May 31, 1966 E. OLSEN ETAL 3,254,319

VARIABLE INDUCTORS

Filed April 25, 1961 2 Sheets-Sheet 1

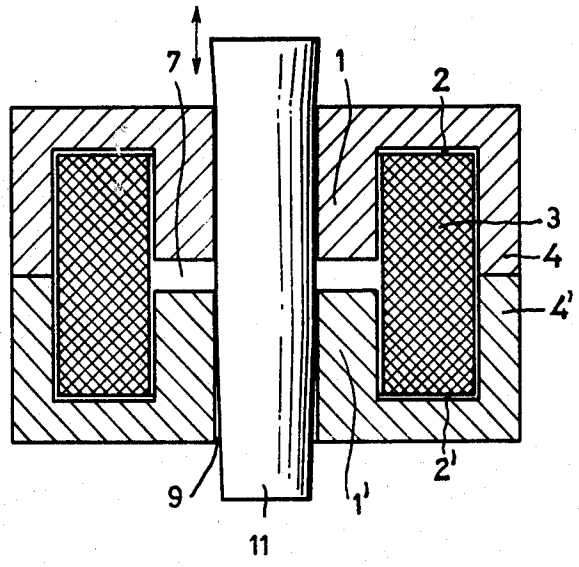


FIG.1

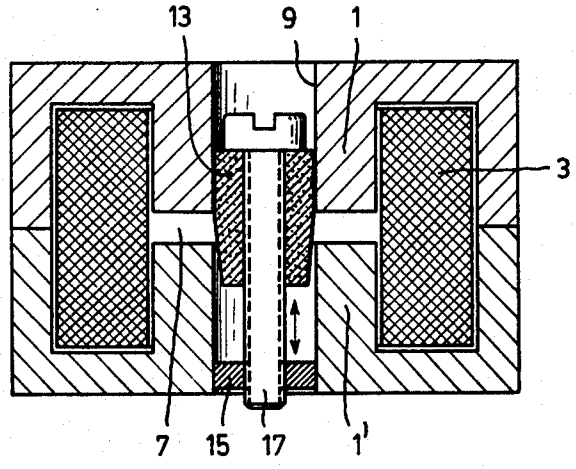


FIG. 2

INVENTOR
Eigil Olsen
Johan Ch. J. Finck
BY
Frank R. Jenfoni
AGENT

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VARIABLE INDUCTORS

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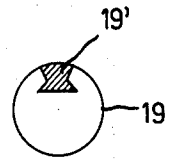


FIG. 3A

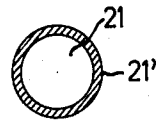


FIG. 3B

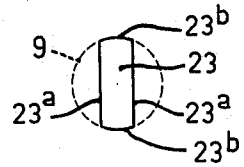


FIG. 3C

INVENTOR
Eigil Olsen
Johan Ch. J. Finck
BY
Frank R. Trifari
AGENT

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3,254,319

VARIABLE INDUCTORS

Eigil Olsen and Johan Christiaan Jacobus Finck, both of Emmasingel, Eindhoven, Netherlands, assignors to North American Philips Company, Inc., New York, N.Y., a corporation of Delaware

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9 Claims. (Cl. 336—136)

This invention relates to inductors, and more particularly to improvements in inductors and the means to vary their inductance.

In order to vary the inductance of some of the inductors of the prior art, a control member composed of ferromagnetic material is placed in close proximity to the associated ferromagnetic core of the inductor. Displacing the control member relative to the core changes the air gap of the associated magnetic circuit causing the inductance of the inductor to be proportionally altered. Means to effect the displacement are provided and include, for example, manual, mechanical, etc. means. In order to obtain different degrees of proportionality, the core, air gap and/or the control member are provided with different configurations.

Generally, in these aforedescribed devices of the prior art, symmetrical configurations of the core, air gap and/or control member are utilized because of the ease in manufacturing and/or ability to determine the type and performance of the change-in-inductance versus displacement characteristic, hereinafter referred to as the variable-inductance characteristic, of the inductor. For example, in one type of variable inductor of the prior art, the core is axially bored along its center axis to provide an air gap having a predetermined diameter. Usually, a cylindrical or conical shaped control member having a maximum diameter somewhat smaller than the diameter of the air gap is placed in close proximity within the air gap so provided. A conical shaped member is generally utilized because an improved gradual variation in the inductance is more readily obtainable than where a cylindrical configuration is utilized. It has been found that in order to obtain suitable control of the variable-inductance characteristic of the inductor, close tolerances must be observed in boring the diameter of the air gap and in shaping the configuration of the control member. However, the control member, like the core, usually consists of a sintered ceramic ferromagnetic material, especially, if the inductor is to be utilized in high frequency applications and the like. As is well known to those skilled in the art, during sintering of these parts a certain degree of shrinkage occurs which is not completely controllable during their manufacturing processes. Thus, the diameter of the bore and of the control member are inherently subjected to liberal tolerances which provide a great variation in the clearance between the core surface surrounding the air gap and the control member. These variations prevent the obtaining of a reliable, reproducible and uniform variable-inductance characteristic of the inductor as well as providing a limited range in which the inductance may vary. In addition, it is difficult to guide accurately the control member within the bore and, therefore, further increases in the irregularity of the variable-inductance characteristic of the coil are realized.

