Aug. 13, 1946. R. D. PARKER ET AL 2,405,603

DATA TRANSMISSION SYSTEM

Filed Dec. 31, 1942 3 Sheets-Sheet 1

FIG. 1

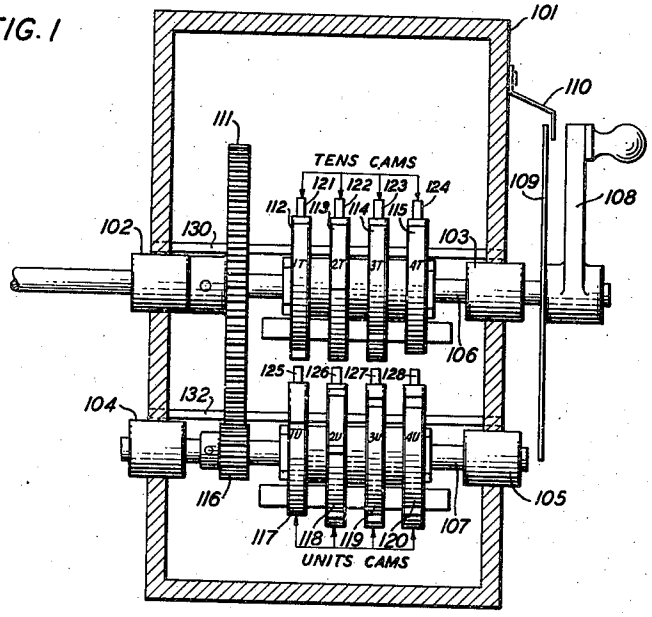
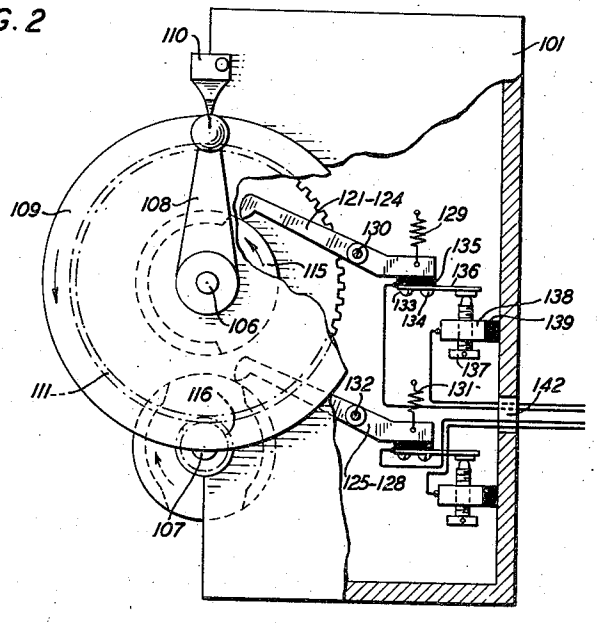


