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(54) IMPROVEMENTS IN OR RELATING TO ELECTRO-MECHANICAL DEVICES

(71) We, AGA AKTIEBOLAG, a Swedish Company of S-181, Lidingö Sweden,

do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:-

The present invention relates to electro-mechanical devices. A known electro-mechanical position indicator has two parts which are movable relative to one another in a predetermined direction. One part is provided with a primary winding so arranged that when supplied with an alternating current it generates alternating magnetic flux substantially normal to said direction of movement, the magnetic flux varying at least in said direction in a predetermined manner. The other part is provided with at least two sensing windings mutually offset in said direction. These sensing windings sense the magnetic flux prevailing within their respective areas of extent.

Rotary devices of this type are particularly useful for measuring angles. Such a device is a resolver, which has two sensing windings set at a relative angle of 90°. A further such device is a synchro which has three windings mutually displaced by 120°. Resolvers and synchros are normally used for transmitting data representing angles from a transmitting device to a receiving device. Continuous or continual angular transmission can be achieved, although they can also be used as angle-measuring devices, particularly when they are made more accurate than those resolvers and synchros which are now commercially available. Such angle-measuring devices could be used to measure angles with the degree of accuracy required, for example, for theodolites or gun-sights etc. In such applications, a device is normally used in which an accurately prepared measuring pattern is placed on, for example, sheets of glass or some other stable material and read off optically or electronically. In order to eliminate the effect of parallax, for example, a reading has been made at two or more positions, the number increasing with the number of parts of the pattern read off, thus lowering the requirement for accuracy of an individual marking of the measuring pattern.

Since angle-measuring devices of the aforementioned optical type must be manufactured to a very high degree of accuracy, they are extremely expensive. They are also very fragile instruments. Consequently, there has long been a need for a highly accurate, robust instrument.

In the case of a conventional, electro-mechanical resolver or synchro, for example, there is used the whole of the mutually movable surfaces for the detection of an angle, since the magnetic field which transfers the angular information between stator and rotor often varies in the manner of a sine or cosine function over said surface. Such a component therefore requires relatively less stability with respect to each individual "electrical loop", of the emitter winding since the output signal of the angle indicator (resolver or synchro) constitutes the mean value of the position of a large number of loops. If the individual loops could be accurately and stably fixed a resolver or a synchro would be an extremely accurate angle-indicator. There is a further problem, however, with the use of a conventional resolver or synchro as an angle measuring device. This problem is due to the fact that such an electromechanical device includes a multiplicity of lamellae which are joined together with other elements, rendering it difficult to match the elements incorporated in the device thermally, so that changes in temperature affect the output signal. This effect can cause measuring variations of the order of magnitude of several minutes of arc.

According to the invention, there is provided electromechanical apparatus comprising two parts, a first of which provides a first surface and a second of which has two parallel surfaces each of which extends parallel to and closely adjacent a respective side of said first surface of the first part, said first surface having secured thereto turns of a main coil and said surfaces of the second part each having secured thereto at least one further coil, the two parts being mounted for relative movement to cause said further coils to translate along a predetermined path relative to said main coil, and the inductive coupling between each said further coil and said main coil being dependent on the relative position of said parts.

Preferably, the first part provides first and second opposed parallel surfaces adjacent respective ones of said parallel surfaces of the second part, each of said surfaces of the first part having said main coil secured thereto.

In one embodiment, each of said surfaces is substantially flat and the individual turns of each said coil occupy a respective single plane parallel to said surfaces.

In a further embodiment, said surfaces are concentric cylindrical surfaces.

Preferably, the individual turns of each further coil are uniformly mutually spaced.

Preferably, said parts are so mutually positioned that when said main coil is energised magnetic flux is equally dense over each surface carrying a said further coil.

Preferably, each said coil is constituted by an electrically conductive layer pattern secured to the relevant said surface.

Each layer pattern is preferably a printed circuit.

In one embodiment of the invention, said surfaces are concentric cylindrical surfaces.

In a further embodiment of the invention, one of said parts is generally plate-like, the parts being mutually rotatable about an axis, and the main coil is generally annular and is centered on said axis.

Preferably, each of the coils has the form of at least one rectangular spiral having two opposite parallel sides parallel to said predetermined path.

Preferably, those conductors of the or each spiral of said main coil extending transversely of said path are includined at an acute angle relative to the corresponding conductors of each further coil, the transverse conductors of each further coil or of said main coil being substantially perpendicular to said path, and said acute angle being such that the distance, in the direction of said path, between the ends of each of the transverse conductors of the main coil or of each further coil is greater than the conductor spacing of the transverse conductors in the other coil or coils.

Preferably, each further coil is such that its shortest conductor extending transversely of said path is longer than the longest conductor extending transversely of said path in said main coil.

Preferably, said main coil has a cyclically repeated winding pattern.

Expediently, each further coil comprises a plurality of part coils, the further coils are substantially identical, and each part coil is wound in the same manner as the main coil at least over one half cycle thereof.

Expediently, each part coil is wound in the same manner as the main coil over a whole cycle thereof.

In one embodiment, said first and second parts are mounted for mutual rotation and there are provided two said further coils mutually offset by 90°.

A resolver may be constructed in this manner.

In a further embodiment, said first and second parts are mounted for mutual rotation and there are provided three said further coils mutually offset by 120°.

In this manner, a synchro may be constructed.

Expediently, to the terminals of said further coils is connected electronic processing means for deriving from said alternating voltage values representing said relative position, said processing means being described in our copending application No. 5159/78 (Serial No. 1585744) and comprising: electronic storage means having a plurality of storage locations individually addressable in response to addressing signals dependent on said alternating voltage and supplied to an address input of the storage means, the storage means being for storing correction values corresponding respectively to angular or linear values of positon in said path and for supplying correction signals representing said correction values; and correction means connected to receive said correction signals to correct said measured values in accordance with said correction values and arranged to provide an output representing each thus corrected measured value.

Preferably, said storage means is a non-volatile memory.

Said storage means may be a read-only memory.

For a better understanding of the invention, and to show how the same may be carried into effect, reference will now be made, by way of example, to the accompanying drawings, in which:-

Figure 1a illustrates a winding patter;

Figure lb is a sectional view of an embodiment suitable for using the winding pattern illustrated in Figure 1a;

Figure 2 illustrates a resolver having a winding pattern of the type shown in Figure 1a;

Figure 3 illustrates a second embodiment of winding pattern;

Figure 4 is a sectional view of a further type of resolver;

Figure 5 illustrates windings of the embodiment illustrated in Figure 4;

Figure 6 illustrates a further embodiment of winding;

Figures 7 to 9 illustrate a further embodiment of apparatus of the type shown in Figure 1;

Figures 10 and 11 show two type of primary winding;

Figures 12 and 13 illustrate two embodiments of windings for a synchro; and

Figure 14 illustrates an embodiment of a circuit for connection to sensing windings for processing a measuring result.