An object of this invention is to provide an inductor of the variable type having a control member with a reliable variable-inductance characteristic.

Another object of this invention is to provide an inductor of the variable type having a simple control member which is self-aligning.

Still another object of this invention is to provide an inductor of the variable type which provides a control member that maintains the aforedescribed advantages but mitigates the afore-described disadvantages of the prior art devices described hereinabove.

A further object of the invention is to provide an inductance device having a ferrite core and a tapered ferrite member coacting therewith which is characterized by relatively liberal tolerances in the manufacture of its different components.

Accordingly, this invention features an inductor having a ferromagnetic core means associated with coil means, and means to vary the inductance thereof. The means to vary comprises at least one air gap with a predetermined volumetric configuration, a predetermined portion of which is formed by at least one part of the core. In addition, a ferromagnetic control member means, adapted to be disposed for relative displacement with the air gap to vary the inductance, is also comprised in the means to vary. The control member means has at least one part with an elastic characteristic which is adapted for compressive coupling relationship with that part of the core which forms a portion of the air gap to align the control member means in a proper manner with that portion of the air gap during relative displacements between the control member and the air gap.

The above-mentioned and other features and objects of this invention will become more apparent by reference to the following description taken in conjunction with the accompanying drawing, in which:

FIG. 1 is a longitudinal section view of the inductor of this invention;

FIG. 2 is a longitudinal section view of another embodiment of the inductor of this invention, and

FIGS. 3A–3C are cross-section views of various types of control members utilized in the inductor of this invention.

While the invention will be described with reference to particular embodiments and a symmetrical system, it is to be understood that these particular embodiments are selected by way of example only to teach the principles of this invention and that other modifications of the configurations of the core means, air gap, or control member, alone or in combination, and/or that an asymmetrical system may also be utilized, as will be obvious to those skilled in the art from the following description.

Thus, in FIG. 1, there is illustrated a symmetrical inductor having core means, illustrated as two annular hollow cylindrical sections **1**, **1'** viewed sectionally along their aligned central longitudinal axes, forming recesses **2**, **2'** respectively to house therein an associated coil means as, for example, schematically illustrated preformed concentric cylindrical-shaped winding **3**. The sections **1**, **1'** are, by way of example only, illustrated in FIG. 1 as being maintained in close contact along their respective outer walls **4**, **4'**, to provide a closed electromagnetic circuit, the coil means having siutable lead out connections, not shown, for coupling to other electrical circuits, in a manner well known to those skilled in the art. An inner portion of the core means is recessed to provide an annular air gap **7**.

A bore **9** of a predetermined diameter and preferably cylindrically shape is provided along the central axes of sections **1**, **1'** and provides a portion of an air gap having a predetermined volumetric configuration and comprising the annular spacing **7** and bore **9**. A control member **11** of ferromagnetic material is arranged within the bore **9** so as to be axially displaceable as illustrated by the arrows. The relative displacement between the member **11** and core means **1**, **1'** provides the means to vary the inductance of the inductor of FIG. 1.