FIG. 2



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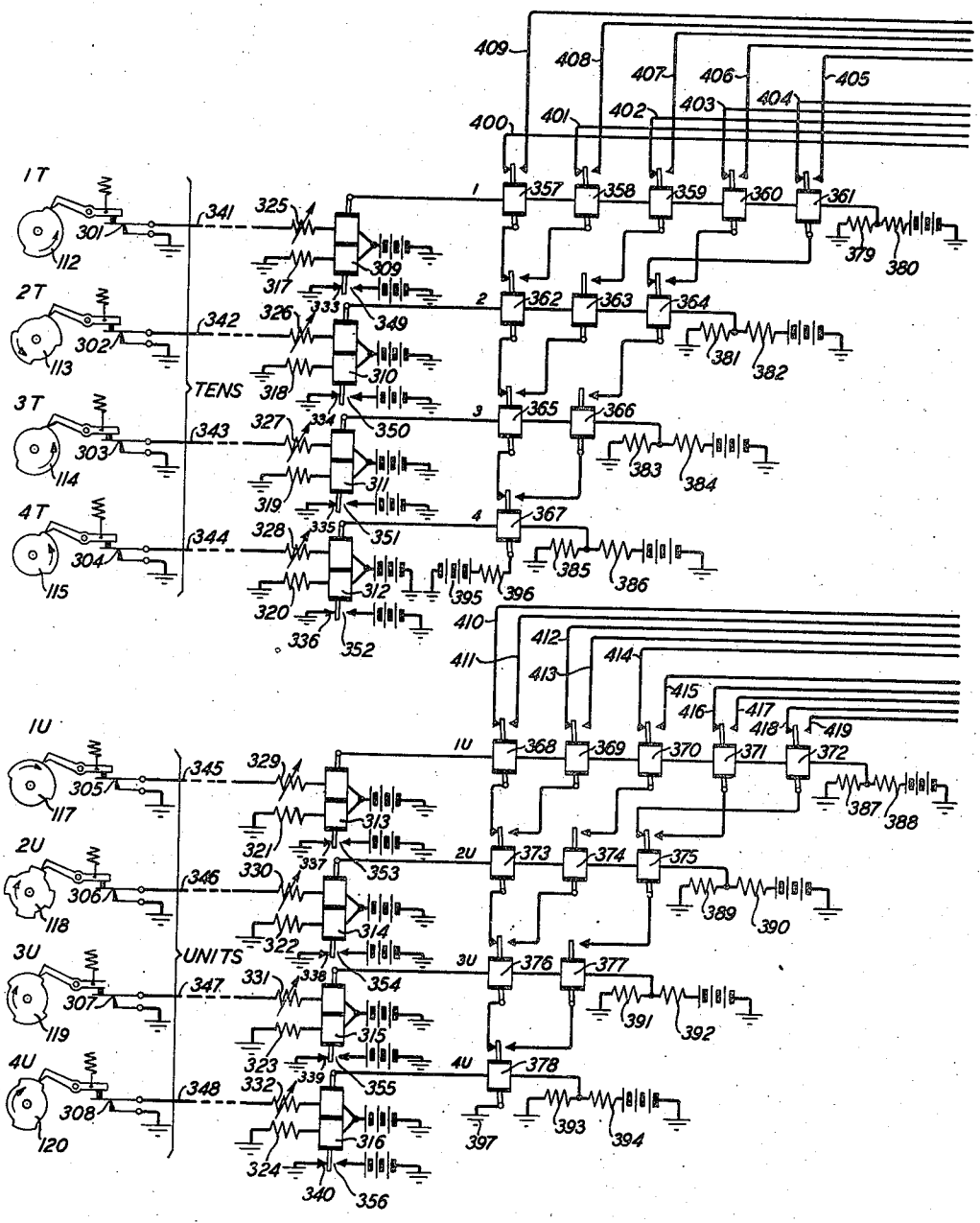
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FIG. 3



