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McLyman

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[54] **HIGH POWER/HIGH FREQUENCY INDUCTOR**

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[73] Assignee: **The United States of America as represented by the Administrator of the National Aeronautics and Space Administration,** Washington, D.C.

[21] Appl. No.: **443,297**

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[51] **Int. Cl.**[5] **H01F 27/30**

[52] **U.S. Cl.** **336/198;** 174/DIG. 8; 336/205; 336/229

[58] **Field of Search** 174/DIG. 8; 336/196, 336/229, 205, 207, 206, 148, 149, 198

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[57] **ABSTRACT**

A toroidal core is mounted on an alignment disc having uniformly distributed circumferential notches or holes therein. Wire is then wound about the toroidal core in a uniform pattern defined by the notches or holes. Prior to winding, the wire may be placed within shrink tubing. The shrink tubing is then wound about the alignment disc and core and then heat-shrunk to positively retain the wire in the uniform position on the toroidal core.

9 Claims, 2 Drawing Sheets

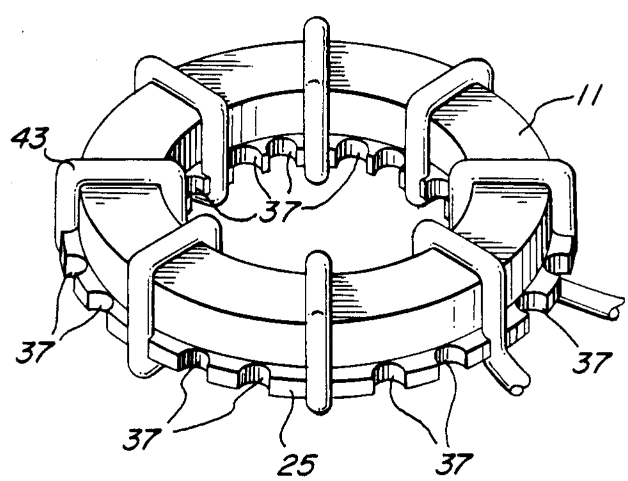


FIG. 1
PRIOR ART

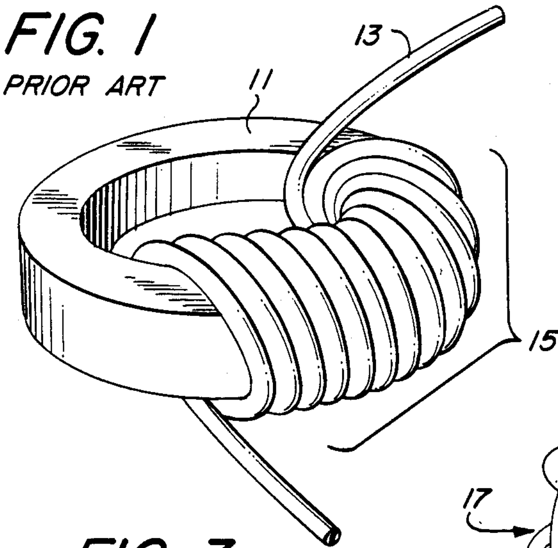


FIG. 2

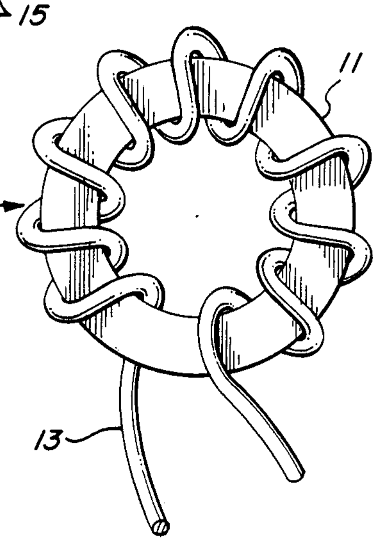


FIG. 3

