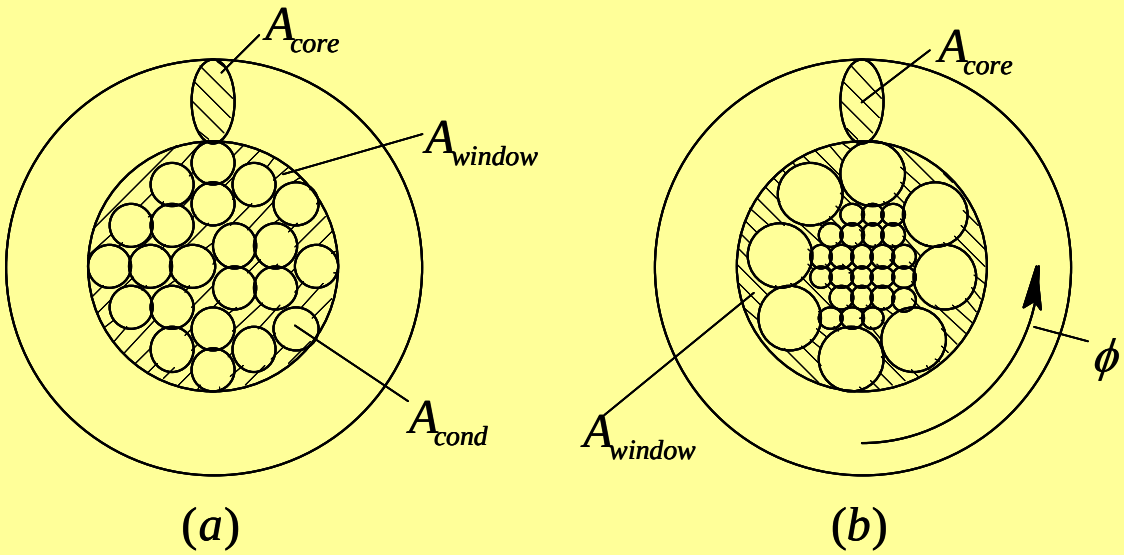
Design of High-Frequency Inductors and Transformers

BASICS OF MAGNETIC DESIGN

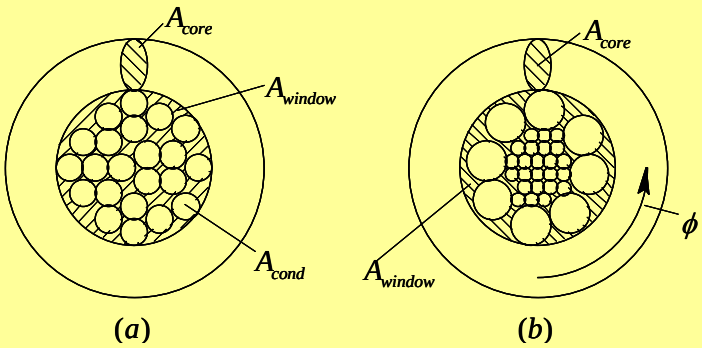
- The peak flux density B_{max} in the magnetic core to limit core losses, and
- The peak current density J_{max} in the winding conductors to limit conduction losses

INDUCTOR AND TRANSFORMER CONSTRUCTION



AREA-PRODUCT METHOD

Core Window Area A_{window}



$$A_{window} = \frac{1}{k_w} \sum_y \left(N_y A_{cond,y} \right)$$

$$A_{cond,y} = \frac{I_{rms,y}}{J_{\max}}$$

$$A_{window} = \frac{\sum_y \left(N_y I_{rms,y} \right)}{k_w J_{\max}}$$

Core Cross-Sectional Area A_{core}

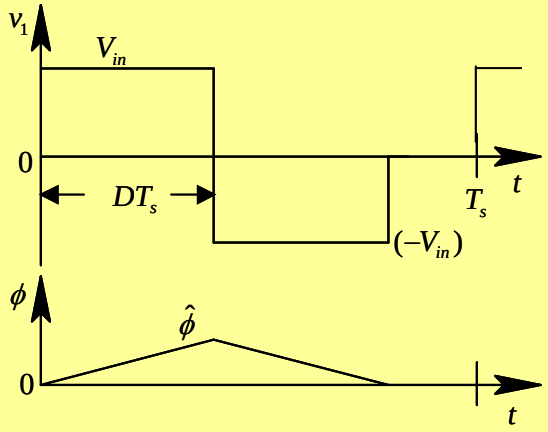
$$A_{core} = \frac{\hat{\phi}}{B_{\max}}$$

inductor: $\hat{\phi} = \frac{L\hat{I}}{N}$ $\qquad A_{core} = \frac{L\hat{I}}{NB_{\max}}$

transformer:

$$\hat{\phi} = \frac{k_{conv} V_{in}}{N_1 f_s}$$

$$A_{core} = \frac{k_{conv} V_y}{N_y f_s B_{\max}}$$



Core Area-Product $A_p = A_{core} A_{window}$

inductor: $A_p = \dfrac{L\hat{I}I_{rms}}{k_w J_{\max} B_{\max}}$

transformer: $A_p = \dfrac{k_{conv} \sum V_y I_{y,rms}}{k_w B_{\max} J_{\max} f_s}$ note: $\dfrac{V_1}{N_1} = \dfrac{V_2}{N_2} = etc$

Design Procedure Based on Area-Product A_p

inductor: $N = \dfrac{L\hat{I}}{B_{\max} A_{core}}$ $L \simeq \dfrac{N^2}{\Re_g}$ $\Re_g \simeq \dfrac{\ell_g}{\mu_o A_{core}}$ $\ell_g = \dfrac{N^2 \mu_o A_{core}}{L}$

transformer: $N_y = \dfrac{k_{conv} V_y}{A_{core} f_s B_{\max}}$

THERMAL CONSIDERATIONS

Designs presented here do not include eddy current losses in the windings, which can be very substantial due to proximity effects. These proximity losses in a conductor are due to the high-frequency magnetic field generated by other conductors in close proximity. To minimize these proximity losses suggests inductors with a single-layer construction. In transformers, windings can be interleaved to minimize these losses, as described in detail in [1]. Therefore, the area-product method discussed in this chapter is a good starting point, but the designs must be evaluated for temperature rise due to additional losses.

Summary

- Design of High-Frequency Inductors and Transformers