ECONOMICAL SOFT FERRITE CORE SELECTION FOR POWER TRANSFORMERS

George G. Orenchak

Ferrite International Company
Wadsworth, IL

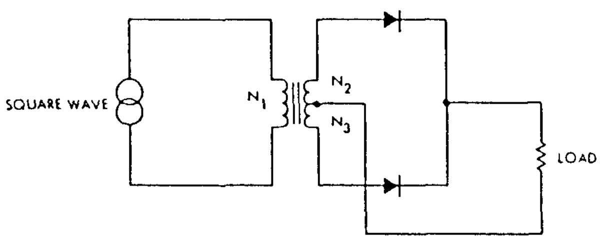
ABSTRACT

Ferrite core material performance, core configuration and size vs. inherent costs are examined in typical high frequency tranformer applications.

THE CORE SELECTION PROCESS

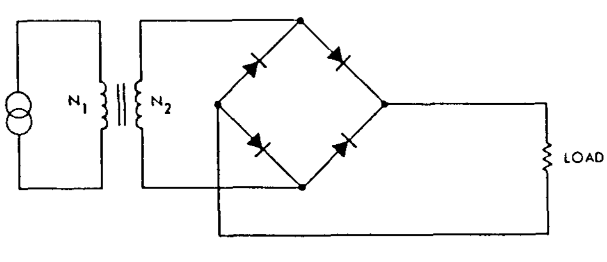
A power transformers core selection is dependent on the power the core will need to handle. The apparent power (Pt) is dependent on transformer configuration.

Full-wave Bridge



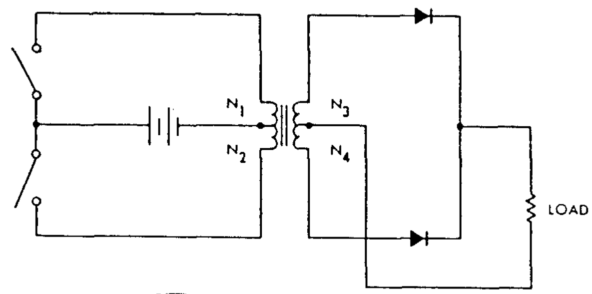
$$Pt = Po\left(\frac{1}{n} + 1\right)$$

Full-wave Center tapped



$$Pt = Po\left(\frac{1}{n} + \sqrt{2}\right)$$

Push-Pull Full-wave Center tapped



$$Pt = Po\left(\frac{\sqrt{2}}{n} + \sqrt{2}\right)$$

Consider a full-wave bridge configuration with the following criteria:

Input voltage Vin = 200V
Output voltages
Vout1 = 12V at 10 amps (120 watts)
Vout2 = 48V at 8 amps (384 watts)
Vout3 = 5V at 15 amps (75 watts)
Total 580 watts
Frequency F = 100KHz
Efficiency = 0.90

Calculate the apparent power (Pt).

$$Pt = Po\left(\frac{1}{n} + 1\right)$$

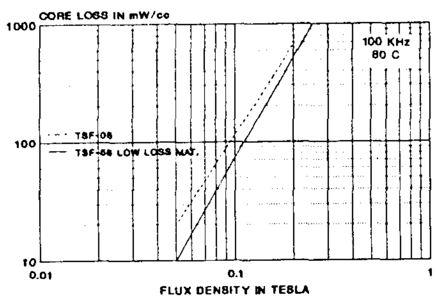
$$Pt = (580)\left(\frac{1}{.90} + 1\right) = 1224$$

A core is needed with sufficient cross-sectional area (Ae) to carry the flux and a window area (Wa) large enough to physically support the needed turns. The following relationship is derived from Faraday's Law.

$$Ap = WaAe = \frac{Pt \times 10^4}{Ku\ Kf\ Bm\ f\ J}$$

Ae	Effective core area	cm^2
Bm	Flux Density	Tesla
f	Frequency	Hz
J	Current density	A/cm^2
Kf	Wave form coefficient	
Ku	Window utilization factor	
Pt	Apparent power	watts
Wa	Window area	cm^2

Before calculating the area product, choose a material grade and determine the flux density according to the maximum permissible core loss. 120 mw/cm^3 typically results in 35 to 40°C temperature rise. Figure #2 shows core loss vs. flux density.



Choose TSF-05 material, 0.1 Tesla.

$$Ap = WaAe = \frac{1224 \times 10^4}{(4)(.4)(.1)(100000)(120)}$$

$$Ap = Wa\,Ae = 5.313\ cm^4$$

Select one of the following cores with area product greater than 6.3 cm^4.

