Division of Spang & Company

Technical Bulletin

BULLETIN CG-03

For Flyback Transformers . . . Selecting a Distributed Air-Gap Powder Core

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) three different materials in toroidal powder cores that have distributed air gaps

(b) gapped ferrites

Gapped ferrites have relatively high losses associated with the discrete air gap, although the material losses are low. Powder cores are made of tiny insulated particles, hence the air gaps are distributed evenly throughout the core structure. The total core losses (air gap *plus* particle losses) of the three powder core materials are usually much lower than those for gapped ferrites.

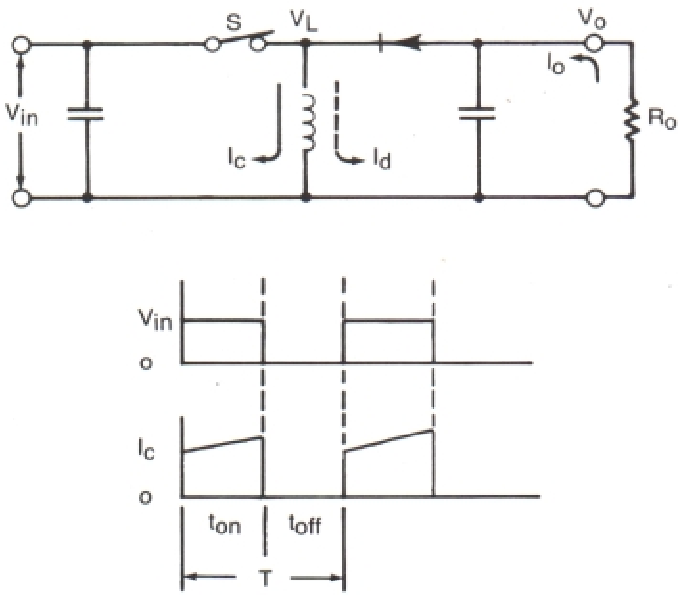

FIGURE 1

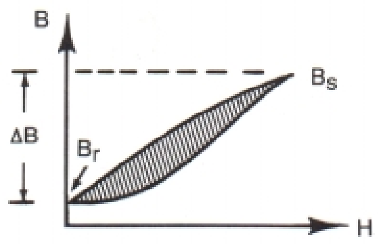

FIGURE 2

Product details are found in these MAGNETICS® catalogs:

MPP-303, Molypermalloy and High Flux Powder Cores

KMC-01, Kool Mu® Powder Cores

FC-601, Ferrite Cores

This brochure, focusing on the three 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.

Materials Comparison

MATERIALS COMPARISON CHART

Core Material	Available Permeabilities	Total Core Losses	DC Bias Stability	Core Size Advantage	Relative Cost
Moly-permalloy powder (MPP)	14, 26, 60, 125, 160, 200, 300, 550	Lowest	Good		Highest
High Flux (HF)	14, 26, 60, 125, 160	Higher than MPP	Best	Smallest size possible	Medium
KOOL MU	26,60,75 90,125	Low	Good		Lowest

(1) Molypermalloy powder (MPP) cores consist of 79% nickel, 17% iron and 4% molybdenum. MPP toroids offer the lowest core losses and the widest range of permeabilities (14μ to 550μ).

(2) High Flux (HF) 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 MU powder cores contain 85% iron, 9% silicon and 6% aluminum. Although KOOL MU cores don't have core losses quite as low as MPP cores and don't have the μ vs dc bias characteristics of the High Flux cores, they do offer satisfactory performance in many designs at a much lower cost. KOOL MU cores substantially outperform iron powder cores (100% iron) as their losses are much lower than iron powder, particularly at higher frequencies.

Core Selection

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

P_{out} = Output power-watts
$V_{in(min)}$ = Minimum input voltage—volts
d_{max} = Maximum duty cycle— $\frac{t_{on}}{t_{on} + t_{off}}$
f = Switching frequency—kHz

Using Equation 1, the peak current can be determined:

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

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

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

Using the L_{pri} and I_{pk} values, the LI^2 core selection procedure described in catalogs MPP-303 and KMC-01 can be used to select the correct core. If the smallest possible core size is desired regardless of core loss, High Flux cores should be considered. The permeability vs. dc bias graph (catalog MPP-303, High Flux cores) can be used in the LI^2 core selection.

Selecting Turns and Wire Size

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

$$N_{pri} = 1000\sqrt{\frac{L_{pri}}{L_{1000}}} \text{ turns} \qquad (3)$$

where L_{1000} = inductance per 1000 turns (milihenries)

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:

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

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:

$$I_{ave} = \frac{P_{in}}{V_{in(min)}} \text{ amperes} \qquad (5)$$

(from Reference No. 1)

By using average current to select the wire size and peak current to select, core size, there should be a 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 or discontinuous mode of operation can influence core selection. To optimize the transformer design, the referenced textbooks can be helpful.

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References

(1) M. Brown, *Practical Switching Power Supply Design,* Academic Press, San Diego, 1990.

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(4) C. McLyman, *Magnetic Core Selection for Transformers and Inductors,* Marcell Dekker, New York, 1982.

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(6) K. Billings, *Switchmode Power Supply Handbook,* McGraw-Hill, New York, 1989.

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