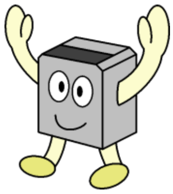
Tips for COIL users (8)



● Introduction

The eighth topic is concerning "**eddy current and magnetic shield**".

● Magnetic shield

To shield a coil, there are three ways; to reflect, to absorb and to divert unnecessary signals.
The magnetic shield which shields a magnetic flux (magnetic field) covers a coil with a magnetic material (the magnetic flux is easier to pass more easily through the magnetic material) as Figure-1.
Then the shield diverts and blocks off the magnetic flux (by concentrating the magnetic flux in the magnetic materials).
Not only the shield can block off but it also prevents unnecessary signals from leaking from inside.
Some shielded inductors have structure which covers outside of coil with the magnetic material, so that the magnetic shield prevents flux inside of the coil from leaking.

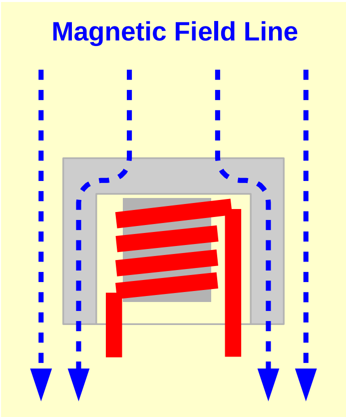


Fig.-1 Magnetic shield

● Eddy current and effect

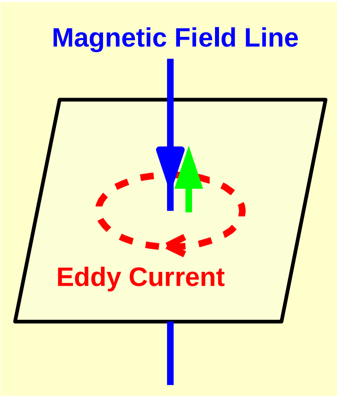


Fig.-2 Eddy Current

When the magnetic flux which passes through the metal varies (magnetic field by alternate current), an eddy current is generated on a metal surface to deny (**Green arrow** in Figure-2) the variation of original magnetic flux as Figure-2.
The magnitude is proportional to the frequency (low frequency = small electromagnetic induction as variation of flux is small).
In addition, the higher conductivity is, the more the current flows. Therefore, the metal materials such as copper or aluminum have large eddy current.
As the eddy current value is proportional to the frequency, we can expect the advantage of offset at high frequency, not at low frequency.
As we explained earlier, the eddy current flows in direction that offsets magnetic flux. Due to that, when the metal is placed near to the coil, the inductance value may decrease or the loss may increase (= decreased Q).
The shielded inductors are not affected so much because it has a small leaking of magnetic flux in structure. Meanwhile, the open magnetic inductors are affected more because the magnetic flux is exposed around the coil.
When the inductor is placed on a printed wiring board, if its position is near to the ground pattern or the metal part of chassis, the eddy current flows and the inductor may be affected by it.

● Magnetic materials used for coil

We can increase inductance by using magnetic material. But as the magnetic flux passes through the magnetic material, the eddy current occurs if the magnetic material has conductivity (metal). As the electrical characteristics get worse when the eddy current flows, it is generally understood that magnetic material for coils must be

insulating material such as ferrite, which no eddy current flows.
There are some power inductors of which DC saturation current has been improved by using the metal as the magnetic material. Even in that case, metals are powdered and insulated to prevent the eddy current from flowing among powders, so that no loss by the eddy current is generated (refer to Figure-3).

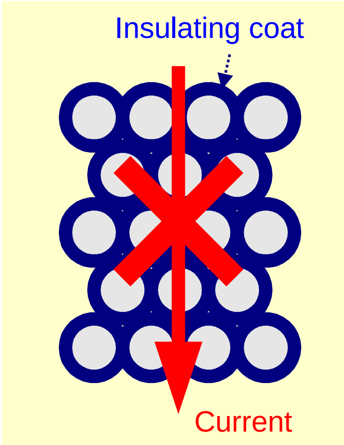


Fig-3 Current does not flow into insulator.

