

[72] Inventors **Ellwood S. Douglas**
Orinda;
Wallace W. Wahlgren, Oakland, both of
Calif.
 [21] Appl. No. **38,966**
 [22] Filed **May 20, 1970**
 [45] Patented **Dec. 21, 1971**
 [73] Assignee **The Rucker Company**
Oakland, Calif.

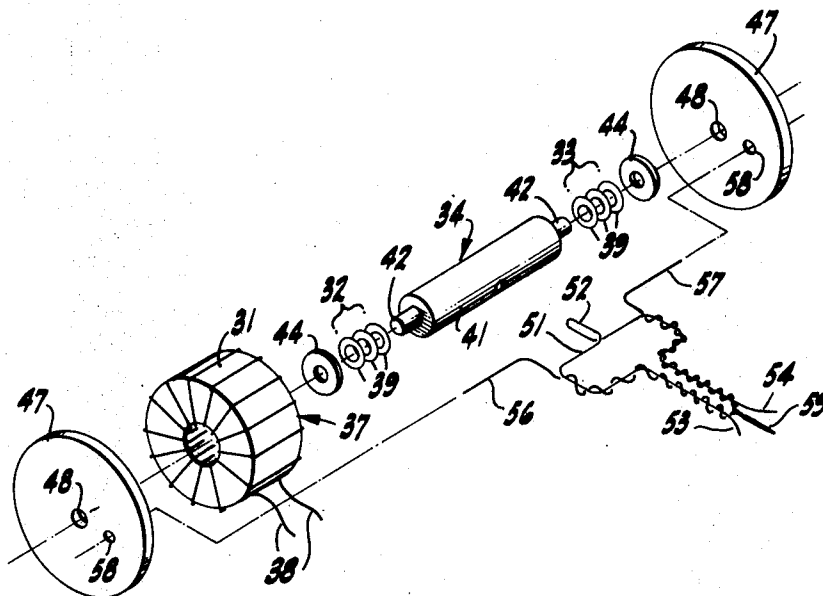
[56] **References Cited**
UNITED STATES PATENTS
 1,953,779 4/1934 Sclater et al. 336/82
 2,829,338 4/1958 Lord..... 336/174 X
 3,020,502 2/1962 Graham..... 336/229 X
 2,901,714 8/1959 Baker..... 336/229 X
 3,493,908 2/1970 Byers et al. 336/229 X
 1,986,884 1/1935 Fassler 336/82

Primary Examiner—Thomas J. Kozma
Attorney—Flehr, Hohbach, Test, Albritton & Herbert

[54] **COUPLING TRANSFORMER ASSEMBLY**
8 Claims, 7 Drawing Figs.

[52] U.S. Cl..... **336/82,**
336/174, 336/175, 336/212, 336/229
 [51] Int. Cl..... **H01f 15/02**
 [50] Field of Search..... **336/82,**
174, 175, 212, 229, 73

ABSTRACT: Transformer assembly having an electrically conductive casing and spindle member forming a one-turn winding linking a plurality of toroidal cores within the casing.



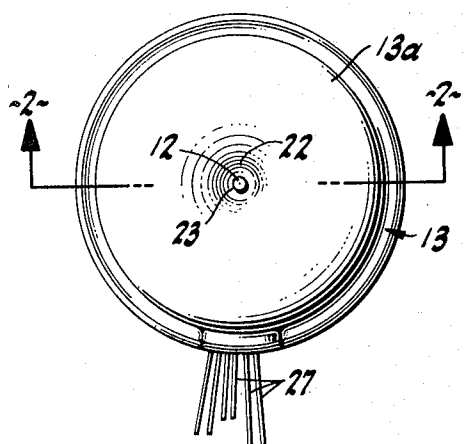


FIG. 1

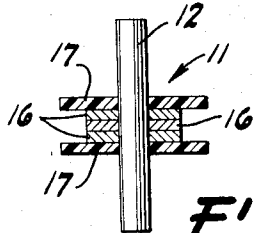


FIG. 3

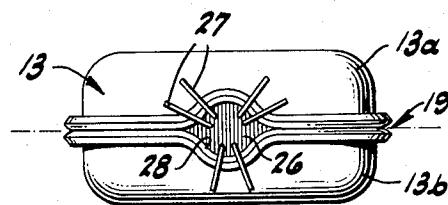
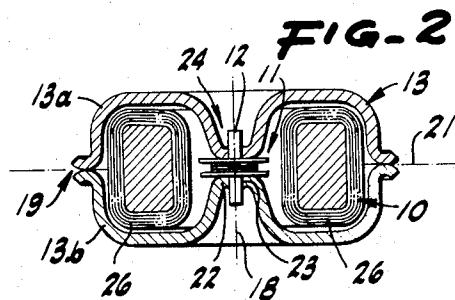


