Determining Inductor Power Losses

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Core, DCR and ACR Losses

Abstract

As power supply output current requirements continue to increase, it is important for the design engineer to pay close attention to inductor power losses and their affect on overall power supply efficiency. This paper introduces the basic formulas to determine the approximate inductor power losses.

Introduction

The demand for an improvement in power supply efficiency, and therefore, inductor efficiency has increased quite rapidly. This demand has come as a result of an increase in power supply output current. At the same time, there has been a renewed effort to reduce the amount of heat that power supplies have to dissipate, which has a direct effect on overall power supply efficiency. The reduction in heat creation is especially important to laptop users. Since heat creation and inductor power loss are directly related, it is extremely important to reduce inductor power losses. To reduce these losses, it is necessary to understand where the they come from.

Inductor Power Loss

The power loss of an inductor is defined by the basic formula:

$$P_{loss} Inductor = P_{core} + P_{dcr} + P_{acr}$$

Each component of this formula is discussed below.

P_{core}

The calculated and/or measured core loss is often directly provided by the inductor supplier. If not, a formula can be used to calculate the core loss. Measuring core loss and getting repeatable results can be a tedious task depending on the test frequency. A general form of the core loss formula for ferrite cores is:

$$P_{core} (mW) = K_1 f^x B^y \times V_e$$

Where:

 K_1 = Constant for core material
 f = Frequency in kHz
 B = Peak Flux Density in kGauss
 x = Frequency exponent
 y = Flux Density exponent
 V_e = Effective core volume (cm^3)

The core loss can be calculated by entering the K_1 coefficient and the frequency and flux density exponents, which are unique to each core material.

P_{dcr}

The wire loss caused by dc resistance is easy to calculate. It is defined by this basic formula:

$$P_{dcr} (W) = I_{rms}^2 \times DCR$$

Where:

 I_{rms} = The rms value of the peak current applied to the inductor
 DCR = The dc resistance of the inductor

P_{acr}

The wire loss caused by ac resistance is more difficult to calculate since ac winding resistance values are not always readily available from magnetics vendors. P_{acr} is defined by the following formula:

$$P_{acr} (W) = I_{rms}^2 \times ACR$$

Where:

 I_{rms} = The rms value of the peak-peak ripple current applied to the inductor
 ACR = The ac resistance of the inductor

The inductor power loss information can be often be provided by inductor suppliers for most of their products. In an effort to speed up the design process for engineers using inductors, Coilcraft has developed a calculator for estimating inductor core and winding loss. The calculator is based on the formula:

$$P_{loss} Inductor = P_{core} + P_{dcr} + P_{acr}$$

Conclusion

This paper has introduced the basic formulas used in determining inductor power loss. It also discussed the importance of knowing where inductor power losses come from in order to reduce heat creation and thus improve overall efficiency.

For a more thorough discussion on ac losses refer to: Document 1400, titled Choosing Inductors for Energy Efficient Power Applications.