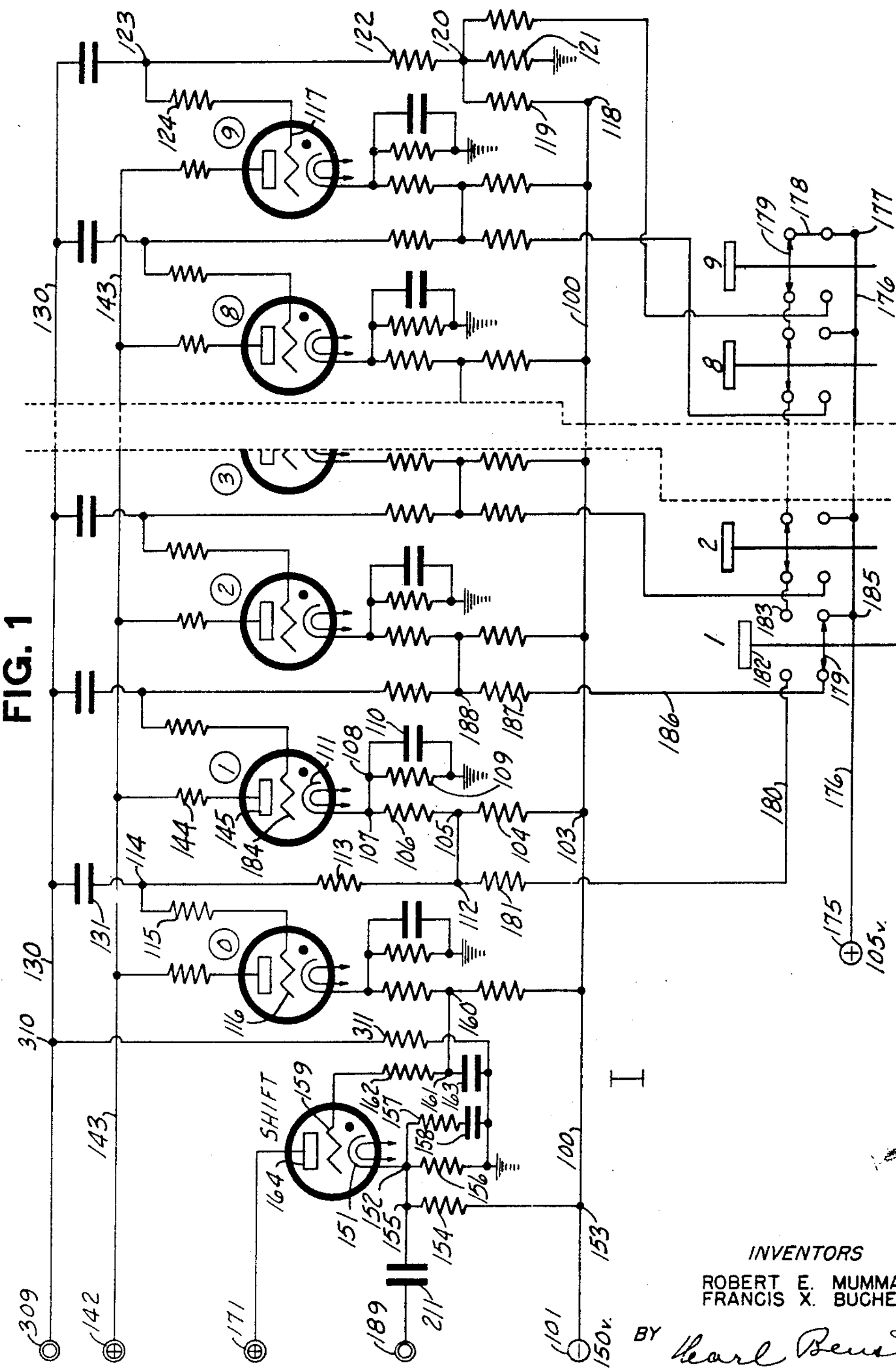
340-359

Sept. 30, 1947. R. E. MUMMA ET AL 2,428,089

COMMUNICATION SYSTEM

Original Filed Feb. 25, 1943 6 Sheets-Sheet 1

FIG. 1



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COMMUNICATION SYSTEM

