DEVICE FOR TRANSMITTING OVER A DISTANCE THE POSITION OF AN OPERATING OR INDICATING MEMBER

Filed May 2, 1946 4 Sheets-Sheet 1

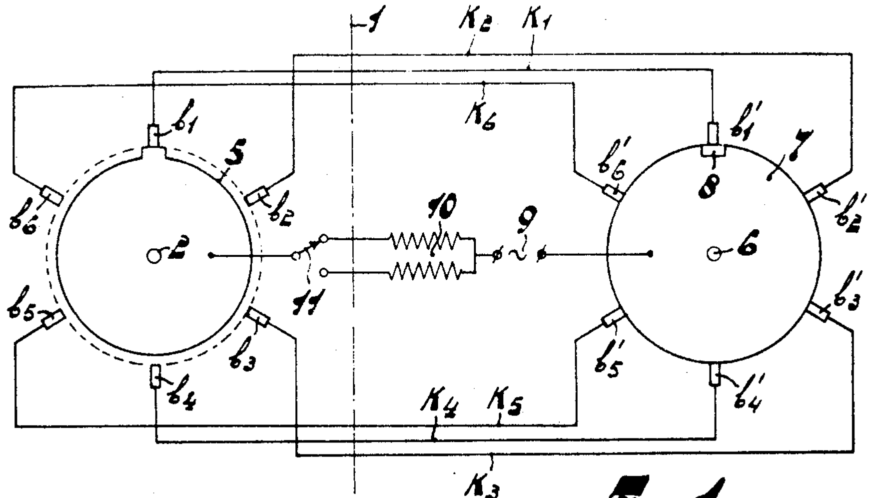

Fig. 1.

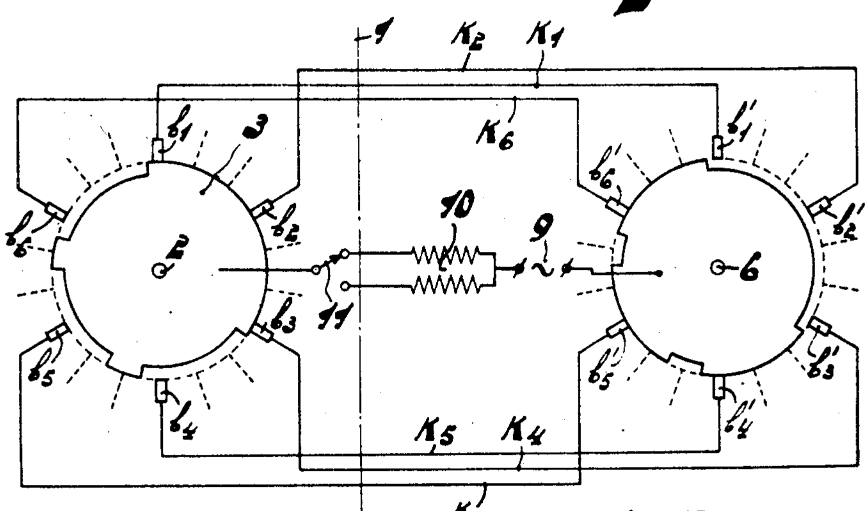

Fig. 2.

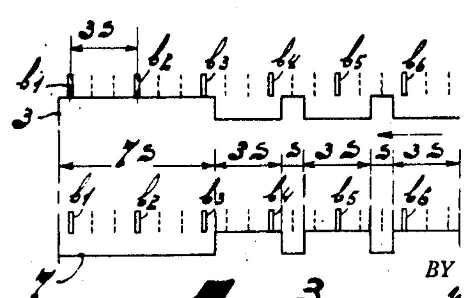

Fig. 3.

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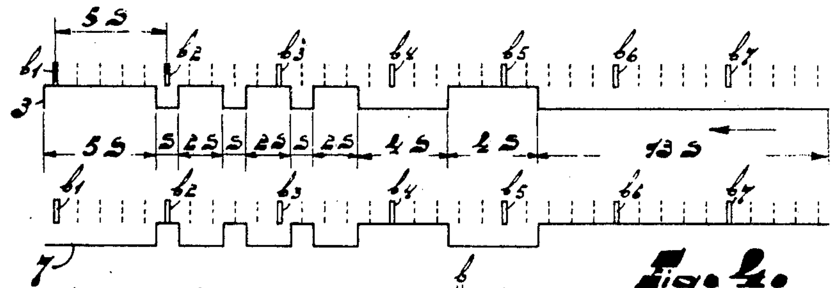

Fig. 4.

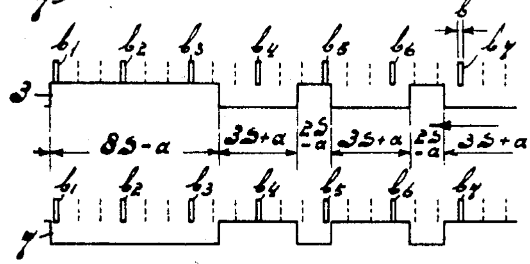

Fig. 5.

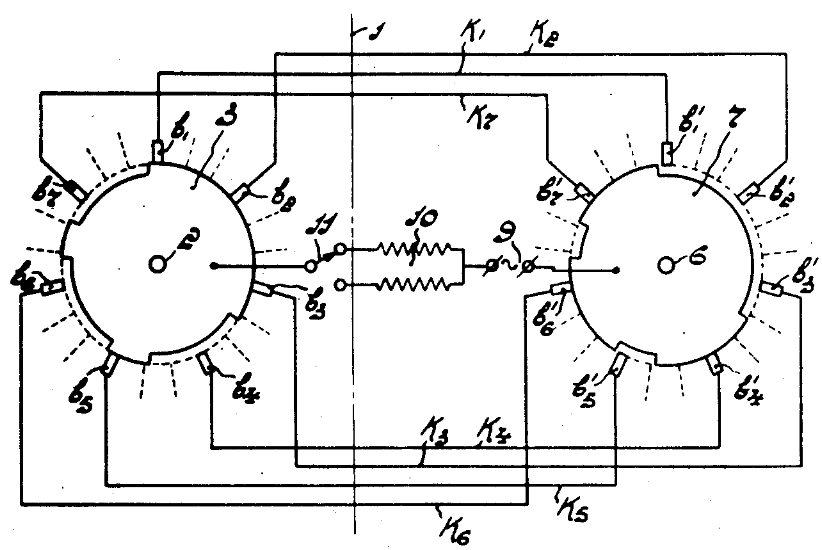

Fig. 5a

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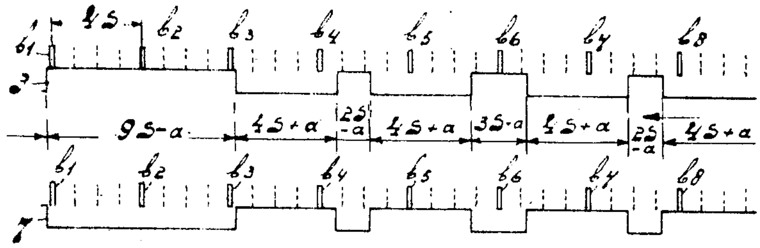

Fig. 6.

