

Choosing Core for Flyback Transformer and Choke Designs

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Soft magnetic materials (materials that can easily be magnetized) come in many forms. For switch-mode power supply flyback transformers and chokes, we would consider gapped ferrites, Iron powder, Permalloy powder (MPP), High Flux Powder, Fe-Si-Al Powder (Cool Mu) and similar. In powder cores, the magnetic material is mixed with a non magnetic bonding material providing a distributed air gap, the mix density allows various permeability's to be obtained.

The three properties of major interest to the designer are the permeability, saturation flux density and core loss. Fig. 1 shows the top quadrant of a typical B/H loop for a ferrite core with a small air gap, a ferrite core with a large air gap, and an iron powder core without an air gap. Also shown is a minor B/H loop for the same powder core for a choke application with a high dc current component but a low (high frequency) ripple current. This type of operation is

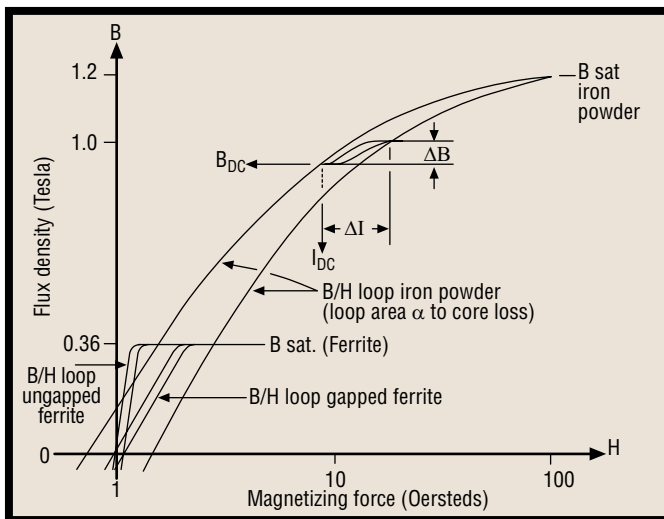


Fig. 1. Top quadrant of a typical B/H loop.

typical of a choke for power factor correction applications, where the high frequency minor B/H loop moves up and down the major loop at low frequency, as the haversine current changes. Remember, in the final wound component, ΔB becomes proportional to the applied volt seconds and translates in to a ripple current ΔI as shown. The flux density swing ΔB and frequency translate to core loss, while B_{dc} and H are proportional to the mean dc current. And this translates to copper loss in the windings.

Also in Fig. 1 you can clearly see the three properties of interest. The relative permeability (the ratio of the permeability of air to that of the core material), is shown by the slope of the B/H loop at zero flux density ($\Delta B/\Delta H$ at $B = 0$), Saturation is shown by the curvature over towards the horizontal at B_{sat} and the core loss is proportional to the area enclosed by the B/H loop. Notice for the minor B/H loop on the powder core, the effective permeability of this loop is lower and changes with the size of the ac fluxing and the dc current bias, (a swinging choke), also the area of the minor B/H loop is quite small giving relatively low core loss.

Choosing a Core Material

Again as in Fig. 1, the iron powder and gapped ferrite B/H loops show the extremes of performance, with the other powder materials tending to fall between these two extremes. Notice, the ferrite core has high cost, low core loss, but saturates at a low flux density, while the powder core has low cost, high core loss, and saturates at a much higher flux density. Hence there is a trade off between parameters, neither being ideal for all applications.

The intrinsic permeability of ferrite type materials is large, ranging from say 1,000 to 10,000 but the effective permeability of the gapped core can be changed to a much lower level by increasing the size of the air gap. The powder cores are more often toroidal and cannot be gapped. They come in various intrinsic permeability's, ranging from around 200 down to as low as 2 depending on the material mix chosen. Some manufacturers provide "E" type powder cores which can be gapped to further reduce the permeability, however, this is rarely done, because choosing a lower permeability mix rather than gapping will normally result in a lower core loss.

The following five factors should be considered when selecting a core material;

- 1 Price. Ferrites and MPP cores are more expensive
- 1 Core form. "E" cores are easier to wind and mount
- 1 Core loss. High frequency prefers lower core loss
- 1 Saturation flux density. High current tends to favor higher saturation flux density
- 1 Permeability. Higher inductance favors higher permeability.

There is a tradeoff between the parameters. For example, higher inductance can be obtained by either choosing a higher permeability mix (or smaller air gap in ferrite), or by

increasing the turns, or by increasing the core area (larger core), or any combination of these. The “trade off’s” being: Higher permeability requires less turns giving lower copper loss but higher core loss. More turns give more copper loss, but the reduced flux swing results in reduced core loss. A larger core takes more room and is more costly, and it can result in more core loss. This complex interplay of parameters means that there is no clear ideal selection in general, just trends, hence the skill and experience of the designer becomes a major factor in the selection process. Equally effective designs can be obtained on several types of core and material selections, partially in the middle frequency range, say from 25 kHz to 75 kHz.

