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DIFFERENTIAL TRANSFORMER

Filed May 5, 1958

Fig. 1.

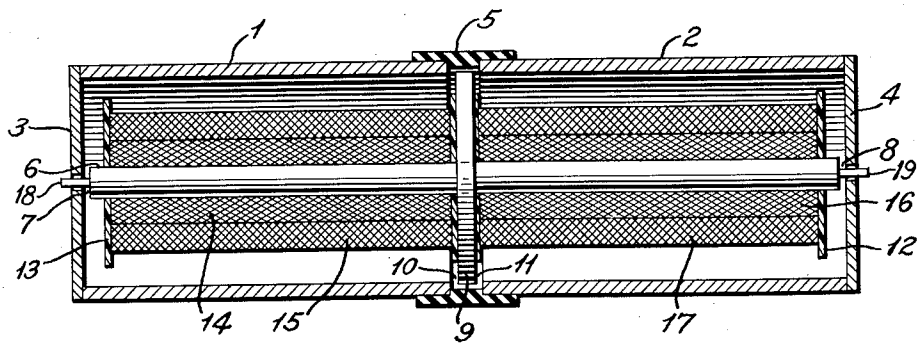
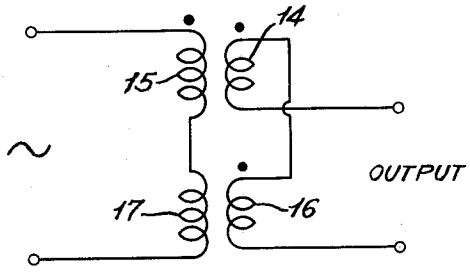


Fig. 2.



INVENTOR

Kelly Verner Shipes

BY

Burns, Doane, Benedict & Ihons

ATTORNEYS

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DIFFERENTIAL TRANSFORMER

Kelly Verner Shipes, Houston, Tex., assignor, by mesne assignments, to Dresser Industries, Inc., Dallas, Tex., a corporation of Delaware

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This invention relates to a differential transformer, and more particularly, to a transformer of peculiarly advantageous construction which supplies an electrical signal linearly proportional to movement of one part of the unit with relation to another part.

The object of the invention is to decrease the size and complexity of the well known differential transformer which is employed to translate linear movement into a voltage proportional thereto. The present invention makes use of a cylindrical housing formed of two housing parts which enclose the coil structure and provide major portions of the magnetic circuits of the apparatus. The housing structure conforms very closely to the natural magnetic path around the transformer coils so that the structure of the apparatus is of minimum size. Moreover, the number of parts required is reduced to a minimum, and bobbin-wound coils may be easily used and assembled in the apparatus, providing for reduction in manufacturing complexity and cost.

The apparatus of the invention, generally speaking, includes a pair of ferromagnetic cylindrical housings each having a ferromagnetic end plate and joined together by a nonmagnetic spacer to form an enclosure for the core and coils. The core of the apparatus is a rod positioned axially in the housing which carries a disc of ferromagnetic material positioned within the gap between the housings. The primary and secondary windings are on forms positioned around the rod at opposite sides of the disc.

The invention will now be more fully described in conjunction with a preferred embodiment thereof shown in the accompanying drawing.

In the drawing,

FIG. 1 is a longitudinal cross-sectional view of the apparatus; and,

FIG. 2 is a schematic diagram of the arrangement of coils of the apparatus.

Referring first to FIG. 1, the differential transformer of the invention includes left and right housings **1** and **2** of cylindrical form and of ferromagnetic material. End plates **3** and **4** are provided for the remote ends of the cylindrical housings, and a nonmagnetic spacer ring **5** is threaded to the outer surfaces of each of the housings **1** and **2**. Thereby, an air gap is provided between the opposing faces of the housings.

The core of the differential transformer is a ferromagnetic rod **6** which extends axially of the cylindrical housings and is of length slightly less than the distance between end plates **3** and **4**, so as to provide left and right air gaps **7** and **8**. A rigid ferromagnetic disc **9** is mounted on the middle portion of the rod and extends radially outward therefrom in the air gap between the housings **1** and **2**. The disc is of outer diameter greater than the inner diameter of the housings **1** and **2** and nearly as large as the inner diameter of the spacer ring **5**. Thereby, left and right gaps **10** and **11** are provided between the axially-spaced, radially outermost portions of the disc and the adjacent surfaces of housings **1** and **2**.

A pair of coil forms **12** and **13** are carried by the core at opposite sides of the disc **9**. The left coil form has secondary coil **14** as its inner layer, and primary coil **15** as its outer layer, wound around the secondary coil. The right coil form **12** has secondary coil **16** as its inner layer and primary coil **17** as its outer layer.

The rod **6** is supported by pin-like extensions **18** and **19** extending through axial holes through the end plates **3** and **4**, respectively. Movement of the rod axially of the housings may of course be accomplished through movement imparted to these extensions.

