

Sept. 11, 1951

C. W. NUTTMAN  
INDUCTANCE COIL

2,567,394

Filed Aug. 9, 1950

2 Sheets-Sheet 1

FIG. 1

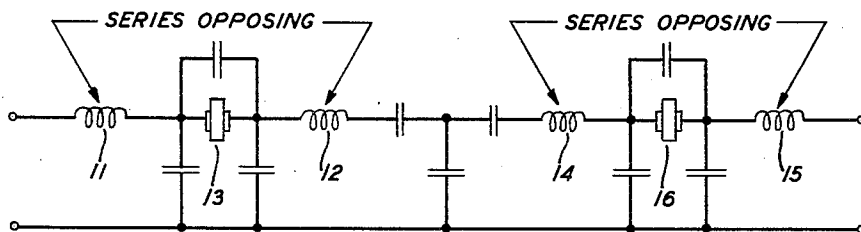
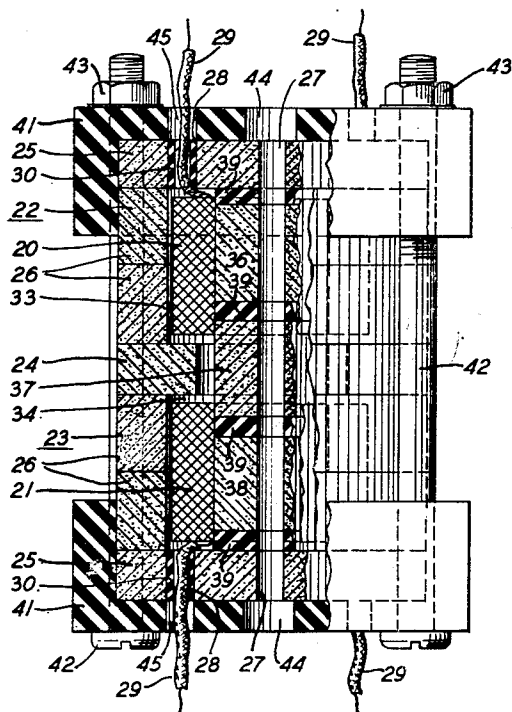


FIG. 2



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2 Sheets-Sheet 2

FIG. 3

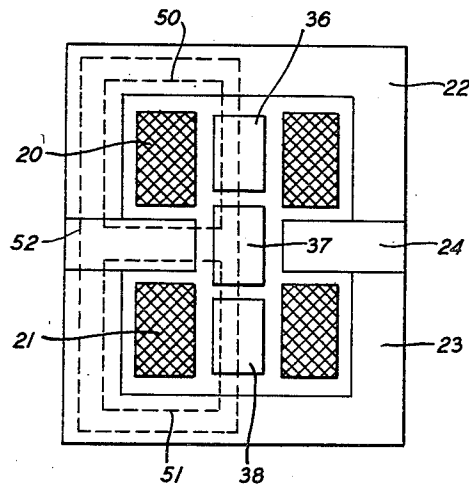
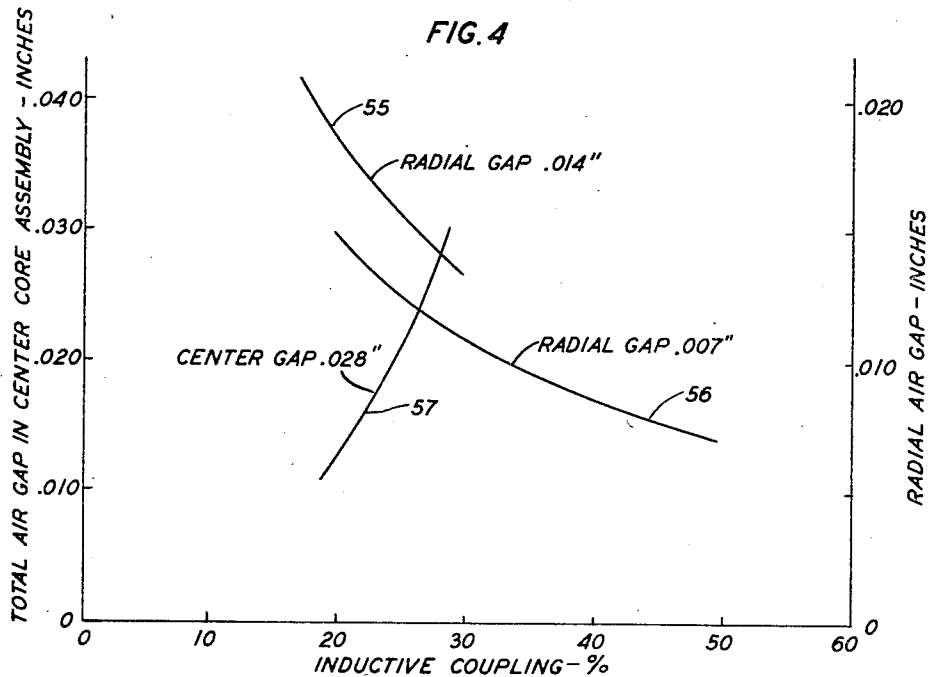