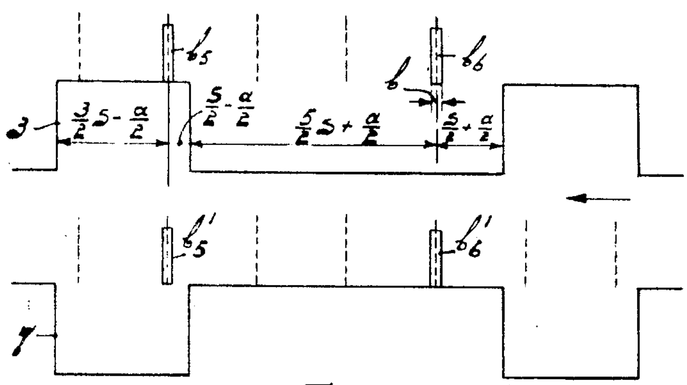

Fig. 7.

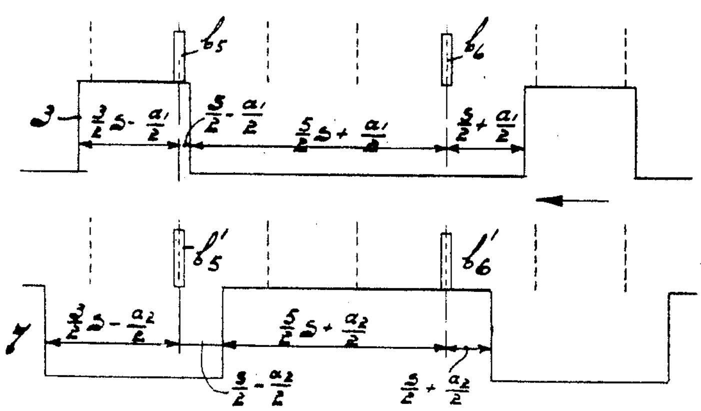

Fig. 8.

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May 15, 1951 J. M. UNK ET AL 2,553,069

DEVICE FOR TRANSMITTING OVER A DISTANCE THE POSITION OF AN OPERATING OR INDICATING MEMBER

Filed May 2, 1946 4 Sheets-Sheet 4

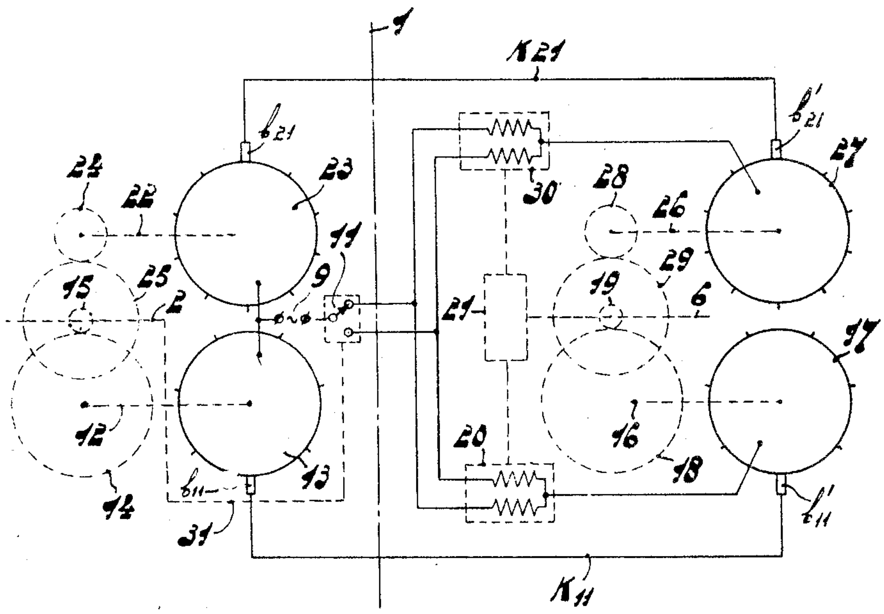

Fig. 9.

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Patented May 15, 1951

2,553,069

UNITED STATES PATENT OFFICE

2,553,069

DEVICE FOR TRANSMITTING OVER A DISTANCE THE POSITION OF AN OPERATING OR INDICATING MEMBER

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Application May 2, 1946, Serial No. 666,804
In the Netherlands June 27, 1941

Section 1, Public Law 690, August 8, 1946
Patent expires June 27, 1961

4 Claims. (Cl. 318—33)

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The invention relates to a device for transmitting the position of a primary operating or indicating member to a remote secondary operating or indicating member and may be utilized inter alia for the remote control of the operating members of a radio transmitter or receiver (tuning, wave-length switching, volume control, adjustment of a directional aerial and the like), for taking measurements from a distance and for transmitting orders (ship's telegraph).

In the device with which the invention is concerned use is made of a plurality of transmission channels for control energy and of a primary and a secondary controlling member, which controlling members are formed so as to be complementary and are driven simultaneously with the primary and the secondary operating member respectively. According to the position of the primary operating or indicating member the primary controlling member opens a determined transmission channel. The secondary operating or indicating member is actuated in this case under the control of the energy transmitted by this channel until it has arrived, at least approximately, in a similar position, in which position the secondary controlling member closes again the transmission channel and thus interrupts the transmission of control energy.

By a complementary construction of the controlling members is meant here a construction such that a transmission channel which is opened in a determined position by the primary controlling member is closed by the secondary controlling member in the corresponding position.

If the control is effected electrically, the controlling members may consist of contact discs of conductive material which are scanned by brushes and the scanned surface of which is formed in such manner that only part of this surface may enter into conductive contact with the brushes. Each brush of the primary contact disc is electrically connected to a similar brush of the secondary contact disc whilst the connecting lines between similar brushes form the transmission channels above referred to. The two contact discs are electrically connected to one another through the intermediary of a source of voltage and of a device for controlling the drive of the secondary operating or indicating member. The last-mentioned device may be constituted, for example, by a motor which drives the secondary operating or indicating member or by a relay by which such a motor is put into operation.

In the figures of the drawings, Fig. 1 represents the prior art, while Figs. 2, 3, 4, 5, 5*a* and 6–9 represent various embodiments of the invention.

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A known device of this type is represented in Fig. 1 of the accompanying drawing. That part of the device which is located to the left of the dotted line 1 is present at the place of remote control whereas the part located to the right of this dotted line is located, for example, at a transmitter or receiver which has to be operated from a distance.

