electronic equipment has recently been rapidly improved and enhanced. At the same time, it is evident that there is a need for a reduction in the size and weight of electronic equipment as well as an accelerated increase in the packaging density of devices mounted in electronic equipment.

Also, in the market for IT terminal products, the dissemination of tablet-type terminals is increasing rapidly. These advances feature handy, stylish designs and easy operation, etc. To cope with such advances, tablet-type terminals have to be slim and light weight, and at the same time they are expected to be equipped with sufficient processing capacity and a long-hour operation performance.

While accelerating the dissemination of tablet-type terminals, notebook PCs are not only required to feature a high processing performance but also need even more size/weight reduction and increased operation hours. Such a trend is expected to be accelerated. In order to cope with such constraints, the choke coil to be used in the DC/DC converter mounted in new notebook PCs featuring compact and slim designs is therefore effectively required to reduce losses in the high frequency band as well as being compatible with a high current.

This paper introduces the MPCG Series of low-loss, high-current choke coils that are optimized for use in the DC/DC converters in the CPU drive systems meeting the requirements for ultra-slim PCs that will become widely available in the markets of the near future.

2. Electrical Energy Losses of Choke Coils

In general, the battery drive time of a notebook PC is determined by the power consumption for the CPU drive, etc. When a DC/DC converter is used to supply the CPU drive power, part of the electrical energy is converted into heat that is dissipated and lost. Among such losses, those of the choke coil can roughly be classified into two types. One is the "iron loss" that is a loss by magnetic hysteresis of the magnetic core materials and eddy currents, and the other is "copper loss" that is a loss by the electrical resistance of the wound coil; both of these consume the supplied electrical energy as heat energy.

The energy consumed as heat does not contribute to the CPU drive and is therefore counted as a loss.

The MPCG Series has achieved more efficient power sup-

ply to CPUs by adopting the low-loss metallic magnetic material "Senntix" that can reduce the above mentioned iron loss substantially. This trend has also resulted in extending the battery drive time and has thereby contributed to a reduction in the amount of heat generation in notebook PCs.

3. Magnetic Core Material

The MPCG Series has adopted Senntix as its magnetic core material. This material has a lower loss characteristic than the metallic magnetic materials used conventionally in magnetic cores. **Fig. 1** shows the core losses for Senntix and for the traditional material. Senntix is a metallic glass material with iron as the main constituent element that has an amorphous crystalline structure. As a result, it has an extremely low hysteresis loss and the overall loss of the coil at 300 kHz is as low as about 1/3rd that of the traditional coils. This low loss characteristic can also be maintained at a higher frequency of 1 MHz. It can thus reduce the core loss even when the material is used in a high-frequency drive such as may be required as a result of the more compact size and thinner profile of notebook PCs. As a result, it is expected that this material will be of increased importance in the future.

In addition to the low loss characteristic, another feature of Senntix is that it offers both a high saturation magnetic flux density that can handle high-current energization and a high relative magnetic permeability.

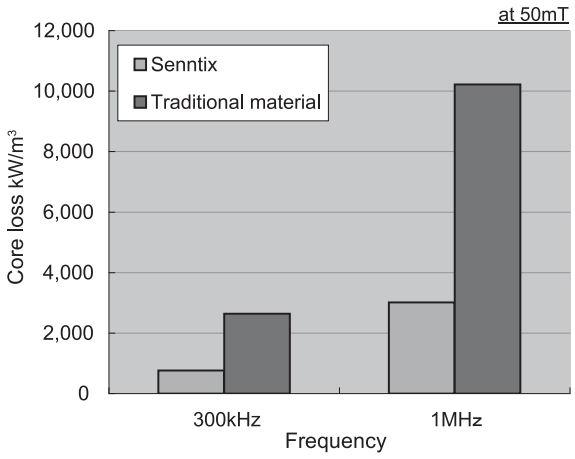


Fig. 1 Core loss comparison per frequency between Senntix and conventional materials.

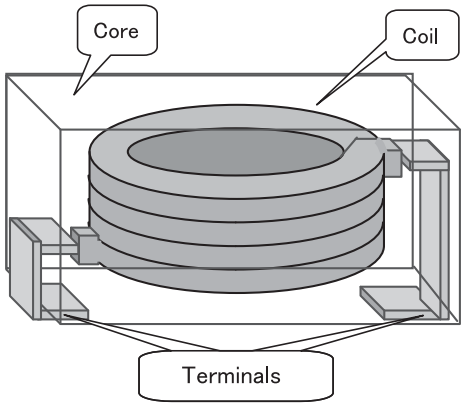
These features make Senntix also suitable for use as the core material of high-frequency driven and high-current energized choke coils for use in the thin profile PCs of the future.

4. Product Structure

The MPCG Series of choke coils have a one-piece construction format that is fabricated by pressure forming a coil composed of edge-wise windings of flat rectangular copper wires, using Senntix (**Photo** and **Fig. 2**).