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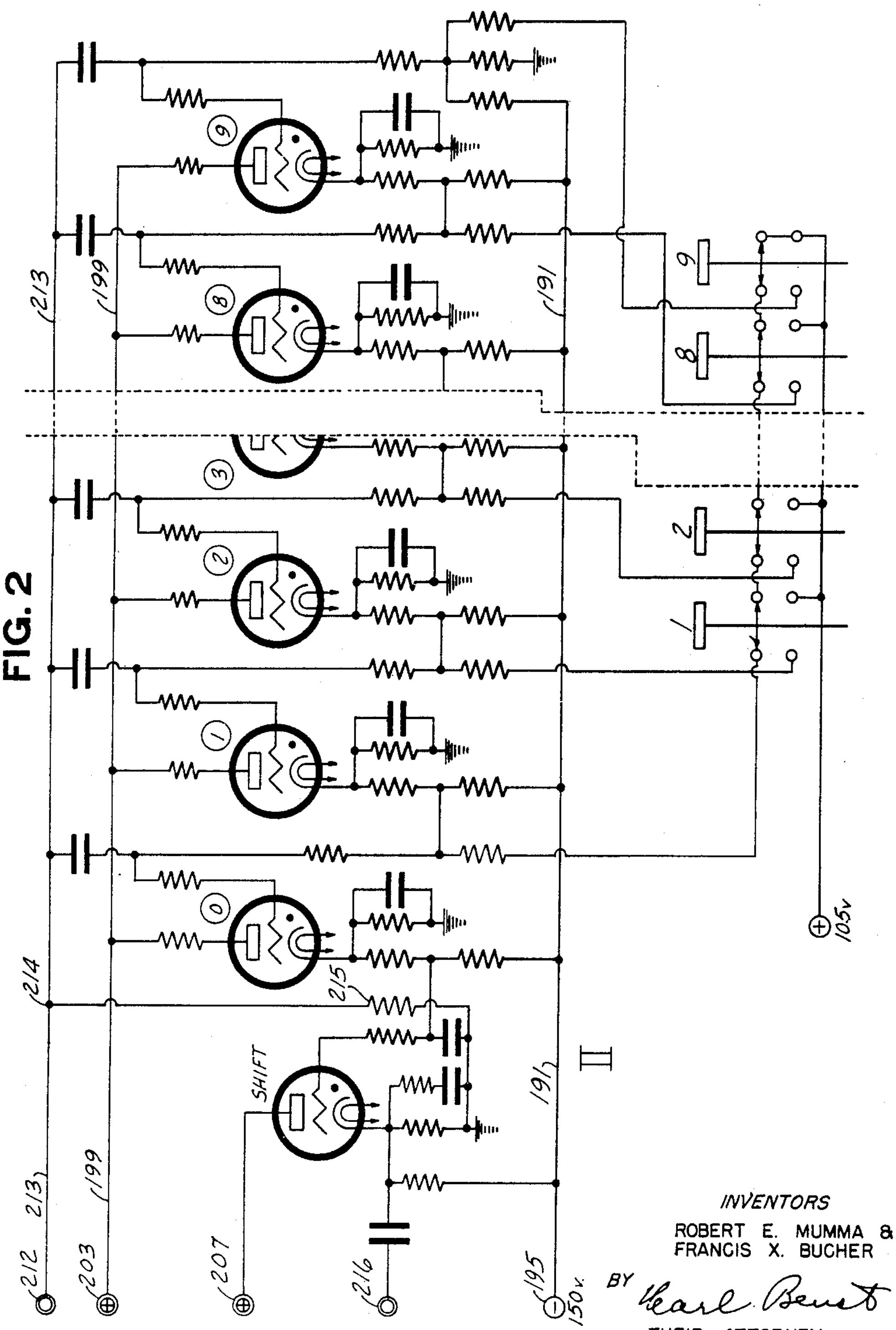

FIG. 2

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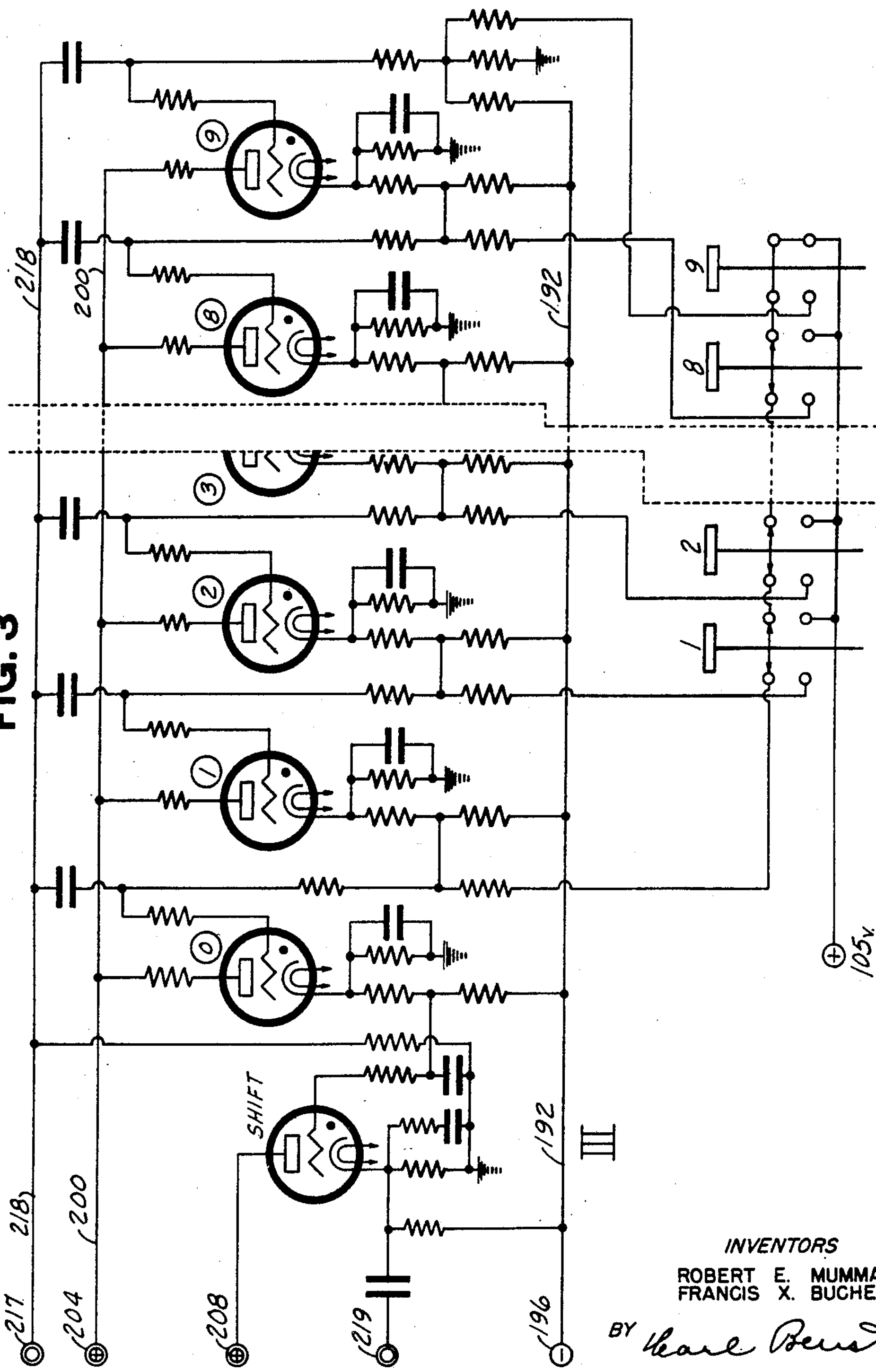
FIG. 3