On the shaft 2 of a primary operating member is mounted a primary contact disc 3 of conductive material whose circumference is scanned by a plurality of brushes b_1—b_6. This disc has a shape such that only the portion 4 of the circumference enters into conductive contact with the brushes. The remaining portion 5 of the circumference is preferably covered with insulating material so that cylindrical body is obtained with which all the brushes are in contact.

On the shaft 6 of the secondary operating member of the transmitter or receiver is mounted a secondary contact disc 7 of conductive material whose circumference is provided at 8 with a recess which is preferably filled with insulating material so that the portion 8 of the circumference cannot enter into contact with the brushes but the remaining portion can.

As may be seen, the two contact discs are complementary, that is to say that the portion 4 of the circumference of the primary contact disc, which may enter into conductive contact with the brushes, corresponds to the portion 8 of the circumference of the secondary contact disc, which is insulated with respect to the brushes, and conversely.

Corresponding brushes of the two contact discs are electrically connected (b_1 to b'_1, b_2 to b'_2, etc.) through the intermediary of connecting lines K_1—K_6 which form the transmission channels for the control energy above referred to.

The contact discs 3 and 7 are connected to one another via a source of alternating voltage 9, an induction motor 10 and a switch 11. The motor 10 comprises two windings of which two corresponding ends are directly connected to one another and the other corresponding ends are connected to one another through the intermediary of a condenser, the arrangement being such that, upon connection of the one winding to a source of voltage, the motor turns in the one direction and, upon connection to the other winding, turns in the other direction. With the aid of the switch 11 it is possible to incorporate at will either of the windings into the circuit and thus to choose the direction of rotation of the motor always in such manner that a new position of the secondary operating member is attained along the shortest possible path. For this purpose the position of the switch 11 is made dependent on the direction in which the primary operating member is displaced, in such manner that, when the primary contact disc is driven in clockwise direction the secondary contact disc is likewise driven in clockwise direction, and conversely.

In the shown position of the contact discs the conductive portion 4 of the circumference of the primary contact disc 3 is located opposite the brush b_1 whilst the secondary contact disc 7 occupies the similar position wherein the insulated portion 8 of the circumference is opposite the brush b'_1.

If now the primary operating member is displaced, for example, to such an extent that the portion 4 of the circumference of the contact disc 3 comes in front of the brush b_2, the transmission channel K_2 is opened, that is to say that a current flows from the source of voltage 9 via the motor 10, the switch 11, the contact disc 3, the brush b_2, the connecting line K_2, the brush b'_2 and the contact disc 7 back to the source of voltage 9. The motor 10 is started and displaces the secondary operating member until the insulated portion 8 of the circumference of the contact disc 7 is opposite the brush b'_2 and, consequently, the channel K_2 is closed again by the contact disc 7. As soon as the contact disc 7 occupies this position, the motor circuit is interrupted so that the secondary operating member stops, and this in a position which corresponds, at least approximately, to the new position of the primary operating member.

The known device has the drawback that there can only be transmitted a number of positions of the operating member which is equal to the number of transmission channels (with the above-described construction consequently only six positions). If it is desired to transmit more positions, the number of transmission channels has to be increased, which makes the device more expensive and more complicated.

The invention has inter alia for its object to provide a device with the aid of which a number of positions can be transmitted which is larger than the number of transmission channels.

According to the invention, the controlling members are formed in such manner that within the variation range of the primary operating or indicating member the primary controlling member successively passes through a number of main positions wherein each time another combination of transmission channels is opened.

With the use of electric control with the aid of contact discs as described above, the contact discs are formed, according to the invention, in such manner that within the variation range of the primary operating or indicating member the primary contact disc successively passes through a number of main positions wherein each time another combination of brushes is in conductive contact with the contact disc.

The invention will be explained more fully with reference to Figs. 2 to 9 of the drawing wherein, by way of example, a few embodiments thereof are represented.

The device shown in Fig. 2 comprises 6 transmission channels for control energy. The primary contact disc 3 is constructed in such manner that upon a complete revolution it passes successively through eighteen main positions in each of which another combination of three brushes is in conductive contact with the contact disc.

In the position shown the primary contact disc 3 is in conductive contact with the brushes b_1, b_2 and b_3. If the disc is rotated in counter-clockwise direction through an angle of 20°, the brush b_3 is insulated whereas the brush b_4 comes into conductive contact with the disc. If the disc is rotated through a further angle of 20°, the brush b_4 is insulated and the brush b_5 enters into contact with the disc, and so on.

In the position shown the secondary contact disc is insulated from the brushes b'_1, b'_2 and b'_3. If this disc is rotated in counter-clockwise direction through an angle of 20°, the brush b'_3 comes into contact with the disc and the brush b'_4 is insulated, and so on. Upon a complete revolution of the secondary contact disc eighteen different combinations of three brushes are thus successively insulated and this in the same order in which with the primary contact disc the corresponding combinations enter into conductive contact with the disc.

The construction of the contact discs as well as the order in which the different combinations of transmission channels are successively opened or closed, may be ascertained in a simple manner with reference to Fig. 3 which shows the developed circumferences of the two contact discs.

It may be seen from Fig. 3 that the circumference of the primary contact disc 3 exhibits three portions which may come into contact with the brushes, which portions have the lengths 7S, S and S respectively and are separated from one another by insulating portions each of which has a length of 3S, S representing the distance between two successive main positions measured along the circumference of the disc. The mutual distance of the brushes amounts to 3S. The secondary contact disc 7 is formed so as to be complementary with respect to the primary contact disc.

Upon a complete revolution of the primary contact disc 3 in the direction of the arrow there are successively opened the combinations of channels which consist of the channels having the following numbers: 1, 2, 3—1, 2, 4—1, 2, 5—1, 2, 6—1, 3, 6—1, 4, 6—1, 5, 6—2, 5, 6—3, 5, 6—4, 5, 6—1, 4, 5—2, 4, 5—3, 4, 5—3, 4, 6—1, 3, 4—2, 3, 4—2, 3, 5—2, 3, 6. As may be seen, each group of three successive combinations may be deduced by cyclic permutation from the previous group of three combinations.

If the primary operating member is shifted from the position shown in Figs. 2 and 3 into a new position, for example into the position wherein the brushes b_2, b_5 and b_6 are in conductive contact with the primary contact disc, a current (Fig. 2) flows from the source of voltage 9 via the motor 10, the switch 11, the disc 3, one or more of the brushes b_2, b_5 and b_6, one or more of the connecting conductors K_2, K_5 and K_6, one or more of the brushes b'_2, b'_5 and b'_6 and the disc 7 back to the source of voltage 9. The motor 10 is actuated and the secondary operating member is displaced until the secondary contact disc simultaneously closes the channels K_2, K_5 and K_6, i. e. until the brushes b'_2, b'_5 and b'_6 are all of them insulated with respect to the secondary contact disc. As soon as such is the case, the motor 10 is cut out of circuit, owing to which the secondary operating member comes at a stop in a position which corresponds, at least approximately, to the new position of the primary operating member.