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DATA TRANSMISSION SYSTEM

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FIG. 4

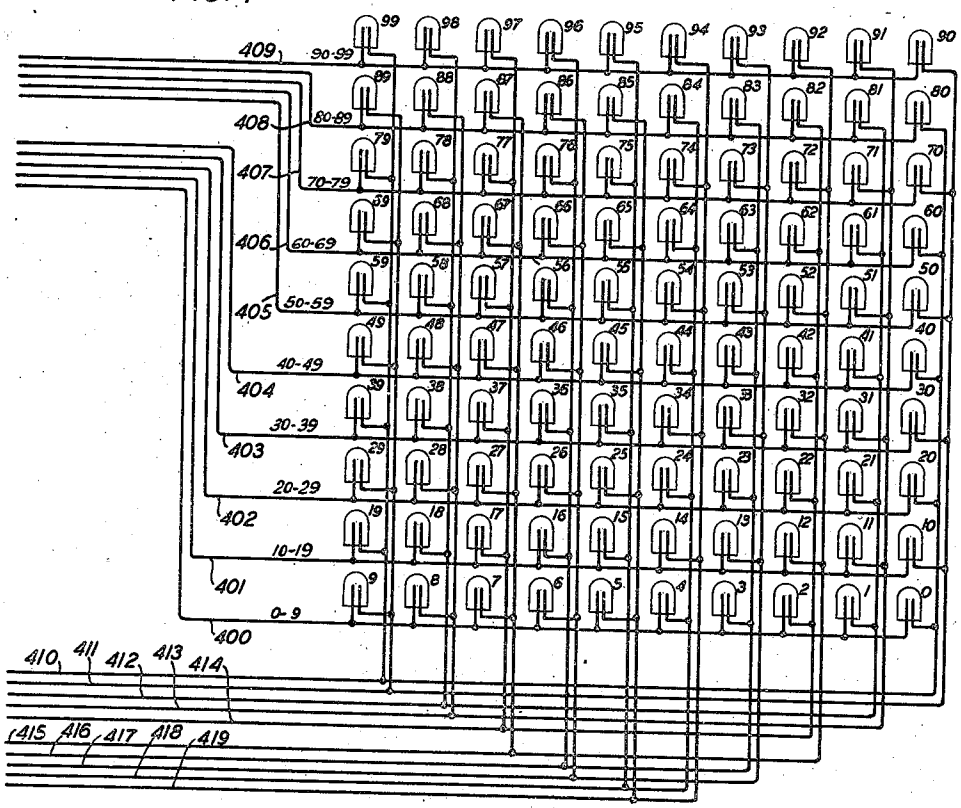


FIG. 5

UNITS CAMS CODE

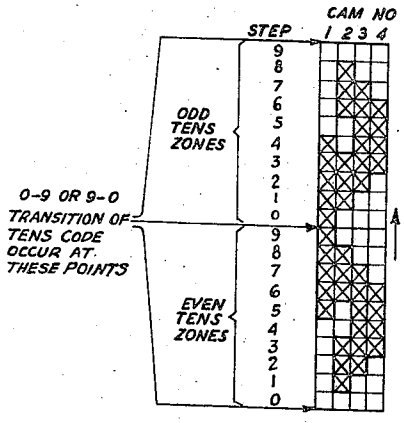
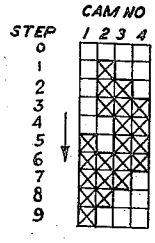


FIG. 6

TENS CAMS CODE



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Patented Aug. 13, 1946 2,405,603

UNITED STATES PATENT OFFICE

2,405,603

DATA TRANSMISSION SYSTEM

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Application December 31, 1942, Serial No. 470,774

10 Claims. (Cl. 177—351)

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This invention relates to data transmission systems and particularly to permutation code signal data transmission signal systems.

More particularly, this invention is a permutation code signal data transmission system arranged for high speed transmission of data signals with a high degree of accuracy.

The data transmission system of this invention is arranged so that two complete groups of permutation code signal elements, each completely defining a portion of a multidigit number, are impressed on two multiconducting channel transmission circuits simultaneously. That is to say, four signal elements in accordance with one permutation code are impressed simultaneously on four separate conducting channels comprising a first transmission circuit to completely define a digit in the right-hand position of a multidigit number. Four signal elements in accordance with a second permutation code, independent of the first code, are impressed simultaneously on four separate conducting channels comprising a second transmission circuit to completely define the digit in the second position from the right in the same multidigit number.

At the receiving station, a separate high speed receiving circuit is provided for each transmission circuit. Separate decoding circuits are also provided for each transmission circuit.

With four conducting channels each arranged to transmit a permutation of two electrical conditions, it is possible to transmit 2^4 or sixteen different sets of signals. Only ten of these are employed to designate any of the ten different digits for a particular place.

By providing four independent channels for each circuit, it is possible to impress all of the signal elements necessary to designate any particular one of the ten digits in a particular place in the number on each circuit simultaneously. The apparatus may be expanded to care for the transmission simultaneously of the permutation code signals necessary to designate a multidigit number having any number of places.

A feature of the invention herein is an arrangement which provides for very speedy selection in that a sufficient number of transmission channels are provided between the sender and the receiver to preclude the need of time discrimination within each code, and the coding apparatus at the sending end and decoding apparatus at the receiving end are capable of very high speed operation of the order of three hundred selections per second.

A further feature of this invention is an arrangement wherein each selection is under complete control of the sending mechanism and the selection is made in accordance with codes sent over the transmission channels and it is not necessary to lock up the decoding apparatus in the receiver.

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A further feature of this invention is an arrangement in which a false selection due to "line hits" or other extraneous interferences will be retained only during the period of interference and the correct selection will be reestablished immediately thereafter. That is to say, no false signal due to a hit or other trouble condition is ever stored.

A further feature of this invention is an arrangement which minimizes troubles caused by interchannel inductance, as current and voltage changes at the sender are made on only one channel of the entire system at a time.

A further feature is an arrangement in which errors in decoding are minimized because the code combinations assigned to successive points on the transmitting mechanism differ by one element only, so that on transitions between successive points, particularly where the change in data and the corresponding change in the mechanism are slow, and successive positions on the transmitting cams may be bridged by their followers, the resultant selections at the receiving station will be one or the other or both of two adjacent and consecutively numbered indicators, corresponding to the positions between which the transmitter is moving, rather than a false random selection of an indicator at wide variance with the true position of the transmitter, as would be the case if the codes were randomly assigned to transmitter positions.

