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G. K. HOUP ET AL

3,287,680

ELECTRICAL DEVICE

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Fig. 1

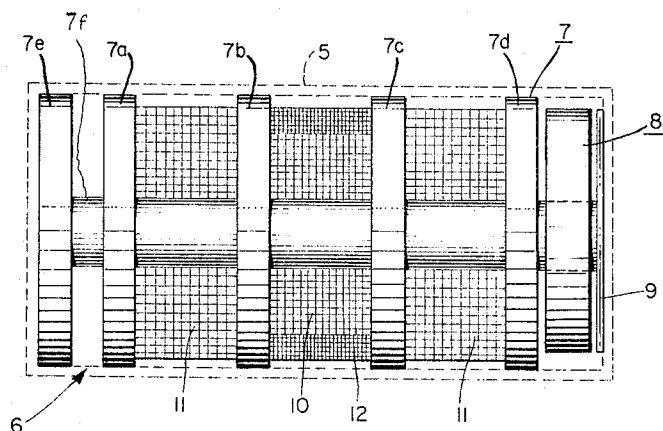


Fig. 2

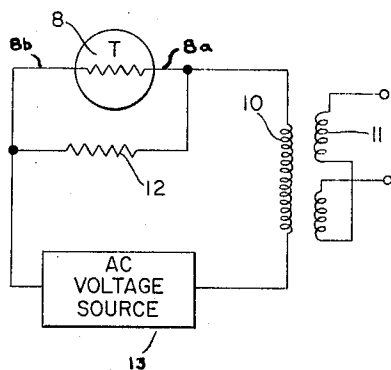
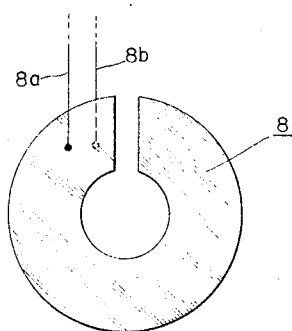


Fig. 3

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1

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2 Claims. (Cl. 336—179)

This invention relates to differential transformers and especially to improved differential transformers which have great stability of output voltage and phase shift despite wide variations in the ambient temperature.

Differential transformers are widely used for various types of instrumentation and similar applications. The primary winding of the transformer is energized by a varying voltage such as sinusoidal alternating current voltage in the audio frequency range. There is thereby produced in the secondary winding of the differential transformer an induced voltage having a polarity and amplitude dependent upon the position of an armature usually located within the primary and secondary winding. When the armature is at a certain axial position in the transformer near its midpoint and if the parts of the secondary windings are series-bucking, a minimal output voltage known as the "null voltage" is obtained. In cases where the parts of the secondary winding are wound series-aiding there is no null voltage produced at the transformer midpoint but it is nevertheless important to have the output signal represent faithfully the displacement of the armature.

The phase of the output voltage may be anywhere from 0° to 90° ahead of the phase of the primary voltage. When the ambient temperature is varied, however, the output signal varies in voltage and/or phase angle and therefore the output signal is rendered inaccurate. These variations occur because of the change in the resistance of the primary winding, especially if it is made of copper, caused by the ambient temperature variation.

In the past, one common method of minimizing changes in the amplitude and phase of the output signal has been to make the primary of a metal, i.e., manganin or other alloy, having a temperature coefficient which is substantially lower than that of copper. In practice, however, this results in lower output voltage and a larger than desired phase angle differential between the respective voltages in the primary and secondary windings.

Another method has been to employ, externally to the transformer, a negative temperature coefficient resistance such as a "thermistor," placed in series with the primary winding. Usually, the thermistor has been shunted by a fixed value of resistance so that the temperature compensation produced thereby is effective over a wide temperature range. In order to maintain the output voltage and phase angle of the differential transformer stable when it is initially energized, the physical size of the thermistor must be large enough to permit the required power dissipation when current is first passed through it without undergoing a significant change in resistance.

It is an object of the present invention to provide a unitary temperature-compensated differential transformer or the like providing stable output voltages and phase angles despite fluctuations in the ambient temperature.

Another object of this invention is to provide an integral thermistor-differential transformer combination having more stable output voltage and phase angle characteristics over wide ambient temperature variations.

Still another object of the invention is to provide a thermistor-differential transformer assembly constructed to maintain minimal null voltages as well as stability of

2

output voltage and phase angle under varying ambient temperature conditions.

Still another object of the invention is to provide a novel differential transformer assembly with built-in temperature compensation that does not adversely affect and, in fact, improves its operating parameters.

