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MASTER-SLAVE SYSTEM

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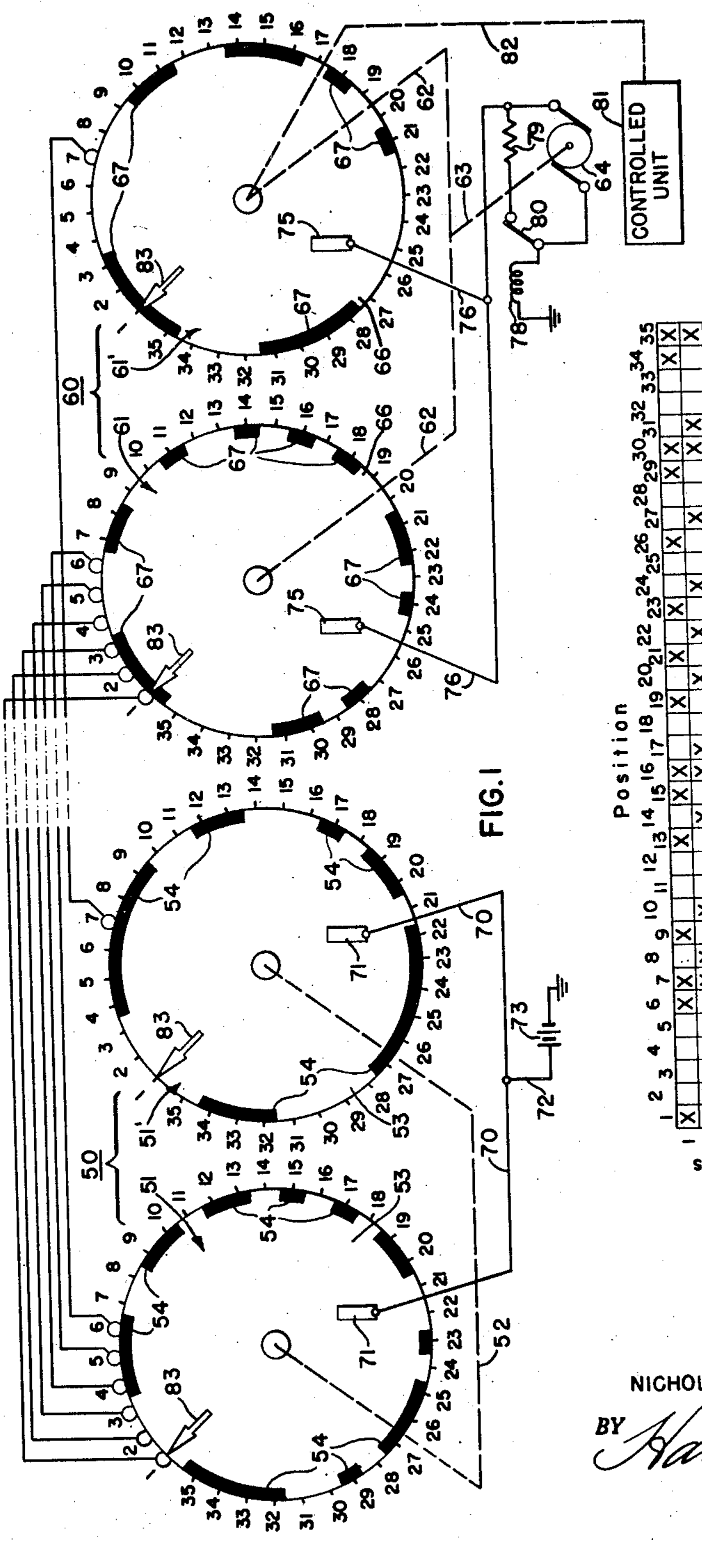

FIG. 1

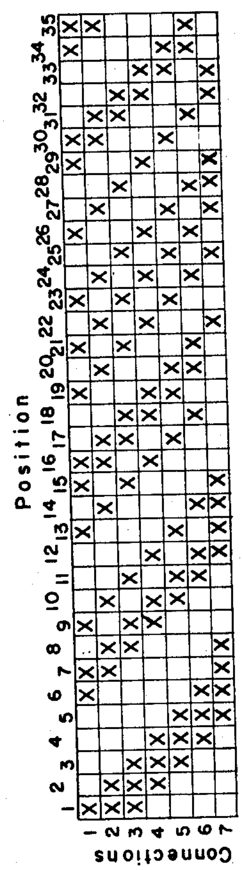

FIG. 2

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MASTER-SLAVE SYSTEM

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13 Claims. (Cl. 318—33)

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This invention is directed to master-slave systems and, particularly, to systems for establishing the position of remotely located apparatus in accordance with the positions of near-by apparatus.