Similar elements are referenced in respective figures by the same references.

In Figure 1a is illustrated a schematic diagram of a first embodiment of winding pattern for a measuring instrument. In the upper and lower part of the Figure there is illustrated the same winding 1 seen from the same direction. Winding 1 has a cylically repeated pattern laid in rectangular spirals, extending horizontally and producing a magnetic flux whose strength perpendicular to the plane of the winding varies along the longitudinal direction thereof. Furthest to the right in the Figure at the top thereof there is illustrated one cycle in extended form. Winding 1 is supplied with a sinusoidal alternating current and will, hereinafter, be called the primary winding. In the upper part of Figure 1a are illustrated two sensing windings 2 and 3 which are movable along one side (side 1) of the primary winding 1, and in the lower part of the Figure are shown two further sensing windings 4 and 5 movable along the other side (side 2) of winding 1. For the sake of clarity winding 1 is illustrated in dash lines, but in reality will, of course, consist of unbroken conductors.

Figure 1b illustrates a section through a device having winding 1. The arrow A shows the direction from which the windings in Figure 1a are shown. In Figure 1b, winding 1 is stably arranged, for example, by means of a printed conductor array, on a plate 7′ of rigid material. Each cycle of winding 1 comprises two spirally-wound sections which are so wound that the magnetic fields generated from said sections will be directed respectively in opposite directions. The sections of each cycle are mutually connected by a respective conductor 6 laid on the other side of the plate 7′ from the winding pattern. On the side of the plate 7′ which carries the winding 1, is arranged a further plate 7″ for stiffening and spacing purposes. A further embodiment of primary winding will be described hereinafter with reference to Figures 5a and 5b. The primary winding illustrated in Figure 5 is to be preferred over the primary winding of Figure 1 since it utilises the plates 7′ and 7″ more advantageously.

On the external sides of plates 7′ and 7″, are respectively arranged further plates 8 and 9 which are parallel with the plates 7′ and 7″. Sensing windings 2 and 3 are arranged on the side of plate 8 facing plate 7′ and sensing windings 4 and 5 are arranged on the side of the plate 9 facing plate 7″. The plate 7′ is provided with the conductors 6 on the side thereof facing plate 8.

As will be seen from Figure 1a, the sensing windings 2 to 5 each comprise two portions of mutually opposite hand which are wound in the form of rectangular spirals, as with the primary winding. The portions of each sensing winding are arranged with mutually opposite winding directions and are so spaced that between them they cover one complete cycle of said primary winding 1. Each of sensing windings 2 to 5 on each side of the primary winding 1 (i.e. above and beneath in the Figure) is so extended that each turn of each sensing winding laterally extends laterally beyond emitter winding 1.

As will be understood, there is provided a pair of "sine"-windings 2 and 4 and a pair of "co sine"-windings 3 and 5 on respective sides of the stationary winding, the windings of the sine-winding pair 2 and 4 and the windings, of the cosine winding pair 3 and 5 being connected together in series. The sensing windings 2 and 3, and sensing windings 4 and 5 are so mutually displaced that the magnetic flux sensed by one pair of sensing windings (2 and 4) is displaced 90° (i.e. 1/4 pole division) in relation to the magnetic flux sensed by the other pair (3 and 5) whereby one winding pair approximately indicates the sine value and the other the co-sine value of the angular position (angular position within a cycle) of the respective pair of sensing windings. Thus, for the reference position with positive angle 0, the sine winding pair 2 and 4 gives a 0-signal and the "co sine"-winding pair 3 and 5 gives a maximum signal.

In order that the output signal from the sensing windings shall be changed as uniformly as possible, the turns of the primary winding are inclined, so that the individual conductors of the winding, which extend transversely to the direction of movement have an approximately inclination such that their end to end displacement in the direction of movement is at least the same distance as that between two adjacent conductors in the direction of movement. The output signal from each series-coupled winding pair 2, 4 and 3, 5 respectively is produced between their ends in each case. Winding 1 is supplied with a sinusoidal alternating current and the voltage induced in each sensing winding is dependent upon that number of turns in which current is induced by the magnetic field from the primary winding 1. The voltage over the sensing windings is, of course, an alternating voltage. The effective value, the top value or mean value may be sensed and constitute in indication of position.

Owing to the fact that the windings 2 and 4 and 3 and 5 respectively have been made symmetrical and placed on respective sides of the winding 1, compensation is introduced for possible relative movement transversely of the plane of the drawing. By making the shortest, transverse conductor path of each sensing winding longer than the extent of the longest conductor path of the primary winding in the transverse direction, the influence of errors in the transverse setting between the units 7, 8 and 9 is reduced. In the Figure 1 embodiment it has been assumed that the winding 1 is arranged on a stationary unit and the windings 2 to 5 on a movable unit. Conveniently, all the windings have the form of printed conductors.

When the position indicator according to the invention is to be used as an angle-measuring device, the winding pattern illustrated in Figure 1 can be arranged on three cylinders in the manner shown in Figure 2. In this respect, the windings can either be formed so that the pattern between the portion B and C shown in chain lines in Figure 1a forms the whole cylindrical winding or, in dependence upon the desired number of poles, the pattern between B and C can be repeated a required number of times. In Figure 2 the winding 1 is arranged on the outer surface of the cylinder 10 with the cross lines 6 on the inside of the cylinder 10. It will be understood that the cylinder 10 may, instead, be provided with a primary winding of the type described hereinafter with reference to Figure 5a and Figure 5b, with winding parts on both the inside and the outside of the cylinder. 10. The windings 2 and 3 are arranged on the outer surface of a cylinder 11 disposed radially inwardly of the cylinder 10 and the windings 4 and 5 on the inner surface of the cylinder 12 disposed radially outwardly of the cylinder 10. As will be seen from the Figure, the cylinders 11 and 12 are connected with a cross wall 13. With this arrangement, either the cylinder 10 can be made the rotor and the parts 11 to 13 the stator, or vice versa. Figure 3 illustrates a further embodiment of the "sine" and "cosine" winding on either side of the winding 1. As will be apparent when making a comparison between Figure 1 and Figure 3, all the sensing windings have been divided into two separate windings at that location where the winding direction changes and have been divided between side 1 and side 2. More specifically the winding 2 has been divided to form winding A_1 mounted on side 1 and winding A_2 on side 2. The winding 3 has been divided into winding B_1 mounted on side 1 and the winding B_2 mounted on the side 2. Subsequently the winding 4 can be divided into a winding A_3, which may either be mounted on side 1 or side 2 with the winding A_4 on the other side, the winding 5 having been divided to form the winding B_3 on the same side as A_3 and the winding B_4 on the same side as the winding A_4. Similarly to the Figure 1 embodiment, the winding pattern between the section D and E shown in chain lines can be repeated and may be arranged in the manner shown in Figure 2. Figure 2 may also symbolize a resolver, preferably having cast copper coils which are iron-free.

