Core Selection for Flyback Transformer/Inductor

There is no "right-way" to select a core, but there are several factors to consider and the process can be somewhat iterative:

- All cores have hysteresis and eddy-current losses, which are a function of flux density and switching frequency. This loss is usually specified as a power density (W/cm²). So for a desired energy (W) and switching frequency (or equivalently a certain power output), a maximum allowed core loss will determine the minimum core volume.

Most manufacturers will offer some guidelines on which materials are best for a certain application or power level or frequency, and volume.

- Once a core material is selected, the core geometry must be chosen. This is influenced by issues of winding losses, required number of turns, and costs. "Optimum" efficiency typically occurs when winding losses are approximately equal to core loss.

In a flyback application the inductor/transformer is required to store energy, which generally means that a gapped core or powder core will be used. So a typical procedure would be:

- Choose an appropriate core material based on frequency, energy/power considerations.
- Choose a core geometry iteratively until desired winding loss, # of turns is satisfied.
since most companies specify an $A_e$ value for their cores, and since this determines the number of turns required for a certain inductance, it is helpful to use this as the scaling parameter.

$A_e$ is expressed in [H] as $N_p = \sqrt{\frac{L_p}{A_e}}$

Once the $N_p$ of turns is known, the core effective area $A_e$ must be chosen large enough to avoid saturation.

$A_e = \frac{V_{in} T_{on}}{N_p B_{rms}} = \frac{V_{in}}{2 N_p f \sigma B_{rms}} = \frac{V_{in}}{2 f \sigma B_{rms}} \sqrt{\frac{A_e}{L_p}}$

At this point $A_e$, $A_l$, $A_c$, and core volume $V_c$ have been specified. The last step is to select a core geometry that meets these specs while also accommodating the required winding.

The wire size must be selected based on thermal issues and ohmic losses. A common and conservative bound on wire size for thermal management is determined by keeping the wire area larger than “500 circular mils per rms ampere” (Pressman). One circular mil is defined as the area of a wire of 1 mil = 0.001 inch diameter, so 1 circular mil = $5.067 \times 10^{-6}$ cm$^2$. Thus, the wire area required is

$m^2 = 2.53 \times 10^{-3} \text{ cm}^2 / \text{rms ampere}$

$= 0.253 \text{ mm}^2 / \text{rms ampere}$
For the flyback transformer the rms. current in the primary is

\[ I_{\text{rms}} = \frac{I_{\text{peak}}}{\sqrt{3}} \sqrt{\frac{T_{\text{on}}}{T}} \quad \Rightarrow \quad A_{\text{wire}} > \frac{0.253}{\sqrt{3}} I_{\text{peak}} \sqrt{\frac{T_{\text{on}}}{T}} \text{ mm}^2 \]

The AWG is related to wire diameter by

\[ d_{\text{wire}} = \left( \frac{5}{1} \right) 92 = (0.127 \text{ mm}) 92 \]

\[ S = 36 - \frac{39}{\log 92} \log \left( \frac{d_{\text{wire}}}{0.127 \text{ mm}} \right) \quad d_{\text{wire}} = \sqrt{\frac{4 A_{\text{wire}}}{\pi}} \]

Now that wire size and # of turns is known, we must choose a core window that can accommodate this. For example, for a toroid with a single layer winding:

\[ N_p \cdot d_{\text{wire}} \leq \pi (\text{I.D.)} \]

This must include wire insulation!

Check winding loss:

\[ P_{\text{wire}} \leq \frac{N_p}{2} \left( 2h_e + \text{O.D.} - \text{I.D.} \right) \]

\[ R_{\text{wire}} = \rho \frac{d_{\text{wire}}}{A_{\text{wire}}} = \rho \frac{d_{\text{wire}}}{\pi} \text{ resistance per unit length} \]

\[ P_{\text{w}} = I_{\text{rms}}^2 R_{\text{wire}} \]