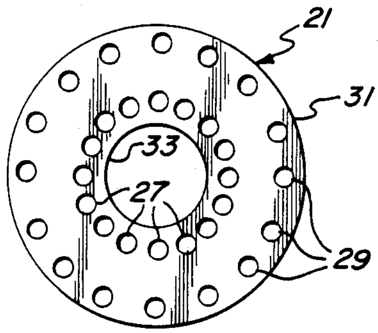


FIG. 4

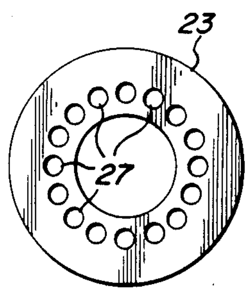


FIG. 5

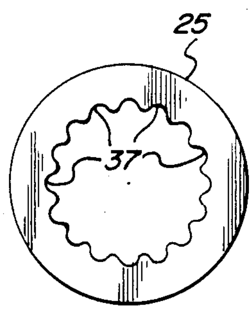


FIG. 6

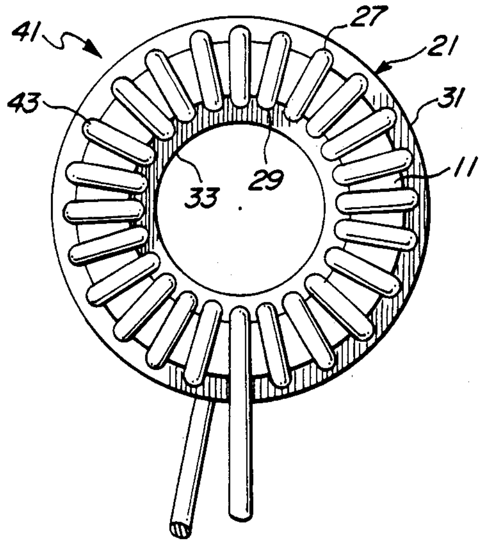


FIG. 7

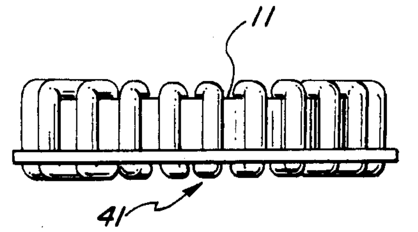


FIG. 8

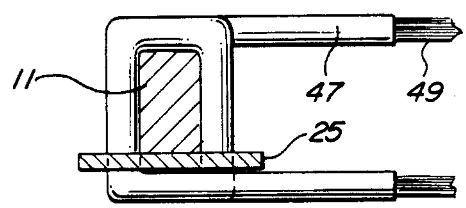


FIG. 9

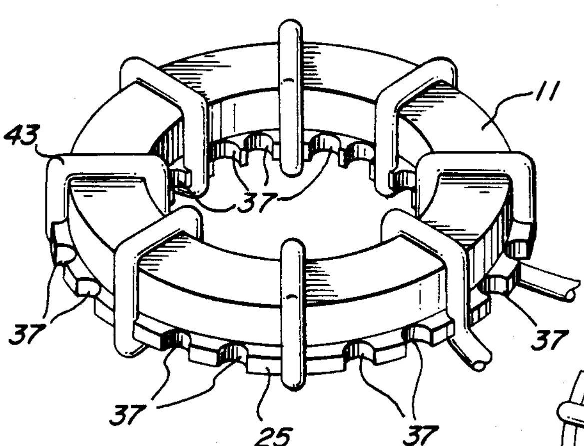
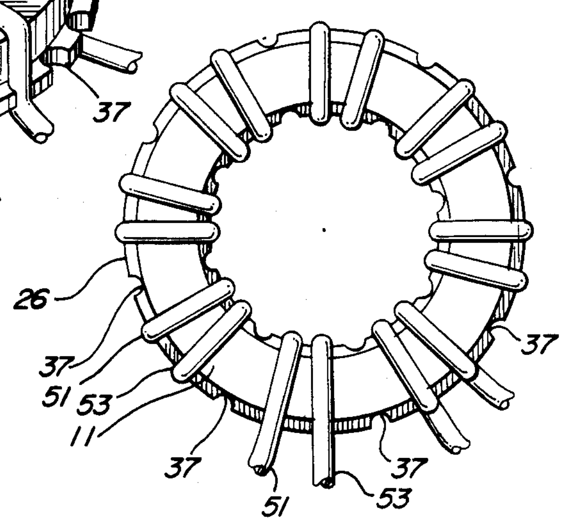


FIG. 10



HIGH POWER/HIGH FREQUENCY INDUCTOR

ORIGIN OF THE INVENTION

The invention described herein was made in the performance of work under a NASA contract, and is subject to the provisions of Public Law 96-517 (35 USC 202) in which the Contractor has elected not to retain title.

TECHNICAL FIELD

The subject invention pertains to electrical components and, more particularly, to an improved inductor design, which exhibits increased repeatability in manufacture of both low and high power, high frequency inductors.

BACKGROUND ART

The present trend in power conversion is to go higher and higher in frequency. Frequencies, such as 0.25–2.0 MegaHertz and higher, have been made possible because of new components which are now available, such as power MOSFETS, better ferrite materials, and quality film capacitors. One of the design approaches in this high frequency field is the resonant converter. The design of a resonant converter requires a high frequency inductor.

