An Introduction to Planars

Planar technology stems from demand for the reduction in size, weight and profile of switching power supplies. This can be achieved by increasing the switching frequency of the device, which allows for the reactive components - capacitors and wound components, to be smaller.

The design of the Planar core range helps combat many of the problems associated with high frequency transformers, including the hysteresis, rotational and eddy current losses, and in the material the skin effect and proximity losses of the windings.

The main losses have been reduced by the development of high frequency power materials F48 and F47, which operate from 100 kHz to 1.0 MHz.

Planars do not rely on the traditional wire wound bobbins but substitute the precision and repeatability of printed circuits overcoming winding error and tolerances.

Planar Design

The utilisation of the Skin Depth or current penetration in the copper conductor at high frequencies is the key to planar design.

The relationship between Skin Depth (penetration) and frequency is:

$D = \frac{k}{\sqrt{f}}$ (mm) where f = frequency (Hz)
k = thermal constant (72 at 70°C)

Therefore, at 100kHz, D = 0.228mm which drops to 0.100mm at 500kHz.

PCBs can closely control the track width and height, helping to optimise this relationship. Proximity and eddy current losses are also reduced by utilising the track thickness.

Key Design Terminology

Thermal resistance Thermal resistance is defined as the temperature in degrees celsius per Watt of power dissipated in the core. It can be used to determine the approximate power loss in the core for a given temperature rise.

$R_{th} = 23 \times AP^{-0.37}$ where AP = Ae x Aw

Flux Density The voltage that passes through the windings sets up a magnetic field, expressed in Tesla, within the core. This is sometimes referred to as the drive voltage and is related to the flux density by:

$B = \frac{Vrms}{\sqrt{2}.\pi.N.Ae.f}$ where N = No. of turns.

Power Loss Density This is the total material losses at a given frequency and flux density for a volume of ferrite.

PLD = power loss / Effective Volume (Ve) also,
Power Loss = Temperature rise/ Thermal resistance.

So, for a given temperature rise in the transformer, a core size can be selected, assuming that losses are split equally between the winding and the core.

Power loss is also proportional to the frequency and flux density as given by the Steinmetz equation:

$PLD = k . f^{1.62} . B^{2.3}$ where k is derived from the power loss data

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Area Product This is the relationship between winding area, Aw, and core cross-sectional area, Ae.

$AP = Ae \times Aw \ (cm^4)$

It is a very useful factor which affects the current density Jp (max) in the primary windings.

$Jp\,(max) = 450 \times AP^{-0.125}$ (emperically derived)

By knowing the current density the wire area can be found by:

$Axp = I(max) / Jp(max) \ (m^3)$

But due to the Skin Effect at high frequencies, as discussed earlier, the cross-section of copper can be reduced. In conventional transformer design the primary would be made from multi strand wire to reduce the leakage inductance. In the planar design this would equate to multi-layer boards with the reduced track thickness.

The secondary copper cross-section can also be calculated from the secondary current

$I\,s = I\,o(max) / \sqrt{2}$ (Amps)

and the cross-section from

$Axs = I\,s / Jp\,(max)$

Then the track size can be calculated as above.

Another useful empirically derived relationship is that with frequency, flux density and input power.

$$AP = \left[\frac{11.1 x P_{in}}{k x \Delta x B x f}\right]^{1.143}$$

where k= circuit topology factor
where k = 0.141 for Half Bridge
where k = 0.20 for Flyback

From this the power handling capability for each core can be found.

However, as with conventional transformers the insulation between windings and the associated creepage distance reduces the winding area Aw, which in turn reduces the core power handling level.

Creepage Distance The distance between the outer and inner most winding of the primary or secondary and the corresponding turns of the next set of windings (Typical values 2 and 4mm).

Core Parameters

Le	Effective magnetic Path Length (mm)
Ae	Effective magnetic Area (mm^2)
Ve	Effective magnetic Volume (mm^3)
C1	Core constant Le/Ae (mm^{-1})

Inductance Factor A_L Used to calculate the inductance for a given number of turns in nano-Henries.

$L = A_L \cdot N^2$ (nH)

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