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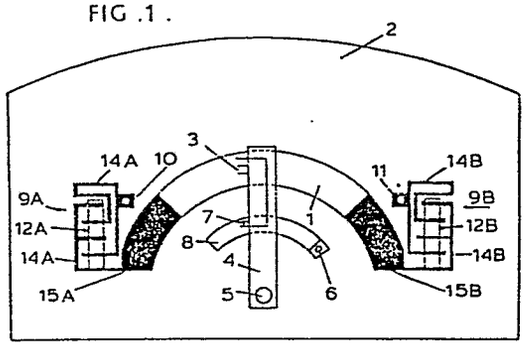
(54) Potentiometer.

(57) A potentiometer, particularly suitable for use in automotive engine management systems, comprises a film resistance track (1) on a substrate (2) and terminals (10, 11) for connection to a voltage source. A wiper (3, 7) traverses the track (1) and a conductive collector (8) which is connected to a terminal (6) at which an output voltage is obtained. A film resistor network (9A, 9B) is provided at one or both ends of the track (1) in series with the track (1) and the terminals (10, 11), or in parallel with a portion (1A) of the track (1) at one or both ends thereof. The networks (9A, 9B) comprise interconnected resistance elements formed by application of conductive film links (14A, 14B) to a single film resistance element (12A, 12B), the links (14A, 14B) being selectively severable to allow adjustment, to a predetermined value, of the resistance of the network(s) (9A, 9B) in series with the track (1) or in parallel with the portion (1A) of the track (1). The networks (9A, 9B) allow the output voltage characteristics of the potentiometer with respect to the wiper position, to be adjusted.

FIG .1 .



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POTENTIOMETER

This invention relates to electical potentiometers of linear or rotary type and particularly to potentiometers for use with automotive engine management systems. Such potentiometers may, for example, find application as throttle position sensors.

Electrical potentiometers, especially of rotary form, are well known for use in microprocessor controlled engine management systems. They are applied, for example, for throttle position sensing where an output voltage, as a wiper traverses an arcuate resistance track, is proportional to the position of the wiper along the track and hence to the position of a throttle connected to the wiper by means of a rotatable spindle.

Problems have been encountered with potentiometers in such systems. Firstly, the potentiometers are designed to provide a voltage output which bears a particular relationship to the angle of rotation of the wiper/spindle assembly. The relationship between the output and the angle of rotation may be required to be linear and with a particular slope. However, it is found that, in practice, the actual slope is often different from that which is

intended. In potentiometers involving screen-printed conductors and resistance tracks this may be due to eccentricity of the resistance track relative to the position of the wiper spindle as a result of printing errors. It may also be due to errors in the effective wiped angle between terminal conductors at opposite ends of the track, resulting from spreading, during printing, of the conductive ink used in the preparation of the terminal conductors or resulting from manufacturing tolerances in screens used to screen print the track and terminal conductors.

There are also applications where it is required to accurately obtain a predetermined output voltage from the potentiometer at a specified angle of rotation of the wiper/spindle assembly. For example, it may be required to provide a potentiometer associated with a switch means, such that at a specified angle of rotation of the wiper/spindle assembly the switch means operates to control some associated circuit. At the instant of operation of the switch it may be required for the output voltage from the potentiometer to accurately attain some predetermined level. This is difficult to achieve because of the limitations of accuracy inherent in the manufacturing processes used in the production of the potentiometer.

As a safety precaution, some potentiometers now require resistors to be provided connected between a source of applied voltage and the ends of the wiped resistance track in the potentiometer in order to ensure that the output voltage from the potentiometer can never reach the level of the applied voltage. The resistors provided at the ends of the track are normally required to have a resistance value which represents a very small proportion (e.g. 1%) of the resistance value of the track. It would be convenient to provide these resistors in film form inside the potentiometer by screen printing using the same resistance material as the resistance track, but it

would be extremely difficult to print resistors of the necessarily small dimensions to achieve the low resistance value to the required accuracy. Unless expensive adjustment techniques, such as those involving lasers, are employed, trimming of the very small resistors to value would be very difficult to carry out, to achieve the required precision.

It is an object of the present invention to overcome or minimise the aforementioned problems.