A further feature of the invention is that the sending and receiving apparatus will function with practically any type of telegraph transmission system, such as a voice frequency carrier, two-wire system or a voice frequency system superimposed on a radio link.

These and other features may be understood from the following description when read with reference to the associated drawings, in which:

Fig. 1 is a plan view partly in section of the transmitting apparatus;

Fig. 2 is a side elevation partly in section of the transmitting apparatus;

Fig. 3 is the left-hand portion of the circuit of the invention;

Fig. 4 is the right-hand portion of the circuits of the invention; and

Figs. 5 and 6 are code diagrams used in explaining the invention.

Refer to Figs. 1 and 2. Secured in housing 101 are two sets of opposed bearings 102, 103, 104 and 105. Shaft 106 is journaled in bearings 102 and 103. Shaft 107 is journaled in bearings 104 and 105. Crank 108 is rigidly secured to the right-hand end of an extension of shaft 106. A disk 109 is also rigidly secured to shaft 106, intermediate crank 108 and bearing 103. Disk 109 is graduated near its periphery in one hundred equal divisions. Pointer 110 is secured to housing 101 and is arranged to register with the divisions on disk 109 as disk 109 is rotated. Gear 111 and cams 112, 113, 114 and 115 are each rigidly secured to shaft 106. Gear 116 and cams 117, 118, 119 and 120 are rigidly secured to shaft 107. Gears 111 and 116 engaged. The gear ratio is such that as crank 108 and gear 111 turn through one revolution, gear 116 revolves five times.

Cam arm shafts 130 and 132 are secured in the right and left-hand walls of housing 101. Cam arms 121 and 124 are mounted on shaft 130 and cam arms 125 to 128 are mounted on shaft 132. As may be seen in Fig. 2, the left-hand ends of lever cam arms 121 to 124 engage the peripheries of cams 112 to 115, respectively. The left-hand ends of lever cam arms 125 to 128 engage the peripheries of cams 117 to 120, respectively. An individual spring, such as 129, secured to the right-hand end of lever arms 121 to 124 tends to rotate each lever arm in a counter-clockwise direction about shaft 130 in which each of lever arms 121 to 124 is journaled. A corresponding spring, such as 131, attached to the right-hand end of each lever arms 125 to 128 tends to rotate each of these arms in a counter-clockwise direction about shaft 132 in which each of arms 125 to 128 is journaled. The left-hand ends of cam arms 121 to 128 are thus maintained in engagement with their corresponding cams as the cams are rotated.

Secured to the right-hand end of each of arms 121 to 128 by two screws, such as 133 and 134, and separated from each arm by an individual strip of insulation, such as 135, is a contact spring, such as 136, which engages a corresponding adjustable screw contact stud, such as 137, mounted in a fixed nut, such as 138, secured to the right-hand inner wall of housing 101 and insulated therefrom by an insulator, such as 139.

Each pair of contacts, such as 136 and 137, coacts to interrupt the flow of current through a corresponding pair of conductors which extend through an opening 142 in the housing. One of each of the eight pairs of wires is connected to ground and the other extends to the receiving station. The eight conductors extending to the receiving station correspond to conductors 341 to 348 in Fig. 3.

The mechanism per Fig. 1 and Fig. 2 is adapted to be operated to follow the changes in magnitude of a measured quantity, such as the size of an angle. For instance, shaft 106 may be coupled in any convenient manner to means for controlling the movement of an azimuth instrument in which case the transmitter would be used for transmitting permutation signals to define the size of a changing angle. It is to be understood, however, that it is not so limited.

Refer now to Fig. 5. Fig. 5 shows is diagrammatic form the manner in which the peripheries of cams 117 to 120 are arranged to transmit twenty sets of permutation code signals for each rotation to define the digits in the units place

of twenty consecutive numbers before repeating to define the digits in the units place for the succeeding twenty numbers on the next rotation.

