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Aug. 10, 1948. A. M. MacCALLUM 2,446,939

FREQUENCY DOUBLING TRANSFORMER

Filed Sept. 16, 1944

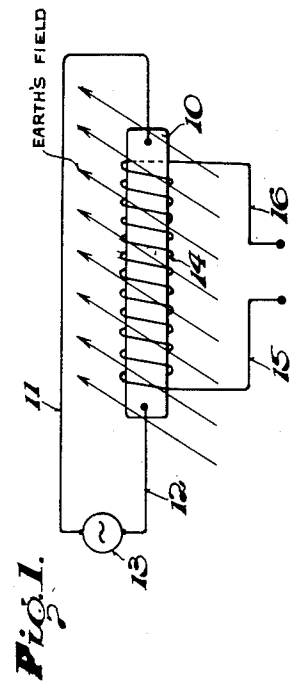


Fig. 1.

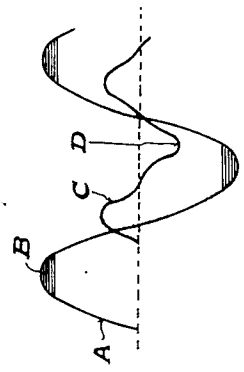


Fig. 2.

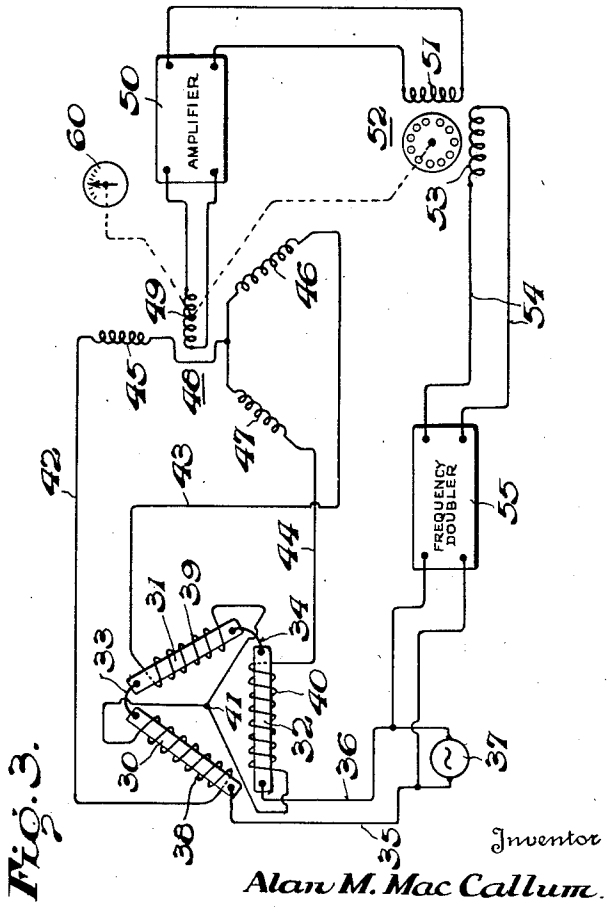


Fig. 3.

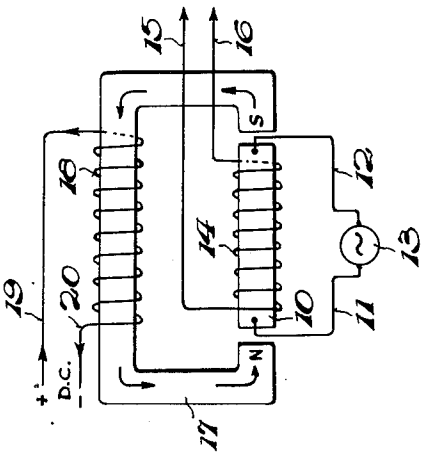


Fig. 4.

Inventor
Alan M. MacCallum.
By
Attorney

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FREQUENCY DOUBLING TRANSFORMER

Alan M. MacCallum, Maywood, N. J., assignor to Bendix Aviation Corporation, Teterboro, N. J., a corporation of Delaware

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9 Claims. (Cl. 177—380)

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The present invention relates to induction systems generally and more particularly to systems embracing magnetic inductor elements having magnetically permeable cores the permeability of which is caused to vary periodically.

It has been the practice, heretofore, to provide the permeable core or cores of the inductor elements with energizing or exciting windings fed by either alternating or pulsating currents and providing about the first winding a second or output winding. The winding of the exciting coil about the core and thereafter the provision of the secondary winding about the core consumed a considerable amount of time. The present invention contemplates the provision of a novel and extremely simple inductor element which may be used as part of an earth inductor compass system or as a frequency doubler or for any other desired use in which the requirement for the usual energizing or exciting winding has been overcome.

An object of the present invention, therefore, is to provide a novel and improved magnetic induction device which requires but one winding thereon, i. e., a secondary or output winding for proper operation.

Another object of the invention is to provide a novel magnetic induction device in which the conventional energizing or exciting winding has been eliminated.