FIG. 4



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## UNITED STATES PATENT OFFICE

2,567,394

## INDUCTANCE COIL

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7 Claims. (Cl. 171-242)

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This invention relates to inductance coils and, more particularly, to such coils having coupled windings.

In certain types of filters and, particularly, those employing crystal units as elements of the filter, it is desirable to provide coupling between two of the inductances in the filter section in order to attain an additional point of infinite attenuation at a finite frequency. By providing slight changes in the percentage of the coupling between the two inductances in a filter section, the frequency at which the additional infinite attenuation occurs is also changed, and, therefore, a different filter performance characteristic is obtained.

In such circuits and in other circuits where different degrees of coupling are required between windings of the same general characteristics and form but electrically positioned in different parts of the circuit, it is desirable that a single basic structure be employed and only slight changes be required during the fabrication of this structure to alter the coupling to the desired percentage. In this way, uniformity of the various piece parts required for the different coupled coils may be obtained with a resultant decrease in the expense of fabricating the different coils.

It is, therefore, one object of this invention to vary the reluctances of the possible flux paths in coils of the general type aforementioned during the fabrication thereof so that a single basic structure may be employed for coils of any desired inductive coupling.

It is another object of this invention to provide a single basic coil structure in which the inductive coupling between the two windings can be facily predetermined at any value between approximately zero and 100 per cent.

It is a further object of this invention to improve the facility with which such coils are fabricated and to diminish the expenses of production that have been necessitated by employing different coil structures and differently dimensioned coil parts for coils with different values of inductive coupling between the windings thereof.

A further object of this invention is to provide an improved inductance coil.

These and other objects are accomplished in one specific illustrative embodiment of this invention in which a hollow enclosed casing of a ferromagnetic material, such as a sintered ceramic ferromagnetic material known as ferrite, is divided into two sections or cavities by a central ring which forms part of the casing and extends into the casing. A center core, which

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also may be of ferrite, is placed in each of these cavities along the axis of the casing, and a winding surrounds each center core. A third center core is positioned inside the casing medially adjacent the central ring along the same axis as the other cores and extends slightly into each of the windings. Air-gaps are provided between each of the three center cores and between the two end center cores and the end sections of the casing by insulating members separating them and between the middle center core and the central ring. By varying these air-gaps in relation to each other, the inductive coupling between the two windings may be varied from approximately zero to 100 per cent.

Specifically, there may be altered the reluctances of the paths of the flux linking each coil singly and coupling the two coils by varying the air-gap between the central ring and the middle center core to particularly affect the individual flux paths, and by varying the air-gaps in the three piece center core, and especially the distance the middle center core extends into the windings, to particularly affect the inductive coupling between the two windings.