When the Figure 2 embodiment is formed as a resolver, certain problems may arise when assembling the device, since the parts 10 to 13 must be accurately positioned relative to one another, particularly in the radial direction. Moreover, this arrangement requires a relatively large amount of space. In view of this a further embodiment has been devised, in which the windings are arranged annularly in mutually parallel planes around circular plates having a common centre. Either that part which carries the primary winding or that part which carries the sensing windings is rotatable about said centre.

Figure 4 is a sectional view of this embodiment. In the Figure 4 embodiment, the primary windings 16 and 17 have been mounted on a centre, a circular plate 15 acting as a rotor and being provided with a shaft 14. Symmetrically around the plate 16 and parallel therewith are stationarily arranged a further two circular plates 18 and 19 which are joined together by a cross wall. The plates 18 and 19 carry the sensing windings. It will be understood that this embodiment can be modified in a manner such that the rotor carries the sensing winding and the primary winding is arranged on the stator on each side of the sensing windings.

Figure 5 illustrates the various windings on the stator and rotor as seen in the direction of arrow G in Figure 4. Similarly to the winding 1 in Figures 1 and 3, the primary windings 16 and 17 in this embodiment are also obliquely placed so that the conductors extending transversely of the direction in which the winding arrangement extends do not run radially, but run inwardly to form tangents with a circle 22 having a radius R. This is seen better in figure 5b, where extensions of the conductors towards the periphery of the circle 22 have been shown in dash lines. R is selected to give a smooth output characteristic of the device.

The primary winding of the embodiment shown in Figures 5a and 5b is to be preferred over the primary winding shown in Figures 1 and 3. As opposed to the primary winding 1, which is arranged solely in one plane, the winding of the Figure 5 embodiment is arranged on both sides of the rotor with lead-throughs between the sides at 23, 24, 25 etc. The windings on both sides of the plate 15 are so wound as to provide co-acting magnetic fields. This means that the winding directions are different at spirals lying opposite each other on respective sides of the rotor when seen from the same direction. The winding on side B is displaced a half conductor distance laterally to the left in the Figure in relation to the winding A, so that each conductor in the winding on side B will lie mid-way between two conductors in the winding on side A. It should be noted that the winding 1 in Figures 2 and 3 can conveniently be replaced by a winding of the type 16, 17, which is then arranged on both sides of the plate 7.

In Figure 5c there is illustrated the sensing "cosine" winding while Figure 5d illustrates the sensing "sine"-winding, a further embodiment of the positioning of these windings relative to the pattern of the primary winding also being illustrated. These are so arranged in this embodiment that each winding part of each sensing winding is arranged across a half-pole division of the primary winding and arranged on each side of the stator every second primary winding pole division. As will be seen from the figure, the directions in which the windings are wound are different on respective sides of the stator (as seen from the sama direction). As will be seen from Figure 5c and Figure 5d, the conductors of the sensing windings extending transversely to the direction of movement are also substantially radial. The embodiment shown in Figure 5 has an 8/16 pattern, i.e. it has 16 poles and the pattern is repeated eight times in one complete revolution and thus gives a succinct output signal within 1/8 revolution.

Figure 5 illustrates at 16′ how a primary winding can be designed so that the magnetic field sensed by a sensing winding in different positons is proportional to a better approximation of sine and cosine for the angular position relative to the primary winding. As will be seen from the figure, the transversely extending conductors are shorter the more centrally they are located in the spiral. The conductors are also inclined differently, i.e. their extensions do not extend towards the periphery of the circle 22. As a result of this design of the winding, there is obtained a greater inclination at zero throughput and smoothing at maximum transition of the field detected by the sensing windings. The innermost conductors are very short compared with the outermost conductors.

Similar to the above, in order to reduce the effect of errors in the axis orientation relative to the centre of the stator, the extent of the shortest conductors of the stator in the transverse direction has been made longer than the longest conductors of the rotor, whereby total overlapping is obtained. The whole of the arrangement is such that compensation is obtained for termperature variations and radial play. Furthermore, the arrangement is able readily to be reproduced. The two stator units have been displaced through one pole division is to obtain compensation for possible irregularities in the field generated by the rotor winding.

In Figure 6 there is shown a further embodiment of an arrangement of one sensing winding for a 24/12 pole resolver. In this embodiment, the sensing winding is arranged in a manner similar to that illustrated in Figure 3, although with the difference that the sides between the dash-dot lines F and E in Figure 3 have changed places.

Figures 7 to 9 show a further embodiment of a flat resolver, in which the sensing windings are obliquely placed and arranged on the centre part, as will be seen particularly from Figure 9. The illustrated resolver is 8/4 pole. The primary winding is not shown in Figures 7 to 9, but comprises windings arranged on both sides of the centre portion, said windings cooperating with each other and each being of the type illustrated in Figures 1 and 3. In this embodiment, however, the primary winding has radially extending transverse conductors.

The "sine" windings are illustrated in Figure 7, A′ indicating the arrangement on one side of the centre portion and A″ the arrangement on the other side of said centre portion.

Figure 8 illustrates the "cosine"-winding with winding portion B′ on one side and B″ on the other. Figure 9 is a perspective view of the centre portion with the "sine"-winding A′, A″ shown. The "cosine"-winding B′, B″ has been omitted for the sake of clarity and the figure clearly shows the positioning of the winding and the requisite lead-throughs. For the sake of clarity, the centre portion in Figure 9 has been made much thicker than in reality.

Figure 10 illustrates a further embodiment of primary winding having obliquely positoned, i.e. not radial, transverse conductors. This embodiment differs from the previous embodiments in so much as the conductors on each side of the centre point of each winding half have a different angle of inclination. Thus, the conductor 25 is inclined in a direction opposite to that of the conductor 26, as illustrated by the dash-dot extensions towards the periphery of the circle 22.

Figure 11 illustrates still a further embodiment of the emitter winding, in which one half-pole division a′ is of the same design as that shown in Figure 10 but in which the other half-pole divisions a″ of the conductor are inclined in the opposite direction to corresponding conductors in a′.

Figure 12 illustrates how the sensing windings can be placed in relation to a primary winding when the position-indicating device or angle-measuring device is a synchro, i.e. has three sensing windings, R_1, S_1, T_1 mutually displaced through 120° on side 1 and R_2, S_2, T_2 on side 2 analogous with Figures 1 and 3. Similarly with the embodiments of these figures, the winding 1 is the same for side one and two. Two dash-dot lines G and H are shown, these lines indicating that the sensing windings can be repeated on the outer side of these lines or when the pattern for the sensing windings is mounted on a cylinder so that the lines G and H coincide. This pattern can also be applied in a ring on planar plates fully analogously with Figures 5 to 11. As will be seen from the figure, the pattern in this embodiment must thus be repeated cylclically 3 · n times for each revolution, where n is the number of times the pattern is repeated between G and H.