Radio equipments employing transmitter and/or receiver oscillators are being utilized rather extensively on aircraft for communication and navigation purposes. In many of these installations it is necessary to mount the oscillators in positions which are at some distance from the operator-controlled selector switch on the control panel of the aircraft. These oscillators are ordinarily tunable to any one of a plurality of different frequencies so that a master-slave system is required operatively to connect the tuning control mechanism of the transmitter and the receiver oscillators with the control panel. Space and weight considerations on such craft are often unusually severe so that it is imperative to maintain the number of interconnecting wires between the control panel and the tuning control mechanism of the oscillators at a minimum. Additionally, electrical connectors associated with the control panels frequently must be small and hence must include terminals for as few wires as possible.

Relays have been proposed for use in the remote-control systems on aircraft to reduce the size of the electrical connectors and the number of conductive connections between the adjustable control switch and the controlled devices. The cost of such a system would ordinarily be more expensive than is desirable due to the number of relays which would be required. Furthermore, since aircraft are subject to considerable vibration and frequently must undergo rapid changes in acceleration and deceleration which may seriously impair the proper operation of relays in such a remote-control system, it is especially desirable to reduce the number of relays therein to a minimum. Heretofore, satisfactory remote-control arrangements which embody a small number of interconnecting wires and relays have not been available.

It is an object of the present invention, therefore, to provide a new and improved master-slave system which avoids one or more of the above-mentioned disadvantages and limitations of prior such systems.

It is another object of the invention to provide a reliable master-slave system which includes a minimum number of connections between various portions thereof and also utilizes a minimum number of relays.

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It is a further object of the invention to provide a new and improved master-slave system which is compact, simple in construction, inexpensive, and yet wholly reliable in operation.

In accordance with the present invention, a master-slave system comprises a master switch and a slave switch each having approximately M different switch positions and each including N contacts, where N is a number greater than four but substantially less than M. The system also includes connections between corresponding ones of the contacts. The master switch and the slave switch are constructed with reference to each other and in accordance with the relation

$$M=\frac{N(N-1)(N-2)\ .\ .\ .\ (N-P+1)}{P!}$$

wherein P is a number which does not exceed one-half the number N, to establish (*a*) operative relations between the switches through a maximum of P of the aforesaid connections, (*b*) to establish operative relations between the switches through at least one of the N connections for any relative position of the switches with the exception of only those relative switch positions at which correspondence is attained, and (*c*) to establish inoperative relations between the switches through the connections for those relative positions at which correspondence is attained.

For a better understanding of the present invention, together with other and further objects thereof, reference is had to the following description taken in connection with the accompanying drawing, and its scope will be pointed out in the appended claims.

Referring now to the drawing, Fig. 1 is a schematic diagram of a master-slave system in accordance with the present invention and Fig. 2 is a chart which is used in explaining the construction of the system illustrated in Fig. 1.

Referring now more particularly to Fig. 1 of the drawing, there is illustrated a master-slave system in accordance with the invention which comprises a master switch **50** and a slave switch **60**, each having M different switch positions which are numbered from 1–35, inclusive. Although it may be unnecessary in some forms of the invention, the present embodiment employs a master switch and a slave switch which are constructed in two parts. Each master switch and each slave switch also includes N conductive contacts, specifically a total of seven stationary contacts designated by the reference characters **1–7**, inclusive, which, in the embodiment of the invention illustrated, correspond in location to the respective switch positions 1–7, inclusive. Accordingly, the number of stationary contacts N is greater than four and is substantially less than the number of switch positions M.