In accordance with our invention these, as well as other objects of the invention which will occur to those skilled in the art, may be accomplished by mounting a thermistor in close proximity to the differential transformer itself, preferably on the same structure. Furthermore, in a preferred form of our invention, the thermistor is slotted to prevent the production of eddy-currents through it thereby minimizing possible adverse magnetic effects by it on the magnetic field of the transformer windings. Another feature of the invention is to provide a shunt resistance for the thermistor which produces a minimal perturbation of the magnetic field of the primary and secondary windings. In one form of the invention, this is accomplished by providing a shunt resistance comprised of a non-inductive winding located in the magnetic center of the differential transformer.

Referring to FIGURE 1 there is shown a composite thermistor differential transformer assembly 6 disposed within a shielding enclosure 5 (broken line). A primary winding 10 is wound between annular dividing portions 7b and 7c of a bobbin 7. Secondary windings 11 are located between annular portions 7a, 7b and 7c, 7d respectively. These secondary windings may be disposed in series-bucking relation as shown in FIG. 3, for example. Other arrangements of the secondary windings may also be employed, however. The bobbin also has a hollow bore section 7f in which an armature (not shown) is arranged for movement relative to the windings 10 and 11. An additional annular portion 7e is provided with apertures (not shown) which run generally parallel to the axis of the bobbin. Through these apertures, leads (not shown) to the primary and secondary windings and to the other elements of the differential transformer may be passed. Of course, the left end portion of the shield 5 is provided with an opening or with openings through which the leads extend to the external circuits and an opening through which an axially movable shaft connected to the armature can extend.

In accordance with our invention, a thermistor 8 is mounted directly upon the bobbin itself between the annular portion 7d and a metallic end cap 9. This thermistor may be a generally flat annular member, as shown in FIG. 2 which is slotted to prevent the production of eddy currents therein. This thermistor may be, for example, Type 21W1 made by the Victory Engineering Company of Springfield, New Jersey. This thermistor includes a central annular portion made of negative-resistance material and has its two outer flat surfaces covered with conductive material. Two leads 8a and 8b are connected to the two outer surfaces respectively of thermistor 8. As is shown in the equivalent circuit of FIG. 3, the thermistor 8 is in series with primary winding 10 and is shunted by a resistance 12 which consists of a resistive winding. In the form of the invention illustrated it is wound around the primary winding 10. In order to prevent adverse effects upon the magnetic field established by the primary and secondary windings, the resistance winding 12 is preferably laid down in non-conductive form, as for example, by conventional bifilar winding techniques, and is located toward the magnetic center of the transformer to lessen the possibility of its disturbing the symmetry (or other desired pattern) of the transformer's magnetic field.

It will be observed that when voltage from an appropriate A.C. source such as the source 13 is applied between one terminal (8b) of the thermistor and the

3

resistance winding 12 and one terminal of the primary winding 10, there will appear across the output terminals of the secondary winding 11 a very stable output voltage with very low shift in the input-to-output phase angle differential. This results from the fact that the thermistor will compensate for the increase or decrease in resistance of the primary winding as ambient temperature increases or decreases. This compensation is especially effective since the thermistor itself is enclosed within the shield 5 so that it is subjected to precisely the same temperature differences as the transformer windings themselves. Moreover, the fact that the thermistor is slotted prevents the development of eddy currents through it which would tend to upset the normal magnetic pattern of the transformer. If a non-slotted washer type thermistor were to be used instead, the eddy-currents would tend to disturb the normal magnetic pattern resulting in a high null voltage which would vary substantially with ambient temperature changes.

While the invention has been explained in terms of the three-winding differential transformer illustrated, it should be understood that it is also applicable to other differential transformer constructions. For example, it can be used with the transformer shown in United States Patent 2,568,587 issued to W. D. MacGeorge on September 18, 1951. This patent covers a four-winding differential transformer. Additionally, it may be used with other differential transformers or their equivalents, which have other numbers of primary and/or secondary windings. Consequently, as those skilled in the art may be aware of modifications or applications of our invention which do not depart from the essence thereof, we desire our invention to be limited only by the claims herein.

We claim:

1. A temperature-compensated transformer assembly comprising:

(a) a primary winding adapted to be coupled to a source of an exciting A.C. voltage,

4

(b) a secondary winding mounted for mutual inductive coupling with said primary winding,
 (c) a resistive winding wound around a selected one of said windings and having a negligible effect on the magnetic fields produced by said primary and secondary windings, said resistive winding being connected in series with said primary winding, and
 (d) a slotted thermistor mounted close to said windings and electrically connected with said resistive winding, said slot being formed therein to prevent production of eddy currents therein.

2. The transformer assembly according to claim 1 wherein said primary winding is disposed between two portions of said secondary winding, wherein said primary and secondary windings are both wound coaxially around a coil form, and wherein said thermistor is generally annular and disposed on said form coaxial with said primary and secondary windings.

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