Figure 13 illustrates a further pattern of primary and sensing windings for a synchro, in which on side two the right-hand pattern division for each part sensing winding has been moved to the left of the left-hand side pattern division as compared with Figure 12. In this way, both the primary winding pattern and the pattern of the sensing windings on both sides of the primary winding can be repeated with respect to vertical lines having the same position K and L, which is an advantage in adapting the patterns during manufacture.

Figure 14 is a block schematic diagram of an apparatus for coupling to the sensing windings of a position - measuring device or an angle-measuring device of the synchro type 10 or of the resolver type 10′, said circuit presenting the obtained position in digital form.

A sinusoidal alternating voltage $E_0 \sin Wt$, is applied to the primary winding 10a of the synchro 10, whose three secondary windings 10b, 10c, and 10d (which are arranged at 120° relative to each other) are coupled in known manner to three inputs on the three-phase side of a Scott-transformer 11, which converts the incoming three-phase signal to a two-phase signal available at its two secondary windings 11c and 11d. The two-phase windings 11c and 11d are each coupled to a respective input of a synchro to digital-converter 12, which presents at its output a digital value representing the measured value of angle. Synchro to digital converters of this type are of standard design and are in the form of integrated circuits having approximately 10 to 15 output lines. These converters are such that when indicating zero degrees all output lines have a "0" -signal and when indicating 360° - / (where / represents a very small number) all the output lines have a "1"-signal. As indicated by the chain line 14 in Figure 2, instead of elements 10 and 11, a position or angle indicator of the resolver type (having two sensing windings mutually phased displaced by 90°) can be coupled directly to the analogue inputs of synchro to digital converter 12. In addition, to a reference input of converter 12 is coupled to the secondary winding of a reference transformer 13 whose primary winding is supplied with a sinusoidal alternating voltage of the same frequency and phase as that which is supplied to the primary winding 10a or 10′a.

Converter 12 presents a digital value representing angular position H on a multiplicity of parallel output lines which are normally between 10 and 16 in number. In the case of 16 outputs, there is obtained a resolution of approximately ± 1 minute of arc.

Lines 25′ and 25″ carrying the most significant binary bits from synchro to digital converter (SCD) 12 are connected to a transition indicator 26 and to a central processing unit 37. In the case of a multi-pole synchro or a multi-pole resolver, the output from SDC 12 passes through a cycle of values a number of times corresponding to the number of poles, and each passage through the cycle corresponds to a rotation by the synchro or resolver of 360°/P where P is the number of poles. In order that a synchro or resolver of this type can be used to measure angles over a complete revolution, these cycles must be indicated and counted. This is effected in an indicator and counter 26, which when the signals on the lines 25′, 25″ change from binary "11" to binary "00", adds 1 to a stored count and when the signal on lines 25′, 25″ changes from binary "00" to binary "11" subtracts 1 from the count. The output of indicator and counter 26 (which when the synchro/resolver has 8-poles includes three lines) is connected to supply the stored count to the address input of a ready-only-memory 38 which thus gives at its output a correction quantity which is particular to the relevant sector of the mechanical revolution in which the synchro or resolver is located.

The output of indicator and counter 26 is also connected to the three most significant bit input lines of one group of input lines ING. 1 of central data processing unit (CPU) 37. Lines ING.1 will hereinafter be referred to by number starting from the top in Figure 14, so that they have numbers 1 to 17. The output of the converter 12 is connected directly to the input lines 4 to 17 of input ING. 1. The output of read-only memory 38 is connected to a second multi-line input ING. 2 of CPU 37. The output lines of CPU 37 having the most significant bits within a part revolution (i.e. in the illustrated embodiment of Figure 3 the lines from the fourth from the top to the 11th from the top, are connected to the address input of a read-only memory 39, in which correction quantities for positions within a part revolution are stored. The output of the memory 39 is coupled to a third multi-line input ING. 3 of CPU 37. In addition, there is provided a control unit 40 which, via lines 41, controls or is controlled by the converter 12 in the following manner. The quantity which is present on the output lines of converter 12 at any moment is retained on the output lines for that period of time for which a control signal from the control unit 40 remains on line 41. In turn, the converter 12 can indicate to the control unit 40, via line 41, whether display by unit 24 should be delayed to allow time for resolver 10′ or synchro 10 to be rotated and the output quantity from converter 12 to be changed. Via lines 42, unit 40 is connected to the control input of CPU 37 in order to cause the central data processing unit 37 to operate a programme to achieve the following steps:

1. Feed the data on input lines ING. 1 to the output lines.

2. Store the information on the third input ING. 3 from the read-only memory 39 in a buffer memory incorporated in CPU.

3. Add one to the number on the input lines ING. 1, which correspond to those output lines of CPU 37 which are connected to the address input of read-only memory 39.

4. Make an interpolation between the correction quantity stored in step 2 above and the new correction quantity present on ING. 3 from the read-only memory 39 the interpolation being carried out in accordance with the number represented by the values on the lines of ING. 1 carrying data less significant than that carried by those lines corresponding to the output lines coupled to the address input of the read-only memory 39.

5. Add the correct value obtained under item 4 above to the correction number on ING. 2 from read-only memory 38 and to the number on ING. 1 and present the thus obtained number at the output of CPU 37.

The output of CPU 37 is connected to the input of a converter 23, which converts the binary data to binary coded decimal data. A display unit 24 is connected to the output of converter 23. Both display unit 24 and converter 23 are controlled by signals from control unit 40 after the signals to the control inputs of CPU 37 have been provided so that the number presented on the output of CPU 37, in accordance with item 5 above, is displayed by unit 24.

Many modifications are possible within the scope of the invention. For example, the outer sides of the stator plates in Figures 1,3,5,12 and 13 may be provided with sensing windings.

WHAT WE CLAIM IS:-

1. Electromechanical apparatus comprising two parts, a first of which provides a first surface and a second of which has two parallel surfaces each of which extends parallel to and closely adjacent a respective side of said first surface of the first part, said first surface having secured thereto turns of a main coil and said surfaces of the second part each having secured thereto at least one further coil, the two parts being mounted for relative movement to cause said further coils to translate along a predetermined path relative to said main coil, and the inductive coupling between each said further coil and said main coil being dependent on the relative position of said parts.

2. Apparatus according to claim 1 wherein the first part provides first and second opposed parallel surfaces adjacent respective ones of said parallel surfaces of the second part, each of said surfaces of the first part having said main coil secured thereto.

3. Apparatus according to claim 1 or 2 wherein each of said surfaces is substantially flat and the individual turns of each said coil occupy a respective single plane parallel to said surfaces.

