MAGNETICS®
Division of Spang & Company

Technical Bulletin BULLETIN TWC-S5

COMPOSITE CORES

- **Combine protective features of gapped cores with lower magnetizing current requirements of uncut cores**
- **Protect electronic circuitry**

Low-loss nickel-iron tape-wound toroidal cores that have a very square hysteresis characteristic (B-H loop) have been used extensively in the design of spacecraft or specialty electronic transformers. Due to the high squareness of the B-H loops of these materials, transformers designed with them tend to saturate quite easily. This can cause large voltage and current spikes, creating undue stress on electronic circuitry. Saturation occurs when there is any unbalance in the ac drive to the transformer, or when any dc excitation exists. Also, due to the square characteristic, a high residual flux state (B_r) may remain when excitation is removed. Reapplication of excitation in the same direction may cause deep saturation; an extremely large current spike, limited only by source impedance and transformer winding resistance, can result. This can produce catastrophic failure.

By introducing a small air gap into the core, the above problems can be avoided, while, at the same time, maintaining the inherent low core loss properties of these materials. The air gap has the effect of "shearing over" the B-H loop of the material such that the residual flux state is low and the margin between operating flux density and saturation flux density is high. Figures 1 and 2 show the effect of gapping on a typical B-H loop of an 80% nickel-iron alloy tape wound core. The air gap thus has a powerful demagnetizing influence upon the square loop materials, but has little effect on the core loss. Properly designed transformers using "cut" toroid or "C-core" square loop materials will not saturate upon turn-on and can tolerate a certain amount of unbalanced drive or dc excitation.

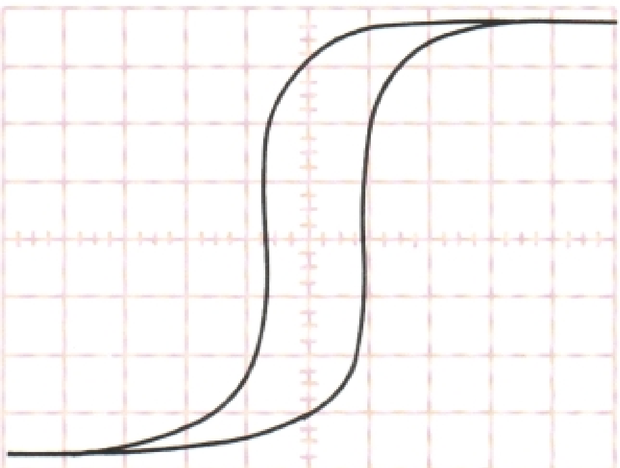


Figure 1. B-H loop of an uncut core.

(Horiz. = 10 mA/cm; vert. = .2T/cm)

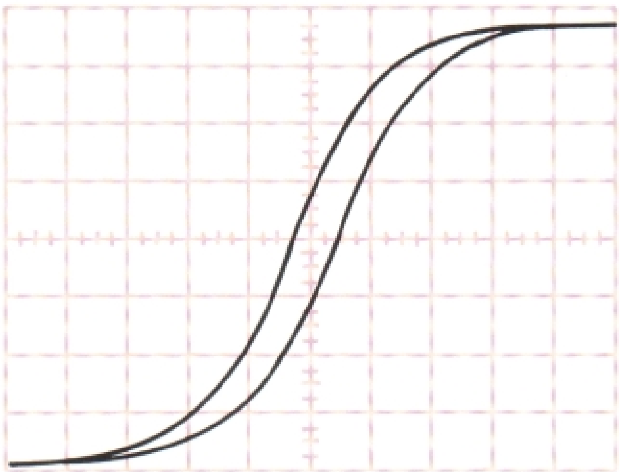


Figure 2. B-H loop of same core as figure 1, only cut.

(Horiz. = 50 mA/cm; vert. = .2T/cm)

NEW CORE CONFIGURATION

A new core configuration, combining the protective feature of a gapped core with the much lower magnetizing current requirement of an uncut core, has been developed. This configuration is a composite of a cut and an uncut core assembled together concentrically, with the uncut core nested within the cut core. The uncut core functions under normal operating conditions, and the cut core takes over during abnormal conditions to prevent high switching transients and their potentially destructive effect on transistors. The uncut core has high permeability and thus requires a very small magnetizing current. On the other hand, the cut core has a low permeability and thus requires a much higher magnetization current.