The magnetic core that forms the product is also fabricated by pressure forming in which metallic particles are bound together by an insulating binder. The insulating binder

Photo MPCG product view.



	MPCG series
Coil	Flat Copper Wire
Core	Senntix
Molding	Pressurization Molding
Terminal	Direct Terminal

Fig. 2 MPCG structure.

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forms gaps distributed between the metallic particles at the same time as binding them (**Fig. 3**). The synergy of the distributed gaps in the structure and the amorphous crystalline structure of the Senntix metallic magnetic material minimizes the eddy currents generated in the magnetic material. A core with extremely low loss is thus implemented that has not been achievable with previous choke coil products. In order to reduce the copper loss the coil is made of a flat rectangular copper wire, which is advantageous for improving the coil space factor in a limited space. The wire is wound in an edge-wise direction in order to reduce the winding height and the lead areas are implemented as directly-mounted terminals by drawing the soldered lead wires from opposite sides after integral pressure forming. This structure eliminates the connection loss that used to be produced in the connection of the wiring materials and the terminals and makes the coil compatible with higher currents.

The integral construction by pressure forming does not leave spaces between the coil and core as was the case in the previous assembly type choke coils, thus enabling high thermal conductivity and achieving both low leakages of magnetic flux and less electromagnetic noise characteristics.

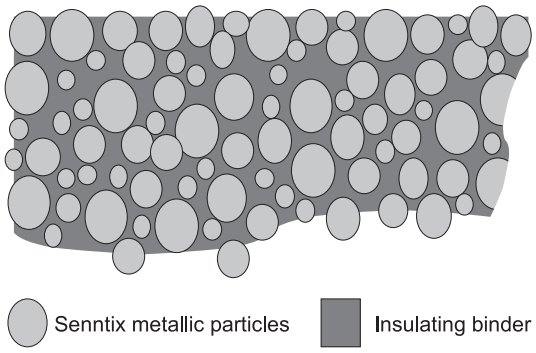

Fig. 3 Magnetic core model.

5. Product Characteristics

5.1 Power Load Efficiency Characteristic

The significant feature of the MPCG Series is that it improves the power load efficiency (I/O efficiency) by using the metallic magnetic material "Senntix" that offers low core loss characteristics.

In general, the core loss mostly affects efficiency on the low-current side, which corresponds to the battery drive time during light-load operation or in standby mode during the actual use of notebook PCs. **Fig. 4** shows a comparison of the power load efficiency characteristics of the new MPCG Series and of the MPC Series, which are our previous products. The adoption of Senntix by the MPCG series has improved the total loss by about 1.5% compared to previous products in the low current load domain of 0.1 to 3 A (ampere) where the core loss exerts effects most noticeably. Senntix with low core loss is used and a product structure with an improved coil space format is adopted in order to decrease the copper loss. Thus, the MPCG Series achieves high efficiency in the low to high current load domains.

The facts outlined above allow us to expect significant improvements in the battery drive time and in the heat generation amount while operating actual notebook PCs.

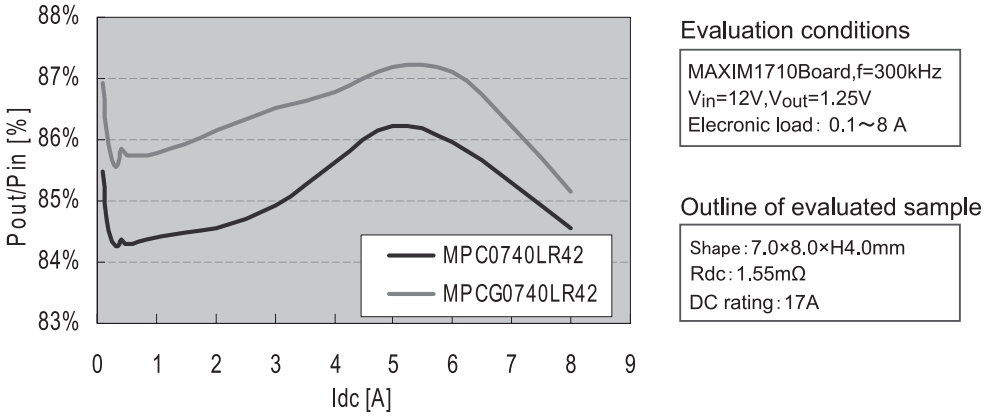

Fig. 4 Power load efficiency characteristics.

5.2 DC Superimposition Characteristics

Thanks to the use of Senntix with its high saturation magnetic flux density, the MPCG Series offer excellent DC superimposition characteristics with a low decrease in inductance under high current loads. In addition, the excellent temperature characteristics are capable of maintaining the saturation characteristics under environmental temperatures of 20°C and 100°C almost equally (**Fig. 5**). This means that the inductance does not deteriorate suddenly even when a rush or eddy current flows in the power line. This makes the MPCG Series optimum for low-voltage, high-current, multi-phase drive choke coils for use in driving the CPUs of notebook PCs, which allows them to manifest stable performances even in the high-temperature environment that results from long hours of operation.