The present invention provides an electrical potentiometer comprising:

an elongate film electrical resistance track on a substrate;

first and second electrically conductive terminals arranged to be connected for application of a voltage source to said resistance track;

a wiper of electrically conductive material arranged to traverse said resistance track, said wiper being electrically connected to a third electrically conductive terminal at which an output voltage may be obtained which is a function of the position of said wiper on said track; a film electrical resistor network provided on said substrate at a first end of said track in series with said track and said first terminal, or in parallel with a portion of said track at said first end of said track, the said network comprising a plurality of interconnected resistance elements formed by application of electrically conductive film links to a single film resistance element, said links being capable of being selectively severed whereby adjustment to a predetermined value of the resistance of the said network is able to be effected, such that a desired relationship between the said output voltage and position of said wiper on said track may be obtained.

Fine adjustment of the resistance value of the said network may be effected by removing a portion of one or more said resistance elements.

The single film resistive element may be in the form of an elongate strip that registers with first and second sets of inter-digitated conductive fingers traversing the strip from opposed sides, portions of the strip between adjoining fingers defining the resistors of the network, the fingers of each set being initially interconnected and the fingers of one set being connected to a conductive termination of the track.

Preferably said single film resistance element is integral with said track, or has been formed simultaneously with said track.

Preferably the said resistance elements in said network are connected initially in parallel by said film links.

If required, a further said film electrical resistor network may be provided on said substrate at a second end of said track in series with said track and said second terminal, or in parallel with a portion of said track at said second end of said track.

Preferably said track, said terminals and the or each said resistor network are provided by screen printing.

A single printing operation may be employed to produce the said track and the said single film resistance element used in said network. Another single printing operation may be employed to provide said terminals and the said conductive film links.

Suitably said track, said terminals and said resistance network each comprise an electrically conductive polymer or paint material having required electrically conductive or resistive properties.

Suitably, mechanical cutting or abrading techniques are used to effect the adjustment of the resistance value of the said network.

In one embodiment of the invention a said resistor network is provided at said first end of said track in series with said track and said first terminal and a

further said network is provided at said second end of said track in series with said track and said second terminal, said networks being adapted and arranged whereby said output voltage from the potentiometer is prevented from reaching a level of the applied voltage, thereby serving as a safety means in said potentiometer.

In a further embodiment, a said resistor network is provided at said first end of said track in series with said track and said first terminal, and/or a said resistor network is provided at said second end of said track in series with said track and said second terminal, adjustment of the resistance value of the or each said network being effected to achieve a required slope for a linear relationship between said output voltage and displacement of said wiper along said track. If said network is provided at an end of said track which when approached by said wiper results in said output voltage approaching a maximum value, adjustment of the resistance of the network to increase the value thereof in series with said track may be effected to reduce, by a desired amount, the said slope for the said linear relationship.

In a still further embodiment, a said resistor network is provided at said first end or said second end of said track in series with said track and said first or said second terminal respectively, adjustment of resistance value of said network being effected to adjust to a predetermined level the said output voltage at a predetermined position of displacement of said wiper along said track. In this embodiment, switch means may be incorporated in the potentiometer for controlling an associated circuit and arranged to operate at said predetermined position of displacement of said wiper. The switch means suitably includes an elongate electrically conductive film extending alongside, but separated from, said track and arranged to be traversed by a further wiper arranged in ganged relationship with the said wiper which traverses said resistance track and such that at the said

predetermined position of displacement of said wiper, said further wiper passes from said conductive film onto an electrically insulating surface. Terminals for said switch are suitably provided electrically connected to said conductive film and said further wiper.

In yet another embodiment a pad of electrically conductive material is provided covering a portion of said track at a predetermined distance from an end of said track, a said resistor network being connected between said pad and a terminal for the potentiometer connected to said end of said track, such that as said wiper passes over said pad the output voltage from said potentiometer remains substantially constant at a level predetermined by means of the resistor network. In this embodiment, the said network also operates such that as the wiper is caused to traverse the track in a particular direction, the rate of change of output voltage as the wiper approaches the pad is different compared with that after the wiper leaves the pad.

The embodiment is particularly advantageous when the potentiometer is used in automotive sensor applications since the provision of the pad allows a degree of mechanical overtravel of the wiper in the potentiometer to be accommodated and excess overtravel to be determined for error detection or to initiate a safety program.

