United States Patent [19]

Renskers

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[54] **LOW RELUCTANCE INDUCTOR**

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[52] **U.S. Cl.** **336/83,** 336/192, 336/212

[51] **Int. Cl.** **H01f 27/24**

[58] **Field of Search** 336/83, 212, 192, 336/210, 233

[56] **References Cited**

UNITED STATES PATENTS

1,815,380	7/1931	Porter et al.	336/212 X
3,500,274	3/1970	Matsuura et al.	336/83 X
3,585,553	6/1971	Muckelroy et al.	336/192
2,801,293	7/1957	Howell et al.	336/83 X
3,028,570	4/1962	Taylor	336/83
1,673,062	6/1928	Davis	336/83

FOREIGN PATENTS OR APPLICATIONS

662,909	12/1951	Great Britain	336/83
897,517	3/1945	France	336/83
1,564,556	7/1969	Germany	336/83

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[57] **ABSTRACT**

A closed magnetic circuit, high inductance device characterized by minimum reluctance and low cost of manufacture.

1 Claim, 8 Drawing Figures

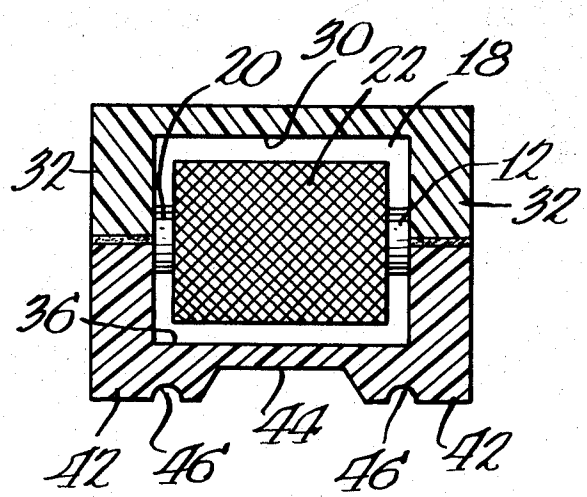


Fig. 1.

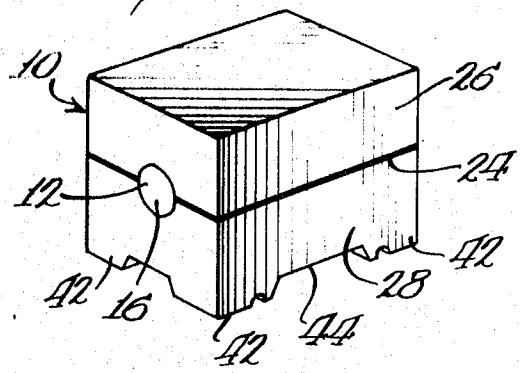


Fig. 2.

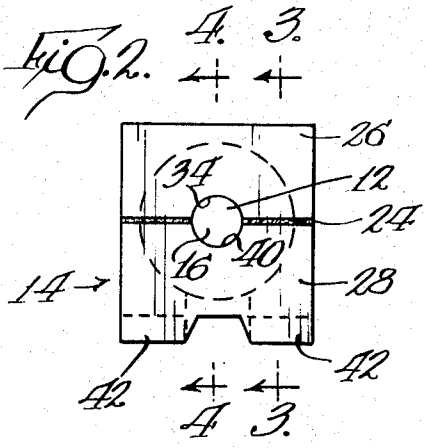


Fig. 3.

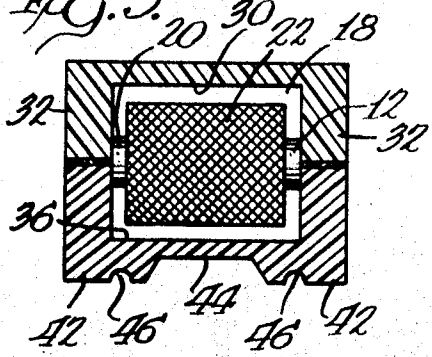


Fig. 4.