	Configuration		
	E core	ETD core	PQ core
P/N	05-42-21-20	05-49-00-00	05-40-40-00
Le	9.723 cm	11.562 cm	10.19 cm
Ae	2.304 cm^2	2.114 cm^2	2.01 cm^2
Ve	22.404 cm^3	24.467 cm^3	20.45 cm^3
Wa	2.769 cm^2	3.744 cm^2	3.26 cm^2
WaAe	6.381 cm^4	7.914 cm^4	6.55 cm^4
Maximum dimensions			
LxWxH	34.42 cm^3	39.21 cm^3	46.12 cm^3

AFFECT OF MATERIALS WITH LOWER CORE LOSS PROPERTIES

If a lower core loss material is chosen, the gauss level can be increased by 20% and smaller less expensive cores may be used.

Choose TSF-55 material, 0.12 Tesla.

$$Ap = WaAe = \frac{1224 \times 10^4}{(4)(.4)(.12)(100000)(120)}$$

$$= 5.313\ cm^4$$

The new area product is 16.7% smaller. One of the following cores can be used.

	Configuration	
	E core	ETD core
P/N	55-43-21-15	55-44-00-00
Le	9.834 cm	10.475 cm
Ae	1.838 cm^2	1.732 cm^2
Ve	18.075 cm^3	18.112 cm^3
Wa	2.888 cm^2	3.053 cm^2
WaAe	5.308 cm^4	5.288 cm^4
Maximum dimensions		
LxWxH	27.94 cm^3	29.06 cm^3

The TSF-55-43-21-15-0000 is 18% less expensive than the TSF-05-42-21-20-0000 for a number of reasons:

1. 20% less material (thinner part).
2. 17% increase in sintering rate (more pieces/kiln tile and faster sintering cycle).
3. 33% increase in grinding rate (thinner part yields more pieces/hour ground at same throughput conveyor speed).

Additional cost savings for smaller bobbins and less wire are also realized.

COST CONSIDERATIONS OF CONFIGURATIONS

Consider a Push-Pull Full-wave Center tapped configuration with the following criteria:

Input voltage	Vin	= 110
Output voltage	Vout	= 12V at 10 amps
(120 watts)		
Frequency	F	= 100KHz
Efficiency	n	= 0.90

Contents | Print | Text Search

$$Pt = 120\left(\frac{\sqrt{2}}{n} + \sqrt{2}\right)$$

$$Pt = 120\left(\frac{\sqrt{2}}{0.9} + \sqrt{2}\right) = 358$$

Choose TSF-55 material, .12 Tesla.

$$Ap = WaAe = \frac{358 \times 10^4}{(4)(.4)(.12)(100000)(245)} = .761\ cm^4$$

Configuration

	E core	Pot	PQ	Toroid
P/N	55-30-15-07	55-30-19-00	55-26-25-00	55-22-14-13
Le Cm	6.607	4.52	5.55	5.418
Ae cm^2	.573	1.36	1.18	5.220
Ve cm^3	3.785	6.15	6.53	2.829
Wa cm^2	1.344	.80	.85	1.478
WaAe cm^4	.770	1.09	1.00	.772
Maximum dimensions				
LxWxH cm^3	6.18	16.90	12.81	6.200

The toroid is the least expensive core, however, it is the most expensive to wind because a coil form cannot be used. The TSF-55-30-15-07-0000 E core is nearly as inexpensive as the toroid and less expensive to wind. The PQ core is 136% more expensive than the E core and the pot core is 218% more expensive than the E core. The reasons are primarily as follows:

1. Configurations with round center posts must be "end molded" with multiple level tooling rather than "side molded" with single layer tooling. This causes tool cost, tool maintenance costs and set-up times to increase while pressing speeds decrease.

2. Shapes other than rectangular waste area on kiln tile. Many more pieces of an E core fit on a kiln tile than do pot cores.

3. Pot cores and PQ cores must be ground on their back sides and their mating surfaces, while E cores need to be ground only on their mating surfaces.

4. E cores can be packaged in shipping containers more densely than pot cores.

5. Pot cores must be gapped individually, while E cores can be gapped in line while grinding mating surfaces on a high speed throughput grinder.

There are many other issues such as VDE and U_L requirements that need to be considered when designing a power transformer. Such issues would affect the core size and cost similarly, regardless of material grade or core configuration.

Other issues such as radiation affects may dictate the core configuration, but if cost is the most important parameter, an E core in a premium low core loss material is most often the best choice.

REFERENCES

George Chryssis, High Frequency Switching Power Supplies McGraw-Hill Inc. 1984

C. Wm. McLyman, Magnetic Core Selection for Tranformers and Inductors Marcel Dekker, Inc. 1982

E. C. Snelling and A. D. Giles, Ferrites for Inductors and Transformers Research Studies Press Ltd., 1983

Nathan R. Grossner, Transformers for Electronic Circuits McGraw-Hill Inc., 1967

Peter Wood, Switching Power Converters Litton Educational Publishing, Inc. 1981

George G. Orenchak, "Application Considerations of the Non-Linear Ferrite Characteristics" Coil Winding Proceedings 1990, pp. 121 - 126.