The use of the said resistor network in the potentiometer of the invention enables the same resistance material to be readily used for the resistance track and for the elements in the network. The track and network thereby have the same temperature coefficient of resistance which is advantageous. The use of a resistor network incorporating elements connected initially in parallel allows dimensionally larger resistance elements to be used in the network compared with the dimensions which would be required for a single resistor of film form if substituted for the network.

The said elongate resistance track may be of arcuate

or rectilinear form.

Embodiments of the invention will now be described, by way of example only, with reference to the accompanying drawings, in which:-

Figure 1 is a plan of a first electrical potentiometer according to the invention;

Figure 2A is an enlarged detailed view of a resistor network forming part of the potentiometer of Figure 1;

Figure 2B is an equivalent circuit of the resistor network of Figure 2A;

Figure 3 is a plan of a second electrical potentiometer according to the invention; and

Figure 4 is a plan view of a third electrical potentiometer according to the invention.

Referring to Figure 1, an electrical potentiometer according to the invention is constructed as follows. An elongate electrical resistance track 1, shown in arcuate form, but for some applications could be of rectilinear form, e.g. comprising an electrically conductive polymer material of known form, of the required electrical resistivity is screen printed onto an electrically insulating substrate 2. An electrically conductive wiper 3 is supported on a carrier 4 and arranged to traverse the resistance track 1, the carrier 4 being secured to a rotatable spindle 5 which is adapted to be mechanically connected to be rotated by an external device (not shown), such as a throttle mechanism in an automobile engine. The wiper 3 is electrically connected to a terminal 6 by way of a further wiper 7 and a conductive collector 8. Film electrical resistor networks generally denoted by reference numerals 9A and 9B are provided at either end of the track 1. A detail of the network 9A is shown in Figure 2A. The networks 9A and 9B are arranged in series with the track 1 and electrically conductive terminals 10 and 11 respectively. The terminals 10 and 11 are arranged to be connected for application of a voltage source to the track 1. The networks 9A and 9B are formed by printing

resistance elements 12A and 12B as extensions of the track 1 and suitably simultaneously with the deposition of the track 1. The single resistance elements 12A and 12B are each formed into a plurality of resistance elements 13A and 13B respectively, connected in parallel, by application of electrically conductive film links 14A and 14B. The links 14A and 14B are suitably provided in the form of a low temperature curable conductive polymer or paint material of suitably high conductivity, by screen printing and are provided simultaneously with the formation of the terminals 10 and 11. The conductive material of the links 14A and 14B also extends to form end conductors 15A and 15B for the track 1.

The resistance value of the networks 9A and 9B, between terminal 10 and track end conductor 15A and between terminal 11 and track end conductor 15B respectively, is able to be adjusted as required, to connect a particular value of electrical resistance in series with the track 1. An example of the adjustment technique is given with reference to Figures 2A and 2B. The network 9A comprises four resistance elements 13A connected initially in parallel by means of the conductive links 14A. If each element has substantially the same resistance value R_E then the initial resistance value R_T of the network between terminal 10 and the end conductor 15A of the track 1 will be equal to $R_E/4$. If a cut is made through one of the conductive links 14A at position C_1, the resistance R_T of the network will increase to $R_E/3$. If instead of cut C_1 a cut is made at position C_2, the resistance R_T of the network will be equal to $R_E/2$. If instead of cut C_1, cuts are made at positions C_2 and C_3, the resistance R_T of the network will be equal to $0.75R_E$. If instead of cuts C_1, C_2 and C_3 a cut is made at position C_4, the resistance R_T will be equal to R_E. Cutting through the film links at any of the positions C_1 to C_4 can readily be achieved by well-known mechanical abrasion techniques. If the stepwise adjustment of the

achieved with accuracy. If for example only resistor network 9B is incorporated in the potentiometer, i.e. at that end of the track 1 which when approached by the wiper 3 will result in maximum output voltage at terminal 6, this network can be used and adjusted to reduce the law output slope if required. A third advantage resulting from the use of one or both resistor networks 9A and/or 9B is the ability to provide precise adjustment of the output voltage at terminal 6 at a predetermined position of displacement of the wiper 3 along the track. This is particularly advantageous when a switch means is associated with the potentiometer and which is to be actuated at this predetermined position of displacement of the wiper along the track. Figure 3 illustrates an example of a potentiometer and switch arrangement of this nature.