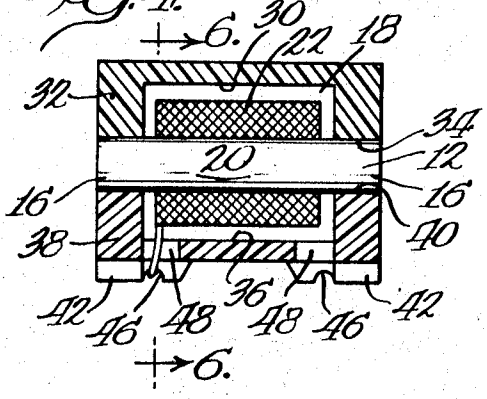


Fig. 5.

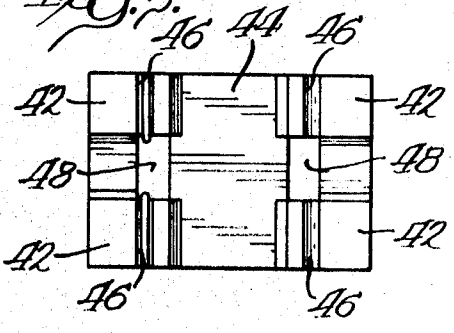


Fig. 6.

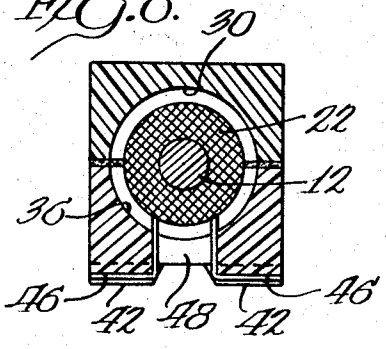


Fig. 7.

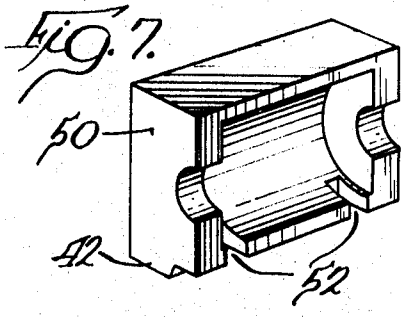
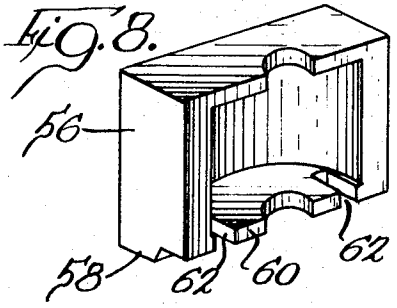


Fig. 8.



LOW RELUCTANCE INDUCTOR

BACKGROUND OF THE INVENTION

Field of the Invention

As inductors are shrunk to meet the needs of microcircuitry, it is desirable to make the magnetic circuit of an inductor as perfect as possible, or in other words, to hold the reluctance to the least possible figure in order to obtain maximum inductive values. This, of course, is achieved by a reduction of air gaps to the least possible extent. As is true with virtually all electronic components, almost any desired degree of perfection can be attained if there is no limit on the cost of the component. In consumer electronics notably, however, cost factors are of prime importance; the field of circuit element manufacture is highly competitive, as is the field of the appliances themselves, and volume sales of the appliances are a direct consequence of low cost in the circuit elements thereof.

SUMMARY OF THE INVENTION

This invention contemplates an inductor including a core and a magnetically permeable shell wherein the magnetic circuit achieves an extremely low reluctance with the least possible air gap at very little cost.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a perspective view of an inductor incorporating the present invention;

FIG. 2 is an end elevation of the inductor of FIG. 1;

FIG. 3 is a section taken along the line 3—3 of FIG. 2 looking in the direction of the arrows;

FIG. 4 is a section taken along the line 4—4 of FIG. 2 looking in the direction of the arrows;

FIG. 5 is a bottom plan view of the inductor of FIG. 1;

FIG. 6 is a section taken along the line 6—6 of FIG. 4 looking in the direction of the arrows;

FIG. 7 is a perspective of half of the inductor shell of FIG. 1 divided in an alternative fashion; and

FIG. 8 is a perspective similar to FIG. 7 showing a shell half formed for a different orientation of the center core.