Vertical columns 1, 2, 3 and 4 of Fig. 5 pertain to cams 117, 118, 119 and 120, respectively. The periphery of each of cams 117 to 120 may be assumed to be divided into twenty segments of equal length arranged in two levels, normal and depressed. Each of columns 1 to 4 in Fig. 5 is divided horizontally into twenty rectangles each corresponding to one segment. Each of the twenty horizontal lines of rectangles indicates the condition of each of cams 117 to 120 in a particular one of the twenty different cam positions. Where a cam position is normal, the rectangle is blank. Where a cam position is depressed, the rectangle is cross-hatched. The combination of normal and depressed cam segments in a particular horizontal row forms a permutation code defining a corresponding digit of the group 0 to 9, 0 to 9 in the adjoining left-hand vertical column. The codes defining units digits 0 to 9 respectively, in numbers having even digits in the tens position, correspond to the units codes defining digits 9 to 0 respectively, in numbers having odd digits in the tens position. In other words, the codes for units digits 0 to 9 for even tens are repeated in reverse order to define units digits 0 to 9 for odd tens. This may be observed from the code pattern for the top and bottom group of ten horizontal lines in Fig. 5, each of which is the inverse of the other so that only ten different permutation code signal combinations are employed.

Refer now to Fig. 6. Columns 1, 2, 3 and 4 in Fig. 6 apply to cams 112, 113, 114 and 115, respectively. The vertical columns in Fig. 6 are divided horizontally into ten rectangles. The peripheries of cams 112 to 115 are assumed to be divided each into ten segments of equal length. Cross-hatched and blank rectangles have the same connotation as in Fig. 5.

Each horizontal row in Fig. 6 corresponds to a code set up on cams 112 to 115 to define a different digit in the tens position in a multidigit number. The numbers 0 to 9 in the vertical column at the left of Fig. 6 are the digits defined by the code in the corresponding horizontal column.

As shown in Figs. 5 and 6 each of the eight cams is cut in accordance with a code pattern arranged with only one change in condition in going from one step to the next, either within the tens group or within the units group. Furthermore, when there is a transition from one code within the tens group to the next, there is no transition in code in the units group because the arrangement of cams is such that the transition between tens groups occurs at points where the units code is the same for two adjacent steps. It is for this reason that the units code is arranged with one code sequence for each odd tens zone and another code sequence which is the inverse of the first for the even tens zone.

Refer now to Figs. 3 and 4. Cams 112 to 115 which control the transmission of the code signal combinations defining the digits in the tens place and cams 117 to 120 which control the transmission of the code signals which define the digit in the units place are shown at the left of Fig. 3. Cams 112 to 115 control the opening and closing of contacts 301 to 304. Cams 117 to 120 control the opening and closing of contacts 305 to 308. Circuits may be traced from positive battery through the bottom windings of relays 309

to 316 and through resistances 317 to 324 to ground. The effect of current flowing in these circuits tends to actuate the armatures of relays 309 to 316 to the right and is effective when no current is flowing through the top windings of these relays to actuate their armatures towards the right to engage contacts 349 to 356 to each of which grounded positive battery is connected. When cams 112 to 120 raise their respective arms, contacts 301 to 308 are closed establishing circuits from ground through contacts 301 to 308, through conductors 341 to 348 connecting the transmitting and receiving stations, variable resistances 325 to 332 and the top windings of relays 309 to 316 to battery. Current flowing in any of these circuits will actuate the armature of the corresponding relay to the left to engage its associated contacts 333 to 340.

When the armature of relay 309 engages contact 333, a circuit may be traced from ground through contact 333 and the windings of polar relays 357, 358, 359, 360 and 361 to the mid-point of the potentiometer which extends from ground through resistance 379, resistance 380 to grounded positive battery. When the armature of relay 310 engages contact 334, a circuit may be traced from ground through contact 334 and the windings of polar relays 362, 363 and 364 to the mid-point of a potentiometer which may be traced from ground through resistances 381 and 382 to grounded positive battery. When the armature of relay 311 engages contact 335, a circuit may be traced from ground through contact 335 and the windings of polar relays 365 and 366 to the mid-point of a potentiometer which may be traced from ground through resistances 383 and 384 to grounded positive battery. When the armature of relay 312 engages contact 336, a circuit may be traced from ground through contact 336 and the winding of polar relay 367 to the mid-point of a potentiometer which may be traced from ground through resistances 385 and 386 to grounded positive battery. When the armature of relay 313 engages contact 337, a circuit may be traced from ground through contact 337 and the windings of polar relays 368, 369, 370, 371 and 372 to the mid-point of a potentiometer which may be traced from ground through resistances 387 and 388 to grounded positive battery. When the armature of relay 314 engages contact 338, a circuit may be traced from ground through contact 338 and the windings of polar relays 373, 374 and 375 to the mid-point of a potentiometer which may be traced from ground through resistances 389 and 390 to grounded positive battery. When the armature of relay 315 engages contact 339, a circuit may be traced from ground to contact 339 and the windings of polar relays 376 and 377 to the mid-point of the potentiometer which may be traced from ground through resistances 391 and 392 to grounded positive battery. When the armature of relay 316 engages contact 340, a circuit may be traced from ground through contact 340 and the winding of polar relay 378 to the mid-point of a potentiometer which may be traced from ground through resistances 393 and 394 to grounded positive battery. When such circuits are established, the armatures of relays 357 to 378 will be actuated towards the left. When the armatures of relays 309 to 316 are actuated towards the right to engage contacts 349 to 356, positive battery instead of ground will be connected to the armatures. In response to this, the armatures of relays 357 to 378 will be actuated towards the right.