FIG. 4

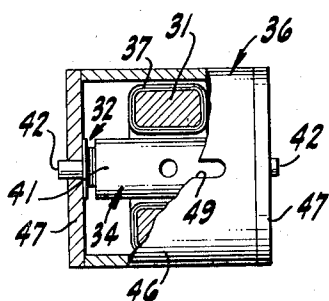


FIG. 5

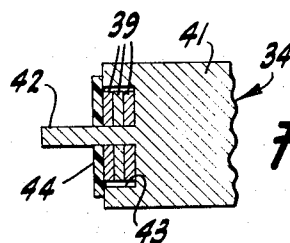


FIG. 6

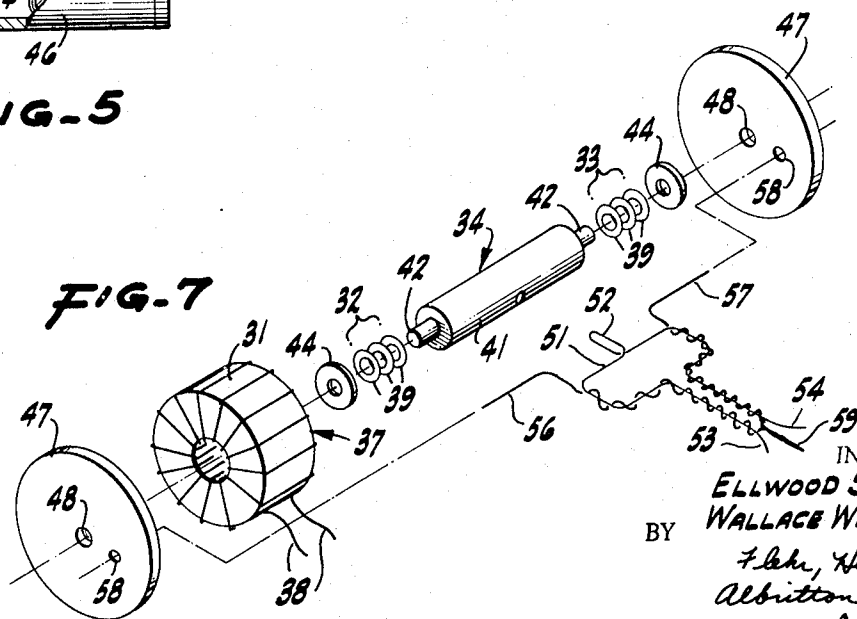


FIG. 7

INVENTORS
 ELLWOOD S. DOUGLAS
 WALLACE W. WAHLGREN
 BY
 Flehr, Hohbach, Vesta,
 Albritton & Herbert
 ATTORNEYS

COUPLING TRANSFORMER ASSEMBLY

BACKGROUND OF THE INVENTION

This invention pertains generally to electrical transformers and inductors and more particularly to a transformer having a plurality of coupled toroidal cores.

In ground fault detectors and current interrupters of the type disclosed in U.S. Pat. application Ser. No. 18,158, filed Mar. 10, 1970 and assigned to the assignee of the present invention, ground fault signals are stored magnetically in inductor cores coupled to the secondary winding of a differential transformer. As is pointed out in the aforementioned application, it is desirable to make this coupling through a coupling transformer having a multiple-turn primary winding connected to the secondary winding of the differential transformer. The coupling transformer is coupled to the inductor cores by a single-turn coupling link. Additional windings can be provided on either the differential transformer or the coupling transformer for reading the stored flux signals out of the inductor cores. Alternatively, the coupling transformer primary winding can serve as a readout winding.

The inductor cores used in such ground fault detectors and current interrupters are typically very small in size, and it is therefore difficult to provide proper coupling between them and the coupling transformer. Conventional coupling links have a resistance and stray inductance which severely limit the signals which can be coupled between the coupling transformer and inductor cores.

There is therefore, need for a new and improved coupling transformer assembly which overcomes the foregoing and other problems encountered with coupling transformers and coupling links of the type heretofore provided.