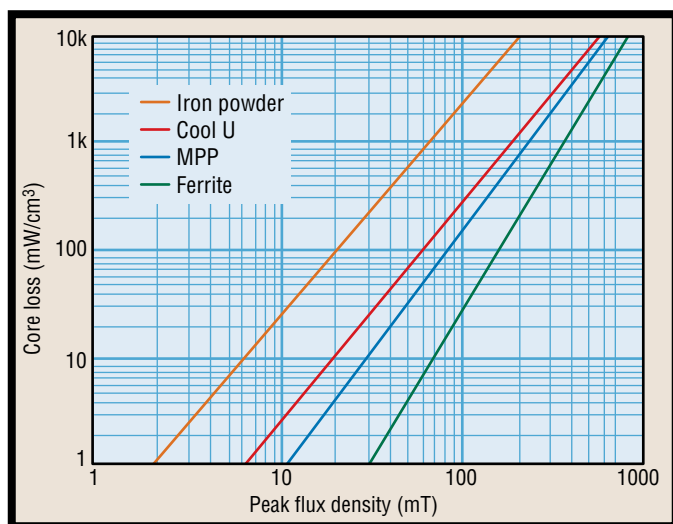


Fig. 2. Examples of core loss trends (shown as milliWatts/volume at 50 kHz).

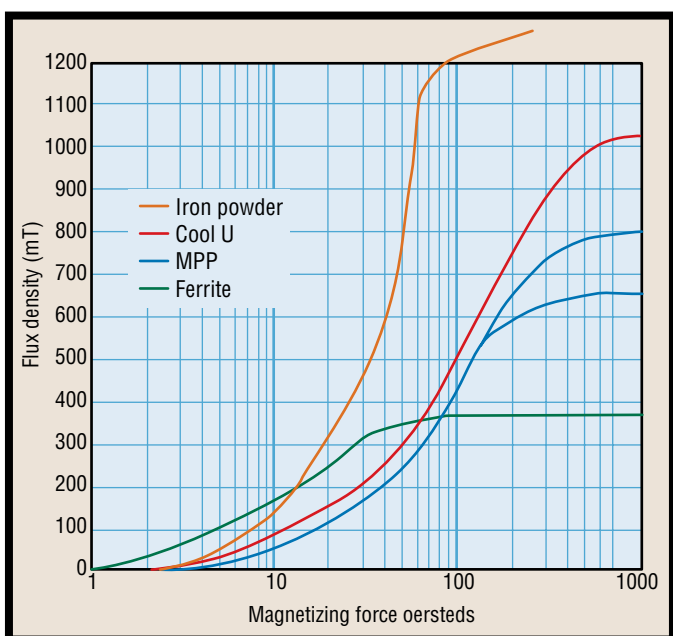


Fig. 3. Typical saturation flux density plotted against dc magnetizing force Oersteds.

However, there are some clear choice parameters. Lower core loss is always an advantage in any design. Fig. 2 shows examples of core loss trends (shown as milliWatts/volume at 50 kHz) for some typical materials plotted against ac flux density ΔB (You can think of ΔB as being proportional to ripple current) Notice the very wide range of core loss. at say 100mT, for example, the ferrite core loss is of the order of 30mW per cm^3 compared with 2500mW per cm^3 for the iron powder. Clearly, high frequency high ripple current applications would favor the gapped ferrite material.

For the same materials, Fig. 3 shows typical saturation flux density plotted against dc magnetizing force Oersteds. (You can think of this in terms of the dc current component if you prefer). Notice the ferrite saturates near 0.35 Tesla compared with >1.1 Tesla for the Iron powder. Clearly, for low frequency high current applications, the Iron powder would be a preferred choice.

Between these two extremes, good results can be obtained from other materials. Gapped ferrite can always be made to provide acceptable results, by adjusting core size turns and core gap. However, it may not provide the lowest cost or smallest size in some applications. Sendust (Cool Mu powder) is an interesting material, being a magnetically eutectic alloy of aluminum silicon and iron to optimize the magnetic properties. Smaller more efficient designs are claimed for this material².

In general choose a powder core mix to meet the required permeability as calculated for the flyback or choke requirement covered in the previous articles. Next choose the type of material in accordance with the cost and efficiency aims. Note that the lower loss materials are higher cost but produce smaller more efficient chokes. For an optimum efficiency design adjust the turns to make the copper and core loss equal. If a defined inductance is required it may not be possible to optimize the design, but if core loss predominates you can always choose a lower loss material.

In the next Power Design column, let's explore the design of a forward transformer.

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