The master switch 50 is preferably a manually operable switch while the slave switch 60 is preferably, although not necessarily, a remotely located slave switch, the drive arrangement for which will be described subsequently. The master switch includes at least one movable member, preferably a rotatable disc 51 which includes conductive and insulating portions 53 and 54, respectively. In the illustrated embodiment, two discs 51 and 51′ are coupled for concurrent operation by any conventional means such as a common drive shaft 52, shown diagrammatically by the broken-line construction. The body portions of the discs 51 and 51′ consist of the conductive portions 53, 53. The configuration of the insulating portions of the pair of discs 51 and 51′ will be described in detail hereinafter. The peripheral portions of these discs are adapted to engage the stationary contacts 1–7, inclusive, while the discs 51 and 51′ are being concurrently moved to any one of the thirty-five different positions.

The slave switch 60, which is generally similar to the master switch 50, includes a pair of unicontrolled rotatable discs 61 and 61′ which are mechanically coupled through a common drive shaft 62 conventionally shown in broken-line construction. The rotatable discs 61 and 61′ are, in turn, adapted to be driven through a shaft 63 by a driving means such as an electric motor 64. The rotatable discs 61 and 61′ of the slave switch 60 include conductive portions 66 and insulating portions 67 which are generally complementary to the corresponding portions of the master switch 50. As previously mentioned, the switch 60 also includes seven stationary contacts numbered 1–7, inclusive, which are selectively engaged by the individual peripheral portions of the discs 61 and 61′ during rotation of the latter.

The master-slave system also includes connections between corresponding ones of the stationary contacts of the master switch and the slave switch. These connections comprise suitable signal-translating means such as conductive wire connections between the stationary contacts 1–6, inclusive, associated with the rotatable disc 51 and the corresponding contacts of the rotatable disc 61 as well as wire connections between contact 7 of disc 51′ and the similarly numbered contact of disc 61′. It will be manifest, however, that other well-known equivalent signal-translating means such as radio transmitters at the master-switch portion of the system and radio receivers at the slave-switch portion of the system may be employed in place of the illustrated solid-wire connections, and that the conductive wire connections represent but one of numerous useful signal-translating means.

The master-slave system also includes means effectively interconnecting the master switch 50 and the slave switch 60. This means comprises the ground connections for the switches. Wires 70, 70 are connected to the conductive portions 53, 53 of the discs 51 and 51′ through conventional brushes 71, 71 and are connected to ground through a wire 72 and a source of potential such as a battery 73. Brushes 75, 75 contact the conductive portions 66, 66 of the discs 61 and 61′ and are connected to ground through wires 76, 76, the motor 64, and a relay winding 78. A damping or dynamic braking resistor 79 is connected in shunt with the motor 64 through a switch blade 80 which is associated with the relay winding 78. Blade 80 is arranged to be closed when winding 78 is de-energized and opened when the latter is energized.

The master switch 50 and the slave switch 60 are constructed with reference to each other with the conductive and the insulating portions 53 and 54, respectively, of the master switch in corresponding relations to the insulating and the conductive portions 67 and 66, respectively, of the slave switch. The master switch 50 and the slave switch 60 are additionally constructed in accordance with the relation

$$M=\frac{N(N-1)(N-2)\ .\ .\ .\ (N-P+1)}{P!}$$

wherein P is a number which does not exceed, but preferably is less than one-half the number N, to establish (*a*) operative relations between the conductive portions of the switches for the motor 64 through a maximum of P of the connections numbered 1–7, inclusive, (*b*) operative relations between the conductive portions of the switches for the motor 64 through at least one of the N connections for any relative position of the switches with the exception of only those relative switch positions at which correspondence is attained, and (*c*) to establish inoperative relations between the switches through the foregoing N connections for those positions at which correspondence is attained.

The above-mentioned relation is therefore an expression for the number of combinations M which may be procured with N things taken at a maximum of P at a time. In the described system, the thirty-five switch positions correspond to the number M while the seven stationary contacts correspond to the term N. It is to be noted that in the design of a master-slave system at least one of the factors M or N is known, it very often being the latter, since that factor is established by the requirements of the system for a particular use. The other factors, therefore, may be determined by substituting the known values in the above equation. The term P in the equation, as applied to the instant system, pertains to the maximum number of N conductive connections or wires which are to be utilized at any one time to carry current. It has been determined experimentally and mathematically that the selected number of wires P should not exceed one-half of the total N wires and, for the simplest design, this number should be less than one-half of the number of wires N. Accordingly, the maximum number of the seven wires which are to carry currents at any one time should be three for the described system.