SUMMARY AND OBJECTS OF THE INVENTION

The coupling transformer assembly of the present invention includes a toroidal core having a winding comprising a plurality of turns wound thereon. One or more inductor cores is disposed coaxially of the toroidal core, and an electrically conductive spindle member extends axially through at least a portion of these cores. An electrically conductive casing encloses the cores and is connected to the ends of the spindle member to form a single-turn winding linking all of the cores. The casing also serves to protect the toroidal core and inductor core against mechanical damage. An additional winding is provided on the toroidal core for reading stored flux signals out of the inductor cores. While intended primarily to provide coupling between the secondary winding of a differential transformer and one or more toroidal inductor cores in ground fault detector, the coupling transformer assembly of the present invention can also be utilized in other situations in which it is desirable to provide coupling between two or more toroidal cores.

It is in general an object of the present invention to provide a new and improved coupling transformer assembly.

Another object of the invention is to provide a coupling transformer assembly of the above character which is particularly adapted for driving a plurality of toroidal inductor cores.

Another object of the invention is to provide a coupling transformer assembly of the above character which is usable over a wide range of frequencies.

Another object of the invention is to provide a coupling transformer assembly of the above character which includes a coupling transformer core and at least one toroidal inductor core in an integral package.

Another object is to provide a coupling transformer assembly of the above character which includes single-turn coupling between the coupling transformer core and at least one toroidal inductor core.

Another object is to provide a coupling transformer assembly of the above character in which the resistance and stray inductance of the coupling link are very small.

Additional objects and features of the invention will be apparent from the following description in which the presently

preferred embodiment are set forth in detail in conjunction with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a top plan view of one embodiment of a coupling transformer assembly incorporating the present invention.

FIG. 2 is a cross-sectional view taken along line 2—2 in FIG. 1.

FIG. 3 is an enlarged sectional view illustrating the construction of the inductor core in the embodiment shown in FIGS. 1 and 2.

FIG. 4 is a front elevational view of the embodiment shown in FIG. 1.

FIG. 5 is a front elevational view, partially sectioned, of another embodiment of a coupling transformer assembly incorporating the present invention.

FIG. 6 is an enlarged sectional view of one end of the spindle assembly of the embodiment illustrated in FIG. 5.

FIG. 7 is an exploded perspective view of the embodiment illustrated in FIG. 5.

DESCRIPTION OF THE PREFERRED EMBODIMENT

The embodiment illustrated in FIGS. 1-4 includes a toroidal transformer core 10, and inductor core 11, a spindle 12, and a casing 13.

The cores 10 and 11 are fabricated of a material having a high magnetic permeability. The core 10 is substantially larger than the core 11, and the core 11 is disposed coaxially of the core 10 and within the opening of that core. In one presently preferred embodiment, the core 10 has an inside diameter on the order of 0.375 inch, and the core 11 has an outside diameter on the order of 0.030 inch. The core 11 is formed of a plurality of individual toroidal core members 16 stacked between a pair of insulative washers 17. The inductance of the inductor core 11 can be varied by changing the number of core members 16 in the stack. While the toroidal core 10 is shown as comprising a single core member, this core can also be formed of a plurality of stacked core laminations if desired.

The spindle 12 lies on the axis 18 of the toroidal core 10 and passes axially through the opening in the inductor core 11. This spindle is fabricated of an electrically conductive material such as copper. The casing 13 is likewise fabricated of an electrically conductive material. This casing is formed in two sections 13a, 13b which are joined together at 19 in the central plane 21 of the toroidal core 10. The casing 13 is generally toroidal in shape, and each of the sections 13a, 13b includes a central web portion 22. These web portions are formed to include axially disposed openings 23 through which the spindle 12 passes. The web portions of the casing sections are connected to the ends of the spindle by conventional means such as soldering, as indicated at 24. The joint at 19 between the two casing sections is likewise formed by conventional means such as soldering.

It is to be noted that the casing 13 and the spindle 12 together form a single-turn winding which links both the toroidal core 10 and the inductor core 11. The casing also protects the cores 10 and 11 from mechanical damage.

A plurality of windings, designated generally by the reference numeral 26, are provided on the toroidal core 10. At least one of these windings is formed of a plurality of turns wound on the core 10 and is thereby adapted for connection to the multiple-turn winding such as the secondary winding of a differential transformer. Each of the windings 26 is provided with a pair of leads 27 which extend through an opening 28 formed in the casing 13.