It is, therefore, one feature of this invention that the enclosed casing of the coil be divided into distinct sections or cavities, each of said cavities having a winding therein, and that said cavities be magnetically linked by a center core member extending between said cavities and partially into each of said windings.

It is a further feature of this invention that the casing comprise a central ring or plate adjacent the above-mentioned center core and extending into the casing towards that center core to divide the casing into two cavities and to provide a flux path from the casing to the center core.

It is a still further feature of this invention that the central magnetic path in the casing comprise a plurality of center cores axially aligned and separated from each other and from the end sections of the casing, the distances between the cores themselves and the end sections providing air-gaps, which, together with the air-gap between the center core and the central ring, may be varied during the fabrication of the coil to obtain any desired degree of coupling between the two windings.

A complete understanding of this invention and of these and other features thereof may be gained from consideration of the following detailed description and the accompanying drawings, in which:

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Fig. 1 is a schematic representation of a portion of a crystal channel filter employing coils having controlled coupling between the two windings thereof;

Fig. 2 is an elevational view of a coil having coupled windings employable in the circuit of Fig. 1, a portion of the coil being shown in section;

Fig. 3 is a representation of the flux paths of the coil of Fig. 2; and

Fig. 4 is a graph illustrating the percentage change in the inductive coupling in the coil of Fig. 2 with change in the reluctances of the flux paths shown in Fig. 3 by variation of the lengths of the radial and central air-gaps.

Referring now to the drawing, Fig. 1 is a schematic representation of a crystal channel filter using coils having controlled coupling between the windings of each coil. The first coil comprises a first winding 11 and a second winding 12 placed in series opposing and with a crystal unit 13 between the two windings. Similarly, the second coil comprises a first winding 14 and a second winding 15 in series opposing and with a crystal unit 16 between the two windings. The percentage of coupling between the windings of the two coils may be different; thus, in one illustrative channel filter circuit, the percentage coupling between the windings 11 and 12 may be 17.09 per cent, and the percentage coupling between the windings 14 and 15 may be 19.10 per cent. However, in accordance with this invention, both coils may advantageously be constructed in the same general structure and from the same component parts as in the illustrative embodiment of this invention shown in Fig. 2.

As seen in that figure, the coil windings 20 and 21 are completely enclosed within a cylindrical casing, the casing being made up of two cup-shaped members 22 and 23 and an annular center plate 24 between them, the casing and other members forming portions of the flux paths of the coil being advantageously of a ferromagnetic material and, particularly, of a sintered ceramic ferromagnetic material known as ferrite. Thus, the magnetic portions of the coil may advantageously be of a manganese-zinc ferrite. In the specific embodiment illustrated in the drawing, the cup-shaped members were themselves constructed of several component parts including end plates 25 and rings 26; however, the cup-shaped members may be made in one piece if desired. Each end plate 25 has an aperture 27 axially therein, the purpose for which will be discussed below, and apertures 28 through which the leads 29 of the coils 20 and 21 extend. Insulating grommets 30 are positioned in the apertures 28 around the leads 29.

The annular center plate 24 extends inwards into the casing further than the sides of the cup-shaped members 22 and 23, or, in this specific embodiment, further than the rings 26. The annular center plate 24 thus divides the casing into two equal cavities 33 and 34. Winding 20 is placed axially in cavity 33 and winding 21 axially in cavity 34. Three center cores 36, 37, and 38, defining a center post, extend axially between the two end plates 25, being separated from them and from each other by air-gap spacers 39, which may be of paper or other insulating material. The spacers 39 are advantageously approximately equal as the maximum Q is attainable when the central air-gaps defined by these spacers are approximately equal. The spacers 39 and the cores 36, 37, and 38 are axially

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apertured and provide, with the apertures 27 in the end plates 25, an open path through the casing, the reason for which will be discussed below.