Since it has been established by the equation that a 35-position master-slave system with seven connections between stationary contacts is feasible, there remains the determination of the electrical connections which are necessary within the master switch and also the slave switch. This may be greatly facilitated by the construction and the use of a chart of the type illustrated in Fig. 2, wherein the horizontal divisions are equal in number to the seven connections between the stationary contacts and the vertical divisions are equal in number to the thirty-five switch positions. For each of the thirty-five positions, a maximum of three wires may carry current at any one time. Beginning with position 1, various cross marks are inserted in the different squares to denote the various combinations of wires which may be employed to carry current for each switch position. For example, with the master switch in position 1, connecting wires 1, 2, and 3, as represented by the cross marks, are selected to carry current if necessary to energize the motor 64 to drive the slave switch to a position of correspondence or to position number 1. Connecting wires 4–7, inclusive, therefore cannot carry current at any time when the master switch is in its position number 1 regardless of the position of the slave switch, as has been established from the above-stated equation and the choice of wires which are to carry current. Similarly for position 2 of the master switch, only the combination of wire connections 2, 3, and 4 may carry current while for position 3 only the combination of wires 3–5, inclusive, may carry current. This charting of the possible three-wire combinations is continued for the remaining switch positions 4–35, inclusive, each combination being entirely different from any other.

In the preliminary design of the master and slave switches, a paper template similar to the arrangement illustrated in Fig. 1 is particularly useful, wherein each of the rotatable discs is rotatably mounted so that the discs may be moved from one position to the next position while the disposition of the conductive and insulating portions of the switches are being marked out on the disc. The insulating portions can then be marked on the discs in pencil as they are determined so that they resemble the dark peripheral regions of the discs 51 and 51′ of Fig. 1 of the drawing. Thus, with the indicator of the master switch 50 set at position 1, the periphery of the conductive portions 53, 53 of each of the discs 51 and 51′ will engage each of the stationary contacts 1–3, inclusive, thereby making a conductive connection therewith while the peripheral portions contiguous with contacts 4, 5, and 6 should be notched or include insulating material, as shown in Fig. 1 of the drawing. It will be noted that point 7 for the disc 51 has no connection extending to the slave switch while the contact 7 cooperating with the disc 51′ includes an electrical contact which, for the combination immediately under consideration, cannot be in circuit. Accordingly, insulation is unnecessary on the periphery of the disc 51 near the point 7 while it is required on the disc 51′ at the corresponding position. It should be noted at this point that the slave switch 60 interrupts any circuit connections when in a position of correspondence with the master switch 50. Consequently, the insulating portions of the discs 61 and 61′ are in reciprocal relationship to the conductive peripheral portions, respectively, of the corresponding discs 51 and 51′ and vice versa. In view of this mutual relationship, the configuration of the discs on the master switch effectively determines the shape of the discs of the slave switch, so that detailed reference to the design of the latter is unnecessary.

In carrying out the next step in the construction, the discs 51 and 51′ of switch 50 are then moved to position 2 and the chart of Fig. 2 is again referred to. The periphery of the disc 51 makes a conductive connection with contacts 2, 3, and 4 while contacts 1, 5, 6, and 7 are not in circuit. The insulating peripheral regions of the disc are marked accordingly. A similar marking on the disc 51′ to signify insulation is made for contact 7 adjacent disc 51′, this being the only contact associated with the last-mentioned disc. The disc 51 and 51′ are then indexed to position 3 and the chart is utilized again for outlining the conductive and insulating peripheral portions of the discs. The marking operation is continued for each of the remaining switch positions until all the insulating peripheral portions of the rotors 51 and 51′ have been marked or laid out. Referring again to the chart of Fig. 2, it will be observed that at position 8 there is a cross mark for connection number 7, thus indicating that the latter must carry current. In view of the pattern which the periphery of the disc 51 acquired for the preceding positions 1–7, inclusive, a second disc, namely the disc 51′, is required to establish operative relations through the switches since a single disc will not suffice. It has been determined that when the combinations are selected in the manner illustrated in Fig. 2, wherein the cross marks assume a diagonal pattern, the presence of four consecutive marks in a horizontal line indicates graphically the need for a second disc for both the master switch and the slave switch. Thus, from the information derived in the manner explained above, operative embodiments of the two sections of the master switch 50 may be constructed. The discs 61 and 61′ of the slave switch 60 bear an inverse relationship, from a conductivity standpoint, to the corresponding portions of the master switch 50. In view of this relationship, it is relatively easy to construct the two sections of the slave switch 60.