Operation and use of the coupling transformer assembly shown in FIGS. 1-4 can now be described briefly. Let it be assumed that one of the windings 26 on the toroidal core 10 has been connected to the secondary winding of a differential transformer in a ground fault detector. Let it further be assumed that a second of the windings 26 has been connected to the output of a pulse generator and that a third of these

windings is utilized as an output winding and is connected to suitable means such as a silicon controlled rectifier. The occurrence of a ground fault produces a current in the secondary winding of the differential transformer and the first of the windings 26. This current produces a magnetic flux in the toroidal core 10. The flux in the core 10 produces a current in the single-turn coupling link formed by the spindle 12 and casing 13. Since this link passes through the opening in the inductor core 11, the current in the link causes a change in the state of flux in the inductor core. This change in flux can be thought of as storing the fault signal in the inductor core.

When a readout pulse of the proper polarity is applied to the second of the windings 26, it is coupled to the inductor core 11 through the spindle and casing. The stored flux signal is read out of the inductor core and delivered back to the toroidal core 10 through the spindle and casing. This readout flux signal produces an output signal in the third of the windings 26. Alternatively, the third winding on the toroidal core 10 can be eliminated in which case the readout flux signal can be delivered by either the primary or secondary winding.

The embodiment illustrated in FIGS. 5-7 includes a toroidal core 31, first inductor core 32, a second inductor core 33, a spindle 34, and a casing assembly 36.

The cores 31-33 are fabricated of magnetic materials and disposed coaxially of each other. The toroidal core 31 is provided with a winding 37 having a plurality of turns wound on the core. A pair of leads 38 provides connections to the winding 37. Each of the inductor cores 32, 33 is formed of a plurality of individual toroidal core members 39, the number of which can be varied to provide the desired inductance in the inductor cores.

The spindle 34 extends along the axis of the toroidal core 31 and passes through the opening of this core. This spindle is formed to include a cylindrical central portion 41 with cylindrical stems 42 extending axially from the ends thereof. An annular recess 43 is formed at each end of the central portion 41 adjacent the stem 42. The inductor cores 32, 33 are mounted on the stems 42 and disposed in the recesses 43. They are retained in place by insulative washers 44 mounted on the stems. The toroidal core 31 is disposed over the central portion 41 of the spindle.

The casing assembly 36 includes a cylindrical sidewall 46, disposed coaxially of the toroidal core 31, and a pair of circular end walls 47. The sidewall is joined to the end walls by conventional means such as soldering. Each of the end walls is formed to include an axially disposed central opening 48 through which the stems 42 extend. The stems are connected to the end walls by conventional means such as soldering. The sidewall 46 is formed to include an opening 49 through which the leads of the transformer pass.

The spindle 34 and casing assembly 36 are fabricated of an electrically conductive material such as copper. Together they form a single-turn winding which links the toroidal core 31 with the inductor cores 32, 33.

An additional one-turn winding 51 is provided on the toroidal core 31. This winding includes a center tap 52 which is connected to the central portion 41 of the spindle. Leads 53, 54 provide means for making connections to the winding 51. Conductors 56, 57 are provided for making additional connections to the end walls 47 of the casing assembly. One end of each of these conductors passes through an opening 58 in the end wall and is soldered thereto. The other ends of these conductors are joined together at 59 to form a common conductor. The conductors 56, 57 are formed of insulated wire and are wrapped around the conductors 53, 54.

Operation and use of the embodiment illustrated in FIG. 5-7 can now be described briefly. Let it be assumed that the winding 37 on the toroidal core 31 has been connected to the secondary winding of a differential transformer in a ground fault detector. Further, let it be assumed that the leads 53, 54 and the common conductor 59 have been connected to a source of pulses. A ground fault signal is coupled to the toroidal core 31 through the winding 37, and from there it is

coupled to the inductor cores 32, 33 through the single-turn winding comprising the spindle 34 and casing assembly 36. As before, the fault signal is stored in the inductor cores in the form of a magnetic flux signal. When a readout pulse of either polarity is applied to the inductor cores through the leads 53, 54 and the common conductor 59, a stored flux signal is coupled back to the toroidal core 31 through the spindle and casing. From the toroidal core it is coupled back to the differential transformer secondary.

While the transformer assembly of the present invention has been described with specific reference to ground fault detectors and current interrupters, its use is not limited thereto. The principles disclosed herein can be utilized in coupling toroidal cores in many other applications, including amplitude, frequency, and phase modulators. The magnetic properties of the toroidal and inductor cores can be chosen in accordance with the requirements of the particular application.

When combined with a differential transformer of the type commonly used in ground fault interrupters, the coupling transformer of the present invention provides an efficient means of coupling the one-turn primary windings of the differential transformer to a small toroidal inductor core having a single-turn winding of very low impedance. At the same time, this coupling transformer assembly permits multiple-turn windings to be used for delivering readout pulses to the inductor core and for delivering output signals therefrom. With this transformer assembly and load currents on the order of 1.5 amperes to hundreds of amperes flowing in the primary windings of the differential transformer, fault currents as small as a few milliamperes produce usable signals in the inductor cores.