Fig. 4 shows how the primary and the secondary contact discs may be formed in the case wherein there are seven transmission channels. The circumference of the primary contact disc comprises here five portions which may enter into conductive contact with the brushes, said portions having lengths of 5S, 2S, 2S, 2S and 4S respectively. These portions are separated by insulated portions the lengths of which amount to S, S, S, 4S and 13S respectively. The mutual distance of the brushes is 5S.

Upon a complete revolution of the primary contact disc in the direction of the arrow this disc passes through 35 main positions in which are opened successively the channels having the following numbers: 1, 3, 5—1, 2, 5—1, 2, 3—1, 3, 4—1, 2, 4—2, 4, 7—1, 4, 7—1, 2, 7—2, 3, 7—1, 3, 7, and so on (each group of five successive combinations may be deduced by cyclic permutation from the previous group of five combinations).

As appears from the above-described embodiments it is possible, when the invention is carried into effect, to transmit with the aid of 6 and 7 transmission channels respectively for the control energy 18 and 35 positions respectively of the primary operating or indicating member to the secondary operating or indicating member.

The number of positions which can be transmitted, upon carrying out the invention, with the aid of K transmission channels, is in general equal to the number of different combinations which can be made from the K channels. The expression "different combinations" has to be understood to mean here such combinations that not a single combination does form part of another combination. If the latter would be the case, more positions of the secondary operating or indicating member would be possible with a determined position of the primary operating or indicating member.

It has been found that the number of different combinations which can be formed from the K transmission channels is largest if each combination, as is also the case in the above-described practical examples, consists of the same number of M channels wherein

$$M=\frac{K\pm 1}{2}$$

if K is odd and

$$M=\frac{K}{2}$$

if K is even.

The controlling members are as a rule so formed that the combinations of transmission channels which are successively opened upon a rotation of the primary controlling member through an angle of

$$\frac{360^\circ}{K}$$

are cyclically permutated upon further rotation of the primary controlling member (cf. the above-described practical examples). The number of positions to be transmitted is in this case always a whole multiple of K whilst the utilized combinations have to satisfy the condition that they must allow of being cyclically permutated K times without return of the same combination. The table below indicates the maximum number of positions which when this condition is fulfilled, can be transmitted with the aid of a given number of transmission channels:

$$K=3\quad 4\quad 5\quad 6\quad 7\quad 8\quad 9\quad 10 \qquad (1)$$
$$N_{max}=3\quad 4\quad 10\quad 18\quad 35\quad 64\quad 126\quad 250$$

It appears from this table that the invention renders it possible to increase considerably the number of positions to be transmitted at a given number of transmission channels provided that the number of transmission channels is at least 5.

In the description of the operation of the device according to Fig. 2, it was tacitly assumed that the new position of the operating or indicating member corresponded to one of the main positions of the primary contact disc wherein three brushes are just in conductive contact with the disc. Now there arises the question, what happens when the primary contact disc is placed in an intermediate position between two main positions, for example, with the device according to Fig. 2, in the intermediate position between the two first main positions wherein the brushes b_1, b_2, b_3 and b_1, b_2, b_4 respectively are in contact with the disc.

Two possibilities may be distinguished in this case. If the primary contact disc is formed as is shown in Fig. 3 wherein the length of the conductive portions is always a whole multiple of the distance between two main positions, the four brushes b_1, b_2, b_3 and b_4 are, in the intermediate position concerned, in contact with the disc. In the corresponding intermediate position of the secondary contact disc, however, only two brushes b'_1 and b'_2 are insulated with respect to this disc. If now the primary operating member is placed in the said intermediate position, the secondary operating member cannot come at a stop since there is not any position of the secondary contact disc with which the brushes b'_1, b'_2, b'_3 and b'_4 are simultaneously insulated with respect to this disc. It would, however, also be possible to give the primary contact disc a shape such that in the intermediate position only those brushes (b_1 and b_2) are in contact with the disc which are common to the combinations pertaining to the adjacent main positions. This may be achieved by giving the conductive portions of the circumference of the primary contact disc a slightly shorter length, consequently (Fig. 3) a length of $(7S-a)$, $(S-a)$ and $(S-a)$ wherein a exceeds the width b of a brush. In this case there is produced between every two main positions an intermediary region with a width of $(a-b)$ in which only two brushes are in contact with the disc. When the primary operating member is placed in the intermediate position above referred to, the secondary operating member comes at a stop as soon as the secondary contact disc insulates the brushes b'_1 and b'_2, that is, according to the direction of the displacement of the secondary operating member, in one of the main positions wherein the brushes b'_1, b'_2, b'_3 or b'_1 b'_2, b'_6 are insulated by the secondary contact disc. In certain circumstances the position in which the secondary operating member comes at a stop, may differ by an amount of 60° from the position of the primary operating member. It is clear that so great a divergence is inadmissible in practice, that is to say that with the device according to Fig. 2 it is inadmissible to place the primary operating member in an intermediate position between two main positions. The same remarks apply to the device described with reference to Fig. 4, which has 7 transmission channels for the control energy.

These devices should therefore preferably be so constructed that it is impossible to place the primary operating member in an intermediate position, which may be effected, for example, by arresting the primary operating member in the main positions with the aid of an arresting disc. If the number of main positions amounts to M, we obtain in this manner a remote control in steps of

$$\frac{360^\circ}{M}$$

It should be considered in this case that the steps of the secondary operating member are not completely regular since they depend on the precision of the secondary contact disc and of the brushes of the secondary contact disc as well as on the path covered by the secondary operating member after the motor circuit has been interrupted. If desired, however, the steps of the secondary operating member may be made regular by arresting this member in the main positions with the aid of an arresting device which does not start operating until the motor circuit has been interrupted.

If it is required that it must be possible for the primary operating or indicating member to be placed in any position desired, care should be taken to ensure that, when this member is placed in an intermediate position between two main positions, the secondary operating or indicating member comes at a stop in a position which corresponds to one of the adjacent main positions. According to a further feature of the invention, this may be achieved by giving the controlling members a shape such that in an intermediate position between two main positions the primary controlling member always opens a combination of $(M-1)$ transmission channels, which combination only forms part of those combinations of M transmission channels which are opened in the two adjacent main positions. The combinations of $(M-1)$ channels which are opened in the intermediate positions may be referred to as partial combinations whilst the combinations of M channels which are opened in the main positions are termed, for distinction, sum combinations.

Fig. 5 shows how the contact discs may be shaped in the case of 7 transmission channels to satisfy the above requirement. The primary contact disc comprises three portions which may enter into contact with the brushes, which portions have the lengths $(8S-a)$, $(2S-a)$ and $(2S-a)$ respectively and are separated by insulated portions, each with a length of $(3S+a)$. In this case $a>b$ if b denotes the width of a brush. The secondary contact disc is formed so as to be complementary with respect to the primary contact disc. The mutual distance of the brushes amounts to 3S.