The uncut core is designed to operate at a flux density which is sufficient for normal operation. Under the abnormal conditions previously described, the uncut core may saturate. The cut core then takes over and supports the applied voltage so that excessive current does not flow. In a sense, it acts like a ballast resistor in some circuits to limit current flow to a safe level.

Figures 3 and 4 show the magnetization curves of an *uncut* nickel steel core at different flux densities. The density of the Figure 3 curve is half that of Figure 4. The tendency toward saturation is clearly visible. Figures 5 and 6 show the magnetization curves of a *gapped* nickel steel core at flux densities as above. Figures 7 and 8 show the magnetization curves for a *composite* core of the same material, at two different flux densities. The much lower B_r characteristic of the composite as compared to the uncut core is readily apparent.

Much of the work covering composite cores has been done by Colonel William T. McLyman of the Jet Propulsion Laboratory, Pasadena, California. Data presented here is provided through the courtesy of Mr. McLyman. Additional details can be found in his comprehensive textbook, "Transformer and Inductor Design Handbook", Publisher: Marcel Dekker, Inc. New York and Basel.

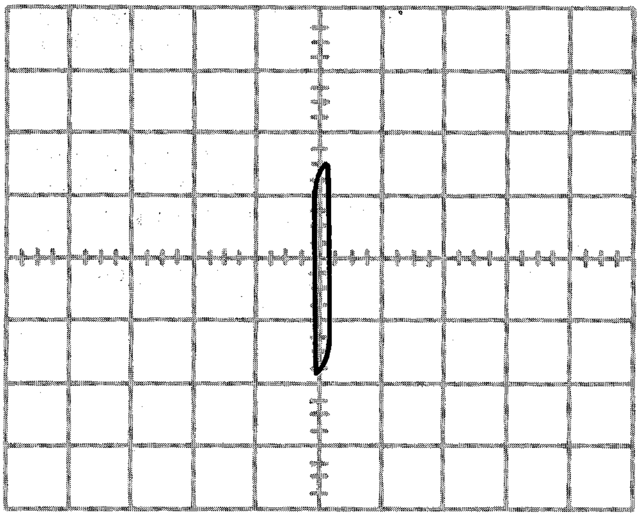


Figure 3

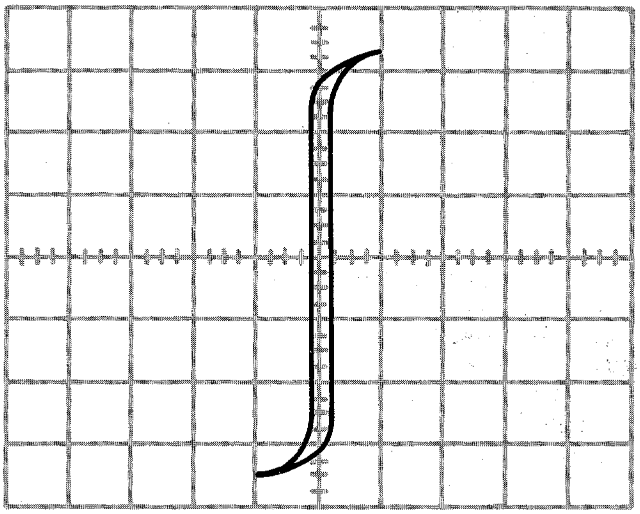


Figure 4

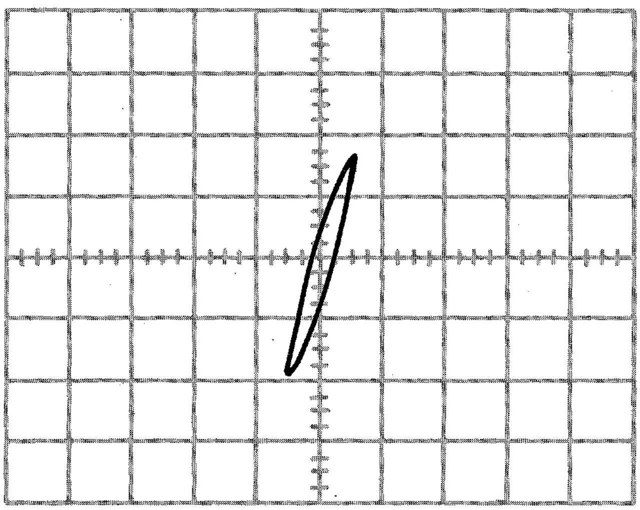


Figure 5

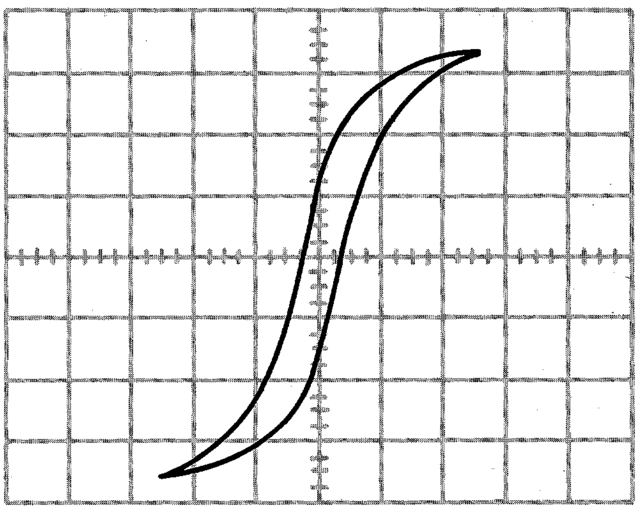


Figure 6

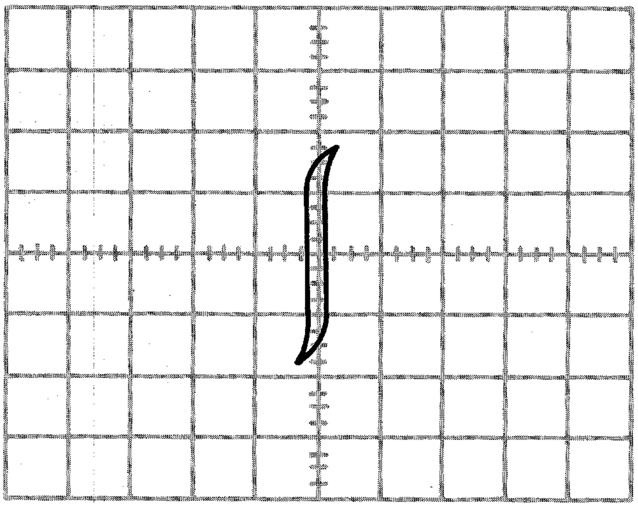


Figure 7

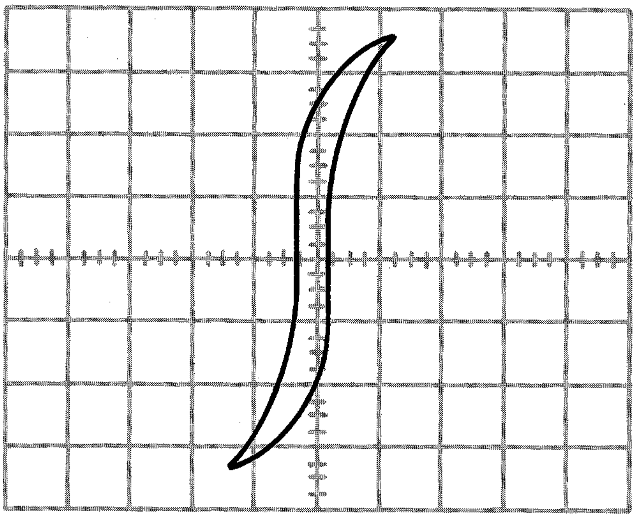
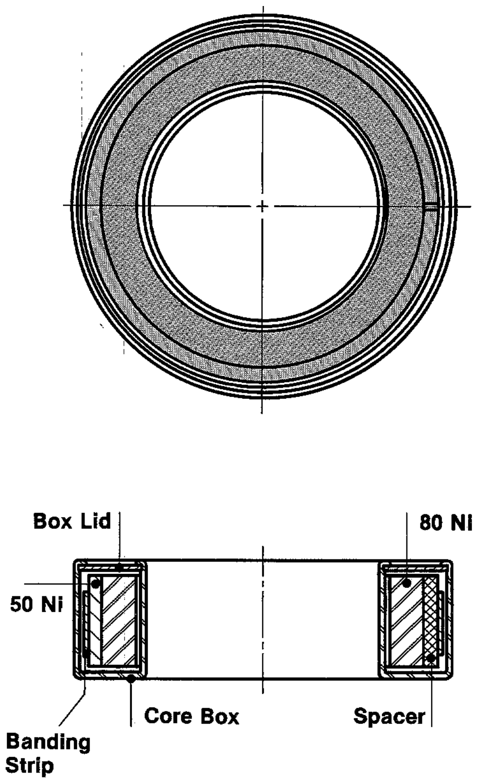


