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

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Abstract

The accelerating trend in the increased density of the components packaged in various electronic devices has been tending to make the requirements of the standards for high current-compatible compact choke coils more severe than ever. In particular, in the case of the mobile notebook PCs, the decrease in voltage and the increase in current demand the more importance to improve 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 efficiencies by using a low-loss magnetic core material called "Senntix." The series incorporates a flat rectangular conductor coil that is wound edge-wise and is fabricated with "Senntix" by a one-piece construction method. The "Senntix" magnetic material features the high saturation magnetic flux density and stable amorphous crystalline structure that are characteristic of metallic glasses. A high-current energization capability and a significant reduction in core loss are also achieved.

Keywords

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

1. Introduction

The rapid recent improvement in the performance and functionality of electronic equipment has enhanced the requirements for reductions in the size and weight of electronic equipment as well as accelerating an increase in the packaging density of devices mounted in electronic equipment.

When we examine the shipment data of PCs, we find that the percentage of notebook PCs is increasing. Promoting this trend are improvements in the performances of notebook PCs, which now incorporate CPUs with a higher processing capability offering operating performances that are not inferior to those of desktop PCs. At the same time a compactness that is convenient both for carrying and storage is achieved. In addition, mobile PCs are not only required to provide high processing performances and size/weight reductions but also to improve the efficiency of power supply circuitry in order to extend the drivable time period.

The recent trend in the solution of the issue of coexistence of high performance and high efficiency is to increase the current and to decrease the drive voltage without changing the power consumption value of the PC. The choke coil to be used in the DC/DC converter of the new notebook PCs featuring low voltage and high current is therefore strongly required to reduce losses at the same time as being compatible with high current and a more compact size.

This paper introduces the MPCG Series of low-loss, high-current choke coils that are optimized for use in DC/DC converters in the CPU drive systems meeting the requirements for mobile PCs.

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 the DC/DC converter is used to supply the CPU drive power, part of the electrical energy is converted into heat and consumed. Among these losses, those at the choke coil can roughly be classified into the "iron loss" and "copper loss," both of which are consumed as heat energy.

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

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3. Magnetic Core Material

The MPCG Series has reduced the iron loss substantially by adopting Senntix as the 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 300kHz 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 600kHz. 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 increases in CPU speeds in the future. 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.

These features make it suitable for use as the core material of high-current energized choke coils for use in PCs.

4. Product Structure

The MPCG Series of choke coils have one-piece construction method that is fabricated by pressure forming a coil composed of edge-wise windings of flat rectangular copper wires, using the metallic magnetic material described above (**Fig. 2** and **Fig. 3**).

The magnetic core is also fabricated by pressure forming in which metallic particles are bound with an insulating binder. The insulating binder forms gaps distributed between the metallic particles at the same time as binding them (**Fig. 4**).

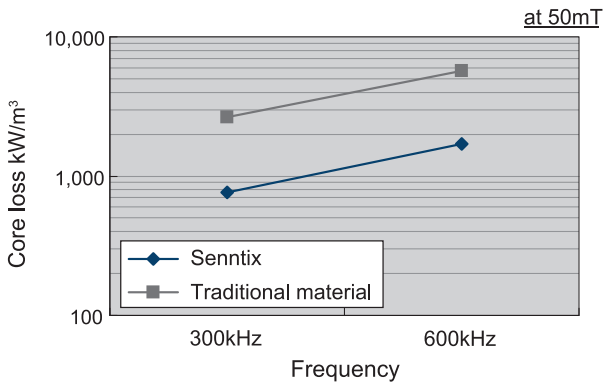
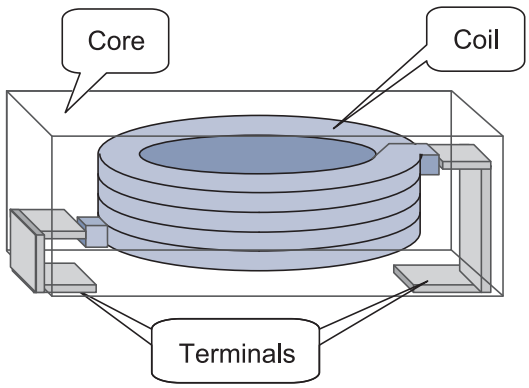


Fig. 1 Core loss comparison per frequency.

Fig. 2 MPCG product view.



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

Fig. 3 MPCG structure image.

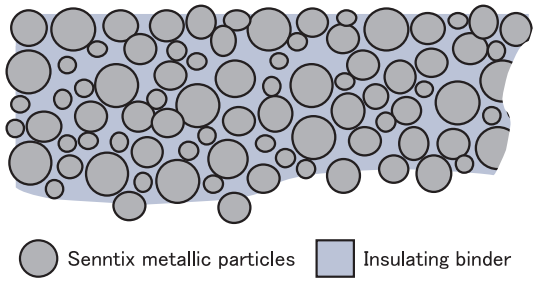


Fig. 4 Magnetic core model image.