Suitable means such as indicators 83, 83 may be employed in connection with the rotary discs to indicate the positions thereof with respect to each of the switch positions. The master-slave system may also include a controlled unit 81 which is responsive to the operation of the driving motor 64. Controlled unit 81 is connected to and driven by the motor 64 through suitable means such as a drive shaft 82.

Considering now the operation of the system of Fig. 1, it will be assumed initially that the slave switch 60 rests on position 2 and that the master switch 50 is adjusted to position 1. Since the foregoing two switches are not in corresponding positions, a circuit is established through the switches so that the battery 73 operates the motor 64. The current flow is from the battery 73 through the connections 72 and 70 to the brush 71 which rests on the conductive portion 53 of disc 51, thence to the stationary contact 1 and connection 1 to contact 1 of the slave switch 60, and then through the conductive portion 66 of disc 61, brush 75, connection 76, the motor 64, and the relay winding 78 to ground. The energization of relay winding 78 is effective to open the switch blade 80, thereby disconnecting the dynamic braking resistor 79 from the motor circuit. Motor 64 thereupon drives the discs 61 and 61′ of the switch 60 by way of the shafts 62 and 63 and also operates controlled unit 81 through the shaft 82. It will be noted that only one of the seven connections between the master and the slave switch is carrying current at this particular moment since the insulating portions on disc 51′ isolate the other six connections. The motor 64 drives switch 60 to position 3 whereupon connections 1 and 2 carry current. After the switch 60 has been indexed to position 4, connections 1, 2, and 3 are energized. When the rotary discs of the slave switch 60 have been indexed around to position 1 so that correspondence in position with the master switch 50 is attained, certain of the insulating portions on the periphery of discs 61 and 61′ interrupt the flow of current to the motor. This de-energizes the relay winding 78 and causes the switch blade 80 to close so that the dynamic braking resistor 79 is connected across the motor terminals. This quickly retards the rotation of the motor and the driven discs 61 and 61′ so that the latter stop at precisely the desired positions and are thereby effective to establish an inoperative relationship for the driving motor 64. Unit 81 is thus controlled as to position exactly as desired. Thus, it will be seen that as the switch 60 is rotated by the motor 64, operative relations are established between the switches for the motor 64 through: (*a*) a maximum of three of the seven connections, (*b*) at least one of the seven connections for any relative position of the switches 50 and 60 with the exception of only those relative switch positions at which correspondence is attained, and (*c*) an inoperative relation is established between the switches when correspondence is attained. Similar operation is experienced when the manually operable master switch 50 is adjusted to any other of the thirty-five switch positions.

While the invention has been described in connection with a 7-wire 35-position master-slave system, this embodiment represents but one of a very extensive number of systems which may be constructed in accordance with the procedure set forth above. By utilizing an arrangement with a greater number of connections between stationary contacts of the master and slave switches, and by energizing a larger number of connections in accordance with the prescribed relations stated above, a greater number of combinations may be realized. For example, with an arrangement which employs eight connections and energizes a maximum of four of these connections at once, seventy switch positions or combinations may be secured. Also by employing eleven connections with a maximum of five connections which are energized at one time, four hundred sixty-two combinations may be realized. These are but a few of the many possibilities.

Although the illustrated embodiment of the invention includes disc-type rotary elements for establishing and interrupting the various electrical circuits because of the relative simplicity and compactness of construction of these elements, the more conventional rotary switches which include a rotary wiper which selectively engages a single switch point at a time may be employed. However, this usually entails a bulkier array of switches with a multiplicity of properly interconnected switch points. Other forms of driving motors which include conventional dynamic braking arrangements in which relays are unnecessary in the construction thereof may be employed in systems of the type described. The illustrated motor and its associated braking system has been illustrated principally because of the simplicity and inexpensiveness thereof.

Master-slave systems in accordance with the present invention are useful in connection with the remote tuning of variable-frequency oscillators and also for transmitting control or bearing information to regions which are remote from the master switch. While the arrangement of the present invention has been described in connection with an electrical system, it will be manifest that the invention is equally adapted for use with respect to the transmission of other forms of energy, for example fluid energy, with a minimum number of conduits.