The winding 20 is supported on the center core 36 in the cavity 33, and the winding 21 is supported on the center core 38 in the cavity 34. The middle center core 37 is adjacent the center ring or plate 24 and extends partially into each cavity 33 and 34 and into each winding 20 and 21. The windings may be secured directly to the cores, as shown, or, if it is intended to operate coils constructed in accordance with this invention at higher voltages than those generally encountered in channel filters, the windings may be wound on insulating spools and the spools secured to the center cores in ways known in the art.

The casing is clamped between two clamping plates 41, which may be square, by clamping screws 42 and nuts 43. The clamping plates 41 have apertures 44 centrally therein aligned with apertures 27 in the end plates 25 and apertures 45 aligned with apertures 28 in the end plates 25 and through which apertures 45 the lead wires 29 extend. The insulating grommets or tubing 30 may also extend into or through the apertures 45.

Referring now especially to Fig. 3, there are three magnetic circuits or paths provided by the above-described arrangement of cup-shaped members, center ring and cores. Magnetic flux may follow the path 50 defined by the center core 36, part of the center core 37, the ring 24, and the cup-shaped member 22 and thus not link the coil 20 with the other coil at all. Similarly, there is a flux path 51 around the cavity 34 for which there is no coupling between the coils. However, there is also a possible flux path 52 through the three cores 36, 37, and 38, through the rim of the ring 24, and the cup-shaped members 22 and 23, all of which flux would link both windings 20 and 21.

It is thus apparent that the flux from each winding that follows the paths 50 or 51 links only the turns of its own winding, whereas the flux from either winding that follows the path 52 links the turns of both windings, inductively coupling them. It has been found that this inductive coupling between the two windings may be varied between approximately zero and 100 per cent by varying the reluctances of these three flux paths and, specifically, by varying the ratio of the lengths of the air-gaps in the individual winding flux paths 50 and 51 and the lengths of the air-gaps in the coupling flux path 52. Thus, the percentage of the inductive coupling between the two windings may be decreased by increasing the air-gaps in the central post of the coil, i. e., between the center cores 36, 37, and 38 and between these coils and the ends of the cup-shaped casing members 22 and 23; or the percentage of the inductive coupling may be decreased by decreasing the radial air-gap between the central annular plate 24 and the middle center core 37. The first alteration of the air-gaps primarily affects the flux path 52 by increasing the reluctance of that path, as that path includes each of the four air-gaps formed between the center cores and the casing ends. The second alteration of the air-gaps primarily affects the flux paths 50 and 51 by reducing the reluctance of those paths. The percentage of coupling can similarly be increased by the opposite of these air-gap variations.

It has been found that in the fabrication of

these coils, when both variations of air-gap spacings from the base value or norm are incorporated in the coil so that their effects are cumulative, the inductive coupling can be varied in this single structural design from approximately zero to 100 per cent and that any coupling desired within these limits may be obtained.

The coil may be assembled by a jig having a non-magnetic dowel or pin extending upwards and onto which the various parts are placed, the dowel extending through the apertures 44 of the clamping plates 41, apertures 27 of the end members 25, the apertured spacers 39, and the hollow center core members 36, 37, and 38. The rings 26 and annular center plate 24 are positioned in place on the jig, as by two semi-cylindrical paper tubes positioned in the jig and bearing against the coil between the clamping plates 41 to centrally locate these members prior to the final clamping of the screws 42 and nuts 43.

The rings 26 and core members 36, 37, and 38 may all be initially of a standard or base size, which size may be the largest that is expected to be needed to obtain any of the percentages of inductive coupling desired. In order to increase the length of the air-gaps in the center core assembly, each of the center cores 36, 37, and 38 would then be slightly reduced in height, as by grinding, and the spacers 39 increased, as by additional layers of paper between the cores. As pointed out above, this tends to decrease the inductive coupling between the two windings 20 and 21. Similarly to decrease the air-gaps in the center core and thus increase the coupling, the heights of the outer rings 24 may be slightly decreased, as by grinding, as the total length of the spacers 39 and the center core members 36, 37, and 38 equals the height of the four outer rings 26 and the center ring 24.