The synergy of the distributed gaps in the structure and the amorphous crystalline structure of the Senntix magnetic material minimizes the eddy current 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 leak magnetic flux and electromagnetic noise characteristics.

5. Product Characteristics

5.1 Power Load Efficiency Characteristic

The MPCG Series improves the power load efficiency (I/O efficiency) significantly by using low core loss Senntix as a magnetic core material.

In general, the core loss mostly affects the 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. 5** shows a comparison of the power load efficiency characteristics of the new MPCG Series and the MPC Series, which are our previous products.

The MPCG Series has improved the total loss by about 1.5% from 0.1 to 3A compared to previous products at locations where the core loss exerts most noticeable effects. The use of Senntix with low core loss and a product structure offering an improved coil space factor allow the MPCG Series to offer high efficiency in the low to high load current domains (Fig. 5).

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

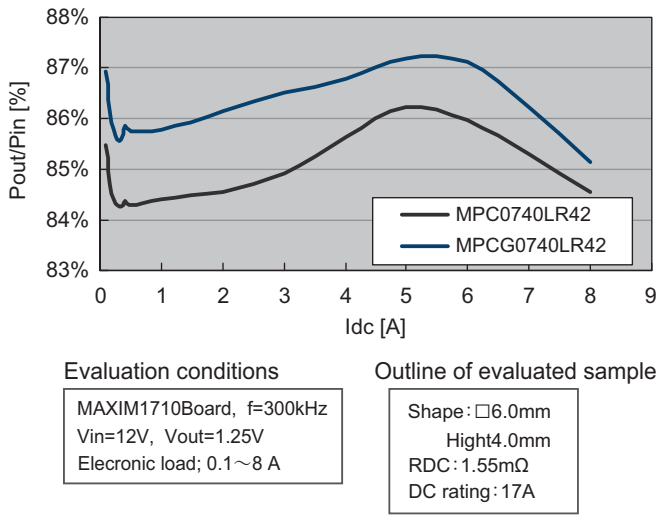


Fig. 5 Power load efficiency characteristics.

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. 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.

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. 6**), thus allowing notebook PCs to manifest stable performances even in the high-temperature environment that results from long hours of operation.

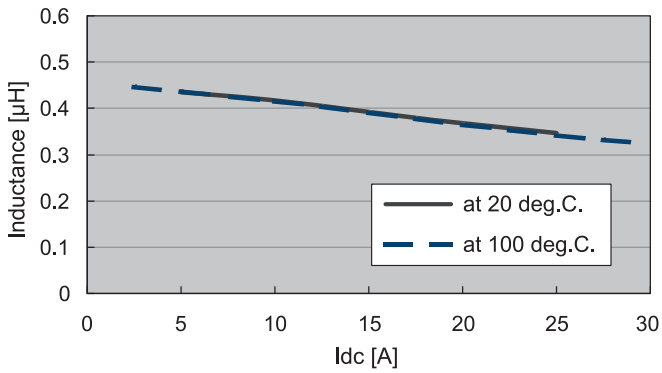


Fig. 6 DC super-posed characteristics.

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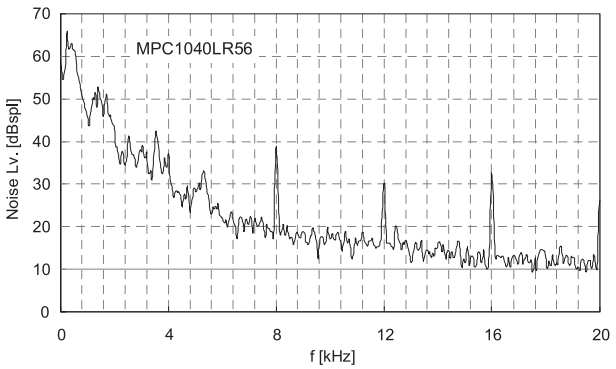

Fig. 7 Sound pressure level.

5.3 Electromagnetic Noise Characteristics

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

On the other hand, 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 40dBs even at the resonance frequency of the electrical load (**Fig. 7**). This feature enables these choke coils to be optimum for use in products required to operate quickly, such as for the CPU drives of notebook PCs.

5.4 Low Leak Magnetic Flux Characteristic

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 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 choke coil and for considerations regarding other components.

Table Dimensions and electrical characteristics of MPCG Series.

Product name	Dimensions [mm]	L[μH] at100kHz	Rdc [mΩ]	Rated current [A]
MPCG0740LR42	7.0×8.0×H4.0	0.42±20%	1.55±10%	17
MPCG1040LR36		0.36±20%	1.05±10%	25.5
MPCG1040LR45	10.3×11.5×H4.0	0.45±20%	1.10±10%	25
MPCG1040LR88		0.88±20%	2.30±10%	17

6. Product Lineup

The MPCG Series consist of compact □7mm and □10mm choke coil products that are compatible with inductances from 0.36 to 0.88μH and currents from 17.0 to 25.5A (**Table**). This lineup will be expanded in the future so that it may offer solutions for the development of various electronic equipment that is capable of offering a wide range of solutions to the 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 current increase/decrease 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 other system power lines (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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