In Figure 3, parts which are the same as those in the arrangement of Figure 1 have the same reference numerals as in Figure 1 and operate in the same manner as described with reference to Figure 1. The arrangement shown in Figure 3 is provided with a switch means constructed as follows. A pair of arcuate electrically conductive tracks 16 and 17 are provided alongside, and spaced from, the resistance track 1. Terminals 18 and 19 are provided on the conductive tracks 16 and 17 respectively, for connection to an external circuit (not shown) in which a switching function is required. Electrically conductive wipers 20 and 21, arranged to traverse the conductive tracks 16 and 17 respectively, are electrically connected together and supported on the same wiper carrier 4 as the wipers 3 and 7 which traverse the resistance track 1 and collector 8 respectively. The wipers 20 and 21 are therefore in ganged operating relationship with the wipers 3 and 7. A film of electrically insulating material 22 is provided covering a proportion of the length of the conductive track 17 and such that a region of the conductive track 17 remains

resistance value R_T of the network is too coarse to achieve a desired value of R_T with sufficient accuracy, a fine trim can be effected by removing a small portion of one or more of the resistance elements 13A in known manner, e.g. by mechanical abrasion or cutting.

Thus by means of the resistor networks 9A and 9B a required resistance value can be introduced in series with track 1 and terminals 10 and 11 respectively.

Although in Figure 1 two resistor networks 9A, 9B are illustrated, if desired only one of the networks 9A or 9B could be provided.

The resistor networks 9A and/or 9B can serve the following roles in a potentiometer. Firstly they can function as safety resistors to ensure that an output voltage at terminal 6 is prevented from ever reaching the level of the voltage applied to terminals 10 and 11. Such a safety feature is becoming increasingly important in the case of potentiometers employed in automobile engine management systems, e.g. for throttle position sensing. Secondly, one or both resistor networks 9A, 9B can be employed to provide a correction for the slope of a graphical linear relationship between the output voltage at terminal 6 and the displacement of wiper 3 along the track 1. This slope, referred to as the law output slope, may, in practice, be different from that which was intended, on account of tolerances in the manufacturing processes of potentiometers. These may result in errors in the effective angle of wipe by the wiper 3 between conductors 15A, 15B at opposite ends of the track 1, particularly on account of spreading, during printing, of the conductive ink used for the end conductors. Printing errors may also result in eccentricity of the resistance track relative to the position of the wiper spindle 5. One or both resistor networks 9A and/or 9B can be used to compensate for this and effectively adjust the law output slope to precisely that which is required, the resistance adjustment facility on the networks allowing this to be

exposed extending from the termination 19. As the wiper carrier 4 is moved by clockwise rotation of the spindle 5 such that the wiper 3 moves away from the end terminal 15A and the wipers 20 and 21 move away from the end terminals 18 and 19 respectively, then initially wiper 20 is in contact with conductive track 16 and wiper 21 is in contact with conductive track 17. In this situation, electrical continuity between terminals 18 and 19 is effected by way of the wipers 20, 21 in contact with the tracks 16, 17. As movement of the wiper carrier is continued, a point 23 is reached where wiper 21 moves from the conductive track 17 onto the overlying insulating film 22. When this occurs, the wiper 21 becomes electrically insulated from the conductive track 17 and terminal 18 is no longer electrically linked to terminal 19 by way of the wipers 20 and 21. This arrangement provides a switch for operating a circuit when connected to terminals 18 and 19. For some applications it may be required for the output voltage at terminal 6 of the potentiometer to be at an accurately predetermined level when the wiper 21 traverses the interface 23 between the conductive track 17 and the insulating film 22, i.e. at the operating point of the switch. This output voltage level is able to be set with the required precision by adjustment of the resistance value of the resistor networks 9A and/or 9B by the method previously described with reference to Figures 1 and 2. This arrangement of potentiometer and switch finds particular application in automotive engine management systems.