A further object is to provide a novel induction device having a core of permeable material in which the permeability of the core is periodically varied by the direct passage of energizing current through the core.

Another object of the present invention is to provide a novel induction device adapted for suspension in the earth's magnetic field or within a magnetic field developed by any local or external source whereby it may be adapted for use as an earth inductor compass, a frequency doubler or for any other desired application.

A further object is to provide a novel magnetic induction system having an inductor element whose core is periodically saturated and unsaturated by the passage of alternating or periodically varying current directly therethrough, the core having but one winding, i. e., an output winding thereon.

The foregoing and other objects and advantages of the invention will appear more fully hereinafter from a consideration of the detailed description which follows, taken together with the accompanying drawings wherein several embodiments of the invention are illustrated by way

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of example. It is to be expressly understood, however, that the drawings are for purposes of illustration only, and are not intended to define the limits of the invention.

In the drawings, wherein like reference characters refer to like parts throughout the several views:

Figure 1 is a diagrammatic representation of the principles involved in the present invention;

Figure 2 is a graphic illustration of the relation of the output to the input of the showing of Figure 1;

Figure 3 is a schematic wiring diagram illustrating an earth induction compass system embodying the subject of the present invention; and,

Figure 4 is a diagrammatic illustration of the present invention as applied to a frequency doubler.

Reference is now made to the drawings and more particularly to Figure 1 thereof for a better understanding of the principles underlying the operation of the novel inductor element of the present invention. As shown, the element comprises a core member 10 of magnetically permeable material which, instead of being provided as heretofore with a separate primary or exciting winding, is directly connected by way of leads 11 and 12 across a suitable source 13 of alternating or periodically varying current. Wound uniformly about the core member is a secondary or output winding 14 provided with output leads 15 and 16.

With the structure thus far described, current from source 13 through core member 10 sets up a periodically reversing flux. However, the field developed by the fundamental or exciting current is parallel to or concentric with the coils of secondary 14 so that in the absence of some external field threading the core member there will be no output signal at leads 15 and 16 due to the fundamental alone.

As soon, however, as an external magnetic field, as shown in Figure 1, is brought to thread core member 10, whether it be the earth's magnetic field or a magnetic field due to a permanent or electromagnet or any other source, a signal will appear at leads 15 and 16. It is believed that such action occurs because the alternating or periodically varying current passing through core 10 causes a periodic increase and decrease in the permeability of the core so that upon increased permeability the flux of the local field threads the core while upon decreased permeability the reluctance of the core increases and

the flux of the local field leaves the core to follow a path of lower reluctance, i. e., air. As shown graphically in Figure 2, the energizing current, designated at A, before reaching its maximum positive value, saturates the core as shown at B. As the current drops toward zero, the core is unsaturated and the local magnetic field rushes into the core but as the fundamental passes through zero toward its maximum negative value, the core is again saturated and the local field leaves the core thereby developing an impulse C which by induction generates a signal in the secondary winding. As the current passes from its negative maximum value toward zero the core is again unsaturated whereupon the local magnetic field again threads the core and leaves the core as the current passes from zero toward its maximum positive value to saturate the core, a second impulse D being thereby generated to induce a second signal within the secondary. Thus, a second harmonic appears in winding 14 having a frequency double the frequency of the fundamental current.

Inasmuch as the signal output at the secondary is double the frequency of the fundamental, it will now be apparent that the novel inductor element may be utilized as a frequency doubler. One practical form that a doubler of this character may take is that shown in Figure 4. The core member 10, as before, is provided with a source 13 of exciting current which is led to traverse the core by way of leads 11 and 12, a secondary winding 14, having output taps 15 and 16, being provided about the core. Mounted adjacent the core is a bar of soft iron 17, which though shown as being rectangular in form may take any form desired, having a coil 18 wound thereon with taps 19 and 20 for connecting it to any suitable source of direct current not shown.

As direct current flows within winding 18 a unidirectional magnetic field is developed thereby which threads bar 17 in the direction of the arrows to leave the bar, thread core member 10, and re-enter the bar at the opposite end of the core. The core member in being traversed by either alternating or periodically varying current from source 13 is saturated and desaturated twice per cycle of the exciting current causing the locally developed field to enter and leave the core twice for each cycle of energizing current thereby developing two impulses, in the manner shown in Figure 2, so that by virtue of induction a second harmonic voltage is generated within secondary 14 having a frequency double the frequency of the energizing current. The system thus acts as a frequency doubler in that for an energizing current having a given frequency an output current is developed having double the frequency of the fundamental.

The subject matter of the present invention is likewise capable of use as the inductor element of an earth induction compass system. As shown in Figure 3, three permeable core members 30, 31 and 32 are arranged in delta with core 30 being connected to core 31 by way of a conductor 33, core 31 connected to core 32 through conductor 34, cores 30 and 32 connected by way of leads 35 and 36 with a suitable source 37 of alternating or periodically varying current whereby energizing current passes directly through the cores which are arranged in series thereby eliminating the use of primary or excitation windings as previously utilized in the manner shown in U. S. Patent No. 2,361,433, issued October 31, 1944, now

Reissue Patent No. 22,699, issued November 27, 1945.