The armature of a particular relay in the relay group 357 to 367 will, therefore, be actuated either to the right or to the left for each code combination defining a particular digit in the tens place dependent upon the manner in which its controlling cam is cut as indicated in Fig. 6. Similarly, the armature of a particular relay in the relay group 368 to 378 will be actuated either to the right or to the left dependent upon the manner in which its corresponding cam is cut as indicated in Fig. 5. The group of relays 357 to 367 will make ten different selections, one for each cam code combination to connect positive battery 395 to some one of the ten conductors 400 to 409, each of which connects to a different group of ten lamps in Fig. 4. For the condition in which the tens cams and their corresponding relays are shown in Fig. 3, namely, with contacts 301 to 304 closed, the armatures of relays 309 to 312 actuated to the left and the armatures of each of the relays 357 to 367 also actuated to the left, a circuit may be traced from positive battery 395 through resistance 396, armature of left-hand contact of relay 367, armature and left-hand contact of relay 365, armature and left-hand contact of relay 362, armature and left-hand contact of relay 357 to conductor 400 which connects to the left-hand terminal of each of the ten lamps in the 0 to 9 bank in parallel.

The group of relays 368 to 378 will also make ten different selections, one for each of the ten different code combinations shown in Fig. 5, to connect ground 397 to some one of the ten conductors 410 to 419 each of which connects a different group of ten lamps in Fig. 4. For the condition shown with the armatures of all of the relays 368 to 378 actuated to the left, a circuit may be traced from ground 397 through the armature and left-hand contact of relay 378, armature and left-hand contact of relay 376, armature and left-hand contact of relay 373, armature and left-hand contact of relay 368 to conductor 410. Conductor 410 connects to a total of ten lamps in the indicator bank in Fig. 4, five in the left-hand vertical column and five in the right-hand vertical column. The reason for the division between the two columns will become apparent from the description hereunder.

For each of the other distinctive code combinations shown in Fig. 5 a path will be established from ground 397 to some other particular one of the nine other conductors, 411 to 419. Each one of these conductors is arranged in a manner corresponding to the arrangement of conductor 410 in that each connects to a total of ten lamps, five in each of two of the vertical columns in Fig. 4. The ten conductors 410 to 419 will serve all hundred of the lamps in Fig. 4. Selecting relays 368 to 378 cooperate to supply ground to the right-hand terminal of ten lamps arranged vertically while relays 357 to 367 cooperate to supply battery to ten lamps arranged horizontally in the bank of Fig. 4. This results in the selection of one lamp of the hundred lamps to define the position indicated on disc 109.

Attention is again particularly called to the fact that in any transition from the code defining a particular digit in either the units or tens places to the code for the next higher or lower digit, it is necessary to change the electrical condition of only one of the four conductors of either circuit. For instance, the code for 0 in the even tens zone as shown in Fig. 5 requires that ground be con-

nected to each of conductors **345** to **348** in Fig. 3. The code for 1 in the same zone requires a single change only, namely, that ground be removed from conductor **346**. In going from 1 to 2 in the same zone, a single change will be required, namely, ground will be removed from conductor **347**. The same condition applies on each transition.

In changing from the units digit 9 in the even tens zones to the units digit 0 in the odd tens zones, it is not necessary to change the condition of any of conductors **345** to **348**. This is apparent from Fig. 5 which indicates conductor **345** remains open and ground remains connected to each of conductors **346** to **348** for each of these codes. The change is effected by changing the code for the tens cams, and from Fig. 6 it is apparent that no matter whether the change is from 9 to 10, from 29 to 30, or 49 to 50, etc., the condition of only one conductor of the four tens conductors **341** to **344** is changed.

