Technical Bulletin

BULLETIN NO. FC-S1

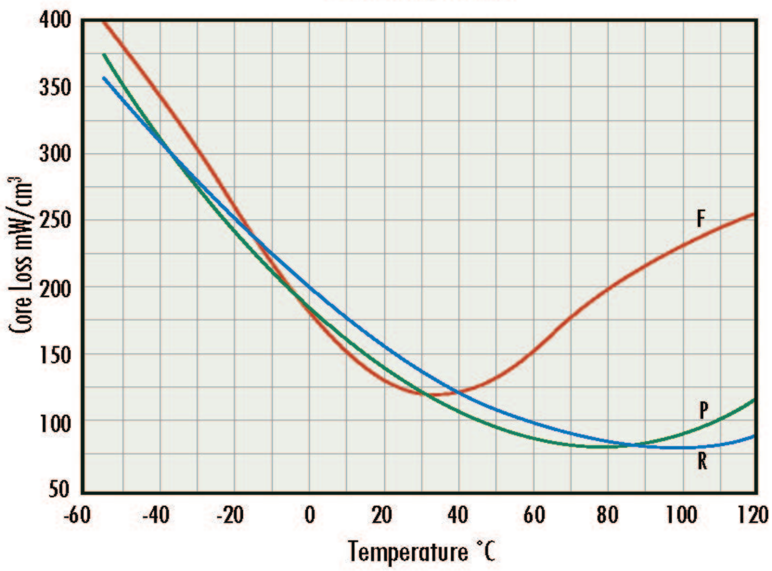
Ferrite Core Material Selection Guide

Introduction

In the design of ferrite core transformers for use in switchmode power supplies, one must take into consideration switching frequency, operating flux density, the resulting core loss, and temperature of operation. Temperature rise above ambient is a direct result of core losses in the ferrite material and of copper losses in the windings. To limit the temperature rise due to core losses, the designer must limit the operating flux density for the specified switching frequency.

The type of ferrite material chosen will influence the core losses at the given operating conditions. The different ferrite materials are designed to have minimum core losses within specific temperature ranges (see Figure 1). From these curves it can be generalized that F material has its lowest losses at room temperature to 40°C, P material has lowest losses at 70°C to 80°C, and R material has lowest losses from 100°C to 110°C. Please reference Magnetics Ferrite Catalog for additional characteristics of the power materials.

Figure 1
Core Loss vs. Temperature
@ 100 kHz, 1K Guass



Performance Factor

For material selection based on frequency, one recent trend has been to plot curves of "performance factor" (B x f) versus frequency at some defined core loss density. The performance factor is a measure of material utility derived by multiplying the operating frequency by the corresponding flux density level that would yield the predefined core loss value, where:

B = Flux Density
f = Operating Frequency

MAGNETICS power materials are plotted in this manner in Figures 3 through 6. By observation of these curves, it appears that an optimum material can be selected for a particular operating frequency. However, this comparison method only yields a relative figure of merit for the chosen material, and the design engineer must perform further analysis to determine a usable value of flux density for a given frequency and core loss density level that will limit the temperature rise value to acceptable levels.