In a further embodiment, illustrated in Figure 4, parts common to and fulfilling similar functions to those shown in Figure 1 and described with reference thereto are given the same reference numerals as in Figure 1. However, in Figure 4 a pad 24 of electrically conductive material is provided covering a portion of the resistance track 1 near to and at a predetermined distance from an end of the track where a conductive terminal 25 is

provided. It is arranged for a voltage source to be connected between terminal 25 and a further terminal 26 provided at the other end of the track 1. A resistor network 9B of the kind previously described is connected between the pad 24 and the terminal 25. As the wiper carrier 4 is rotated such that the wiper 3 traverses the track 1 starting from the end at which the terminal 26 is connected, an output voltage is obtained at terminal 6 which increases proportional to the displacement of the wiper 3 along the track 1.

When the wiper 3 contacts the pad 24 and moves across it the output voltage at terminal 6 remains substantially constant at a level predetermined by adjustment of the resistance value of the resistor network 9B. When the wiper is caused to be traversed further and moves off the pad 24 onto region 1A of the track 1 the output voltage at terminal 6 increases again but the rate of change of voltage is now smaller than previously as a result of the effect of the network 9B. This embodiment is advantageous when the potentiometer is used in automotive applications, e.g. as a throttle position sensor. The wiper 3 would normally be arranged to operate between the terminal 26 and the pad 24. Any mechanical overtravel in the system would cause the wiper to move further over the pad 24 without any increase in output voltage occurring, the dimensions of the pad 24 providing prescribed limits for the amount of overtravel which can be accommodated. If excess overtravel occurs such that the wiper 3 leaves the pad 24 and traverses the region 1A of the track 1 towards the terminal 25, the increasing output voltage at terminal 6 will cause an error detection or safety program to be executed in an associated electronic system.

If required, a network similar to network 9A in Figure 1 may be provided in addition to, or instead of, network 9B, but at the opposite end of track 1 and functioning in similar manner to network 9B.

Combination of the arrangments of Figures 3 and 4 may also be envisaged.

CLAIMS:

1. An electrical potentiometer comprising: an elongate film electrical resistance track (1) on a substrate (2); first and second electrically conductive terminals (10, 11) arranged to be connected for application of a voltage source to said resistance track (1); a wiper (3) of electrically conductive material arranged to traverse said resistance track (1), said wiper (3) being electrically connected to a third electrically conductive terminal (6) at which an output voltage may be obtained which is a function of the position of said wiper (3) on said track (1); characterised by a film electrical resistor network (9A, 9B) provided on said substrate at a first end of said track (1) in series with said track (1) and said first terminal (10) or in parallel with a portion (1A) of said track (1) at said first end of said track the said network comprising a plurality of interconnected resistance elements (13A) formed by application of electrically conductive film links (14A) to a single film resistance element (12A) said links being capable of being selectively severed so that adjustment to a predetermined value of the resistance of the said network (9A, 9B) can be effected and a desired relationship between the said output voltage and position of said wiper on said track can be obtained.

2. A potentiometer according to Claim 1, wherein a portion of one or more said resistance elements (13A) has been removed by mechanical cutting or abrading to effect adjustment of the resistance value of said network.

3. A potentiometer according to Claim 1 or 2, wherein the track (1), the terminals (6, 10, 11) and the resistor network (9A, 9B) are provided by screen printing an electrically conductive polymer or paint material having required electrically conuctive or resistive properties onto the substrate (2), the single film resistive element (12A, 12B) of the or each said network (9A, 9B) being integral with or formed simultaneously with said track (1)

and being produced at a single printing operation, a second single printing operation providing the terminals (6, 10, 11) and conductive film links (14A, 14B).

4. A potentiometer according to any preceding claim, wherein first and second resistor networks (9A, 9B) are provided beween opposed ends of the track (1) and terminals at which voltage is applied across said track (1) whereby the output voltage from the potentiometer cannot reach a level of the applied voltage, thereby serving as a safety means in said potentiometer.

5. A potentiometer according to any of Claims 1 to 3, wherein a said resistor network (9A) is provided at the first end of the track (1) and/or a second said resistor network (9B) is provided at the second end of the track (1), adjustment of the resistance value of the or each said network being effected to achieve a required slope for a linear relationship between said output voltage and displacement of said wiper (3) along said track (1), a network (9B) being provided at an end of the track that when approached by the wiper (3) results in the output voltage approaching a maximum value, adjustment of the resistance of the network (9B) to increase the value thereof being able to be effected to reduce by a desired amount the slope for the linear relationship.