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COMMUNICATION SYSTEM

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FIG. 4

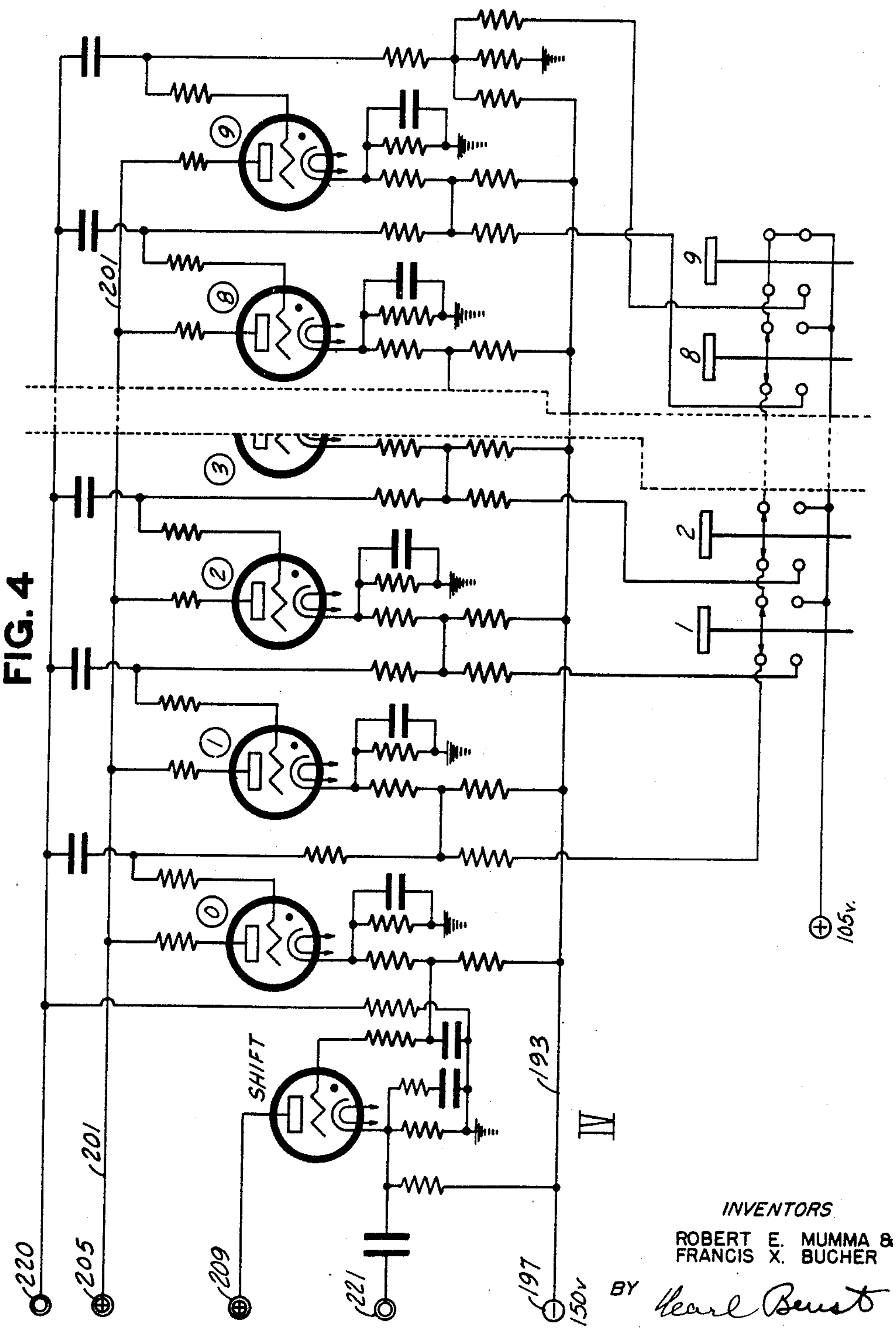

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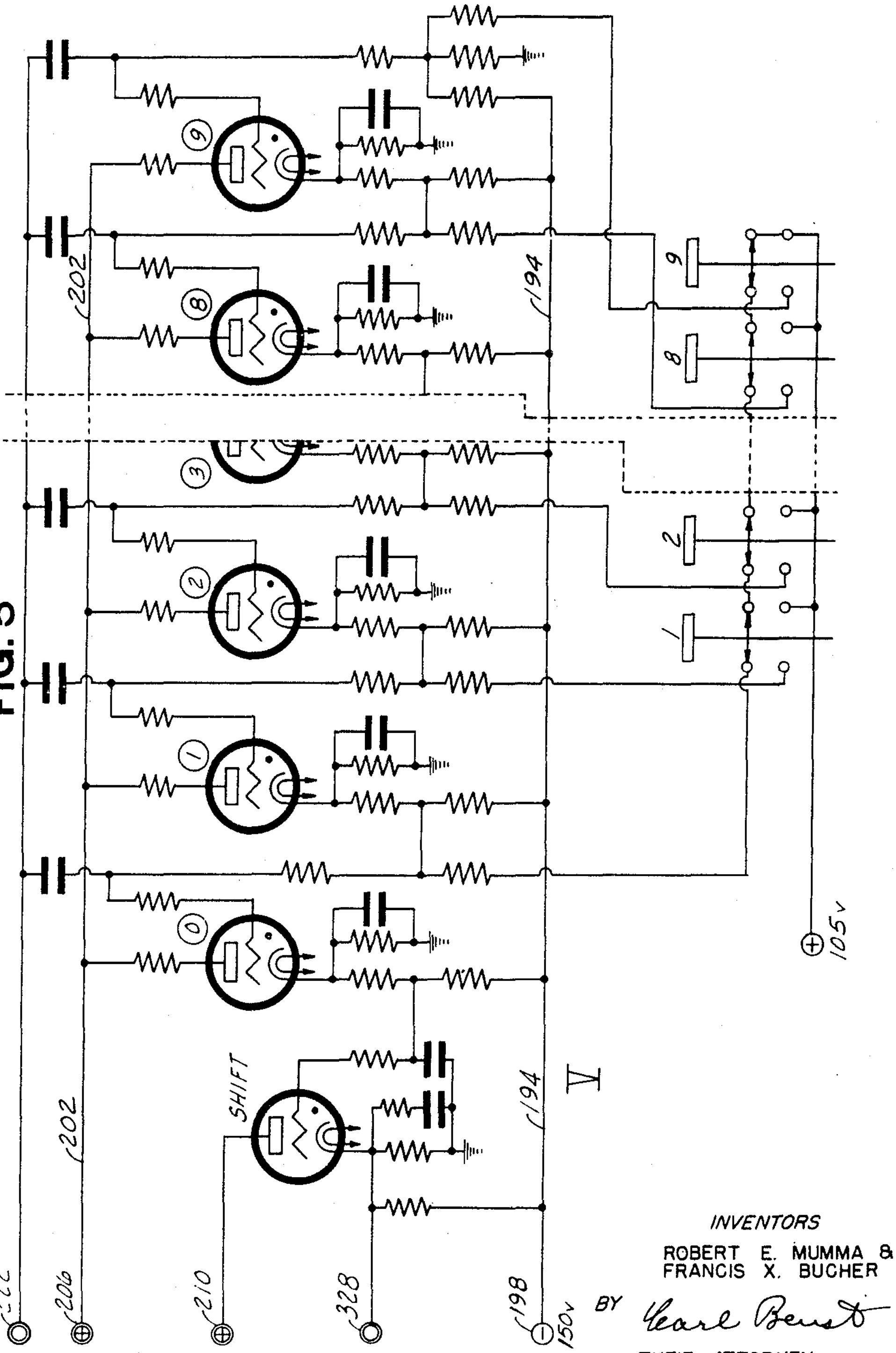
FIG. 5