In the position shown the brushes b_1, b_2, b_3 and b_5 are in conductive contact with the circumference of the primary contact disc **3**. If the disc is rotated through an angle of

$$\frac{360^\circ}{21} \text{ (distance S)}$$

in the direction of the arrow, the contact of the brush b_5 with the disc is interrupted whereas the brush b_6 enters into contact with the disc. Since a has been taken larger than b, the contact of the brush b_5 with the disc is, however, already interrupted for some time before the brush b_6 comes into contact with the disc so that in the intermediate position between the two first main positions only the brushes b_1, b_2 and b_3, which are common to the combinations formed in the two first main positions, are in conductive contact with the disc.

Upon a complete revolution of the primary contact disc the latter successively passes through 21 main positions in which each time another sum combination of 4 channels is opened whilst in the intermediate positions is opened each time another combination of 3 channels which only forms part of the two adjacent sum combinations. The successively opened sum and partial combinations of channels consist of the channels having the following numbers: 1, 2, 3, 5—1, 2, 3—1, 2, 3, 6—1, 2, 6—1, 2, 4, 6—1, 2, 4—1, 2, 4, 7—1, 2, 7—1, 2, 5, 7—1, 5, 7—1, 3, 5, 7—1, 3, 7—1, 3, 6, 7—1, 6, 7—1, 4, 6, 7—4, 6, 7—2, 4, 6, 7—2, 6, 7—2, 5, 6, 7—5, 6, 7—3, 5, 6, 7—3, 5, 6—1, 3, 5, 6—1, 5, 6—1, 4, 5, 6—4, 5, 6—2, 4, 5, 6—2, 4, 5—2, 4, 5, 7—4, 5, 7—3, 4, 5, 7—3, 4, 5—1, 3, 4, 5—1, 3, 4—1, 3, 4, 6—3, 4, 6—2, 3, 4, 6—2, 3, 4—2, 3, 4, 7—2, 3, 7—2, 3, 5, 7—2, 3, 5. As may be seen, every group of three successive sum combinations with the three intermediate partial combinations may be deduced by cyclic permutation from the preceding group of three sum combinations and three partial combinations.

If now the primary contact disc is placed in an intermediate position between two main positions, the secondary contact disc is displaced until it has reached a position which corresponds to one of the adjacent main positions, in which position the brushes which pertain to the partial combination of the intermediate position concerned, are insulated with respect to the secondary contact disc.

It may furthermore be observed that the intermediate region with a length of $(a-b)$ in which only $(M-1)$ channels are opened must naturally be smaller than the distance S between two main positions so that a must always be less than $S+b$.

Figure 5a shows an embodiment of the invention including the circumferential arrangement of the disc scanning surface as shown in Figure 5. It is obvious that with this arrangement the combinations of transmission channels opened for the energy supply to the secondary member in the intermediate positions of the primary member, each of the combinations of transmission channels opened by the primary member is composed of channels which occur in the combinations of channels formed in the two adjacent main positions of the said primary member.

Fig. 6 shows how with the use of 8 transmission channels the contact discs may be shaped to satisfy the above-mentioned requirements. The primary contact disc comprises here 4 portions which may enter into conductive contact with the brushes, said portions having the lengths $(9S-a)$, $(2S-a)$, $(3S-a)$ and $(2S-a)$ respectively and being separated by insulated portions which have all of them the length $(4S+a)$. In this case $S+b>a>b$ whilst the spacing between two brushes amounts to 4S. The secondary contact disc is formed so as to be complementary with respect to the primary contact disc.

Upon a complete revolution of the primary contact disc in the direction of the arrow, this disc passes through 32 main positions, in which event are formed successively the sum and partial combinations which consist of the channels having the following numbers: 1, 2, 3, 6—1, 2, 6—1, 2, 4, 6—1, 2, 4—1, 2, 4, 7—1, 2, 7—1, 2, 5, 7—1, 2, 5—1, 2, 5, 8—1, 5, 8, 1, 3, 5, 8—1, 3, 8—1, 3, 6, 8—1, 6, 8—1, 4, 6, 8—1, 4, 8, and so on (every group of four sum combinations and four partial combinations may be deducted by cyclic permutation from the preceding group).

With the devices according to Figs. 5 and 6 the primary operating or indicating member may be continuously displaced, in which event the secondary operating or indicating member follows the position of the primary member in steps which are substantially equal to the distance S between two main positions. The accuracy with which the position of the primary operating or indicating member is transmitted to the secondary member is consequently greater according as the distance S is taken smaller, that is to say according as the number of the main positions increases.

As appears from the above-described embodiments, it is possible, when the primary operating or indicating member can be displaced continuously, to transmit with the aid of 7 and 8 transmission channels 21 and 32 main positions respectively.

The maximum number of main positions which can be transmitted in the case of a continuous displacement of the primary operating or indicating member with the aid of a given number of channels, is in general equal to the number of sum combinations of M channels which are to be formed from the available channels and which may be grouped in such manner that every two adjacent sum combinations have in common a partial combination of $(M-1)$ channels which only forms part of these two sum combinations. This maximum number of main positions is smaller than the number of main positions given in Table 1 which can be transmitted with the aid of a given number of channels in the case of step-wise displacement of the primary operating or indicating member. The table given below indicates the maximum number of main positions which can be transmitted in the case of continuous displacement of the primary operating or indicating member.

$K=$	3	4	5	6	7	8	9	10
$N_{max}=$	3	4	5	6	21	32	54	100

(2)

It appears from this table that a considerable increase of the accuracy of the transmission can be obtained if the number of transmission channels is at least 7.

Since in the embodiments according to Figs. 5 and 6 the secondary operating or indicating member follows the position of the primary member in steps, the position of the secondary member always differs in general slightly from that of the primary member. This divergence, called hereinafter "play," will be considered more fully with reference to Fig. 7.

In Fig. 7 those portions of the primary and the secondary contact discs of the device according to Fig. 5 which are located in the immediate vicinity of the brushes b_5, b_6 and b'_5, b'_6 respectively are represented to an enlarged scale. As in Fig. 5, the contact discs are shown here in medium position, that is to say in a position which corresponds to the middle of a main position. In this main position, referred to hereinafter as "first main position" the brushes b_1, b_2, b_3 and b_5 (cf. Fig. 5) are in conductive contact with the primary contact disc whereas the brushes b'_1, b'_2, b'_3 and b'_5 are insulated with respect to the secondary contact disc.

When the primary contact disc is displaced in the direction of the arrow, the first main position is left as soon as the brush b_5 is insulated with respect to the disc, i. e. after a displacement through a distance equal to

$$\frac{S}{2}-\frac{a}{2}+\frac{b}{2}=\frac{S-a+b}{2}$$

The disc then passes through an intermediate region with a length of $(a-b)$ wherein only the brushes b_1, b_2 and b_3 are in contact with the disc. As soon as the brush b_6 enters into contact with the disc, that is to say after a displacement through a distance

$$\frac{S}{2}+\frac{a}{2}-\frac{b}{2}=\frac{S+a-b}{2}$$

the second main position is attained wherein the brushes b_1, b_2, b_3 and b_6 are in contact with the disc.