Some remote-control arrangements which are constructed in accordance with the teachings of the present invention may not employ the entire M different switch positions since all the switch positions need not be utilized for control purposes. For example, a particular use may require but thirty-three positions and accommodations for seven electrical connections between the master switch and the slave switch may be available. The 35-position system may prove to be the most economical to construct for the purpose at hand so that two of the positions, although being present in the system, need not be used as control points during the controlling operation. Thus in an arrangement of this type, the master switch and the slave switch each has approximately M different switch positions.

It will be apparent from the foregoing description that a master-slave system embodying the present invention includes a minimum number of connections between the control switch and the remotely located controlled switch although it does provide a maximum number of useful combinations.

While there has been described what is at present considered to be the preferred embodiment of this invention, it will be obvious to those skilled in the art that various changes and modifications may be made therein without departing from the invention, and it is, therefore, aimed in the appended claims to cover all such changes and modifications as fall within the true spirit and scope of the invention.

What is claimed is:

1. A master-slave system comprising: a master switch and a slave switch each having approximately M different switch positions and each including N contacts where N is a number greater than four but substantially less than M; and connections between corresponding ones of said contacts; said master switch and said slave switch being constructed with reference to each other and in accordance with the relation

$$M=\frac{N(N-1)(N-2)\ .\ .\ .\ (N-P+1)}{P!}$$

wherein P is a number which does not exceed one-half the number N, to establish (*a*) operative relations between said switches through a maximum of P of said connections, (*b*) to establish operative relations between said switches through at least one of said N connections for any relative position of said switches with the exception of only those relative switch positions at which correspondence is attained, and (*c*) to establish inoperative relations between said switches through said connections for those relative positions at which correspondence is attained.

2. A master-slave system comprising: a master switch and a slave switch each having approximately M different switch positions and each including N stationary contacts where N is a number greater than four but substantially less than M; and connections between corresponding ones of said stationary contacts; said master switch and said slave switch being constructed with reference to each other and in accordance with the relation

$$M=\frac{N(N-1)(N-2)\ .\ .\ .\ (N-P+1)}{P!}$$

wherein P is a number which does not exceed one-half the number N, to establish (*a*) operative relations between said switches through a maximum of P of said connections, (*b*) to establish operative relations between said switches through at least one of said N connections for any relative position of said switches with the exception of only those relative switch positions at which correspondence is attained, and (c) to establish inoperative relations between said switches through said connections for those relative positions at which correspondence is attained.

3. A master-slave system comprising: a master switch and a slave switch each having approximately M different switch positions and each including N contacts where N is a number greater than four but substantially less than M; and connections between corresponding ones of said contacts; said master switch and said slave switch being constructed with reference to each other and in accordance with the relation

$$M=\frac{N(N-1)(N-2)\ .\ .\ .\ (N-P+1)}{P!}$$

wherein P is a number which is less than one-half the number N, to establish (a) operative relations between said switches through a maximum of P of said connections, (b) to establish operative relations between said switches through at least one of said N connections for any relative position of said switches with the exception of only those relative switch positions at which correspondence is attained, and (c) to establish inoperative relations between said switches through said connections for those relative positions at which correspondence is attained.

4. A master-slave system comprising: a manually operable master switch and a remotely located slave switch each having M different switch positions and each including N stationary contacts where N is a number greater than four but substantially less than M; driving means for said slave switch; and connections between corresponding ones of said stationary contacts; said master switch and said slave switch being constructed with reference to each other and in accordance with the relation

$$M=\frac{N(N-1)(N-2)\ .\ .\ .\ (N-P+1)}{P!}$$

wherein P is a number which does not exceed one-half the number N, to establish (a) operative relations between said switches for said driving means through a maximum of P of said connections, (b) to establish operative relations between said switches for said driving means through at least one of said N connections for any relative position of said switches with the exception of only those relative switch positions at which correspondence is attained, and (c) to establish inoperative relations between said switches for said driving means through said connections for those relative positions at which correspondence is attained.