In the past, such inductors have been typically fabricated by hand winding Litz wire on a toroidal core. Litz wire is finer than human hair and has no strength. Such prior art high frequency inductor designs result in large amounts of leakage flux, the order of which could be as much as 1.5 to 2.0 times greater than the desired inductance. This variation in leakage flux seriously interferes with production of repeatable designs

STATEMENT OF THE INVENTION

Accordingly, it is an object of the invention to improve inductor structures and performance;

It is another object of the invention to provide an inductor structure which exhibits improved repeatability; and

It is another object of the invention to provide improved high frequency, high power inductor structures.

According to the invention, alignment discs are provided which assist in accurate alignment of fine conductor wire during fabrication of the inductor. The alignment discs employ notches, serrations, or holes to guide the coil wire in uniform fashion about a toroidal core mounted on the disc. The uniform distribution of the coil wire yields a repeatable leakage factor, which, in turn, permits a repeatable inductor design.

An additional feature according to the invention is the provision of shrink tubing through which the fine wire is first pulled. The shrink tubing and wire are thereafter wrapped around a toroidal core in a uniform fashion with the assistance of an alignment disc. Finally, the shrink tubing is heated to rigidly retain the fine wire in precise, uniformly distributed position.

BRIEF DESCRIPTION OF THE DRAWINGS

The just-summarized invention will now be described in detail in conjunction with the drawings, of which:

FIG. **1** illustrates a prior art inductor design;

FIG. **2** is a side top view of a uniformly wound inductor;

FIGS. **3** to **5** illustrate alignment discs according to the preferred embodiment;

FIG. **6** is a top view of an inductor according to the preferred embodiment;

FIG. **7** is a side view of the embodiment of FIG. 7;

FIG. **8** is a side sectional view illustrating an alternate embodiment;

FIG. **9** is a perspective view of an alternate embodiment of the invention; and

FIG. **10** is a top view illustrating a transformer fabricated according to an alternate embodiment.

DETAILED DESCRIPTION OF THE INVENTION

A typical prior art toroidal power core **11** is shown in FIG. **1**. This core **11** is wound with a number of turns **15** of Litz wire **13**. As is well-known to those skilled in the art, Litz wire is fine and fragile wire typically used to wind high power, high frequency inductors. In the typical prior art high frequency, high power design, the number of turns **15** is relatively few, for example, 20 or so turns. These turns **15** are wound adjacent one another on one segment of the toroidal core **11** as shown. The toroidal core **11** typically varies from between 0.125 to 6.0 inches in outside diameter. The core **11** exhibits extremely low permeability, on the order of e.g., **4**. Typical core materials are powdered iron or powdered moly permalloy. The prior art design shown in FIG. **1** exhibits large amounts of leakage or fringing flux, for example, one to two times greater than the desired inductance.

According to the preferred embodiment, the inductor winding is fabricated in a controlled, uniformly distributed manner, in order to obtain repeatability of the electrical parameters. The approach of the preferred embodiment thus avoids the closely packed winding approach of FIG. **1**, while being applicable to various diameter cores.

A winding **17** according to the preferred embodiment is illustrated in FIG. **2**. In this embodiment, the relatively few turns of Litz wire **13** are disposed uniformly around the entire 360-degree circumference of the toroidal core **11**.

In order to repeatably wind an actual core **11** in the uniform fashion illustrated in FIG. **2**, alignment discs **21**, **23**, **25** as illustrated in FIGS. **3–5** are employed. The embodiment of FIG. **3** employs inner and outer sets of alignment holes **27**, **29** in an otherwise annular disc **21**. Both sets of alignment holes **27**, **29** are uniformly spaced about the respective inner and outer circumferences **31**, **33** of the disc **21**. The centers of the inner set of holes **27** are at a common distance from the center of the annular disc, as are the centers of the outer set of holes **29**. In use, a toroidal core **11** is placed between the sets of holes **27**, **29** and the Litz wire is then wrapped about the core and through the holes **27**, **29**. The core **11** may be glued to the disc **21** for additional stability.

The alternative alignment disc **23** shown in FIG. **4** employs only the inner set of circumferentially spaced alignment holes **27**, while the embodiment of FIG. **5** employs notches or serrations **37** instead of holes in an otherwise annular disc **25**. The notches or serrations **37** are again equally spaced apart about the inner circumference of the disk **25** at a uniform distance from the center of the disc **25**. Notches **37** can be placed on either the inner or outer circumference of the disk **25**, or both. All these discs **21**, **23**, **25** are reliable and easily manufactured, for example, from plastic or fiberglass.

FIGS. **6** and **7** show a completely wound toroidal inductor **41** employing a toroidal core **11** mounted on an alignment disc **21**. Litz wire **43** is wound through the holes **27, 29** so as to be uniformly distributed about the toroidal core **11**. Such a design is typically dipped in a coating such as a urethane polymer or semirigid epoxy to positively hold the wire **43** in place, while at the same time providing environmental protection.