4. Apparatus according to Claim 1 or 2 wherein said surfaces are concentric cylindrical surfaces.

5. Apparatus according to any one of Claims 1 to 4 wherein the individual turns of each further coil are uniformly mutually spaced.

6. Apparatus according to any one of Claims 1 to 5 wherein said parts are so mutually positioned that, when said main coil is energised magnetic flux is equally dense over each surface carrying a said further coil.

7. Apparatus according to any one of Claims 1 to 6 wherein each said coil is constituted by an electrically conductive layer pattern secured to the relevant said surface.

8. Apparatus according to Claim 5 wherein each layer pattern is a printed circuit.

9. Apparatus according to any one of Claims 1 to 8 wherein one of said parts is generally plate-like, the parts being mutually rotatable about an axis, and the main coil is generally annular and is centered on said axis.

10. Apparatus according to any one of Claims 1 to 9 wherein each of the coils has the form of at least one rectangular spiral having two opposite parallel sides parallel to said predetermined path.

11. Apparatus according to Claim 10 wherein those conductors of the or each spiral of said main coil extending transversely of said path are inclined at an acute angle relative to the corresponding conductors of each further coil, the transverse conductors of each further coil or of said main coil being substantially perpendicular to said

path, and said acute angle being such that the distance, in the direction of said path, between the ends of each of the transverse conductors of the main coil or of each further coil is greater than the conductor spacing of the transverse conductors in the other coil or coils.

12. Apparatus according to Claim 10 or 11 wherein each further coil is such that its shortest conductor extending transversely of said path is longer than the longest conductor extending transversely of said path in said main coil.

13. Apparatus according to any one of the preceding Claims wherein said main coil has a cyclically repeated winding pattern.

14. Apparatus according to Claim 13 wherein each further coil comprises a plurality of part coils, the further coils are substantially identical, and each part coil is wound in the same manner as the main coil at least over one half cycle thereof.

15. Apparatus according to Claim 13 wherein each part coil is wound in the same manner as the main coil over a whole cycle thereof.

16. Apparatus according to Claim 14 or 15 wherein said first and second parts are mounted for mutual rotation and there are provided two further coils mutually offset by 90°.

17. A resolver constructed in accordance with Claim 16.

18. Apparatus according to Claim 14 or 15 wherein said first and second parts are mounted for mutual rotation and there are provided three said further coils mutually offset by 120°.

19. A synchro constructed in accordance with Claim 18.

20. Apparatus according to any one of the preceding Claims wherein to the terminals of said further coils is connected electronic processing means for deriving from said alternating voltage values representing said relative position, said processing means comprising: electronic storage means having a plurality of storage locations individually addressable in response to addressing signals dependent on said alternating voltage and supplied to an address input of the storage means, the storage means being for storing correction values corresponding respectively to angular of linear values of position in said path and for supplying correction signals representing said correction values; and correction means connected to receive said correction signals to correct and measured values in accordance with said correction values and arranged to provide an output representing each thus corrected measured value.

21. Apparatus according to Claim 20 wherein said storage means is a non-volatile memory.

22. Apparatus according to Claim 21 wherein said storage means is a read-only memory.

wherein said storage means is a read-only memory.

23. Electromechanical apparatus substantially as hereinbefore described with reference to the accompanying drawings.

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1585745 COMPLETE SPECIFICATION

9 SHEETS *This drawing is a reproduction of the Original on a reduced scale*

Sheet 1

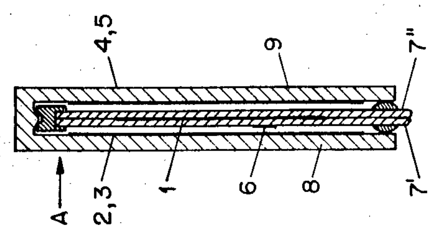

Fig 1b

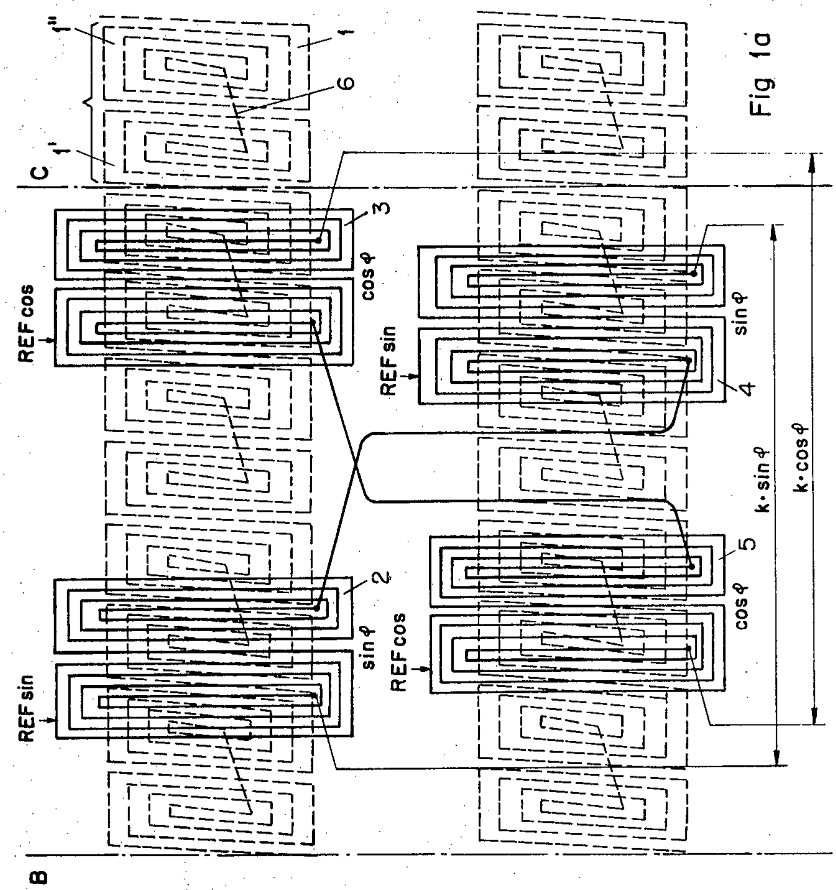

Fig 1a

1585745 COMPLETE SPECIFICATION
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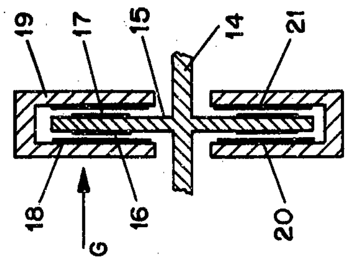