5. A master-slave system comprising: a master switch and a slave switch each having M different switch positions and each including N stationary contacts where N is a number greater than four but substantially less than M, said master switch and said slave switch each including conductive and insulating portions; and connections between corresponding ones of said stationary contacts; said master switch and said slave switch being constructed with reference to each other with said conductive and said insulating portions of said master switch in corresponding relations to said insulating and said conductive portions, respectively, of said slave switch and in accordance with the relation

$$M=\frac{N(N-1)(N-2)\ .\ .\ .\ (N-P+1)}{P!}$$

wherein P is a number which does not exceed one-half the number N, to establish (a) operative relations between said conductive portions of said switches through a maximum of P of said connections, (b) to establish operative relations between said conductive portions of said switches through at least one of said N connections for any relative position of said switches with the exception of only those relative switch positions at which correspondence is attained, and (c) to establish inoperative relations between said switches through said connections for those relative positions at which correspondence is attained.

6. A master-slave system comprising: a master switch and a slave switch each having M different switch positions and each including N stationary contacts where N is a number greater than four but substantially less than M, said master and said slave switches each including a movable member having conductive and insulating portions for engagement with said stationary contacts; and connections between corresponding ones of said stationary contacts; said master switch and said slave switch being constructed with reference to each other with said conductive and said insulating portions of said movable member of said master switch in corresponding relations to said insulating and said conductive portions, respectively, of said movable member of said slave switch and in accordance with the relation

$$M=\frac{N(N-1)(N-2)\ .\ .\ .\ (N-P+1)}{P!}$$

wherein P is a number which does not exceed one-half the number N, to establish (a) operative relations between said conductive portions of said switches through a maximum of P of said connections, (b) to establish operative relations between said conductive portions of said switches through at least one of said N connections for any relative position of said switches with the exception of only those relative switch positions at which correspondence is attained, and (c) to establish inoperative relations between said switches through said connections for those relative positions at which correspondence is attained.

7. A master-slave system comprising: a master switch and a slave switch each having M different switch positions and each including N stationary contacts where N is a number greater than four but substantially less than M, said master and said slave switches each including a rotatable member having conductive and insulating portions for engagement with said stationary contacts; and connections between corresponding ones of said stationary contacts; said master switch and said slave switch being constructed with reference to each other with said conductive and said insulating portions of said rotatable member of said master switch in corresponding relations to said insulating and said conductive portions, respectively, of said rotatable member of said slave switch and in accordance with the relation

$$M=\frac{N(N-1)(N-2)\ .\ .\ .\ (N-P+1)}{P!}$$

wherein P is a number which does not exceed one-half the number N, to establish (a) operative relations between said conductive portions of said switches through a maximum of P of said connections, (b) to establish operative relations between said conductive portions of said switches through at least one of said N connections for any relative position of said switches with the exception of only those relative switch positions at which correspondence is attained, and (c) to establish inoperative relations between said switches through said connections for those relative positions at which correspondence is attained.

8. A master-slave system comprising: a master switch and a slave switch each having M different switch positions and each including N stationary contacts where N is a number greater than four but substantially less than M, said master and said slave switches each including a pair of concurrently rotatable members having conductive and insulating portions for engagement with said stationary contacts; and connections between corresponding ones of said stationary contacts; said master switch and said slave switch being constructed with reference to each other with said conductive and said insulating portions of said pair of rotatable members of said master switch in corresponding relations to said insulating and said conductive portions, respectively, of said pair of rotatable members of said slave switch and in accordance with the relation

$$M=\frac{N(N-1)(N-2)\ .\ .\ .\ (N-P+1)}{P!}$$

wherein P is a number which does not exceed one-half the number N, to establish (a) operative relations between said conductive portions of said switches through a maximum of P of said connections, (b) to establish operative relations between said conductive portions of said switches through at least one of said N connections for any relative position of said switches with the exception of only those relative switch positions at which correspondence is attained, and (c) to establish inoperative relations between said switches through said connections for those relative positions at which correspondence is attained.