The secondary contact disc leaves the first main position as soon as the brush b'_5 enters into contact with the disc, that is to say after a displacement through a distance equal to

$$\frac{S-a-b}{2}$$

then passes through an intermediate region with a length of $(a+b)$ wherein only the brushes b'_1, b'_2 and b'_3 are insulated with respect to the disc, and attains the second main position as soon as the brush b'_6 is insulated with respect to the disc, i. e. after a displacement through a distance

$$\frac{S+a+b}{2}$$

Assuming that the primary contact is placed in the second main position or in the intermediate position between the second and the third main position, the secondary contact disc, upon attaining the second main position, switches the motor out of circuit. After the motor has been cut out of circuit the secondary contact disc naturally continues to run for a short time; the maximum path which is covered by the secondary contact disc in its continued rotation is denoted by c. Since the disc must come at a stop within the region of the second main position, C must be smaller than $S-a-b$.

In the above-described instance the primary contact disc is displaced with respect to the position shown through a distance which is comprised between

$$\frac{S+a-b}{2}$$

and

$$\frac{3S+a-b}{2}$$

The secondary contact disc comes at a stop in a position in which this disc has been displaced with respect to the position shown through a distance which lies between

$$\frac{S+a+b}{2}$$

and

$$\left(\frac{S+a+b}{2}+c\right)$$

The play consequently lies between $-(b+c)$ and $(S-b)$ that is to say that the secondary contact disc comes at a stop in a position which lies at the most through a distance $(b+c)$ beyond and at the most through a distance $(S-b)$ before the position of the primary contact disc.

So far it has been assumed that the brushes of the primary and the secondary contact discs have the same width b and that the discs are completely complementary so that the length a by which the conductive portions of the primary contact disc are shortened, is equal to the length by which the insulating portions of the secondary contact disc are shortened. Under certain conditions, however, it may be advantageous to take for the two discs different shortenings and/or different widths of the brushes, for example equal to a_1 and b_1 respectively for the primary contact disc and equal to a_2 and b_2 respectively for the secondary contact disc. This is always admissible if only the conditions

$$0<a_1-b_1<S \text{ and } 0<a_2+b_2S-c$$

are satisfied.

In the above-described instance the primary contact disc is displaced with respect to the position shown through a distance which lies between

$$\frac{S+a_1-b_1}{2}$$

and

$$\frac{3S+a_1-b_1}{2}$$

whilst the secondary contact disc comes at a stop in a position wherein the disc has been displaced with respect to the position shown through a distance which lies between

$$\frac{S+a_2+b_2}{2}$$

and

$$\left(\frac{S+a_2+b_2}{2}+c\right)$$

The amount of play consequently lies between

$$\left(\frac{a_1-b_1-a_2-b_2}{2}-c\right)$$

and

$$\left(S+\frac{a_1-b_1-a_2-b_2}{2}\right)$$

Under certain conditions it may now be desirable to ensure that the play is always positive, that is to say that the secondary contact disc always comes at a stop in a position which is located before the position of the primary contact disc. This may be achieved by choosing a_1, b_1, a_2 and b_2 in such manner that

$$\left(\frac{a_1-b_1-a_2-b_2}{2}-c\right)>0$$

that is to say that $(a_1-b_1)>(a_2+b_2)+2c$. The length of the intermediate region of the primary contact disc consequently must exceed the length of the intermediate region of the secondary contact disc by at least $2c$, or in other words, the length of the region wherein the secondary controlling member closes a determined sum combination of m channels, must exceed the length of the region wherein the primary controlling member opens this combination of channels, by an amount which is at least equal to twice the maximum path which is still traversed by the secondary controlling member after the interruption of the transmission of control energy.

Fig. 8 shows how the contact discs may be constructed to satisfy this condition. This figure represents to an enlarged scale the same portion of the contact discs according to Fig. 5 which is also represented in Fig. 7, however, with modified lengths of the conductive and insulated portions of the contact discs. In the figure a_1 is taken to $\frac{3}{4}S$ and a_2 equal to 0 whilst for both discs the width of the brushes is about $\frac{1}{8}S$. Now we find: $a_1-b_1=\frac{5}{8}S$, $a_2+b_2=-\frac{1}{8}S$ so that

$$\frac{a_1-b_1-a_2-b_2}{2}$$

is equal to $\frac{1}{4}S$. By taking C smaller than $\frac{1}{4}S$ it may consequently be achieved that the secondary contact disc always comes at a stop in a position which is located before the position of the primary contact disc, the amount of play lying in this case between 0 and $^5/_4S$.

Suitable values are in practice also: $a_1-b_1=\frac{5}{6}S$, $a_2+b_2=\frac{1}{6}S$, $C<\frac{1}{3}S$, the amount of play lying between 0 and $^4/_3S$.

The maximum distance C which is still traversed by the secondary contact disc after the motor has been switched out of circuit, is determined by the electrical and mechanical inertia of the system and by the speed of revolution of the secondary contact disc. If desired, the distance c may be reduced by braking the secondary operating or indicating member after the motor has been switched out of circuit. It will be evident, however, that a limit is set to the maximum speed of revolution of the secondary contact disc by the requirement that c must be less than $S-a_2-b_2$ (and in the above-described particular case even less than $\frac{1}{4}S$). If the accuracy of the transmission is increased by taking a larger number of main positions it is necessary to take a smaller speed of revolution in order to keep c sufficiently small. In practice the maximum speed of revolution of the secondary contact disc is approximately so high that the distance S between two main positions is traversed in 0.06 sec. For $n=100$ a complete revolution of the disc consequently takes 6 seconds.

If, however, in order to obtain a greater accuracy n would be taken equal to 1000, a complete revolution of the disc would take 60 seconds so that at the most 30 seconds would be necessary for the transmission (taking into account the reversibility of the direction of rotation of the motor). This lapse of time is too long for most applications.

Besides, in connection with the precision with which the discs can be manufactured, very large discs would be necessary in the case of 1000 main positions.

In practice the number of main positions may therefore not be taken too large. A device having 10 transmission channels and 100 main positions affords a very satisfactory transmission over a distance.

According to a further feature of the invention, if a greater accuracy of the transmission is desired, this may be obtained by utilizing two primary and two secondary controlling members, in which event the two primary and secondary controlling members respectively are coupled with one another in a similar manner as the pointers of a clock, that is to say in such manner that one of the primary or secondary members performs t revolutions during one revolution of the other primary or secondary controlling member. During one revolution the one primary controlling member opens successively a number of different combinations out of a group of transmission channels, which combinations of transmission channels are closed by the corresponding secondary controlling member in the corresponding main positions. The other primary or secondary controlling member acts in a similar manner on a second group of transmission channels. The secondary operating or indicating member does not come at a stop until in both groups of transmission channels the transmission of control energy has been interrupted.

