Integrated Inductive Component Reduces Radiated Emissions in Power Applications

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The geometry of magnetic components can affect the incidence of unwanted low frequency radiation in the magnetic field.

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INTRODUCTION

The miniaturization trend has resulted in smaller components and greater board densities in electronic applications. This very density, which “packs” components into ever-smaller spaces, makes it more important than ever to examine the effect—including possible damage—each component may have on signals in nearby circuit paths and on other components. This article examines the way in which the geometry of magnetic components, such as inductors or transformers, may affect the incidence of unwanted, low-frequency radiation in the magnetic field. In the following experiment, commercially available inductors are used as an output choke in a DC/DC converter. Two types of inductors are used; drum cores which are magnetically-open paths and an integrated inductive component (IIC) with a full gap and a magnetically-closed path.

MAGNETIC PATH

The electrical properties of magnetic components, such as transformers and inductors, are based on three main parameters:

- The winding that transforms the electric current into a magnetic field.
- The magnetic properties of the material, such as magnetic permeability, that determine the magnetic flux induced by the magnetic field.
- The shape of the component that determines the path of the magnetic field.

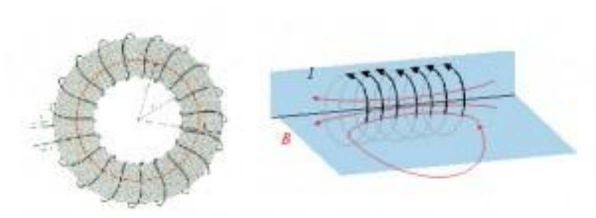

Figure 1. Flux distribution in a toroid (closed magnetic circuit) where no radiation can be noticed, and in a rod (open magnetic circuit) with radiation leaving the product.

The relationship of these three parameters will determine the basic properties of the magnetic component. With relatively simple formulas, it is possible to calculate the inductance, maximum current, and power loss of the inductor—*i.e.*, most of the electrical parameters needed to design a component for a given application. Also, the geometry of the component will influence the “radiation capability” of the magnetic component, a capability uninfluenced by any of the electrical parameters used in the design. For a clearer understanding of the crucial role of geometry *vis-a-vis* radiated emissions, magnetic components can be broken into two groups.First, in closed magnetic circuits, the magnetic flux remains inside the magnetic core, and most of the magnetic-field lines are closed lines surrounded by the winding. A good example of this first geometry is a toroid (Figure 1).

Figure 2. An integrated inductive component (left) and a drum core (right) are shown.

Second, in open magnetic circuits, the magnetic flux flows briefly in the magnetic core and is then radiated. The magnetic-field lines are open; or if they are closed, most of their length is not within the magnetic core but passes through the ambient air. A sample of the second geometry is a rod (Figure 1). In fact, there are many geometric configurations that will lead to designs that “radiate” to a greater or lesser extent depending on just how “open” they are. The products examined in this article are two examples of the aforementioned geometries and show similar electrical properties.

Inductance is about 5 µH, DC resistance below 10 m., saturation current of approximately 7 A for the Integrated Inductive Component and approximately 10 A for the bobbin core. They have similar volumes: the IIC is about 576 mm3, and the bobbin core is about 650 mm^3 (Figure 2).

WHY IS MAGNETIC RADIATION AN ISSUE?

In many power applications, such as power conversion, magnetic components are subjected to high currents and, consequently, to very high magnetic fields. Depending on the core geometry, strong fields may be radiated. Such a low frequency field is relatively strong in the area near the magnetic components and most probably will couple with any loop present on any PCB close to the component.

This likelihood means that harmful switching harmonics can appear anywhere in the circuit, degrading the quality of digital signals, or even damaging other ICs.Functionality may be the first criterion in choosing a component; but ultimately, the equipment containing that component must comply with EMC regulations. Several committees have set limits for both conducted and radiated interference. In Europe, CISPR 16 sets forth the measuring procedures/methods for such low frequency radiation (9 kHz to 30 MHz). Measurement specifics applicable in the United States can be found in FCC, Part 15.

TEST METHODS AND EXPERIMENTS

This experiment relies on the so-called "van Veen method."[1] Using this method, the device-under-test (DUT) is placed within a loop antenna two meters in diameter. This loop antenna is made of RG223/U coaxial cable with two slits (fitted with resistor networks) placed symmetrically, each 90° from the current probe. Figure 3 depicts the antenna setup.