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COMMUNICATION SYSTEM

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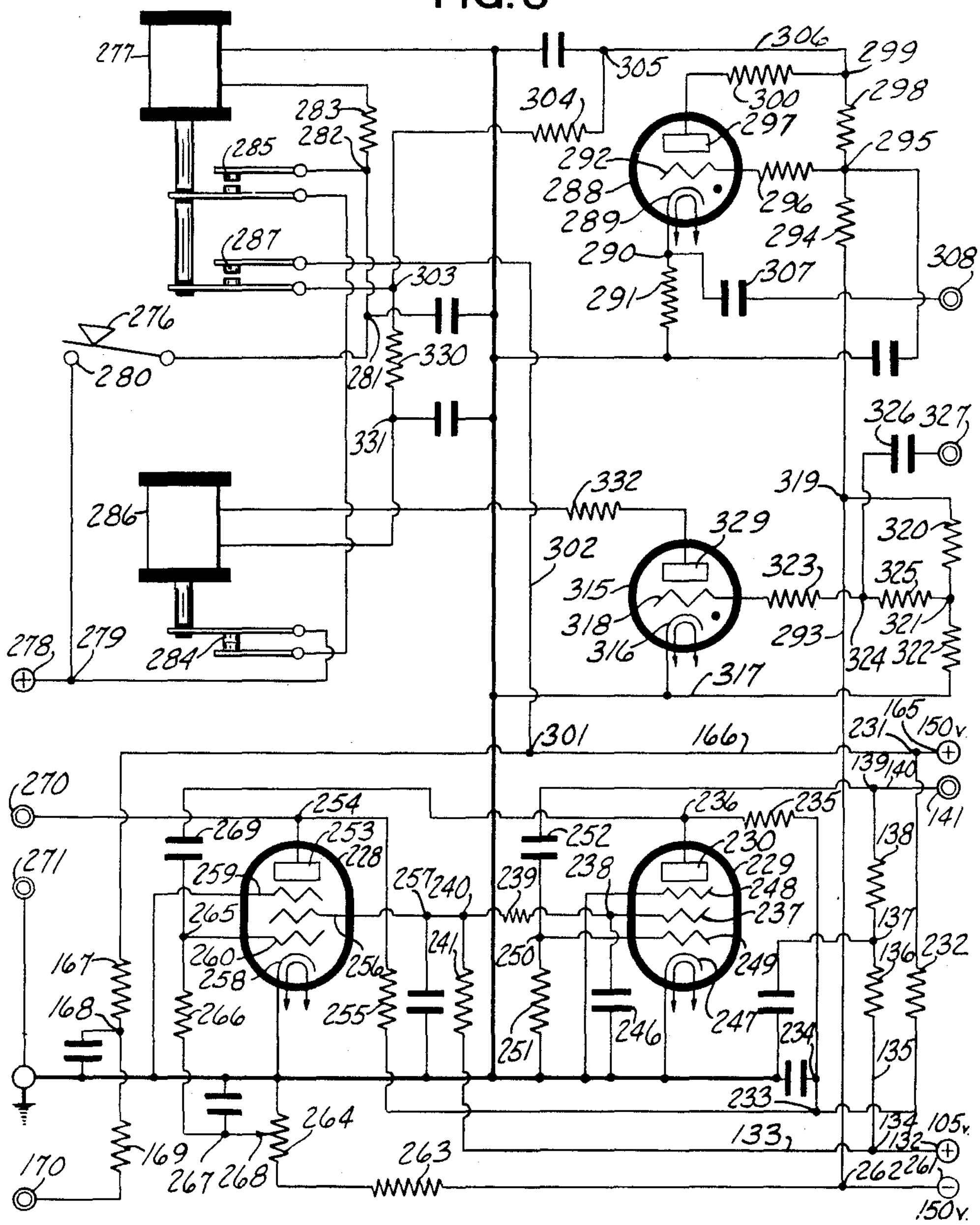
FIG. 6



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Patented Sept. 30, 1947 2,428,089

UNITED STATES PATENT OFFICE

2,428,089

COMMUNICATION SYSTEM

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Original application February 25, 1943, Serial No. 477,096. Divided and this application May 30, 1945, Serial No. 596,751

6 Claims. (Cl. 177—380)

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This application is a division of our co-pending application Serial No. 477,096, which was filed on February 25, 1943.

This invention relates to communication systems and is directed particularly to a signal-generating means for use in a system in which data is transmitted in the form of bursts of different numbers of substantially identical signals.

In the instant system, each of the several symbols that may be transmitted is transformed into a burst or train containing an assigned predetermined number of substantially identical signals having like significance. Accordingly, it is the number of signals in a burst by which each symbol is represented and not the variations in the signals, per se, which make up the bursts. Under these conditions, the signals used to transmit the data can be so chosen that slight variations which might occur in the signals during transmission will not be effective to cause errors in the reception of this data. The novel system and means employed therein, therefore, provide a reliable communication system in which slight variations in signals during transmission are not effective to cause erroneous reception of the data.

A sending station is provided with means for transforming the symbols into bursts of signals and generating the number of signals required in each burst according to the symbols being sent. The signals by which the symbols may be represented may take any desired form; for instance, they may consist of discrete rapidly recurring impulses and/or interruption or modulation of a continuous carrier wave. The signals can be transmitted from the sending station to a receiving station in any desirable manner, as, for instance, over a wire or by radio.