● Electromagnetic shield

For the magnetic shields, the coils are shielded with the magnetic materials. On the other hand, some shields reflect and block off outside by using the eddy current.
When the frequency is low, the eddy current is hard to flow (= shield effect is small), so the advantage may not be expected.
However, when the frequency is high, the magnetic field (electromagnetic shield) can be generated by making use of the phenomenon that the eddy current offsets the magnetic flux. In general, effect of electromagnetic shields with metal is expected from more than approximate 10 kHz in frequency.
In this case, the materials for shield are not the magnetic materials, but the metal materials in which the current flows well (such as copper, copper alloy and aluminum). In addition, for the electromagnetic shields, by connecting the metal to the ground, the advantage can be expected as the electrostatic shield.

● Effect of electromagnetic shield

We covered the open magnetic inductor with phosphor-bronze plate in thickness of 0.1mm, and measured it (Photo-1).
Characteristics are shown in Graph-1 as follows: a single coil（**Red line**）, a coil which avoids contact with the edge of phosphor-bronze（**Blue line**）, and a coil which is fully connected to the edge by solder（**Green line**, image is shown in Photo-1, right side）.

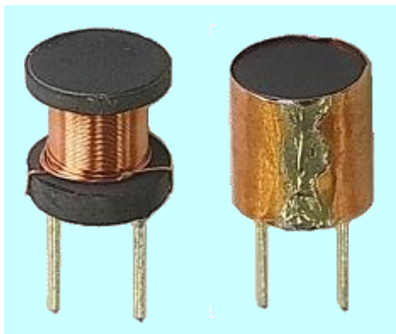
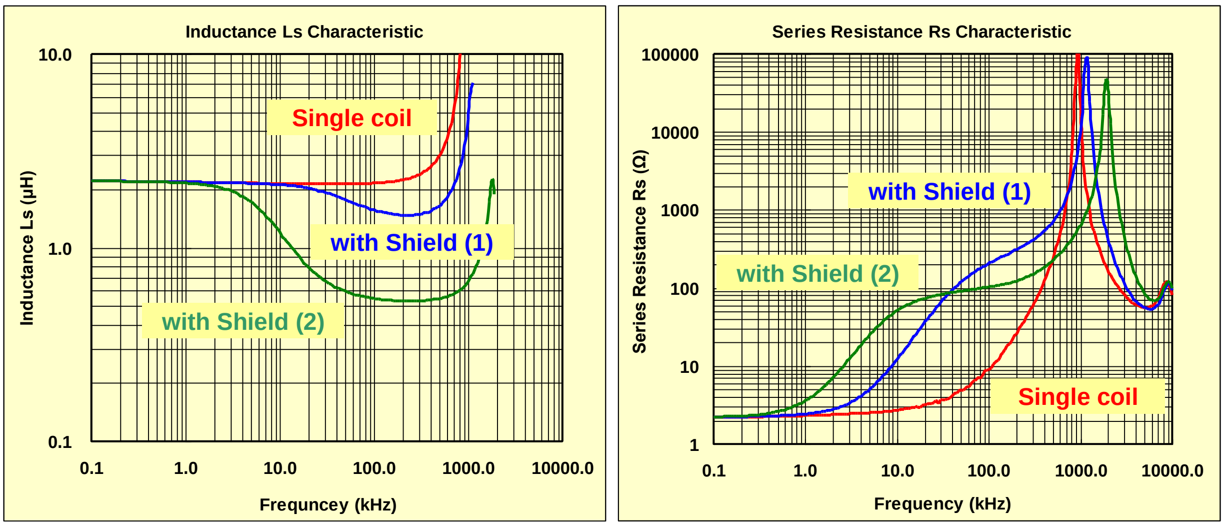


Photo-1 Evaluated Coils



Graph-1 Effect of Metal shield

The way of the eddy current flows varies among them as well as characteristics. Especially, the eddy current itself is small at low frequency, so we can find that the effect (the advantage as shield) is also small.

For electromagnetic shields, it is important to ensure the conduction of connection area.

For the radio frequency coils, the metal case is used to shield, but it isn't used for the power inductors.
Because in the case of the open magnetic inductors the electrical characteristics decrease significantly (inductance decreases and loss increases) against the advantage of shield. Also in the case of the shielded inductors, advantage of shield is low despite the increased cost.

Y.Hoshino