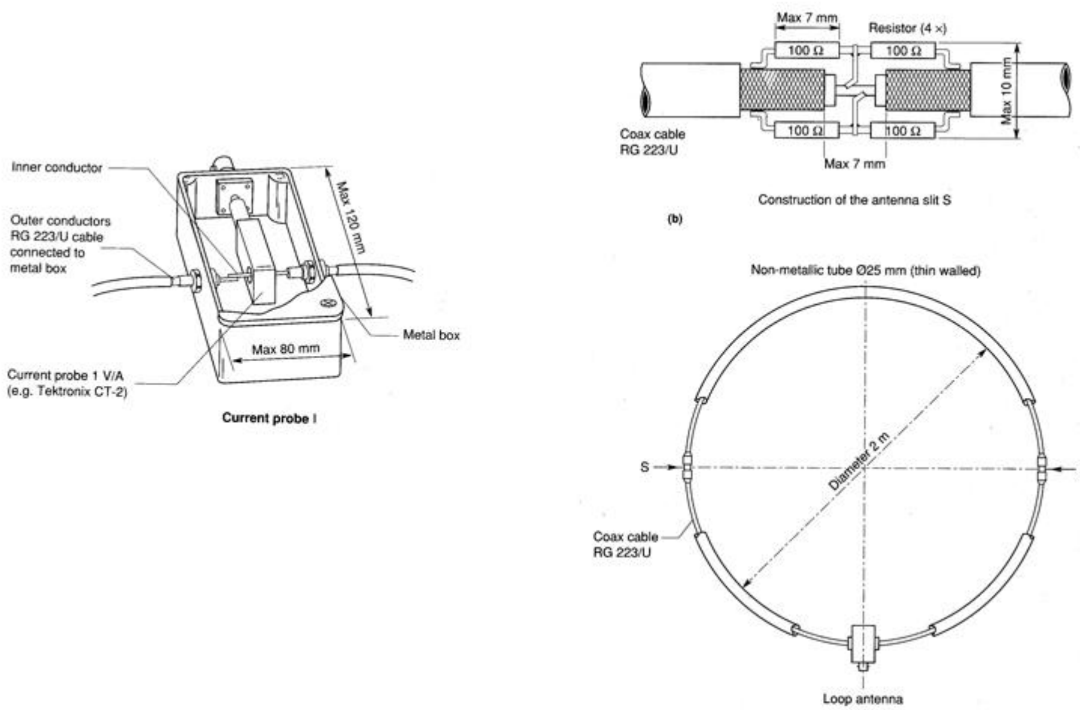

Figure 3. Antenna loop used to carry out H-field measurements in the range 9 kHz to 30 mMHz. The current probe translates the current in the loop to voltage.

The current induced in the loop is measured by a current probe connected to a spectrum analyzer and is expressed in dBµA. In this test setup, the noise from the environment will be negligible as compared to the currents from the DUT. To check the effect of radiation, the DUT was connected to an RF power amplifier, using a 100-kHz square wave of 2.8-A amplitude. The objective of this experiment is to measure the radiation under similar conditions for both the open magnetic circuit and the closed magnetic circuit.

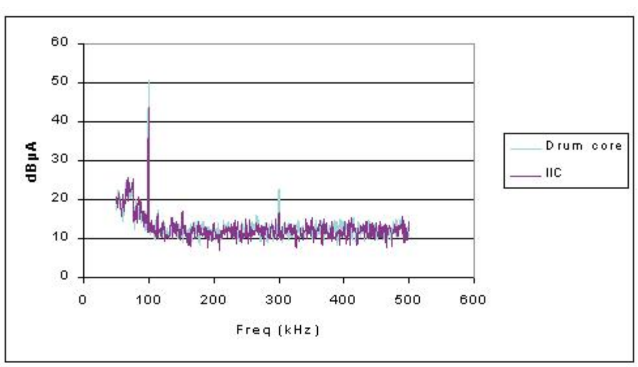

Figure 4. Radiation on a drum core and a IIC excited with a square wave: 100 kHz, 2.9 Amps peak-peak. The square voltage becomes triangular current when passed across the inductors. The main frequency and the third harmonic can be seen at 100 and 300 kHz.

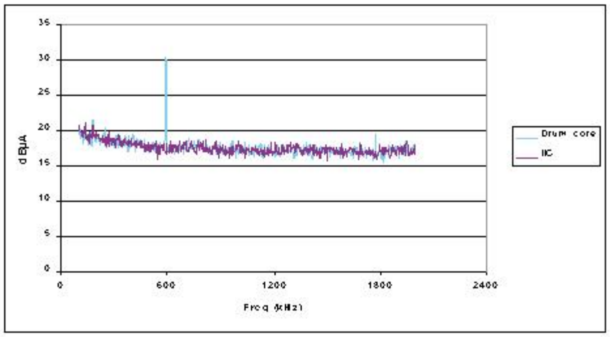

Figure 5. IIC and drum core working as output choke on a DC/DC converter, IIC shows negligible radiation (comparable with the noise generated by the rest of the circuitry), while on the drum core, two harmonics can be seen at 600 and 1800 kHz.

Figure 4 shows the radiation generated by both components expressed in dBμA; these results confirm that open circuits have much higher radiation levels than closed circuits. Note the amplitude of the harmonics. The difference between the two components is 8 dBμA at 100 kHz (main frequency) and 6 dBμA at 300 kHz (third harmonic). Given these figures, it can be derived that the difference in radiation is almost constant, independent of the amplitude of the signal. Consequently, the advantage of using closed magnetic circuits holds true in every case even where radiation is relatively low.

The next experiment compared the inductors in a real application, a DC/DC converter working as an output choke. The converter is a standard design and the operating test conditions were as follows: 2.3-V output voltage delivering 2 A and a switching frequency of 600 kHz. The results given in Figure 5 clearly depict the advantage of using the integrated inductive component versus the drum core. When the IIC is used, radiation levels stay within the radiation values of the overall system. At this higher frequency (600 and 1800 kHz), there is a marked difference between the two components as compared to the disparity at low frequencies (100 and 300 kHz). A comparison between Figures 4 and 5 shows that the radiation of the DC/DC converter is 5 dBμA, in the frequencies unaffected by the radiation of the inductors.

CONCLUSION

At low frequencies, both conducted and radiated interference should be taken into account. These design principles are necessitated not just by regulatory limits but by the demands for functionality and design integrity in the completed system. Magnetic components with a closed magnetic circuit design (*e.g.*, an integrated inductive component) produce very little or negligible radiation. The use of IICs helps forestall such problems as inducing currents on the tracks, currents that could damage components, and currents that might influence other signals. These closed magnetic circuit devices are, therefore, well suited for use in any kind of equipment where other circuits or PCBs might be affected by magnetic radiation.

REFERENCES

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