The use of a multiple-turn secondary winding on the differential transformer and a multiple-turn primary winding on the coupling transformer provides a close coupling with very little leakage inductance. In the preferred embodiment, these windings include a full layer of turns on each of the cores. This construction has been found to provide optimum coupling between the one-turn primary windings of the differential transformer and the one-turn winding of the inductor core. The differential transformer secondary and coupling transformer primary windings are connected together to form a transmission line loop having impedance values of more convenient proportions than the one-turn windings would permit. The size of the toroidal core in the coupling transformer can be chosen to accommodate any additional windings that may be desirable for purposes such as modulation, biasing, and readin or readout.

It is apparent from the foregoing that a new and improved coupling transformer assembly has been provided. This assembly permits the coupling of two or more toroidal cores with a minimum of resistance and stray inductance. In addition, it provides protection for the cores against mechanical damage. While only the presently preferred embodiments have been described herein, as will be apparent to those familiar with the art, certain changes and modifications can be made without departing from the scope of the invention as defined by the following claims.

What is claimed is:

1. In a coupling transformer assembly, a first toroidal core fabricated of a material having a high magnetic permeability, a winding comprising a plurality of turns wound on said first toroidal core, a second toroidal core of substantially smaller size than said first toroidal core coaxially disposed within the opening of said first core at the central plane thereof, said second core being fabricated of a material of high magnetic permeability and having no windings wound thereon, an electrically conductive spindle member extending coaxially through said second toroidal core and through at least a portion of said first toroidal core, and an electrically conductive casing enclosing said first and second toroidal cores and connected to the ends of said spindle member to form with said spindle member a single-turn winding linking both of said cores.

2. A coupling transformer assembly as in claim 1 together with at least one additional winding wound on said first toroidal core.

3. A coupling transformer assembly as in claim 1 wherein said casing comprises a generally toroidal shell formed of two parts joined together at the central plane of said first toroidal core, each of said parts being formed to include a central web portion to which the ends of said spindle member are connected.

4. A coupling transformer assembly as in claim 1 wherein said second toroidal core comprises a plurality of annular inductor core members coaxially stacked in intimate contact with each other.

5. In a coupling transformer assembly, a first toroidal core fabricated of a material having a high magnetic permeability, second and third toroidal cores spaced apart from each other and disposed coaxially of said first toroidal core, a winding comprising a plurality of turns wound on said first core, an electrically conductive spindle member extending axially through said toroidal cores, an electrically conductive casing enclosing said first and second toroidal cores and connected to the ends of said spindle member to form with said spindle member a single-turn winding linking said cores, and an additional single-turn winding on said first toroidal core, said additional winding having a center tap connected to said spindle member intermediate its ends, and a common conductor connected to said casing proximate the ends of said spindle member.

6. In a coupling transformer assembly a first toroidal core fabricated of a material having a high magnetic permeability, second and third toroidal cores spaced apart from each other and disposed coaxially of said first toroidal core, a winding comprising a plurality of turns wound on said first core, an

electrically conductive spindle member extending axially through said toroidal cores, and an electrically conductive casing enclosing said first and second toroidal cores and connected to the ends of said spindle member to form with said spindle member a single-turn winding linking said cores, said spindle member including a cylindrical central portion, a pair of cylindrical end portions of smaller diameter than said central portion, and an annular recess formed in each end of said central portion adjacent said end portions, said first toroidal core being disposed over said central portion and said second and third toroidal cores being disposed over said end portions and in said annular recesses.

7. In a transformer assembly, a first toroidal core fabricated of a material having a high magnetic permeability, a second toroidal core of smaller size than said first toroidal core disposed coaxially of said first core, a winding comprising a plurality of turns wound on said first core, an electrically conductive spindle member extending axially through the cores, said spindle member including a cylindrical central portion and a cylindrical end portion of smaller diameter than said central portion, said first toroidal core being disposed over said central portion and said second toroidal core being disposed over said end portion, and an electrically conductive casing enclosing said first and second toroidal cores, said casing being connected to the ends of said spindle member to form with said spindle member a single-turn winding linking said cores.

8. A transformer assembly as in claim 7 wherein the central portion of said spindle member is formed to include an annular recess adjacent to the end portion of said spindle member, said second toroidal core being disposed in said recess.

* * * * *

35

40

45

50

55

60

65

70

75