Reference to the top and bottom horizontal lines of Fig. 5 show that the code for units digit 0 in the even tens zone is the same as the code for units digit 9 in the odd tens zone, so that there is no change in the condition of conductors **345** to **348** on transition between 19 and 20, 39 and 40, etc. The change is again effected by a change in the condition of a single conductor of the tens group **341** to **344**.

Therefore since the four units code conductors remain unchanged on such a transition, while but a single change is made in the condition of the four tens conductors, the change in the electrical condition of the eight conductors comprising the system is limited to a single change in the condition of a single conductor while the other conductors are maintained in their former condition. This limits the transmission of signals to the absolute minimum and maintains the effect of inductive disturbances caused by signal changes to a minimum.

It is particularly pointed out that a number having any number of places may be instantly defined in this manner and further that it is necessary to change only one signal element on transitions between consecutive numbers whatever the number of places.

It was mentioned heretofore that the ten conductors **410** to **419** which control the selection of the units digits are not connected to all ten lamps corresponding to the same digit in a particular vertical row in the indicator bank but are connected instead to five lamps in each of two different vertical rows corresponding to two different unit digits. For instance conductor **410** connects to lamps **0**, **20**, **40**, **60** and **80** in the right-hand vertical row and to lamps **19**, **39**, **59**, **79** and **99** in the left-hand vertical row. This is necessary as the same units code is used for two different units digits, namely, the even 0's and the odd 9's as shown in Fig. 5. Each of the ten distinctive codes is used twice as shown in Fig. 5 to define two different groups of five numbers each. The units digit is the same within each group of five but different for the two groups. So the wiring of the lamp indicator bank must correspond to the repeated inverse code of Fig. 5.

This invention is described by reference to an exemplary system employing a 4-unit code and the decimal system but its principles are applicable to systems employing other multiple unit codes and other numerical systems such as the quintesimal system or the duo-decimal system or to mixed systems; it is therefore the intention that the expressions "digit," "multidigit number," "number," etc., be construed broadly to include all possible systems of numeration.

What is claimed is:

1. In an electrical data transmission system, a transmitting station, a receiving station, a first multichannel transmitting circuit connecting said stations, means at said transmitting station for impressing on each of said channels simultaneously a signal element of a first permutation code combination in a first multielement permutation code to completely define any one of ten digits in a first particular position in a multidigit number, a second multichannel transmitting circuit connecting said stations, means at said transmitting station for impressing on each of said second channels simultaneously a signal element of a second permutation code combination in a second multielement permutation code, independent of said first code, to completely define any one of ten digits in a second particular position in said multidigit number, means in said system for defining consecutive numbers in sequence, means, comprising instrumentalities for inverting the sequence of the code signal combinations defining successive groups of ten digits in said first position of said number, at said transmitting station for changing the condition of not more than one signal element of the total signal elements comprising said two code combinations on transitions between any successive code settings and means at said receiving station for identifying consecutive numbers in response to all of said consecutive settings.

2. In an electrical data transmission system arranged to define progressive or retrogressive sequential measurements in terms of consecutive multidigit numbers, a measuring station, a receiving station, a plurality of circuits each having a plurality of separate transmission channels interconnecting said stations, means at said measuring station for generating a separate multielement permutation code signal combination to completely define each separate digit in each place in each of said numbers corresponding to each of said measurements, means at said measuring station for transmitting each separate element of each of said multielement code combinations defining each of said digits of any of said multidigit numbers over a corresponding separate one of said channels, means at said measuring station for transmitting all of the elements of each particular combination simultaneously, means at said measuring station for transmitting all of said combinations corresponding to any particular multidigit number simultaneously and means at said measuring station for changing one element only in one of said channels only to define any multidigit number on a transition from any multidigit number to any consecutive multidigit number.

3. In an electrical data transmission system, four separate transmission channels comprising a first circuit, four separate transmission channels comprising a second circuit, means connected to said channels in said first circuit for impressing a signal on each of said channels in said first circuit simultaneously, to define any digit of ten digits in the units place in a number, means connected to said channels in said second circuit for impressing a signal on each of said channels in said second circuit simultaneously to define any digit of ten digits in the tens place in said number and means connected to said channels for changing a signal on one only of said eight channels on transitions from

one to another of any consecutive two-digit numbers.