The radial air-gap between the medially located center core member 37 and the annular plate or ring 24 is determined by the diameter of the core member and the inner diameter of the ring 24. As the core member 37 fits into each of the windings 20 and 21 to provide the low reluctance flux path between them, its outer diameter cannot be altered. Thus, I have found it advisable to vary the radial air-gap and thus vary the reluctances of the flux paths 50 and 51, which link only their respective windings, by changing the inner diameter of the annular plate member 24.

In certain illustrative embodiments of this invention constructed in accordance with Fig. 2 and described above, different radial and total central air-gaps have been employed, and the following table is exemplary of the variations in the inductive coupling that I have been able to obtain with this single basic structure by means of these different air-gaps:

| Total Air-gap<br>in Central<br>Core Assembly | Radial Air-<br>gap | Inductance and Approximate Turns of Winding |                          | Inductive Coupling<br>between Wind-<br>ings in the Series<br>Opposition Con-<br>nection |
|----------------------------------------------|--------------------|---------------------------------------------|--------------------------|-----------------------------------------------------------------------------------------|
|                                              |                    | 20                                          | 21                       |                                                                                         |
| .015"                                        | .007"              | 160 turns, 15.30 mh.....                    | 160 turns, 14.89 mh..... | Per Cent<br>47.0                                                                        |
| .028"                                        | .007"              | 160 turns, 7.52 mh.....                     | 160 turns, 6.75 mh.....  | 21.3                                                                                    |
| .028"                                        | .014"              | 212 turns, 17.39 mh.....                    | 212 turns, 18.84 mh..... | 28.2                                                                                    |
| .040"                                        | .014"              | 212 turns, 12.30 mh.....                    | 212 turns, 13.32 mh..... | 18.7                                                                                    |

These measurements were made at 100 kilocycles and with .001 ampere through the windings 20 and 21.

Fig. 4 graphically represents this data, curve 56 being drawn for the constant radial air-gap of .007" and curve 55 being drawn for the constant radial air-gap of .014", each being a curve of total central core air-gap as against the percentage of inductive coupling. As is readily apparent, the coupling increases for each curve with decrease in the total central air-gap, for the reasons explained above. Similarly, curve 57 is a curve of radial air-gap against percentage inductive coupling for a constant total center core air-gap of .028"; as is also readily apparent by this curve, the percentage of inductive coupling between the coils increases with an increase in the radial air-gap, for the reasons explained above.

It is to be understood that although these curves have been plotted in a specific percentage range of inductive coupling, the coupling may be predetermined at any value from approximately zero to 100 per cent by extensions of these curves and of the principles of this invention, whereby different curves for different values of air-gap lengths are attainable. Thus, by preparing a series of curves of, for example, central air-gap length against inductive coupling for different constant radial air-gap lengths, the air-gap lengths necessary for any desired coupling can be read directly off the chart thus prepared and the parts ground or otherwise slightly varied to the lengths thus determined. In that way, the complete range of inductive coupling may be covered by a single structure employing in each instance the same piece parts but readily varied during the fabrication in accordance with information easily obtainable from priorly prepared charts, thereby allowing a multitude of different coils, as for different locations in filter circuits, to be fabricated without the equal multitude of different parts that must be stored and differently fabricated.

It is to be understood that the above-described arrangements are illustrative of the application of the principles of the invention. Numerous other arrangements may be devised by those skilled in the art without departing from the spirit and scope of the invention.

What is claimed is:

1. In an inductance coil, a hollow enclosed casing, said casing including a member extending into said casing and dividing said hollow casing into two sections, a center core in each of said sections, a winding around each of said cores, a middle center core extending within said member and defining a first air-gap therewith, said middle core being in juxtaposition with the first mentioned center cores in said sections, said casing and said cores being of a ferromagnetic material, and means providing second air-gaps between said center cores whereby the

percentage coupling between said two windings is determined by the relationship between the lengths of said first and second air-gaps.