DESCRIPTION OF THE PREFERRED EMBODIMENT

The present invention is directed to a core and shell structure for an induction device. The material of the structure is preferably a high resistivity, high permeability material such as a ferrite or powdered iron, although the shell may be ceramic where low inductive values are wanted. The induction device **10** includes a cylindrical core **12** and a shell **14** engaging the ends **16** of the cylindrical core and providing a cylindrical cavity **18** about the interior portion **20** of the cylindrical core to accommodate an induction or transformer winding **22** on the central portion **20** of the core **12**. The shell is divided into two halves substantially on a plane **24** extending through the axis of the core **12**. In other words, the shell may be regarded as being longitudinally split with reference to the core **12**. The division **24** separates the shell into a top half **26** and a bottom half **28**.

The top half **26** is a plain block with a semicylindrical cavity **30** formed in the underside thereof leaving planar ends **32** having notches **34** in the free, bottom edges

thereof slightly less than semicircular conforming in radius to the cylindrical core **12**.

The bottom half **28** likewise possesses a semicylindrical cavity **36** in the top surface thereof leaving planar ends **38** with, again, slightly less than semicircular notches **40** formed in the upper edge thereof to confront the notches **34** in the top half, and, with the notches **34**, to embrace the ends **16** of the cylindrical core **12**.

The bottom half **28** has downwardly protruding integral feet **42** at the corners of the bottom surface **44** thereof. The feet **42** have transverse grooves **46** therein extending across the feet to the outside edge of the bottom half **28**. Slots **48** are formed in the bottom of the semicylindrical cavity **36** at each end thereof to extend through the bottom shell and open between the end pairs of feet **42**.

The bottoms of the feet **42** may be coated with a conductive solder or conductive cement for attachment to a hybrid microcircuit "thick film" ceramic plate.

This invention will be best appreciated from some illustrative dimensions. A commercial model has been disigned wherein the shell has a length 0.187 inches, a width of 0.125 inches and an overall height of about 0.125 inches. The core designed to be accommodated in the notches **34** and **40** is equal in overall length to the shell, that is 0.187 inches, and has a diameter of 0.032 inches. The thickness of the end walls of the shell halves is 0.035 inches.

The inductive device illustrated will be formed in the following fashion. The shell halves **10** and **28** will be molded and sintered or fired with the notches formed. The core pins **12** will be molded and sintered and trued to the formed notch diameter by centerless grinding, probably on a batch basis to conform to the lots of shell halves. Since the core extends to the external surface of the shell and is cylindrical and of uniform diameter over its length, it will be appreciated that its length is not critical as long as the necessary minimum is provided.

The notches and shell half edges are interrelated such that, in the dimensionally specified embodiment described, the center of the notch arc is 0.001 of an inch outside the line of the facing edge such that if the two halves conform exactly to specification and are assembled on opposite sides of a core **12**, there will be a 0.002 separation between the shell halves. The tolerance assigned to the outward displacement of the center of the arc in the above embodiment actually is ± 0.001 inches. Thus, combined notches describing a complete circle is a limiting case, and in practice, there is always a positive gap existing between the shell halves when closed on a core.

In view of the smallness of the unit, the coil or transformer will probably be wound directly upon the core **12** although, of course, there is always the possibility that the coil may be wound on a tubular form to encompass the core. In view of the likelihood of direct winding, the extension of the core to the exterior of the shell provides some elongation of the core for greater ease of handling.

The core with the coil on it will be situated in the arcuate notches **40** of the bottom half and the leads of the winding extended through the slots **48** and bent over to lodge within the grooves **46** in the feet **42** of the bottom half and soldered therewithin. The leads thus become conductively connected to the conductive material de-

posited on the bottom of the feet but are recessed into the surface of the feet allowing the feet to make broad contact with the appropriate pads on the thick film for connection thereto.