6. A potentiometer according to any of Claims 1 to 3, wherein a said resistor network (9A, 9B) is provided at the first end or the second end of the track (1) adjustment of the resistance value of said network (9A, 9B) being effected to adjust to a predetermined level the output voltage at a predetermined position of displacement of the wiper (3) along the track (1).

7. A potentiometer according to Claim 6, wherein switch means is incorporated therein for controlling an associated circuit and arranged to operate at said predetermined position of displacement of the wiper, the switch means including an elongate electrically conductive film (17) extending alongside but separated from the track

(1) and arranged to be traversed by a further wiper (21) arranged in ganged relationship with the wiper (3) that traverses the resistance track (1) and such that at said predetermined position of displacement of said wiper (3) said further wiper (21) passes from said conductive film (17) onto an electically insulating surface (22).

8. A potentiometer according to any prceding claim, wherein said resistance elements (13A) in said network (9A) are connected initially in parallel by said film links (14A).

9. A potentiometer according to any preceding claim, in which a pad (24) of electrically conductive material is provided covering a portion of said track (1) at a predetermined distance from an end of said track, a said resistor network (9B) being connected between said pad (24) and a terminal (25) for the potentiometer connected to said end of said track, such that as said wiper (3) passes over said pad (24) the output voltage from said potentiometer remains substantially constant at a level predetermined by means of the resistor network (9B).

10. A potentiometer according to Claim 9, wherein the said network (9B) also operates such that as the wiper (3) is caused to traverse the track (1) in a particular direction, the rate of change of the output voltage as the wiper (3) approaches said pad (24) is different compared with that after the wiper (3) leaves the pad (24).

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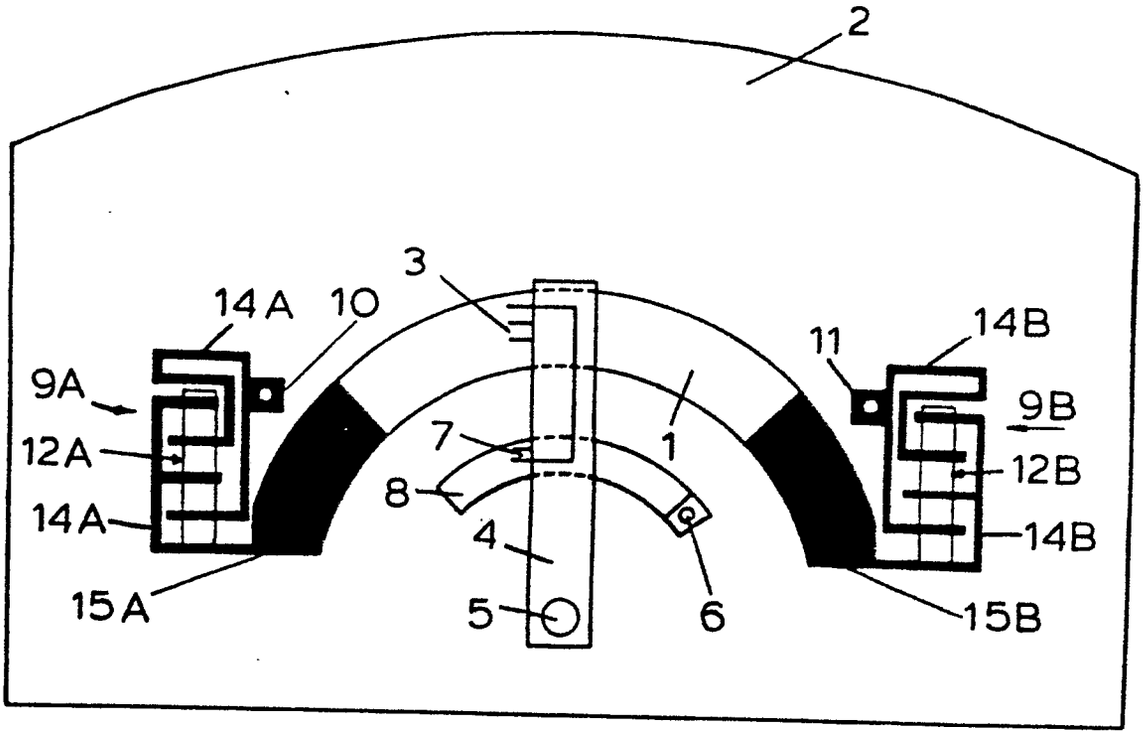
FIG .1 .