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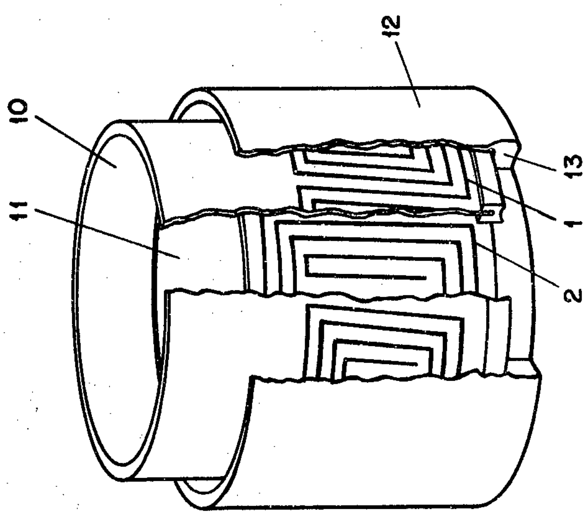

Fig 2

1585745 COMPLETE SPECIFICATION

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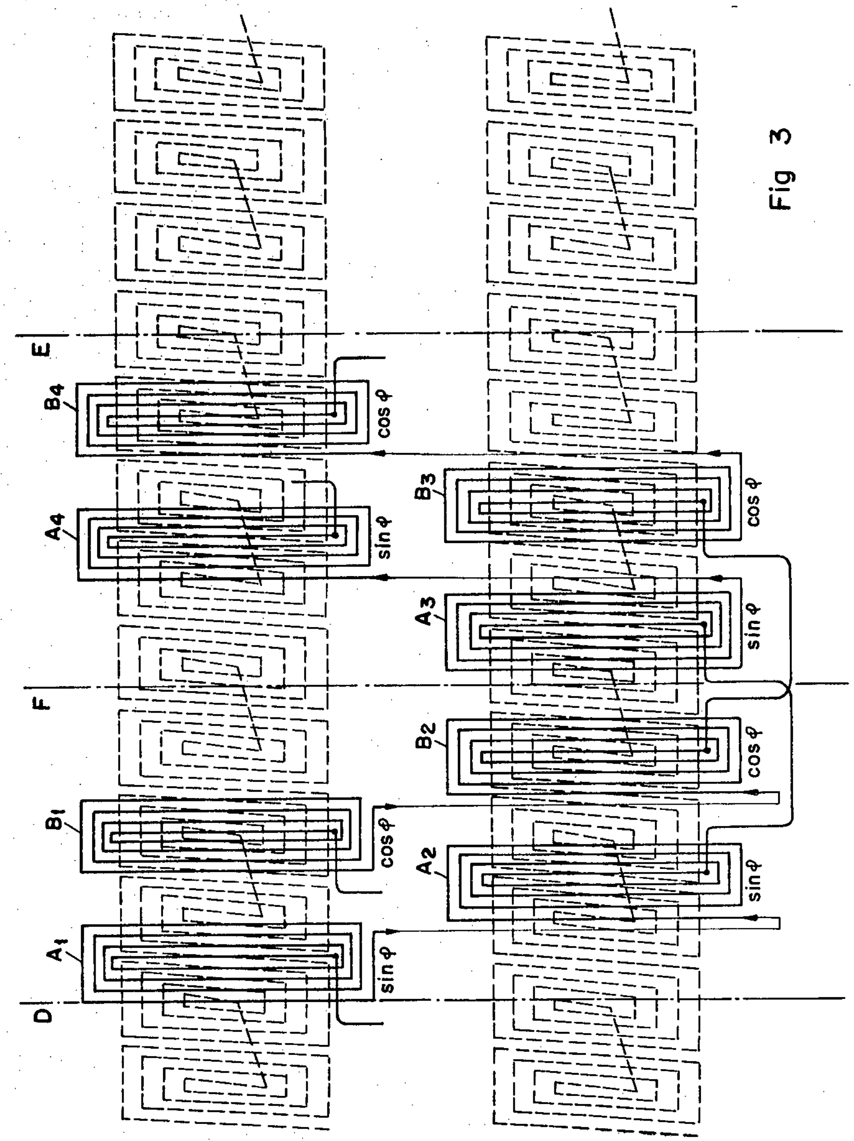

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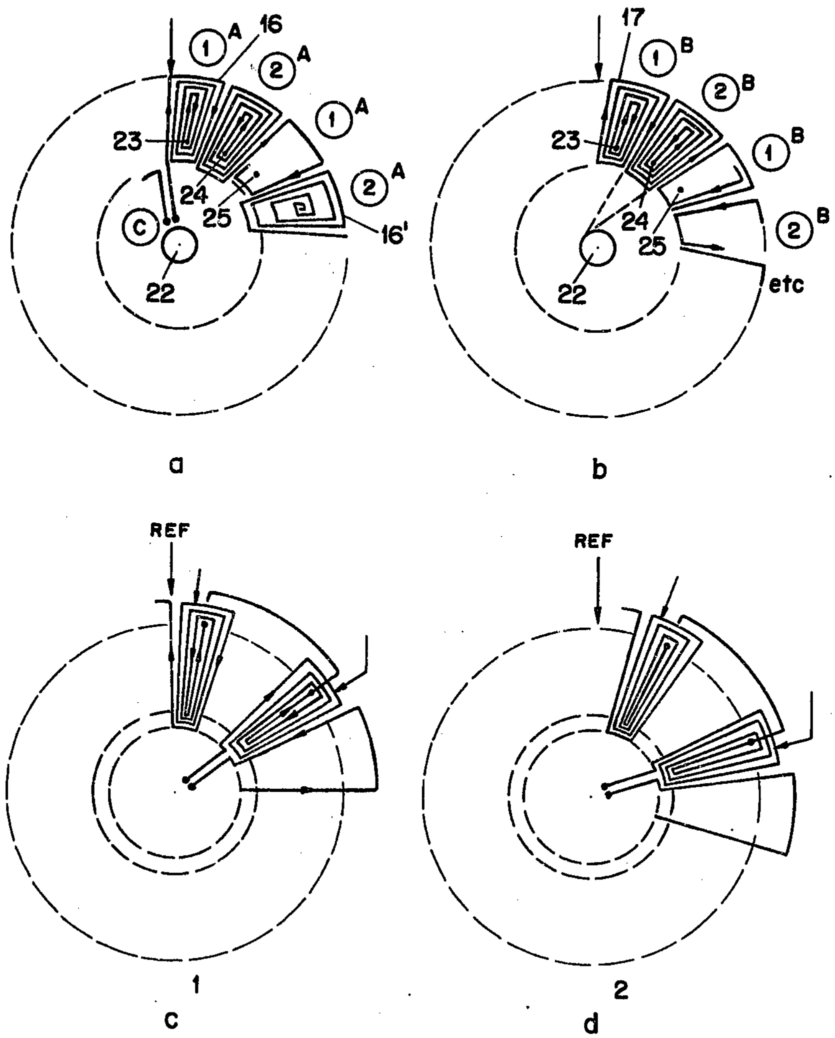
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1 A
2 A
1 A
2 A
23
24
25
C
22
16'
a
17
1 B
2 B
1 B
2 B
23
24
25
22
etc
b
REF
1
c
REF
2
d