A polymerizing cement such as epoxy or polyester will be applied to the facing edges of the shell halves to span the separation imposed by the core. The two shell halves are then pressed together to obtain a pressure bearing of the arcuate notches against the core **12** and the adhesive cured. The adhesive is preferably not applied in the area of the notches to avoid an adhesive film which necessarily has some thickness and thus enlarges the air gap to that extent.

An optional shell structure or method of making the shell is illustrated in FIG. **7**. Here, the shell is vertically instead of horizontally divided. Thus, two identical shell halves **50** are employed to make up the whole shell **14**. In this situation, the line of division separates the slots **48** into open-ended notches **52**.

FIG. **8** shows a shell structure designed to have the center core thereof extending perpendicularly to the mounting structure. In this situation, the shell halves **56** have the feet **58** formed on the bottom end walls **60** and the divided slots for the passage of coil leads to the feet again present as notches **62** in that same bottom end wall.

Although the shell halves of FIGS. **7** and **8** might appear to be adaptable to a simple compression molding, in actuality, the feet present difficulties. Accordingly, the feet are best formed by molding ribs to extend to the parting line of the shell halves, firing, and grinding off the inner ends of the ribs to leave the outer ends to constitute the feet. The grinding operation, while an additional step in manufacture, is simple and non-precise and, therefore, inexpensive.

The separation of the slots into the facing notches **52** or **62** may readily facilitate assembly of the complete inductor. Laying the leads of the winding of the inductor in open notches may in many cases be a simpler and quicker procedure than threading them through the slots **48** of the principal described form, and thus offset the added expense of the shell halves incurred from the grinding operation, above.

Some of the advantages of this invention have been set forth above. Others going directly to the matter of improved permeability of the whole magnetic circuit or minimal reluctance are first that the division of the shell into the two halves is axial or longitudinal with respect to the core rather than transverse to the axis thereof. Thus, the fact of the division of the shell into halves imposes no air gap reluctance in itself to the development of flux therewithin. The division is parallel to the lines of force.

Second, the formation of the arcuate notches to less than a semicircle provides for direct and positive contact between the shell halves and the cores to reduce the air gap to an absolute minimum. It will be appreciated that this device as described interposes not even an adhesive film therebetween. The curing of the adhesive while the shell halves are held under pressure results in an effective frictional binding of the ends of the core between the shell halves.

Third, the containment of the ends of the cylindrical core between the notches in the shell halves results in a maximum of confronting surfaces of area of gap, so minimizing reluctance.

These advantages of this invention will be best understood by consideration of alternative forms presently employed. One of these is the center post type pot core closed either by a plate or by a second opposing similar pot core. This configuration has the advantage of only two air gaps in the magnetic circuit, as does the present invention. The confronting area of the center post air gap in either case is πr^2 whereas with the contained core end of the present invention the area is πdh. In order to obtain the same gap area from the center post pot core configuration as is present in the specified inductor above, the center post would have to be four times the diameter of the center core of the present invention, or be equal in diameter to the given shell itself.

Other problems pertain. The center post pot core requires jig grinding to obtain true aligned surfaces which is expensive. Adhesive or dirt enlarges the width of the gap. Avoidance of adhesive requires an outside clamp, adding substantially to the cost.

A second existant option is a pair of facing cup cores with holes in their bottoms and a cylindrical center core contained in the holes to give the πdh gap area. This structure, however, imposes first, a third air gap. Second, there is the conflict of tolerances. The minimum diameter of the holes must be at least equal to the maximum diameter of the center core, so the normal assembly will include a gap of positive width between the core and holes.

I claim:

1. An inductive device comprising a brittle, sintered cylindrical core, a winding thereon, and a brittle, sintered shell having side wall, end walls and a cavity therewithin containing said core and enclosing said winding, said shell being longitudinally divided on a plane containing the axis of said core and having arcuate notches in the free edges of the end walls thereof conforming to and encompassing the cylindrical ends of said core, said notches being less than semicircular so that the facing edges of said shell parts are spaced narrowly apart when said core is contained in said notches, adhesive means spanning said facing edges of said shell parts to secure said shell parts together and in direct contact with said cylindrical ends of said core, said device being characterized by the absence of adhesive between said core and said notches.

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