The bursts of signals representing the different symbols to be transmitted are sent one after another over a single communication channel, with a predetermined time interval or space between the bursts. The signals in the various bursts are used to cause the operation of means at the receiving station to set up direct representations of the symbols, and the spaces between successive bursts of signals are used to enable means at the receiving station to generate control signals which control routing means at the receiving station to govern the allocation and storage of the symbols in the means for setting up direct representations of the symbols.

Reliable high-speed communication of data is obtained with our novel arrangement because

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apparatus at the sending station can generate the signals at a high frequency and because the signal bursts, which are used to represent the various symbols, are made up of signals having like significance, require only the time necessary to produce the number of signals needed to represent the symbols, and can follow one after the other in transmission without unnecessary loss of time between bursts.

Furthermore, there is no particular sequential relation between the various symbols and the number of signals which may be used to represent them, so that the number of signals which are assigned to represent any symbol may be chosen arbitrarily. Because of this condition, the symbols used most frequently can be represented by the smaller number of signals, and this will also reduce the time required for the communication of data.

It is an object of the invention, therefore, to provide a novel high-speed means for sending data in the form of bursts of different numbers of substantially identical signals.

A further object of the invention is to provide a means for producing bursts of signals, each burst comprising a predetermined number of signals of equal amplitude and the several bursts being separated by uniform time intervals.

A further object of the invention is to provide a means upon which may be set a plurality of symbols comprising data to be transmitted, which symbols are transformed one after another into bursts of different numbers of substantially identical discrete signals representing the symbols and are sent out at spaced intervals over a single communication channel.

With these and incidental objects in view, the invention includes certain novel features of construction and combinations of parts, the essential elements of which are set forth in appended claims and a preferred form or embodiment of which is hereinafter described with reference to the drawings which accompany and form a part of this specification.

In the drawings:

Fig. 1 shows a portion of a set of keys for setting up a symbol in the sending apparatus and a portion of the symbol-transforming means controlled thereby for generating the number of impulses which will be sent to represent the symbol set up on the keys.

Figs. 2 to 5 inclusive are similar to Fig. 1 and together with Fig. 1 show means for setting up and generating the signals to represent five symbols in succession.

Fig. 6 shows the start and stop controls for the sending apparatus and also shows the means for amplifying and sharpening the impulses which have been generated to represent the several symbols.

GENERAL DESCRIPTION

The symbols which may be sent by the novel apparatus may represent any selected data such as the digits of numerical notation, the letters of the alphabet, or any other arbitrary data which may be chosen.

The disclosed embodiment is shown with a capacity for automatically transmitting five symbols in succession and is arranged to transmit the digits 0 to 9 inclusive of a numerical notation.

For the purposes of this disclosure, the signals by which the symbols are represented will consist of discrete rapidly recurring negative impulses of substantially uniform amplitude, and these impulses will be transmitted from the sending apparatus to the receiving apparatus over a wire. However, it is not intended to limit the invention to this particular form of signal and transmission medium, as the invention is capable of being carried out by using other equivalent arrangements.

The sending apparatus contains five groups or banks of keys. The keys of each group represent the symbols for the digits 1 to 9 inclusive and are used for setting up symbols to be transmitted. Associated with each bank of keys is a bank of gaseous electron tubes which contains a tube corresponding to each symbol represented by the keys, and, in addition to these tubes, contains a tube corresponding to the "0" symbol, and a shift tube.

The tubes of each bank are connected in a chain to be fired automatically one after another in sequence from the "9" tube through the "0" tube, and, as they are fired, they generate the impulses which make up the burst. The depressed key in any bank selects the starting point in the firing sequence by preparing its related symbol-representing tube to be fired in response to an impulse commonly impressed on all of the symbol-representing tubes; however, if no key is depressed in the bank, the "0" tube is prepared and will be fired by the impulse. Once a tube in a bank is fired, it will start the automatic firing of the other tubes in the sequence one after another until the shift tube is fired and becomes conducting. By means of these tubes, the symbol is transformed into a series of rapidly recurring impulses. The symbol-representing tubes are connected to an impulse line and send an impulse over the line each time one of the tubes is fired, and these impulses are amplified and sharpened and sent as substantially equal-amplitude impulses to a receiving apparatus.

When the last symbol-representing tube in a chain is fired, it causes the shift tube of this bank to be fired and send an impulse to the symbol-representing tubes of the next bank of tubes to fire the prepared symbol-representing tube therein and start the sequential firing of the tubes of that bank. By means of the shift tubes, various banks of tubes are rendered operative one after another in succession and enable the impulses representing the different symbols to be sent in succession over a single communication channel. The output from these generating tubes will therefore consist of a plurality of bursts of rapidly recurring equal-amplitude impulses, one burst of impulses for each bank of tubes.

After the keys in the various banks have been set according to the symbols to be transmitted, the transmission of the symbols is initiated by the operation of a start key, which causes a firing impulse to be sent to the symbol-representing tubes of the first bank of tubes to start the sequential firing of the tubes therein. The remaining banks of tubes will be rendered operative automatically in succession, and the shift tube of the last bank will cause the termination of the transmitting operation.