Fig 5

1585745 COMPLETE SPECIFICATION

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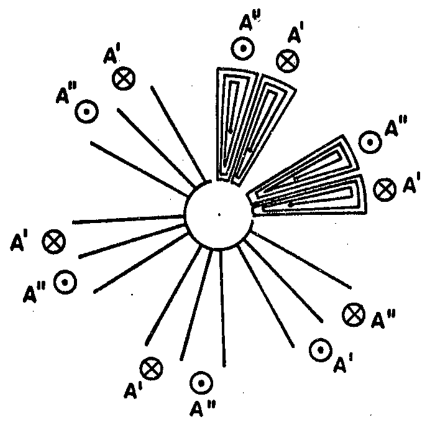
Sheet 5



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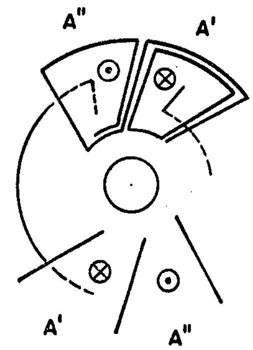

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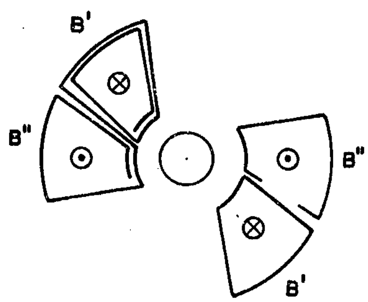
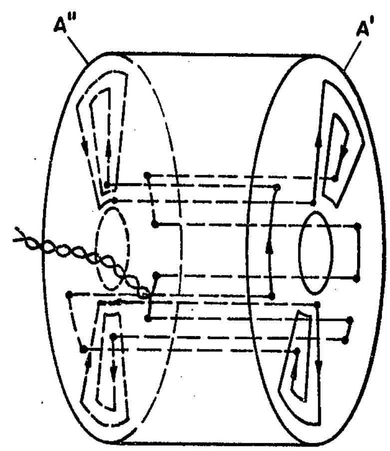


Fig 8



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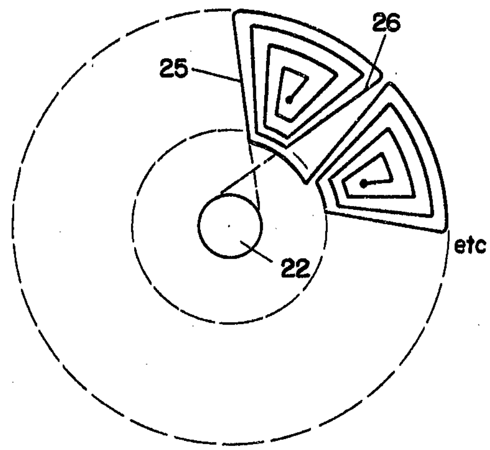

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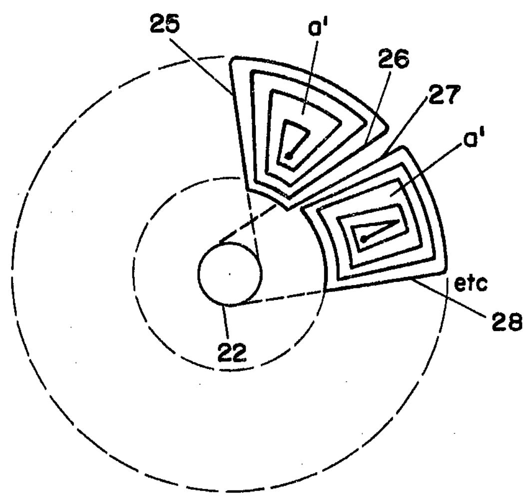

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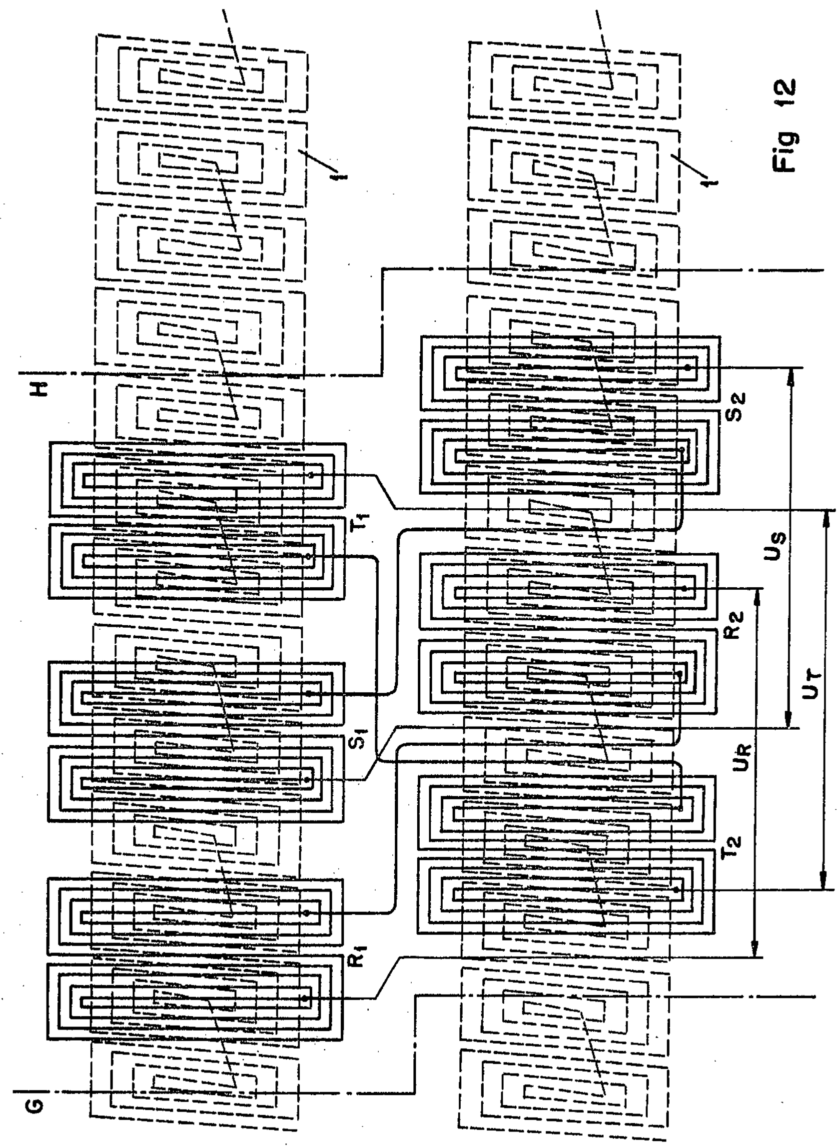