FERRITE MATERIAL UTILITY
(B x f) vs. FREQUENCY
@ constant core loss = 300mW/cm³

Figure 3

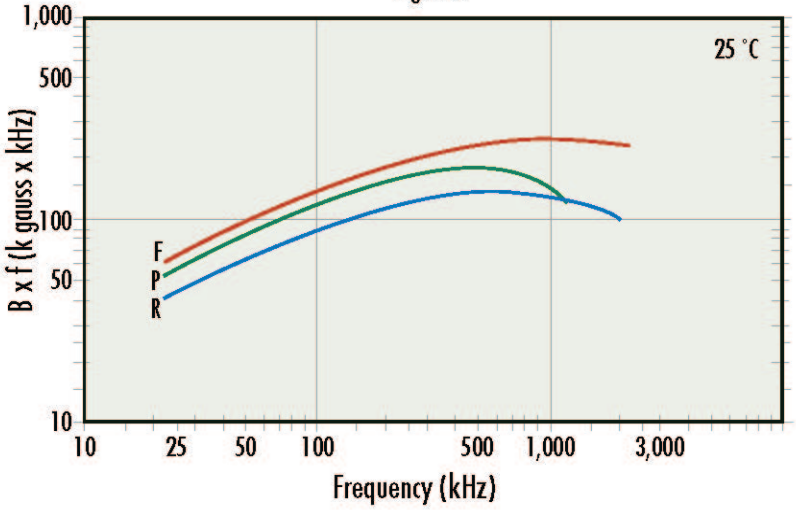


Figure 4

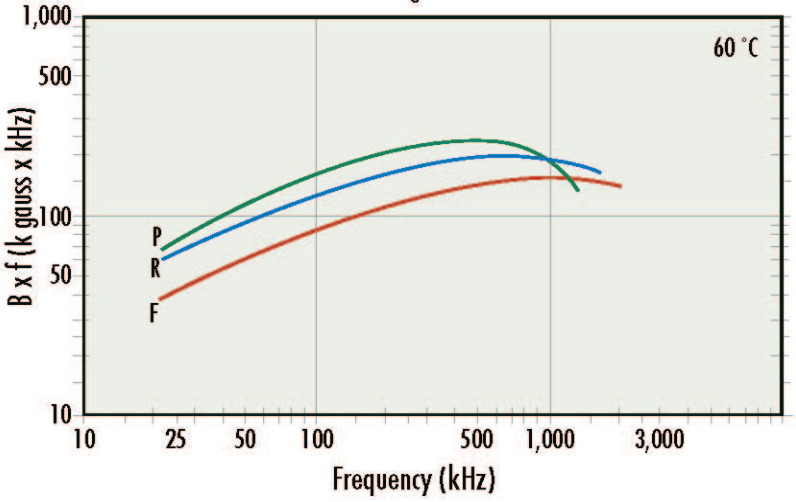


Figure 5

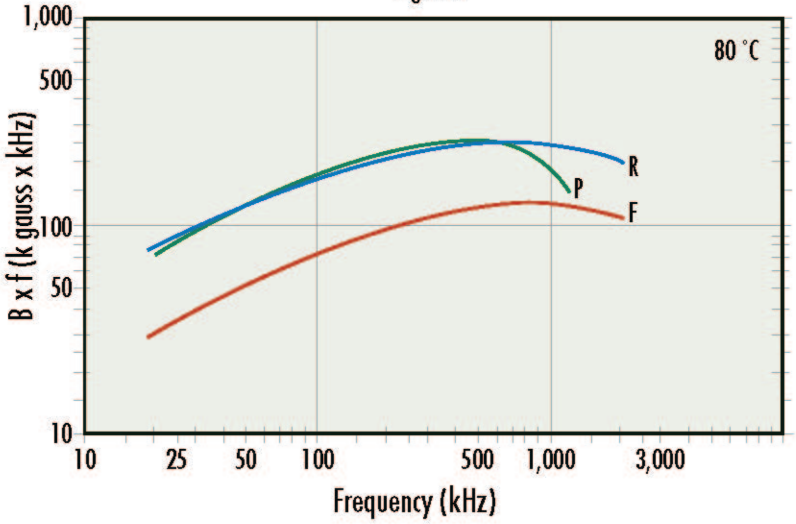
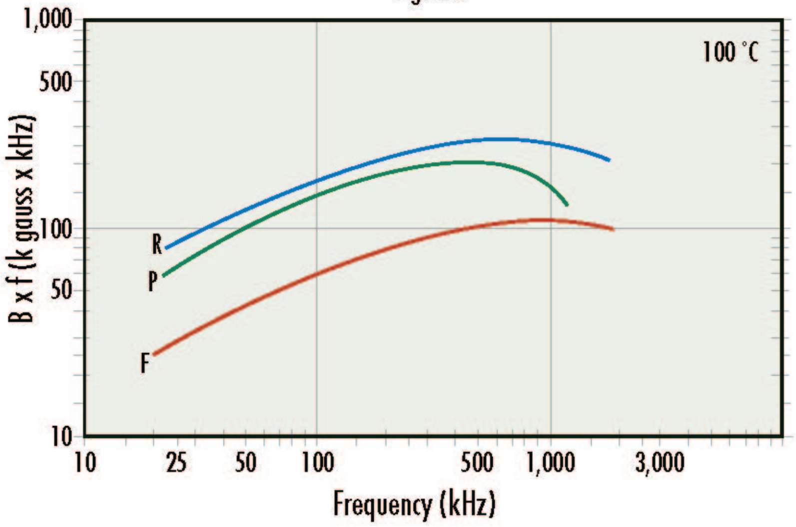


Figure 6



Temperature Rise Consideration

It should be noted at this point that the designer is not always free to choose the switching frequency of the power supply so as to optimize the usage of the chosen core material. The upper limit of the frequency may be dictated by the individual characteristics and economics of other components in the power supply.

As operating frequency increases, it is necessary to adjust the flux density in order to limit core temperature rise. MAGNETICS has developed a set of curves that best illustrates this. Figures 7 through 10 are based on limiting the core loss density to 100 mW/cm³, a figure that would keep the temperature rise at approximately 40°C **for medium sized cores.** Using these curves, the designer can quickly choose the flux density for his device at any frequency while maintaining the core loss at 100 mW/cm³. Multipliers are provided with the curves to account for a higher flux density value when designing for a higher core loss density.

USABLE FLUX DENSITY vs. FREQUENCY
@ constant core loss = 100 mW/cm³

@150 mW/cm³, multiply B by 1.15
@200 mW/cm³, multiply B by 1.30
@300 mW/cm³, multiply B by 1.45

Examples

For example, if an engineer has a requirement for a medium sized core used at 200 kHz, and the design can be operated at 100°C (75°C temperature rise above ambi-ent), what material and operating flux density should be chosen? The first step is to locate 200 kHz on the 100°C curves (Figure10). Keep in mind that the design is for a temperature rise of 75°C. From the curves one can see that R material will yield the highest usable flux density for 100 mW/cm³ (i.e., 800 gauss). But this only gives a temperature rise of approximately 40° C; a loss density of 200 mW/cm³ will produce about 70°C Δ T. Therefore, from the multipliers, the R mate-rial core can be operated at 1.30 x 800, or 1040 gauss. The design efforts can now be centered on using R material at the flux density in this example.

Summary

Figures 7 through 10, and the two examples above, provide a method for choosing among the various MAG-NETICS power ferrite materials. The actual temperature rise for a given core loss density will vary with core size, core geometry, winding losses and the method of heat removal. Small cores will develop a much lower temperature rise than large cores at the same core loss density, and the open shapes of E cores will dissipate heat more readily than enclosed shapes of pot cores.

Magnetics provides a wide range of power ferrites that have been opti-mized for various frequency and typi-cal temperature ranges. A complete description of each of these materials and the available geometries is pro-vided in Magnetics Ferrite Catalog.

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