Fig. 9 represents an embodiment of such a device. That portion of this device which is located to the left of line 1 is present at the point of remote operation whilst the portion located to the right of line 1 is present at the place of the secondary operating or indicating member, for example, at the place of a transmitter or receiver which has to be operated from a distance. The mechanical portion of the device is represented in dotted lines and the electric portion by full lines.

On the shaft 2 of the primary operating or indicating member is mounted a pinion 15 which meshes with a gear wheel 14 mounted on a shaft 12. On the shaft 12 is provided a primary contact disc 13 which is consequently driven by the shaft 2 at a reduced speed.

On the shaft 2 there is furthermore a gear wheel 25 which engages a pinion 24 mounted on a shaft 22. On the shaft 22 is mounted a second primary contact disc 23 which is driven by the shaft 2 at an increased speed.

The ratios of transmission are so chosen that the contact disc 23 performs approximately 15 revolutions during one revolution of the contact disc 13 (t=15).

In a similar manner the shaft 6 of the secondary operating or indicating member actuates, by means of gear wheels 18 and 19, the shaft 16 on which a secondary contact disc 17 is mounted and, by means of gear wheels 28 and 29, a shaft 26 on which a secondary contact disc 27 is mounted, the construction being such that the contact disc 27 performs approximately 15 revolutions at one revolution of the contact disc 17. The ratio of transmission t must be the same with the two primary and with the two secondary contact discs.

The contact discs 13 and 17 are each scanned by 7 brushes of which only one (b_{11} and b'_{11} respectively) is shown in the figure. The circumferences of these discs are divided into portions which can enter and cannot enter into conductive contact with the brushes (this is not shown in the figure) in such manner that in one revolution the primary contact disc 13 passes successively through 21 main positions wherein each time another combination of four brushes is in contact with the disc. In the corresponding positions the corresponding 4 brushes are insulated with respect to the secondary contact disc 17. Corresponding brushes of the contact discs 13 and 17 are connected to one another through the intermediary of conductors of which only one (K_{11}) is shown in the figure.

The contact discs 23 and 27 are each scanned by 10 brushes of which only one (b_{21} and b'_{21}) is shown in the figure. These discs are constructed in such manner that in one revolution the primary contact disc 23 passes successively through 100 main positions wherein each time another combination of 5 brushes is in contact with the disc whereas in the corresponding positions the corresponding brushes are insulated with respect to the secondary contact disc 27. Corresponding brushes of the contact discs 23 and 27 are connected to one another through the intermediary of conductors of which one is denoted in the figure by K_{21}.

The contact discs are furthermore constructed in such manner that without any objection both the contact disc 13 and the contact disc 23 can be placed in an intermediate position between two main positions. This is effected in the previously described manner by suitable grouping sum combinations and partial combinations.

The primary contact disc 13 is connected to its secondary contact disc 17 through the series-connection of a source of voltage 9, a reversing switch 11 and an induction motor 20 whilst the primary contact disc 23 is connected in a similar manner to its secondary contact disc 27 via an induction motor 30. The number of revolutions of the motor 20 is considerably larger than that of the motor 30. The two motors jointly drive the shaft 6 of the secondary operating or indicating member through the intermediary of a differential 21 so that the speed of the shaft 6 is always equal to the sum of the speeds of the motors 20 and 30. If desired, the motors 20 and 30 may also be given the same number of revolutions and the differential may be constructed in such manner that it reduces the speed of the motor 30 in the required measure. For a satisfactory operation of the differential 21 it is advisable to brake each of the motors 20 and 30 as soon as the motor concerned is cut out so that one of the motors cannot drive the other motor via the differential. The reversing switch 11 is controlled in dependence of the direction of rotation of the shaft 2 as is diagrammatically indicated by a dotted line 31, and this in such manner that a new position of the secondary operating or indicating member is always attained in the shortest way.

When the primary operating or indicating member is placed in any new position, the circuits of the motors 20 and 30 are closed with the result that both motors start rotating in the direction determined by the position of the switch 11. The shaft 6 of the secondary operating or indicating member is driven via the differential 21 at a speed which is equal to the sum of the speeds of the two motors. Each time the motor 30 is cut out for a short time when the secondary contact disc 27 passes through a position which corresponds to the position of the primary contact disc 23. Since the number of revolutions of the motor 20 considerably exceeds that of the motor 30, the shaft 6 continues, however, to rotate at a speed which is substantially not reduced. A short time before the desired position of the secondary operating or indicating member is attained, the secondary contact disc 17 attains a position such that the motor 20 is cut out of circuit. Driven exclusively by the motor 30, the shaft 6 continues to rotate slowly until the desired position is attained; at this moment the motor 30 is also cut out of circuit and the secondary operating or indicating member consequently comes at a stop.

If the number of main positions of the disc 23 is assumed to be equal to N_2, we consequently obtain with the above described device a continuous remote control the accuracy of which is approximately

$$\frac{1}{N2t}=\frac{1}{1500}$$

Such accuracy is sufficient in practice, for example, for the adjustment of the tuning members of a radio-receiver. Notwithstanding the attained great accuracy the remote control takes place, however, in very short time which may amount in the embodiment described, for example, to 5 seconds at the most.

When upon the attainment of the described position by the secondary operating or indicating member the motor **30** becomes currentless the motor **20** must already have come at a stop since otherwise there is the risk of the motor **20** driving the secondary operating member beyond the correct position, in which event it would be impossible for the secondary operating member to come at a stop. The discs **13** and **17** must therefor be constructed in such manner that the motor **20** always comes at a stop before the secondary contact disc **17** occupies the position which corresponds to the position of the primary contact disc **13**. To thus end, as has been deduced above, (a_1-b_1) must be taken larger than $(a_2+b_2)+2c$ wherein c represents the coasting path of the motor measured on the circumference of the disc **17**.

As has also been deduced in the foregoing, the maximum amount of play which may occur between the positions of the primary contact disc **13** and the secondary contact disc **17** is equal to

$$S+\frac{a_1-b_1}{2}-\frac{a_2+b_2}{2}$$

In order to prevent the secondary operating or indicating member from coming at a stop in an incorrect position, this amount of play must be smaller than the path

$$\frac{N_1S}{t}$$

which is traversed by the primary contact disc **13** during one revolution of the primary contact disc **23** (N_1 representing the number of main positions of the disc **13**). If, for example, the maximum amount of play amounts to $5/4$S,

$$\frac{N_1}{t}$$

must be more than $5/4$ or t must be less than $4/5$ N_1. If the maximum amount of play is, for example, $3/4$ S then t must be less than $3/4$ N_1. In the practical example according to Fig. 9 $N_1=21$ and $t=15$ so that these conditions are amply satisfied. In general the ratio of transmission must always be smaller than the number of main positions of the controlling member which has the smallest speed, namely so much smaller that the maximum amount of play between the positions of the two contact discs running at a low speed is smaller than $1/t$ times the circumference of these discs.