To provide the inductor of FIG. 1 with a reliable variable inductance characteristic, at least a part of the control member **11** is provided with an elastic characteristic adapted for compressive coupling relationship with that part of the core means which forms the portion of the air gap provided by the bore **9**. The upper surface of control member **11** has a larger diameter and the lower surface has a smaller diameter than that of bore **9**, resulting in a gradual taper of control member **11** along its longitudinal axis. The control member **11** is adapted to be introduced into the bore **9** to the extent that the elastically compressed portion of its surface completely bridges the air gap **7**, thereby providing a completely closed magnetic path within the core member. In this manner, the maximum inductance of the inductor is rendered substantially independent of any variations in the dimensions of the bore and/or the control member. Control member **11** is preferably composed of magnetic material having a relatively low permeability, thereby substantially minimizing any irregularities in the variable inductance characteristic of the inductor. It has been found that any adverse effects on the range of control available due to the low permeability of the control member is more than compensated for by the lack of any substantial air gap between control member **11** and the wall of the bore **9** in the vicinity of the air gap **7**. The control member **11** is thus provided with a cross-sectional configuration having at least one dimension in at least one plane normal to the cross-section configuration slightly larger than the diameter of the bore. For example, in the particular embodiment of FIG. 1, the control member **11** is a symmetrical conical frustum, illustrated along the lateral axis thereof as having at least one lateral sector with a diameter slightly larger than the diameter of the bore. Thus, in operation, this sector of the control member **11** would be compressed in that part of the core means which forms a portion of the air gap volumetric configuration; viz., the portion of the air gap formed by the bore **9**. In practice, it is preferred that the bore and outer surface be machined and/or be fabricated smooth to facilitate the insertion and removal of the member **11** from the bore **9**, the actual displacement of the member **11** being performed manually or by automatic means, not shown, in a manner well known to those skilled in the art. It will be noted, in this regard, that the control member **11** will also be self-aligned as it is displaced within the bore **9** due to the tensile reaction of the elastic part of the control member **11** in opposing the compression forces acting on the sector of the member **11** when it is placed in compressive contact with the wall of the bore **9**. Furthermore, since the control member **11** is in elastic compressive contact with the wall of bore **9**, once adjusted the control member is reliably fixed in position without requiring any separate fastening means. In addition, by providing the control member **11** with a conical shape, the advantages of a gradual variation in the inductance are realized, and in this respect, it is preferred that the control member be also provided with a lateral sector having a diameter slightly less than the diameter of the bore **9**.

Referring to FIG. 2, there is illustrated an inductor according to this invention, similar to the inductor of FIG. 1, but in which the control member **13** is also provided with a center bore. Nut **15** and threaded bolt **17**, which passes through the center bore of member **13**, are also provided and coact to displace the member **13** therein and, consequently, vary the inductance of the inductor of FIG. 2 whenever bolt **17** is rotated, the nut **15** being firmly positioned to the core means **1**, **1'** as, for example, in the bore **9**. In addition, the arrangement of FIG. 2 prevents the control member from being displaced, once it has been adjusted, because of, for example, vibrations and the like.

In practice, it is preferred that the control element **11** or **13** be composed of an elastic ferromagnetic material, such as an elastic binder of, for example, rubber impregnated with iron powder or ferrite powder to provide it with its elastic and ferromagnetic characteristics. It is apparent that the control member need not be composed completely of an elastic ferromagnetic material, but that a lateral segment thereof, which will be adjacent to the wall of the bore **9**, and having an elastic characteristic, which may or may not include a ferromagnetic characteristic, may also be utilized without departing from the scope of this invention. Thus, for example, in FIG. 3A, there is illustrated a control member **19**, having an elastic segment **19'** dovetailed therewith. Likewise, it is obvious that in the alternative, the lateral elastic segment may be disposed in the bore of the core means. In FIG. 3B, there is illustrated another alternative for the control member, in which an elastic tubular sheath **21'** is disposed about the control member **21**.

It is apparent that other configurations of the volume and/or cross-section, of the core means, air gap or control member, alone or in combination, may be utilized without departing from the scope of this invention. For example, as illustrated in FIG. 3C, the control member **23** may have a cross-sectional configuration having parallel linear sides **23***a* and two arcuate sides **23***b*, said cross-section being that of a conical or cylindrical frustum. In this regard, at least one of the arcuate sides **23***b* is in elastic coupling relation with the bore **9**.

Nor is it intended that this invention be made applicable to variable inductors only, but the principles of this invention may be utilized in the production of inductors with a constant inductance, which after being adjusted to the desired inductance by means of the elements of this invention, to wit the core and control means, are then permanently maintained in the position associated with the adjusted inductive value as, for example, by a glue compound or the like.

The principles of this invention, and in particular the embodiments of FIGS. 1 and 2, have been found to be particularly adaptable to control members and/or core means composed of a sintered ceramic ferromagnetic material such as the type, for example, utilized in variable high frequency coils.

Thus, while we have described above the principles of our invention in connection with specific apparatus, it is to be clearly understood that this description is made only by way of example and not as a limitation to the scope of our invention as set forth in the objects thereof and in the accompanying claims.

