Chapter 5

CORE SIZES-DESIGN CONSIDERATIONS IN POWER ELECTRONICS

INTRODUCTION

The last few chapters, the choices of components for power electronics were considered based on the circuit topology, component function, material and shape. This chapter will be concerned with the selection of the size of the core. First consideration will center on satisfying the electrical input requirements with regard to input and output voltages and currents, followed by efficiencies, regulation, temperature-rise and safety requirements. The first section will concentrate on output transformers and output inductors, followed by common-mode chokes, EMI suppression cores and magnetic amplifier components. The appendices will deal with design examples for the various functions.

5.1-DETERMINING SIZE OF THE TRANSFORMER CORE

Years ago, transformers were designed by using cut-and-try methods involving many modifications and final optimization. Such techniques are time-consuming and ineffective procedure and although some use of them remains, many design aids have been established to assist the designer in at least a close fit to the required circuit with only some minor adjustment needed. Several schemes of sizing the core and completing the circuit design are presented in this chapter. The first approach is the use of the core area-window area product that has been adopted by many manufacturers of power magnetic components. These vendors correlate the area products with certain core sizes and materials. Variations of the product area have been used by the manufacturers or authors in books. The next approach involves the use of other power specifications offered by the vendors. These may include the core losses for the cores (either per cc or gm), the core surface areas and the thermal resistances. In many cases when not all the input and output conditions are specified, some reasonable assumptions will be made in the initial designation of the core size. Since no universal scheme for sizing the core has yet emerged, the variety of different methods will be discussed.
5.1.1-Initial Considerations in Designing a Power Transformer Core

In the design of a core for a power transformer used in SMPS converters, we must take into account the input current requirements to provide the ac field to drive the core to the proper B level. This will be determined by the following equation;

\[ H = \frac{.4\pi NI}{I} \]  

[5.1]

In strict operational terms, the NI of the primary winding will provide the flux variation to induce the necessary secondary voltage. This voltage is related to the operating conditions by the following equation;

\[ E = 4.44 BNAf \times 10^{-8} \]  

[5.2]

for sine wave with the coefficient changing to 4 for square wave. Although part of the dimensions (cross sectional area) of the magnetic core is related directly to the flux requirements imposed by the second equation, all the windings in a power core are contained inside the core. This includes the primary turns, \( N_p \), determined by the magnetizing current equation and the secondary turns, \( N_s \), given by the induction equation. These windings are contained either inside the window of the toroid or a U or E core or are on a bobbin surrounding the center post in a pot core. Consequently, the size of the window or bobbin winding space does directly affect the overall size of the core. Therefore, it is these two requirements that are related in the design determining the shape and size of the core.

In other words, the flux equation contains the cross sectional area of the core. The NI requirements must be met by a certain number of turns each having a certain capacity to carry a current \( I \). Achieving a higher current may allow only a few turns with a larger cross sectional area per turn as opposed to a design carrying a larger number of turns with a smaller cross sectional area per turn. It is the product of the NI which is a measure of the total copper cross sectional area and which will determine the window area.

Therefore, there are two areas that will at first determine the size of the core. One criterion used for years by design engineers is the product of these areas that is called the Area Product, \( A_p \), (Magnetics 1987) described by;

\[ A_p = W_a A_c \text{ (cm}^4) \]  

[5.3]

Where; \( A_p = \) Area Product
\( W_a = \) Area of the window (cm\(^2\))
\( A_c = \) Area of the window (cm\(^2\))

Of course, the \( A_c \) is the area transverse to the flux and the \( W_a \) is the area transverse to the current flow. The area of the window is not completely usable because of the space between the wires and also the insulation thickness. Therefore, we introduce a copper-filling factor, \( K \), which is the fraction of the