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2. In an inductance coil, a hollow enclosed casing, said casing including a member extending into said casing and dividing said hollow casing into two sections, a center core in each of said sections, a winding around each of said cores, a middle center core extending through said member and defining a first air-gap therewith, said middle core extending into each of said sections, said casing and said cores being of a ferromagnetic material, and means providing second air-gaps between said center cores and between the outer of said center cores and said casing whereby the percentage coupling between said two windings is determined by the relationship between the lengths of said first and second air-gaps.

3. In an inductance coil, a hollow enclosed casing, said casing including a member extending into said casing and dividing said hollow casing into two sections, a center core in each of said sections, a winding around each of said center cores, a middle center core extending through said member and defining a first air-gap therewith, said casing and cores being of a sintered ceramic ferromagnetic material, said middle core extending into each of said windings and providing a low reluctance flux path between said two windings, and means providing second air-gaps between said center cores and between the outer of said center cores and said casing whereby the percentage coupling between said two windings is determined by the relationship between the lengths of said first and second gaps.

4. In an inductance coil, a hollow cylindrical body closed at both ends, said body including a center ring extending into said hollow body and dividing said hollow body into two sections, a central post in said body, said central post comprising a center core in each of said sections and a middle center core extending adjacent said center ring and defining a first air-gap therewith, said body and said cores being of a ferromagnetic material, a winding around each of said outer cores in said sections, and means providing second air-gaps in said central post and between said post and said body, the percentage of inductive coupling between said windings being determined by the relative widths of said first and the total of said second air-gaps.

5. In an inductance coil, a hollow cylindrical body closed at both ends, said body including a center ring extending into said hollow body and dividing said hollow body into two sections, said body being of a ferromagnetic material, a central post in said body, said central post comprising a center core in each of said sections and a middle center core extending adjacent said center ring and defining a first air-gap therewith, said cores being of a ferromagnetic material, a winding around each of said outer cores in said sections, said middle center core extending into each of said windings and providing a low re-

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luctance flux path between said windings, and means providing second air-gaps in said central post and between said post and said body, the percentage of inductive coupling between said windings being determined by the relative widths of said first and the total of said second air-gaps.

6. In an inductance coil, a hollow cylindrical body closed at both ends and having apertures centrally located in said ends, said body including a center ring extending into said body and dividing it internally into two sections, a center core in each of said sections, a middle center core extending between said sections adjacent said ring and defining a radial air-gap therewith, said body and said cores being of a ferromagnetic material, said cores being aligned axially in said body and having apertures there-through aligned with said apertures in said ends of said body, a winding around each of said outer cores in said sections, said middle core extending partially into each of said windings, apertured spacers between each of said cores and between said cores and said ends of said body, the apertures of said spacers being axially aligned with said other apertures, said spacers defining a plurality of central air-gaps, the percentage inductive coupling between said windings being determined by the relationship between said radial air-gap and the total of said plurality of central air-gaps, and means clamping said body together.

7. An inductance coil comprising a hollow cylindrical body comprising a pair of end members, each of said members having an aperture centrally therein, a plurality of ring members, and a central annular plate member, said annular plate member extending into said body and dividing said body into two sections, a center core axially in each section, a winding around each center core, a middle center core extending axially between said sections adjacent said annular plate member and defining therewith a radial air-gap, said body and said cores being of a sintered ceramic ferromagnetic material, said middle core extending partially into each of said windings, each of said cores being axially apertured, apertured spacers between each of said center cores and between the outer center cores and said end members, the apertures of said spacers being axially aligned with said other apertures, said spacer members defining four approximately equal central air-gaps, the lengths of said central air-gaps being determined by the relative lengths of said cores and said rings, the percentage inductive coupling between said windings being determined by the relationship between said radial air-gap and the total of said four central air-gaps, and means clamping said body together.

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No references cited.