FIG. **8** illustrates a further improved embodiment wherein shrink tubing **47** is wound about a core **11** with the assistance of an alignment disc **25**. While any of various disc designs **21, 23, 25** could be used, it is presently felt that the disc **25** of FIG. **5** is the most appropriate for the design of FIG. **8**. Prior to wrapping the shrink tubing **47** about the core **11** and the disc **25** in a uniformly distributed manner, the Litz wire **49** is pulled through the shrink tubing **47**. Hence, after winding, both the shrink tubing **47** and the interiorly contained Litz wire **49** are uniformly spaced around the disc **25** and the core **11**. The shrink tubing **47** is then heated with a heat gun, which causes it to shrink up and freeze rigidly around the toroidal core **11** and disc **25**, thus securing the Litz wire **49** in a uniform pattern around the core **11**, such as that illustrated in FIG. **2**.

It may be appreciated that not every hole **27, 29** in the alignment disc **21** need be used. For example, the Litz wire **43** could be wound through every other hole, with the holes color coded to indicate the appropriate holes through which to insert the wire **43**. FIG. **9** shows an exemplary embodiment wherein the wire **43** is retained by every third notch **37** of a disc **25**.

FIG. **10** shows an embodiment wherein two wires **51, 53** are wound adjacent one another about an alignment disc **26** and a toroidal core **11**. As shown, one notch **37** is skipped between pairs of notches **37** which are occupied by respective turns of the wires **51, 53**. The resulting structure functions as a transformer of precise, repeatable design.

While the above disclosure has employed the use of Litz wire, a strand of fine enameled wire could also be used. Such enameled wire can be glazed, for example, with an epoxy film for rigidity.

A significant advantage of the foregoing design is that the amount of leakage flux can be precisely and repeatedly controlled so that accurate inductor values can be reliably and repeatedly determined in the design process. For example, if one wants an inductor of value X and knows the leakage flux will be Y, then the number of turns and other parameters of design can be computed to provide a nominal value of X-Y. An additional advantage attendant to the ability to accurately design the inductor is that padding capacitor values do not have to be extremely large.

In summary, a high-power, high-frequency AC (alternating current) inductor has been disclosed which accommodates the undesirable effect of fringing flux. The winding of the inductor is fabricated in a manner so as to acquire repeatability of the electrical parameters with inside core diameters ranging from 0.125 to 6.0 inches, thereby controlling the inductance in a simple, reliable, and easily repeatable manner.

Those skilled in the art will appreciate that various modifications and adaptations may be made in the just-disclosed embodiments without departing from the scope and spirit of the invention. Therefore, it is to be understood that, within the scope of the appended claims, the invention may be practiced other than as specifically described herein.

I claim:

1. A high frequency AC inductor formed of turns of a single continuous Litz wire strand and comprising:
- an alignment disc, said disc comprising the only alignment disc associated with said inductor;
- a toroidal, magnetic core mounted on said alignment disc;
- means in said alignment disc for distributing said turns of Litz wire about the entire toroidal surface of said toroidal core with uniform spacing between the turns of said wire and shrink tubing surrounding said Litz wire, said tubing having been shrunk to positively retain said wire in said uniform spacing about said cove.

2. The inductor of claim **1** wherein said alignment disc comprises a flat annular ring having first and second circumferences within which said toroidal core is disposed, and wherein said means comprises a first plurality of holes positioned around a first circumference of said annular ring.

3. The inductor of claim **2** wherein said first circumference comprises the outer circumference of said ring and said means further includes a second plurality of holes positioned around the inner circumference of said annular ring.

4. The inductor of claim **3** wherein said first plurality of holes comprises a first set of holes uniformly spaced about said outer circumference, each hole of said first set having a center equidistant from the center of said annular ring; and wherein said second plurality of holes comprises a second set of holes uniformly spaced about said inner circumference, each hole of said second set having a center equidistant from the center of said annular ring.

5. The inductor of claim **1** wherein said alignment disc comprises a flat, substantially annular ring and said means comprises notches formed in said ring.

6. The inductor of claim **5** wherein said notches comprise a first set of notches uniformly spaced about a first circumference of said ring.

7. The inductor of claim **5** wherein said first circumference comprises the outer circumference of said ring and wherein said notches comprise a second set of notches uniformly spaced about the inner circumference of said ring.

8. The inductor of claim **7** wherein said notches comprise a first set of notches uniformly spaced about the first circumference of said ring.

9. The inductor of claim **2** wherein said wire is wound about said core and through a first set of said first holes and wherein said wire is not wound through a second set of said first holes, said second set of holes being distributed in a uniform manner about said first circumference.

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