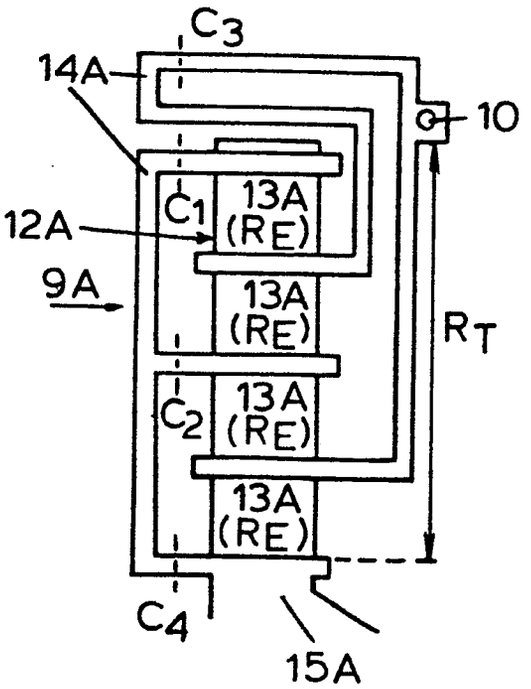


FIG.2A.

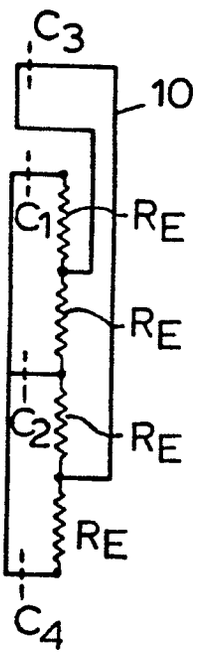


FIG. 2 B

FIG .3.