In some cases the remote operation, for example, of a radio receiver, may also be effected in such manner that the operating member concerned is driven with the aid of a motor which is switched into circuit at the place of remote operation whilst with the aid of a device according to the invention the position of the operating member concerned is indicated at the place of remote operation. That member of the receiver which is to be operated constitutes in this case the primary operating or indicating member in the spirit of the invention whilst the secondary indicating member is formed by a scale which is provided at the place of remote operation and on which the position of the member to be operated is read off.

With such an application of the invention for indicating the position of a member operated from a distance at the place of remote operation, it is advisable to utilize means which prevent the primary controlling member from being driven at a higher speed than the secondary controlling member since otherwise the position indicated does not correspond to the position occupied by the member to be operated.

This may be achieved by limiting the speed of the primary controlling member with the aid of a regulator or by driving the primary controlling member by means of a motor at a speed which is lower than the speed at which the secondary controlling member is driven.

In the foregoing we have only discussed embodiments of the invention wherein the control energy is electrically transmitted. The invention may, however, also be applied to devices which operate, for example, pneumatically or hydraulically. To that end the connecting conductors k_1 etc. are replaced by gas or liquid conduits and the contact discs **3** and **7** (**13**, **17**, **23** and **27** respectively) by similarly shaped cam discs which control valves for opening or closing the gas or liquid conduits.

What we claim is:

1. A device for transmitting over a number of transmission channels the position of a primary controlling member to a remote secondary member which is driven by driving means, which comprises a source of energy, a driving means, a plurality of transmission channels of control energy, a primary member having means for connecting with a first predetermined number of said plurality of said transmission channels in each of a plurality of main positions and with a second predetermined number of said plurality of said transmission channels in each of a plurality of intermediate positions between two of said main positions, said second predetermined number being one less than said first predetermined number, a secondary member connected to the said primary member, through said channels, said source of energy, and said driving means, said secondary member having means for disconnecting from said first predetermined number of said plurality of said transmission channels in each of a plurality of main positions and from said second predetermined number of said transmission channels in each of a plurality of intermediate positions, said second predetermined number being one less than said first predetermined number, said disconnecting main positions of said secondary member being complementary to the connecting positions of the said primary member whereby the said secondary member interrupts said energy supply from the said channels to the said driving means when the said secondary member has been driven by said driving means to the position at least approximately corresponding to the position of the said primary member, the said primary and secondary members being further characterized in that they are shaped such that in the said intermediate positions of the said primary member each of the said combinations of said transmission channels connected by the said primary member is composed of channels which occur in the combination of channels forming in the two adjacent main positions.

2. A device for transmitting over a number of transmission channels the position of a primary controlling member to a remote secondary member which is driven by driving means, which comprises a source of electrical energy, an electric motor driving means, a plurality of transmission channels of control energy comprising electrical conductors, a primary disc-shaped member having means for connecting with a first predetermined number of said plurality of said transmission channels in each of a plurality of main positions and with a second predetermined num-

ber of said plurality of said transmission channels in each of a plurality of intermediate positions between two of said main positions, said second predetermined number being one less than said first predetermined number, a secondary disc-shaped member connected to the said primary member, through said channels, said source of energy, and said electric motor driving means, said secondary member having means for disconnecting from said first predetermined number of said plurality of said transmission channels in each of a plurality of main positions and from said second predetermined number of said transmission channels in each of a plurality of intermediate positions, said second predetermined number being one less than said first predetermined number, said disconnecting main positions of said secondary member being complementary to the connecting positions of the said primary member whereby the said secondary member interrupts said energy supply from the said channels to the said electric motor driving means when the said secondary member has been driven by said driving means to the position at least approximately corresponding to the position of the said primary member, the said primary and secondary members being further characterized in that they are shaped such that in the said intermediate positions of the said primary member each of the said combinations of said transmission channels connected by the said primary member is composed of channels which occur in the combination of channels forming in the two adjacent main positions.

3. A device for transmitting over a number of transmission channels the position of a primary controlling member to a remote secondary member which is driven by driving means, which comprises a source of electrical energy, an electric motor driving means, a plurality of transmission channels comprising electrical conductors each having a brush at either end thereof, a primary member having means for connecting with a first predetermined number of said brushes in a plurality of main positions and with a second predetermined number of said brushes in each of a plurality of intermediate positions between two of said main positions, said second predetermined number being one less than said first predetermined number, a secondary member connected to the said primary member, through said brushes, said channels, said source of energy, and said driving means, said secondary member having means for disconnecting from said first same predetermined number of said brushes in each of a plurality of main positions and from said second predetermined number of said brushes in each of a plurality of intermediate positions, said second predetermined number being one less than said first predetermined number, said disconnecting main positions of said secondary member being complementary to the connecting positions of the said primary member whereby the said secondary member interrupts said energy supply from the said channels to the said driving means when the said secondary member has reached the position at least approximately corresponding to the position of the said primary member, the said primary and secondary members being further characterized in that they are shaped such that in the said intermediate positions of the said primary member each of the said combinations of said brushes connected by the said primary member is composed of brushes which occur in the combination of brushes forming in the two adjacent main positions.

4. A device for transmitting over a number of transmission channels the position of a primary controlling member to a remote secondary member which is driven by driving means, which comprises a source of electrical energy, an electric motor driving means, a plurality of electric conductors, a brush at either end of each of said plurality of electric conductors, a primary member having means for connecting with a first predetermined number of said plurality of said brushes in each of a plurality of main positions and with a second predetermined number of said plurality of said brushes in each of a plurality of intermediate positions between two of said main positions, said second predetermined number being one less than said first predetermined number, a secondary member connected to the said primary member, through said brushes, said channels, said source of energy, and said electric motor driving means, said secondary member having means for disconnecting from said first same predetermined number of said plurality of said transmission channels in each of a plurality of main positions and from said second predetermined number of said transmission channels in each of a plurality of intermediate positions, said second predetermined number being one less than said first predetermined number, said disconnecting main positions of said secondary member being complementary to the connecting positions of the said primary member whereby the said secondary member interrupts said energy supply from the said channels to the said driving means when the said secondary member has reached the position at least approximately corresponding to the position of the said primary member, said connecting and disconnecting means comprising discontinuous electric conducting surfaces positioned peripherally of said primary and secondary members, respectively, the said primary and secondary members being further characterized in that said discontinuous surfaces are proportioned such that in the said intermediate positions of the said primary member each of the said combinations of said transmission channels connected by the said primary member is composed of channels which occur in the combination of channels forming in the two adjacent main positions.

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