Wound on each of the cores are secondary or output coils 38, 39 and 40 having given ends connected at a common junction 41 and opposite ends connected by leads 42, 43 and 44 with the multiphase windings 45, 46 and 47 of the stator member of an inductive device 48 having an angularly movable rotor winding 49 inductively coupled therewith. Winding 49 is connected to the input of a conventional vacuum tube amplifier 50 the output of which is fed to the variable phase 51 of a two phase inductor motor 52, the second or fixed phase 53 of which connects by way of leads 54 with source 37 through a conventional frequency doubler 55. Motor 52 is mechanically coupled with rotor winding 49 in any suitable manner as indicated by the broken line connection.

The inductor element comprising the three core members and their windings is suitably stabilized and suspended within the earth's magnetic field whereby upon displacement of the inductor relative to the earth's field, secondary harmonics are developed within each of the secondary windings 38, 39 and 40 of an intensity proportional to the angular relation of each core relative to the direction of the earth's magnetic field. The variation in the voltages of each secondary is reproduced at windings 45, 46 and 47 of device 48 causing a resultant magnetic field at the stator having a position other than normal relative to rotor winding 49 so that a signal is induced therein. The signal so induced is amplified within amplifier 50 to energize variable phase 51 of motor 52 whereupon the motor operates to drive rotor winding 49 angularly until it reaches a position normal to the resultant magnetic field at the stator at which time the signal in winding 49 falls to zero and the motor is de-energized. An indicator 60 or any controlled member may be associated with rotor 49 in the manner known to the art. For a more detailed description of the theory and operation of earth inductor compass systems of this character reference is made to U. S. Patent No. 2,240,680 issued May 6, 1941.

There has thus been provided a novel and simplified magnetic induction device in which the primary or exciting winding has been eliminated and which is adapted for many and various uses such as frequency doublers, earth induction compass systems, etc.

Although but two embodiments of the invention have been illustrated and described, various changes and modifications in the form and relative arrangement of the parts, which will now appear to those skilled in the art, may be made without departing from the scope of the invention. Reference is therefore to be had to the appended claims for a definition of the limits of the invention.

I claim:

1. A magnetic induction device comprising a core of magnetically permeable material adapted to be traversed by the flux of a magnetic field, means for passing energizing current through said core to periodically vary the permeability of said core whereby said flux periodically enters and leaves said core, and coil means wound on and inductively coupled with said core energized by the passage of said flux in said core.

2. A magnetic induction device comprising a core of magnetically permeable material adapted to be traversed by the flux of a magnetic field, means for passing energizing current of a given

frequency through said core to periodically vary the permeability of said core whereby said flux enters and leaves said core twice per cycle of the energizing current, and a secondary wound on said core having voltages generated therein by the passage of said flux of a frequency double the frequency of said energizing current.

3. A magnetic induction device comprisinng a core of magnetically permeable material adapted to be traversed by the earth's magnetic field, means for passing energizing current through said core to periodically vary the permeability of said core whereby the earth's field periodically enters and leaves said core, and coil means wound on and inductively coupled with said core energized by the passage of the earth's field within said core.

4. In combination with a core of magnetically permeable material, a source of periodically varying current connected to said core for periodically varying the permeability of said core, means providing a locally developed magnetic field for threading said core whereby due to said varying current said field periodically enters and leaves said core, and coil means wound on said core and energized by the passage of said magnetic field into and out of said core.

5. In combination with a core of magnetically permeable material, a source of periodically varying current connected to said core for periodically varying the permeability of said core, an electromagnet for developing a magnetic field for threading said core whereby due to said varying current said field periodically enters and leaves said core, and a winding arranged on said core and energized by the passage of said magnetic field into and out of said core.

6. A frequency doubler comprising a core of magnetically permeable material, a source of periodically varying current connected to said core for periodically varying the reluctance thereof, means for developing a unidirectional magnetic field for periodically entering and leaving said core, and coil means wound on said core and energized by the passage of said magnetic field into and out of said core.

7. A frequency doubler comprising a conductor in the form of a core of magnetically permeable material adapted to be traversed by the flux of a uni-directional magnetic field, a source of periodically varying current connected to said core for periodically varying its reluctance to the traversal of flux therethrough, and coil means wound on said core.

8. A frequency doubler comprising a conductor in the form of a core of magnetically permeable material, electromagnetic means for developing a unidirectional magnetic field whose flux threads said core, a source of periodically varying current connected to said core for periodically varying its reluctance to the threading of the flux therethrough, and coil means wound on said core.

9. A magnetic induction device comprising a triangular core element of magnetically permeable material adapted to be traversed by the flux of a magnetic field, means for passing energizing current through said core element to periodically vary the permeability thereof whereby said flux periodically enters and leaves said core element, and coil means wound on and inductively coupled with said core element energized by the passage of said flux in said core element.

ALAN M. MacCALLUM.

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