The invention is not limited to the use of a multiple-bank sending apparatus, because a single bank could be used repeatedly to send out successive bursts of impulses which the receiving apparatus would allocate and transform into successive settings representing the symbols in the same manner as explained above for the five-symbol sequence.

Thus it is seen that we have provided a novel signal-generating means for use in a system for communicating data over a single communication channel at a high rate of speed.

DETAILED DESCRIPTION

Sending Apparatus

The sending apparatus is shown in Figs. 1 to 6 inclusive.

The disclosed embodiment of the invention is adapted to send five symbols automatically in succession in the form of bursts of impulses having substantially the same amplitude, which bursts contain different numbers of these impulses, depending upon the particular symbols represented thereby. The burst by which the symbol "0" is represented contains one impulse; the burst for the symbol "1" contains two impulses; and the burst for the symbol "2" contains three impulses. This relation between the number of impulses and the symbols which they represent extends to the symbol "9," which is represented by ten impulses; however, the invention is not limited to this particular relation between the symbols and the numbers of impulses assigned thereto, as any desired number of impulses can arbitrarily be assigned to represent any symbol.

In the following description, the numerals "I," "II," "III," "IV," and "V" indicate the order in which the symbols are transmitted, and similar numerals will be applied to the parts of the apparatus which take part in the transmission of these symbols.

Symbol-transforming means

Five banks of keys are provided for setting up the symbols, and associated with each bank is a symbol-transforming means which generates the different numbers of impulses by which the symbols are represented. The banks are shown in Figs. 1 to 5 inclusive, and, as the banks are substantially alike, it is believed that the operation of all the banks will be clear from a description of the elements of one bank and their operation.

In this disclosure, the values of the various applied potentials are given with reference to ground. It is not intended that the invention be limited to the use of the particular potentials and values of resistance and capacitance given in the following description, because the potentials applied to the various elements of the tubes are merely selected as convenient potentials for the disclosure, and the circuit elements of resistance and capacitance correspond in relative value to the potentials chosen. It is obvious that other potentials may be used and the values of the circuit elements adjusted accordingly to maintain the proper relation between the various parts of the circuit. Throughout the drawings, the cathode heater elements are shown conventionally.

Referring to Fig. 1, which shows a symbol-transforming means for the first symbol to be transmitted, it will be seen that the symbol-transforming means is made up of a plurality of gaseous electron tubes. These tubes are of the type having an internal potential drop of about 15 volts when conducting, and having an anode, a cathode, and a control grid which is given a negative bias with respect to the cathode and will prevent the tube from firing until this bias is reduced to less than 15 volts negative with respect to the cathode.

As many symbol-representing tubes will be included in each bank as there are symbols which may be selected for transmission, and these tubes will generate the different numbers of impulses by which the symbols are represented. In the present embodiment, each group will include a tube for the symbols for the digits "0" to "9," though in Fig. 1 only the "0," "1," "2," "3," "8," and "9" tubes are shown, the symbol-representing tubes for the digits "4" to "7" inclusive having been omitted to simplify the showing of the bank because the circuits for these tubes are identical with those of other symbol-representing tubes and the operation of the symbol-transforming means can be readily understood without a showing of them.

One shift tube "Shift" is provided for the bank and is operated to shift the control of the sending of impulses, from one bank to another, by impressing a starting impulse on another bank to start the sending of another burst of impulses after the last symbol-representing tube of one bank has operated to generate the last impulse in the burst of the symbol-representing impulses.

The circuits for supplying potential to the elements of the symbol-representing tubes and for interconnecting these tubes for sequential operation are similar for all these tubes and will be clear from the explanation of the circuits shown.

Negative potential is supplied to the cathodes of the symbol-representing tubes by means of parallel circuits, one for each tube, extending to ground from a negative potential supply conductor **100**, to which a negative potential of 150 volts is applied at terminal **101**. The circuit for the "1" tube is representative and extends from the supply conductor **100** at point **103** over resistor **104** of 150,000 ohms, point **105**, a resistor **106** of 75,000 ohms, points **107** and **108**, and over resistor **109** of 15,000 ohms and capacitor **110** of .002 microfarad in parallel, to ground.

The cathode **111** of the "1" tube is connected to this circuit at point **107** and has a negative potential of approximately 9 volts when the tube is not conducting. When the tube is conducting, the cathode is also conductively coupled to its related anode by the discharge path through the tube, so that the positive potential which is applied to the anode will also be impressed on the cathode potential supply circuit and will cause the potential of the cathode to rise from a negative potential of 9 volts to a positive potential of about 70 volts.

Each cathode potential supply circuit is utilized to supply negative biasing potential for the control grid of the next tube in the sequence, which is, in this case, the "0" tube. From the point **105** in the cathode potential supply circuit for the "1" tube, a connection extends through point **112**, over resistor **113** of 500,000 ohms, point **114**, resistor **115** of 50,000 ohms, to the control grid **116** of the "0" tube and provides this grid with a negative biasing potential of approximately 56 volts. This connection between the cathode potential supply circuit of one tube and the control grid of the next adjacent tube of the series enables the potential rise of the cathode of one tube to reduce the bias of the control grid of the next tube in the sequence to a value below its critical potential and will cause the next tube to automatically fire and become conducting.