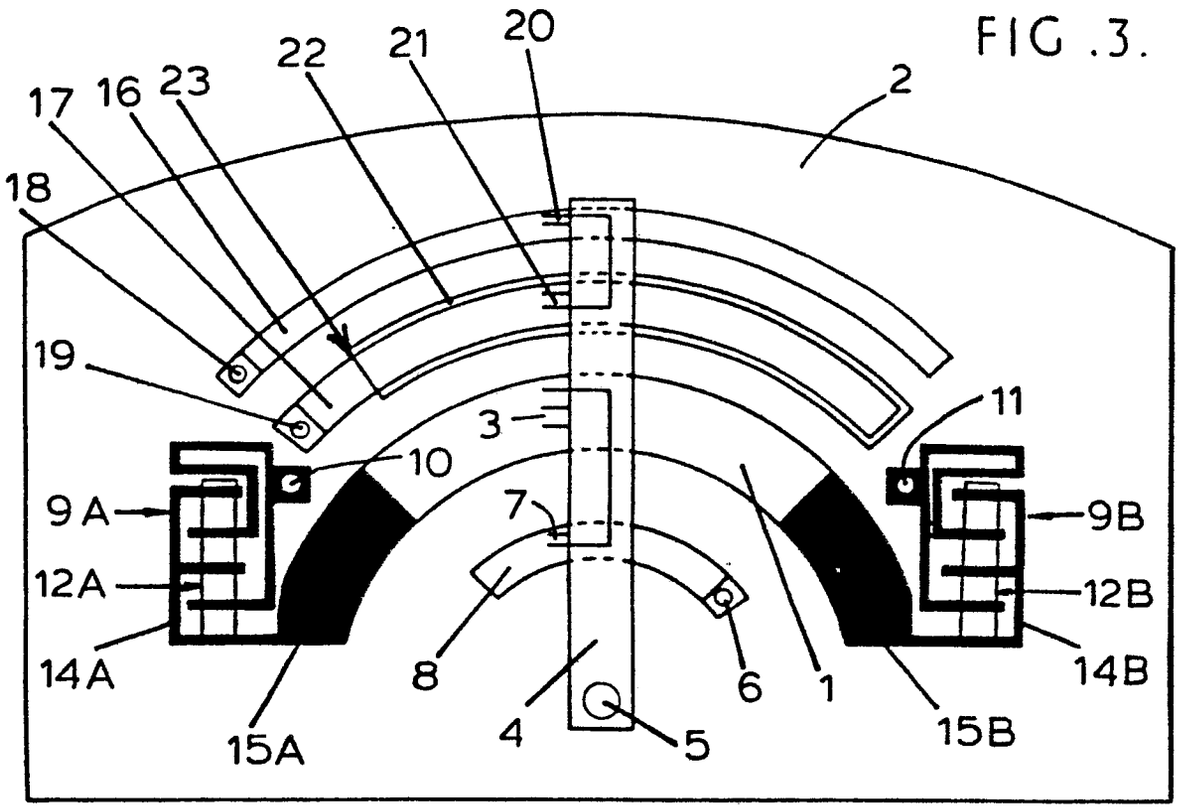

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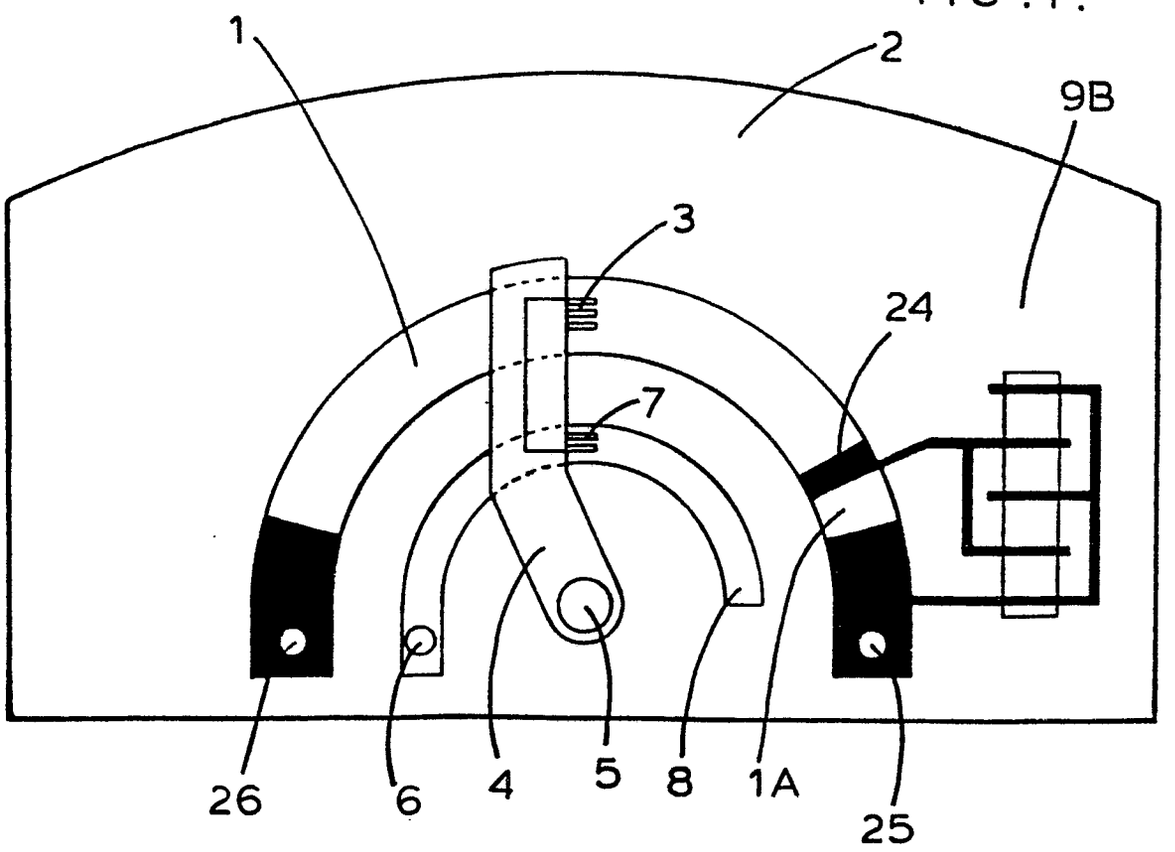
FIG .4.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