Technical Bulletin

BULLETIN NO. CG-03

Selecting a Distributed Air-Gap Powder Core for Flyback Transformers

Introduction

Flyback converters are based on the storage of energy in an inductor during the “on” charging time period t_{on}, and discharge of this energy to the load during the “off” time period, t_{off}, as shown in Figure 1. The operation is unipolar and utilizes the first quadrant of the B-H curve of a magnetic core (Figure 2). The usable flux density is ΔB. The ideal core material should have a maximum available ΔB and low core losses (proportional to the shaded area).

For flyback transformers, Magnetics offers:

a) Four different materials in toroidal powder cores that have distributed air gaps
b) Gapped Ferrites

Powder cores are made of tiny insulated particles, hence, the air gaps are distributed evenly through the core structure. In comparison, ferrites require a discrete air gap to achieve a lower effective permeability and prevent saturation at high current levels. Powder cores offer the advantages of soft saturation under a drive current as well as elimination of losses associated with the discrete air gap in gapped ferrites. Ferrites generally have lower material losses, however losses due to fringing flux from the air gap can be substantial.

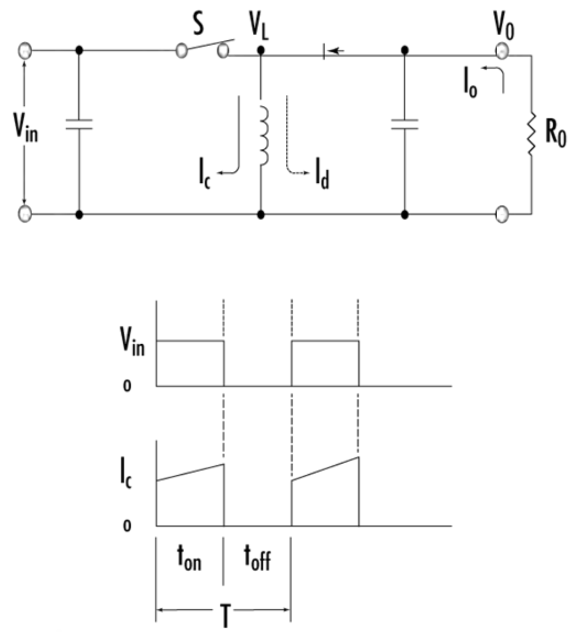

FIGURE 1

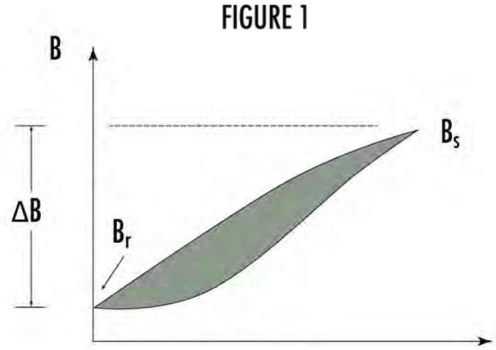

FIGURE 2

Product details are found in the Magnetics® Powder Core catalog, product datasheets, and the Magnetics website (www.mag-inc.com).

This article, focusing on the four powder core types, serves as a guide to selecting core sizes and obtaining an estimate of the number of turns of wire in flyback applications.

Material Comparison Chart

	MPP	High Flux	Kool Mµ®	XFLUX®
Permeability	14 – 550	14 – 160	26 – 125	26 – 60
Core Loss	Lowest	Moderate	Low	High
Perm vs. DC Bias	Better	Best	Good	Best
Temperature Stability	Best	Very Good	Very Good	Good
Nickel Content	81%	50%	0%	0%
Relative Cost	High	Medium	Lowest	Low

(1) Molypermalloy powder cores consist of 81% nickel, 17% iron and 2% molybdenum. MPP toroids offer the lowest core losses and the widest range of permeabilities (14µ to 550µ).

(2) High Flux powder cores consist of 50% nickel and 50% iron. Although HF cores have higher losses than MPP cores, they offer the advantage of sustaining their permeability under higher dc bias conditions. This usually results in the smallest core size if core losses are not too critical. HF cores are available in permeabilities of 14µ through 160µ.

(3) Kool Mµ powder cores contain 85% iron, 9% silicon and 6% aluminum. Kool Mµ is a low-cost material that delivers low loss performance for high efficiency designs. Kool Mµ cores substantially outperform iron powder cores (100% iron) as their losses are much lower than iron powder, particularly at higher frequencies.

(4) XFLUX powder cores are made from a 6.5% silicon iron powder. XFLUX is an ideal material for low to medium frequency inductors and, like High Flux, it provides maximum inductance at high DC bias conditions. Compared to Kool Mµ, this can also lead to more economical solutions for certain applications as smaller cores can be used at the expense of higher losses. XFLUX is currently available in 26µ, 40µ, and 60µ permeabilities.

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Core Selection

The core can be determined once the peak current (I_{pk}) and primary inductance (L_{pri}) are calculated. The requirements should be analyzed to determine the following:

P_{out} = Output power - watts

$V_{in\ min}$ = Minimum input voltage - volts

δ_{max} = Maximum duty cycle -

$$= \frac{t_{on}}{t_{on} + t_{off}}$$

f = Switching frequency - kHz

Using Equation 1, the peak current can be determined:

$$I_{pk} = \frac{2P_{out}}{V_{in\ min}\ \delta_{max}}\ \text{Amps} \quad (1)$$

Once the peak current is determined, the primary inductance can be calculated from:

$$L_{pri} = \frac{V_{in\ min}\ \delta_{max}}{I_{pk}\ f}\ \text{mH} \quad (2)$$

Using the L_{pri} and I_{pk} values, the LI^2 core selection procedure described in Magnetics catalog beginning on page 11 can be used to determine core choice. If the smallest possible core size is desired regardless of core loss, High Flux or XFLUX cores should be considered.

Selecting Turns and Wire Size

The LI^2 core selection procedure also describes how to determine the primary number of turns using equation 3:

$$N_{pri} = 1000\sqrt{\frac{L_{pri}}{A_L}}\ \text{Turns} \quad (3)$$

where A_L = inductance per 1000 turns (millihenries)

The number of turns for a secondary winding can be determined if the following are known:

V_{out} = Output voltage -- volts

V_D = Diode voltage drop -- volts (typically 1 volt)

Equation 4 calculates the number of turns on the secondary:

$$N_{sec} = \frac{(V_{out}+V_D)(1-\delta_{max})N_{pri}}{V_{in\ min}\ \delta_{max}} \quad (4)$$

Although the core must be selected based on I_{pk} due to core saturation concerns, wire size selection can be based on the average current.

Average current is determined by:

$$I_{avg} = \frac{P_{in}}{V_{in\ min}}\ \text{Amps} \quad (5)$$

By using average current to select wire size and peak current to select core size, there should be sufficient window area for a secondary winding if needed.

Summary

The above procedure allows the designer to determine the approximate core size and number of turns for a flyback transformer. Other factors such as continuous mode of operation can influence core selection. To optimize the transformer design, the referenced textbooks can be helpful.

For specific design inquiries, please contact Magnetics Sales Engineering and technical support staff at https://www.mag-inc.com/company/contact-magnetics.

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References

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