9. A master-slave system comprising: a master switch and a slave switch each having M different switch positions and each including N stationary contacts where N is a number greater than four but substantially less than M, said master switch and said slave switch each including a rotatable member having conductive and insulating portions for engagement with said stationary contacts; connections between corresponding ones of said stationary contacts; said master switch and said slave switch being constructed with reference to each other wtih said conductive and said insulating portions of said rotatable member of said master switch in corresponding relations to said insulating and said conductive portions, respectively, of said rotatable member of said slave switch and in accordance with the relation

$$M=\frac{N(N-1)(N-2)\ .\ .\ .\ (N-P+1)}{P!}$$

wherein P is a number which does not exceed one-half the number N, to establish (a) operative relations between said conductive portions of said switches through a maximum of P of said connections, (b) to establish operative relations between said conductive portions of switches through at least one of said N connections for any relative position of said switches with the exception of only those relative switch positions at which correspondence is attained, and (c) to establish inoperative relations between said switches through said connections for those relative positions at which correspondence is attained; means for indicating the positions of said rotatable member of said master switch with respect to each of said switch positions thereof, and means for indicating the positions of said rotatable member of said slave switch with respect to each of said switch positions thereof.

10. A master-slave system comprising: a manually operable master switch and a remotely located slave switch each having M different switch positions and each including N stationary contacts where N is a number greater than four but substantially less than M; driving means for said slave switch; connections between corresponding ones of said stationary contacts; said master switch and said slave switch being constructed with reference to each other and in accordance with the relation

$$M=\frac{N(N-1)(N-2)\ .\ .\ .\ (N-P+1)}{P!}$$

wherein P is a number which does not exceed one-half the number N, to establish (a) operative relations between said switches for said driving means through a maximum of P of said connections, (b) to establish operative relations between said switches for said driving means through at least one of said N connections for any relative position of said switches with the exception of only those relative switch positions at which correspondence is attained, and (c) to establish inoperative relations between said switches for said driving means through said connections for those relative positions at which correspondence is attained; and dynamic braking means for said driving means effective to retard said driving means when an inoperative relation is established.

11. A master-slave system comprising: a master switch and a slave switch each having M different switch positions and each including N contacts where N is a number greater than four but substantially less than M; connections between corresponding ones of said contacts; and means effectively interconnecting said master switch and said slave switch; said master switch and said slave switch being constructed with reference to each other and in accordance with the relation

$$M=\frac{N(N-1)(N-2)\ .\ .\ .\ (N-P+1)}{P!}$$

wherein P is a number which is less than one-half the number N, to establish (a) operative relations between said switches through a maximum of P of said connections and said interconnecting means, (b) to establish operative relations between said switches through at least one of said N connections and said interconnecting means for any relative position of said switches with the exception of only those relative switch positions at which correspondence is attained, and (c) to establish inoperative relations between said switches through said connections and said interconnecting means for those relative positions at which correspondence is attained.

12. A master-slave system comprising: a master switch and a slave switch each having M different switch positions and each including N stationary contacts where N is a number greater than four but substantially less than M, said master switch and said slave switch each including conductive and insulating portions; and connections between. corresponding ones of said stationary contacts; said conductive and said insulating portions of said master switch and said slave switch being constructed with reference to each other and in accordance with the relation

$$M=\frac{N(N-1)(N-2)\ .\ .\ .\ (N-P+1)}{P!}$$

wherein P is a number which does not exceed one-half the number N, to establish (a) operative relations between said conductive portions of said switches through a maximum of P of said connections, (b) to establish operative relations between said conductive portions of said switches through at least one of said N connections for any relative position of said switches with the exception of only those relative switch positions at which correspondence is attained, and (c) to establish inoperative relations between said switches through said connections for those relative positions at which correspondence is attained.

13. A master-slave system comprising: a manually operable master switch and a remotely located slave switch each having M different switch positions and each including N stationary contacts where N is a number greater than four but substantially less than M; driving means for said slave switch; connections between corresponding ones of said stationary contacts; said master switch and said slave switch being constructed with reference to each other and in accordance with the relation

$$M=\frac{N(N-1)(N-2)\ .\ .\ .\ (N-P+1)}{P!}$$

wherein P is a number which does not exceed one-half the number N, to establish (a) operative relations between said switches for said driving means through a maximum of P of said connections, (b) to establish operative relations between said switches for said driving means through at least one of said N connections for any relative position of said switches with the exception of only those relative switch positions at which correspondence is attained, and (c) to establish inoperative relations between said switches for said driving means through said connections for those relative positions at which correspondence is attained; and driven means coupled to said driving means for positioning thereby.

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REFERENCES CITED

The following references are of record in the file of this patent:

UNITED STATES PATENTS

Number	Name	Date
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