Fig 12

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Sheet 8

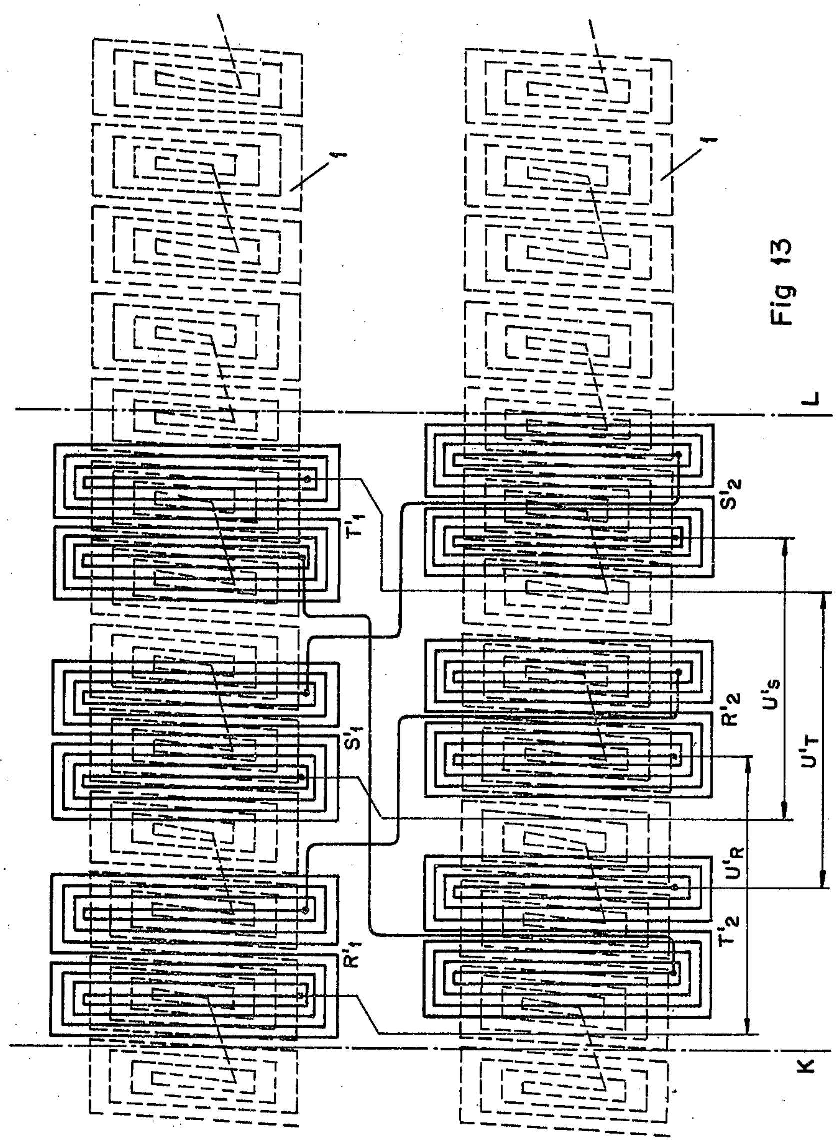
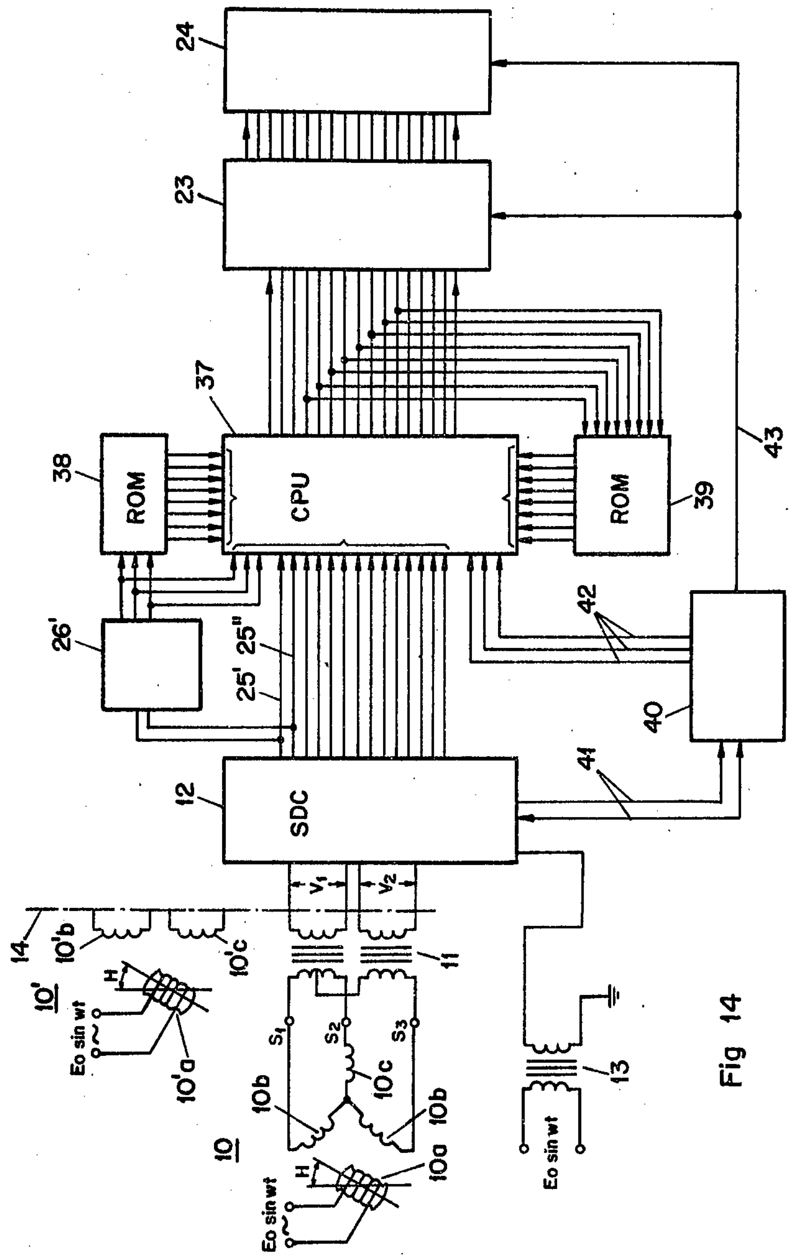


Fig 13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25' 25''
42
40
12
SDC
41
14
10'b
10'c
11
10'
Eo sin wt
10'a
S1
S2
S3
10b
10c
10b
10
10a
13
Eo sin wt

Fig 14