It will be apparent that the magnetic circuit for each of the primary coils **15** and **17**, and therefore for each of secondary coils **14** and **16**, includes a portion of rod **6**, disc **9**, the housings **1** and **2** and end plates **3** and **4**, respectively. Each magnetic circuit has a pair of gaps therein, the gap between the end of rod **6** and the adjacent end plate, and the gap between its housing and the adjacent surface of the disc **9**. The rod, the disc, and the coil forms, together with the coils, are designed for linear axial movement reciprocably within the housings **1** and **2** in accordance with the linear movement to be detected.

When the rod **6** is moved to the left of FIG. 1, the air gaps in the magnetic circuit of coils **14** and **15** are both decreased in size, since the disc moves closer to the adjacent surface of housing **1**, and the rod moves closer to end plate **3**. On the other hand, the air gaps in the magnetic circuits of coils **16** and **17** are increased in dimension, since the disc moves away from housing **2** and the rod moves away from end plate **4**. As a result of the decrease in size of the air gaps of coils **14** and **15**, the flux in their magnetic circuits increases and increases the voltage developed across secondary coil **14**. The increase of size of the air gaps in the magnetic circuit of coils **16** and **17** causes decrease in the flux in this magnetic circuit and corresponding decrease in the voltage across secondary coil **16**.

Referring now to FIG. 2, the primary coils **15** and **17** are connected in series aiding, and are supplied with the voltage from the usual source (not shown). The secondary coils **14** and **16** are connected in series opposition and supply an output voltage having an amplitude proportional to the extent of movement of the bar **6**. When the core and coils are in their central position, the corresponding air gaps in each magnetic circuit are of the same size, so that the voltages across coils **14** and **16** are equal and the output voltage of the transformer is zero. However, when the core is moved in the left direction as described above, the decrease in size of the air gaps in the magnetic circuit of coil **14** causes increase in the voltage across that coil, while the increase in size in the gaps of the magnetic circuit of coil **16** causes decrease in the voltage across that coil. Therefore, the voltage in coil **14** exceeds that in coil **16** and an output voltage equal to the difference in coil voltages is developed. This output voltage has a phase which is either the same as the input voltage or 180° spaced with respect thereto, depending upon the direction of movement. Therefore, the output voltage defines the direction and amplitude of movement of bar **6**.

It will be appreciated that I have described a particularly simple and advantageous arrangement of parts to perform the differential transformer function. The transformer coils may readily be assembly line-wound and merely slipped over the rod **6** during assembly of the apparatus. Likewise, they may readily be replaced if they become defective during operation.

Since many minor changes could be made in the apparatus described as the preferred embodiment of this invention, the invention should not be considered limited to the embodiment described herein, but rather only by the scope of the appended claims.

I claim:

1. A differential transformer comprising a pair of cylindrical housings of ferromagnetic material each having an end plate of ferromagnetic material, a spacing ring of nonmagnetic material connecting the spaced open ends of said housings to provide a cylindrical air gap therebetween, a ferromagnetic rod extending axially within said

housing and of less length than the distance between said end plates to provide a pair of air gaps between the rod and the end plates, a rigid ferromagnetic disc supported by said rod with its peripheral surface positioned in the air gap between said housings, and two pairs of windings on said rod at opposite sides of said disc, said rod, disc and windings being movable together axially of said housing in opposite directions to simultaneously change the dimensions of the air gaps between the rod and the end plates and between the disc and the housings in opposite directions and thereby to change the reluctances of the magnetic circuits linking the coils of each pair of coils in opposite directions.

2. A differential transformer comprising a pair of cylindrical housings of ferromagnetic material each having an end plate of ferromagnetic material, a spacing ring of nonmagentic material connecting the spaced open ends of said housings to provide a cylindrical air gap therebetween, a ferromagnetic rod extending axially within said housing and of less length than the distance between said end plates to provide a pair of air gaps between the rod and the end plates, a pair of coil forms each carrying a primary and a secondary coil, a rigid ferromagnetic disc supported by said rod with its radially outer surface between the opposing surfaces of said housings to provide air gaps between the axially-spaced surfaces of the disc and the adjacent housing, said coil forms being positioned on said rod at opposite sides of said disc, said rod, coil forms and disc being reciprocable axially with respect to said housings to change dimensions of the air gaps in the magnetic circuits of the primary coils in the opposite directions.

3. The apparatus of claim 2 in which said spacing ring is threaded on the outer surfaces of both said housings and said disc has a diameter greater than the inner diameter of each housing so as to have the outermost portion of its axially-spaced surfaces axial of said housings.

4. The apparatus of claim 3 in which each coil form has its secondary winding in an inner layer and its primary winding on an outer layer, said primary windings being connected in series aiding and said secondary windings being connected in series opposition.

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