We claim:

1. An inductance device comprising a core structure including first and second pot-shaped opposed members composed of magnetic material and having outer rims disposed in abutting relation, said core structure further comprising first and second tubular members coaxially arranged in confronting relationship to define an axial bore having a cylindrical configuration of uniform diameter and with their adjacent ends spaced apart to define a coaxial annular air gap, said pot-shaped members and said tubular members defining a substantially closed annular recess therebetween, a coil mounted in said annular recess, and an adjustable member mounted for axial movement within said bore, said member comprising a conical frustrum of elastic ferromagnetic material having a maximum diameter normally larger than and a minimum diameter smaller than the diameter of said bore.

2. An inductance device comprising a core of ceramic ferromagnetic material having a central axial portion comprising first and second coaxially arranged tubular projections extending into said core with their adjacent ends separated to define an air gap, said tubular projections together forming a smooth axial cylindrical bore of constant diameter and together with said core defining an annular recess therebetween, an inductive winding disposed around said axial portion within said recess, an

adjustable conical member positioned within said bore, said member comprising an elastic ferromagnetic material having an externally smooth lateral surface and having at least one diameter normally larger than the diameter of said bore, said member being arranged to engage a wall portion of said bore in compressive coupling relationship.

3. Apparatus as defined in claim 2 wherein said air gap has an annular configuration coaxial with the bore axis and wherein said conical member is composed of low permeability magnetic material and is mounted for relative axial movement within said bore.

4. An inductance device comprising first and second cup-shaped elements of ceramic ferromagnetic material arranged in confronting relationship, each of said elements comprising an inner tubular member, said tubular members being coaxially arranged in confronting relationship and spaced apart to define an air gap, an inductive winding arranged within said cup-shaped members, and means for varying the inductance of said inductive winding comprising a conical member positioned for axial movement within said tubular members in the proximity of said air gap, said conical member comprising an elastic ferromagnetic material having an externally smooth lateral surface which has at least one diameter smaller than and at least one diameter normally larger than the internal diameter of said tubular members and arranged to engage a wall portion of said tubular member in compressive coupling relationship.

5. An inductance device according to claim 4 further comprising a threaded rotatable pin associated with said conical member, and a compatible threaded member disposed on said tubular member for engagement with said pin to displace said conical member axially within said tubular members whenever said pin is rotated.

6. An inductance device comprising a coil, a shell-like core structure of ferromagnetic material enclosing said coil to form a magnetic path thereabout and having an axial central portion, said central portion comprising first and second coaxially disposed tubular members extending from said shell in confronting relationship to define an axial bore and spaced apart to define an air gap therebetween which interrupts the magnetic path about said coil, a conically shaped movable elastic ferromagnetic control member located within said bore and arranged to engage a wall portion of said bore in compressive coupling relationship, said bore having a cylindrical configuration of uniform diameter, and means for axially displacing said control member within said bore to vary the reluctance of said magnetic path.

7. An inductance device comprising a hollow core of magnetic material having a pair of end portions and an axial central portion comprising first and second tubular projections extending from said end portions into said core to define a cylindrical bore having a predetermined diameter and with their adjacent ends separated to define an air gap, said hollow core and said axial central portion defining a substantially closed annular space therebetween, a coil disposed around said central portion within said space, an adjustable conical ferromagnetic control member located within said bore and having at least one diameter normally larger than the diameter of said bore and at least one segment thereof having an elastic characteristic for engaging an internal wall portion of said bore in compressive coupling relationship, and means for displacing said control member within said bore to vary the reluctance of the magnetic path about said coil.

8. An inductance device comprising a core structure in the form of a hollow shell of ferromagnetic material and coil supporting means extending axially in said shell to define a substantially closed annular space between said shell and said supporting means, said supporting means comprising first and second tubular members coaxially arranged in confronting relationship to define an axial bore having a cylindrical shape of a given diameter and with their adjacent ends spaced apart to define an air gap, a coil surrounding said axial supporting means within said annular space, an elongated ferromagnetic control member in the shape of a conical frustrum having at least one diameter which is normally larger than and at least one diameter smaller than the diameter of said bore, said control mmeber being positioned within said tubular members and in the proximity of said air gap for relative displacement with respect to said core along the core axis, said member having at least one segment thereof which has an elastic characteristic whereby said member engages a wall portion of said bore in compressive coupling relationship.

9. An inductance device according to claim 8, further comprising mechanical means to displace said conical member with respect to said bore, said mechanical means comprising a rotatable threaded member means associated with said control member and compatible threaded member means affixed to said core to receive said rotatable member means and displace said control member axially within said bore whenever said rotatable member means is rotated.

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ROBERT K. SCHAEFER, *Primary Examiner.*

JOHN F. BURNS, *Examiner.*

W. M. ASBURY, *Assistant Examiner.*