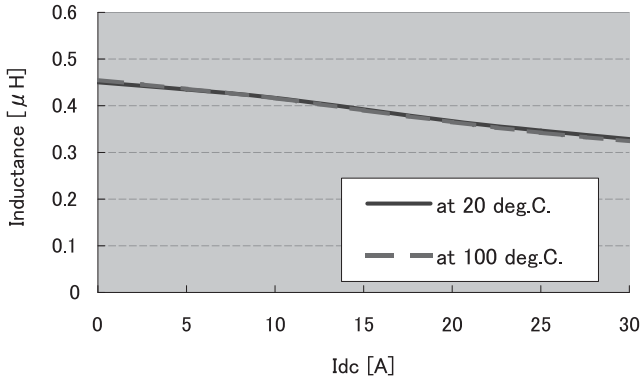

Fig. 5 DC superimposition characteristics.

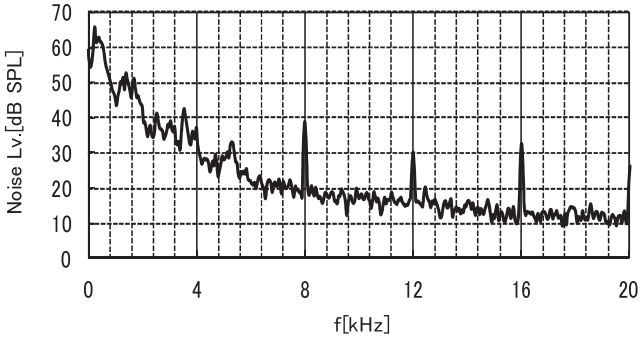

Fig. 6 Sound pressure level.

5.3 Electromagnetic Noise Characteristics

Conventional assembled-type choke coils have hitherto been fabricated by assembling a pair of internal coils. This arrangement tended to produce gaps both between the cores as well as between the cores and the coil, so that this structure often required the use of an adhesive to fix the gaps in order to optimally form the product and reduce rattling.

The MPCG Series integrates the coil and the metallic magnetic material by means of pressure forming and does not leave gaps between the coil and the magnetic material. As a result, a low electromagnetic noise characteristic is featured with a noise level below 40 dBs even at the resonance frequency of the electrical load (**Fig. 6**). This feature enables these choke coils to be optimised for use in products required to operate quietly such as for the CPU drives of notebook PCs.

5.4 Other Characteristics

The MPCG Series has a low leak magnetic flux characteristic thanks to a closed magnetic path construction with single-piece pressure forming of the coil and a metallic magnetic material. These choke coils do not produce electromagnetic coupling with other electronic components, even in the case of high-density packaging. Therefore they can alleviate the care required in the board design, such as for the placement of the choke coil and for considerations regarding other components.

6. Product Lineup

As shown in **Table** , the products lineup of the MPCG Series consist of compact choke coil products that are compatible with inductances from 0.36 to 0.88 μH and currents from

Table Dimensions and electrical characteristics of MPCG Series.

Product name	Dimensions [mm]	L [μH] at 100kHz	Rdc [mΩ]	Rated current [A]
MPCG0740LR42	7.0×8.0×H4.0	0.42±20%	1.55±10%	17
MPCG1040LR36	10.3×11.5×H4.0	0.36±20%	1.05±10%	25.5
MPCG1040LR45		0.45±20%	1.10±10%	25
MPCG1040LR88		0.88±20%	2.30±10%	17

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17.0 to 25.5 A. This lineup will be expanded in the future so that it may offer solutions for the use in ultra-thin PCs that are capable of offering even more compact and thinner products to our customers.

7. Conclusion

The MPCG Series of high current-compatible compact choke coils have electrical characteristics that are suitable for use in DC/DC converters with the associated large increase/decrease of voltages that are necessary for power supply lines. The features of these products including their large current compatibility and low loss characteristics make them suitable as choke coils for DC/DC converters for driving the CPUs of mobile notebook PCs and power supply lines of other systems (GPU, etc.). The actual adoption of such products in these areas is currently expanding.

Aiming at improving the energy efficiency of mobile electronic equipment that will lead the information society in the future, we intend to expand the specifications and product lineup and to position the range as optimum products that are compatible with various applications. It is our intension to promote these products as ones that may be used to provide optimum solutions for our customers.

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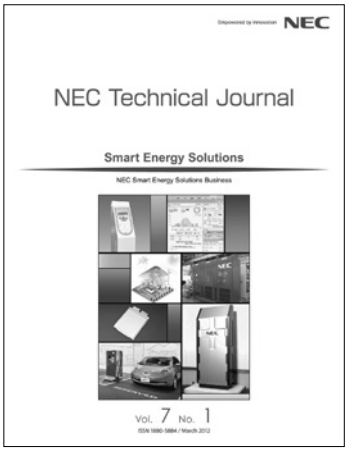

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