4. In an electrical multielement permutation code signal data transmission system comprising a plurality of multichannel transmission circuits arranged to define a plurality of digits in a multidigit number simultaneously, means for transmitting a complete multielement permutation code signal combination over each of said circuits at substantially the same instant to completely define separate portions of said number substantially simultaneously, and means for varying the electrical condition of only one signal element of all of the signal elements in the combined code combinations defining any multidigit number to define a consecutive multidigit number.

5. In an electrical permutation code data transmission system, a plurality of multiconducting channel transmission circuits each having a separate conducting channel for a corresponding signal element of a multielement permutation code signal combination completely defining a separate digit in a multidigit number, means for impressing ten different multielement permutation code signal combinations on each of said circuits to define ten different digits in each place in said number and means for changing the signal impressed on a single one of said channels only to define all consecutive numbers.

6. In an electrical data transmission system, means for transmitting n separate permutation code signal combinations, where n is any number greater than one, to define any first multidigit number having n places in said number, means for retransmitting said combinations while varying the condition of a single signal element only of a single one of said combinations of said n combinations on all transitions between all consecutive numbers and means, responsive to the reception of said retransmitted combinations having said single varied element, for establishing a selection defining a second multidigit number, consecutive respectively to said first multidigit number.

7. In an electrical data transmission system, means for transmitting a plurality of first multielement permutation code signal combinations in accordance with each of a plurality of separate codes simultaneously to define a plurality of parts of any first multidigit number, means responsive to the reception of said first combinations for establishing a selection defining said first number, means for maintaining all of the signal elements of all said first combinations unchanged, except one signal element of one of said first combinations only while changing said one signal element, to define a plurality of parts of any second multidigit number consecutive to said first number, means for transmitting said second combinations defining said second number, and means responsive to the reception of said combinations defining said second number for effecting a selection defining said second number.

8. In a data transmission system, a first station, a second station, four separate transmission channels in a first circuit and four separate transmission channels in a second circuit interconnecting said stations, means connected to said channels for defining two digit numbers substantially instantaneously, said means comprising instrumentalities, at said first station, for impressing a first and a second code combination, of four signal elements each, individually on said four channels of each of said circuits substantially instantaneously, means connected to said channels at said first station for changing one of said elements only on one of said channels only of one of said circuits only on each one of one hundred changes to define each one of one hundred consecutively numbered digits, and means, connected to said channels at said second station, for selecting in sequence each one of one hundred consecutively numbered indicators in response to said changes.

9. A measuring device, a first and a second transmission circuit each comprising four separate channels connected to said device, means for impressing four signal elements of each of a first and a second code combination in a first and a second multi-element permutation code individually on said four channels of each of said circuits simultaneously, to define a two-digit number corresponding to a measurement by said device, in response to the operation of said device, and means for changing one signal element only of one of said combinations only, on transitions between any consecutive measurements by said device, to define said measurement in terms of a corresponding two-digit number.

10. In an electrical multielement permutation code data transmission system, a transmitting station, a single measuring device thereat, a first and a second group of electrical impulse transmitting contacts thereat, each group comprising at least three contacts, a first and a second transmitting circuit, each circuit comprising at least three separate transmitting channels, one for each of said contacts, connected individually to said contacts, a receiving station, means for extending said channels to said receiving station, a first and a second group of receiving relays, a first and a second decoding circuit, and a bank of indicators, all at said receiving station, means responsive to the operation of said measuring device for measuring a quantity expressible as a multidigit number, means responsive to said measuring operation for translating said number into two separate combinations of permutative settings of said contacts simultaneously, means responsive to the setting of said contacts for impressing a separate multielement code combination of electrical impulses on each of said circuits simultaneously, one impulse on each of said channels, means responsive to the reception of said impulses at said receiving station for establishing a first and a second multielement code combination of permutative settings of relay contacts of said first and second group of relays, means responsive to the establishing of said relay contact settings for controlling the operation of said decoding circuits, means responsive to the operation of both of said decoding circuits for establishing a single selection of an indicator in said bank to define said multidigit number, means in said system for translating all successive measurments into consecutive multidigit numbers and means in said system for changing the setting of a single one of all of said transmitting contacts only on any transition between consecutive measurments, to effect a corresponding change in said indicator by the transmission of a single signal element only in one or the other of said two code combinations over one of said channels.

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