Figure 8

The desired features of the composite core can be obtained more economically by using different materials for the cut and uncut portions of the core. When designs require high nickel (4/79), the cut portion can be low nickel (50/50); and because low nickel has twice the flux density of high nickel, the core is made of 66 percent high nickel and 33 percent low nickel. Also, because of the higher flux density of the low nickel material, a greater energy absorption is possible than with a composite core of the same material. Gap structure is such that variations produced by thermal cycling will not affect this gap greatly.

Composite cores are placed in aluminum boxes and sealed with a protective insulation (GVB) coating.



Composite Core Construction

A partial list of composite cores manufactured by Magnetics is presented below. Two-thirds of the core area is of Square Permalloy (4/79) and one-third is of Orthonol® strip (50/50). Material thickness is .002".

Also listed are MAGNETICS® equivalent standard core part numbers.

Composite Core	Standard Core(1)	WaAc(2) (x10⁶)	Kg(3) (cm^5)
01605-2D	52000	0.017	.001447
01754-2D	52002	0.030	.002369
01766-2D	52033	0.053	.007479
01755-2D	52076	0.059	.009146
01609-2D	52061	0.079	.0103
01756-2D	52106	0.089	.013122
01606-2D	52094	0.119	.030741
01761-2D	52318	0.158	.036045
01757-2D	52029	0.222	.035528
01760-2D	52188	0.237	.07094
02153-2D	52181	0.250	.056315
01758-2D	52032	0.297	.059691
01607-2D	52026	0.445	.121
01966-2D	52030	0.470	.087934
01759-2D	52038	0.593	.194341
01608-2D	52035	0.939	.285298
01623-2D	52425	1.055	.362265
01624-2D	52169	1.407	.578012

(1) Additional details in MAGNETICS Catalog TWC-300.
(2) Product of window area (circular mils) and core area (cm^2) calculated for .002" material.
(3) Core geometry coefficient as described in "Transformer and Inductor Design Handbook", by Colonel W.T. McLyman.

OTHER SPECIAL CORES

One need not limit his designs with magnetic cores to standard catalog sizes and shapes. Often a design may call for a special configuration, unusual machining, or particular processing. Special cores of many types and configurations are manufactured on a custom basis. The following are capabilities within which these special parts can be produced.

RECTANGULAR CUT CORES

A) Tape thickness—.0005” to .014”
B) Tape width—1/8” to 4”
C) Window dimensions—1/8” x 1/8” to 21” x 21”
D) Materials—all magnetic materials.
E) Cutting
  1. Single cut through parallel legs
  2. Multiple cuts through parallel legs
  3. Cuts at angles other than 90° to the plane of the core
F) Vacuum-impregnating—to 24” OD
G) Testing
  1. Exciting current and watt loss to 100 KHz—square or sine wave excitation—with or without DC bias.
  2. Test equipment available—CCFR, series & parallel bridge inductance, pulse permeability.

TOROIDAL CORES

A) OD—to 36”
B) Cutting wheels available—.008” to .062” thick
C) Smallest effective air gap after cutting and lapping—approx. .00025”. Normal effective gap is .0005”.
D) Spacer material for banding with controlled gap—.0002” and up
E) Multiple cuts to specific segment dimensions

OTHER TYPES OF PARTS

A) Formed, annealed shapes
B) Milling machine capability for slotting tape cores
C) Laminated bars

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