Since the "9" tube is the first tube in the sequence, the control grid **117** of this tube is given a biasing potential of the same value as the grids of the other tubes by means of a circuit which is equivalent to the other cathode potential supply circuits and extends from the negative potential supply conductor **100** at point **118**, over resistor **119** of 150,000 ohms, point **120**, and resistor **121** of 90,000 ohms to ground, to which circuit the grid **117** is connected from point **120** over resistor **122** of 500,000 ohms, point **123**, and resistor **124** of 50,000 ohms.

Each control grid of the symbol-representing tubes is electrostatically connected to a firing impulse conductor **130**, the connection for the grid **116** of the "0" tube extending from point **114** in the grid circuit, over a capacitor **131** of 10 micro-microfarads to the conductor **130**. The firing impulses, which are positive potential impulses impressed on conductor **130**, tend to reduce the negative bias of the control grids below their critical value but are not sufficient to overcome the normal negative bias. The firing impulse will be effective to cause a tube to be fired only if that tube has been "primed" or has its grid bias reduced to near the critical point so that the firing impulse can reduce the bias below its critical point and cause the tube to fire and become conducting. The manner in which the tubes can be "primed" will be explained hereinafter.

Positive potential is supplied to the anodes of the symbol-representing tubes by a circuit which extends from terminal **132** (Fig. 6), upon which is impressed a positive potential of 105 volts, and continues over conductor **133**, point **134**, conductor **135**, a resistor **136** of 250 ohms, point **137**, a resistor **138** of 3,000 ohms, point **139**, and conductor **140** to the common anode potential supply terminal **141** for the symbol-representing tubes.

Point **137** in this circuit is connected to ground over a capacitor of 8 microfarads, which capacitor absorbs the shock of any abrupt potential application or change in the circuit.

Terminal **141** is connected to terminal **142** (Fig. 1), to which is connected an anode potential supply conductor **143** for the symbol-representing tubes of this bank. Each of the anodes of the symbol-representing tubes of this bank is connected over a resistor of 1,000 ohms to the anode potential supply conductor **143**, as, for instance, resistor **144**, over which the anode **145** of the "1" tube is connected to the anode potential supply conductor **143**.

When none of the symbol-representing tubes is conducting, a positive potential of 105 volts is applied to the anodes; however, when one of these tubes is conducting, the potential will be reduced to about 85 volts due to the drop across the resistors **136**, **138**, and **144**.

At the moment one of these tubes is fired, its cathode will remain at a negative potential of 9 volts, while the capacitor, as 110, is charging, and, due to the resistance in the common anode potential supply circuit for the symbol-representing tubes and the internal potential drop of the tube, the potential of the anode will drop to within about 15 volts of the cathode potential. This will cause a drop in potential of the anode potential supply conductor 143, which drop provides a negative potential impulse on the conductor. As the anodes of all the symbol-representing tubes of a bank are connected to the anode potential supply conductor 143, a series of negative impulses will occur on the conductor as these tubes are fired one after another. These impulses are sent to the receiving apparatus after they have been amplified and sharpened.

The drop in the potential of the anode potential supply conductor 143 is also used to extinguish any previously conducting tube which has its anode connected to the common source of anode potential for the symbol-representing tubes, which includes the resistors 136 and 138. The extinguishing action occurs because the potential of all the anodes of these tubes will drop as the potential of the anode supply conductor 143 drops, and this will cause the potential of the anode of a previously conducting tube to drop below the potential of its cathode, which has risen due to conduction in the tube, and will cause conduction to cease in that tube and enable the control grid to regain control.

Cathode 151 of the shift tube is normally supplied with a negative potential of approximately 9 volts by being connected at point 152 in a circuit extending from point 153 on the negative potential supply conductor 100, over resistor 154 of 390,000 ohms, point 155, point 152, and to ground over resistor 156 of 25,000 ohms in parallel with resistor 157 of 2,500 ohms in series with capacitor 158 of .002 microfarad. When the shift tube fires and becomes conducting, the potential of the cathode 151 will rise to a positive potential of about 110 volts, and this potential rise is used as a firing impulse to start the sequential firing of the tubes in bank II.

The control grid 159 of the shift tube obtains its negative bias from the cathode potential supply circuit for the "0" tube. This connection is from point 160 in the cathode potential supply circuit of the "0" tube and over point 161 and resistor 162 of 500,000 ohms to the control grid 159. The potential rise of the cathode of the "0" tube, when that tube is conducting, is effective to reduce the negative bias on the control grid 159 and cause the shift tube to fire and become conducting. A capacitor 163 of 3,000 micro-microfarads is connected between point 161 in this circuit and ground to delay potential rise of the control grid 159 and the consequent firing of the shift tube after the firing of the "0" tube. This delay in the firing of the shift tube provides a time interval between bursts, which interval may be made longer or shorter as desired by varying the capacity of capacitor 163.

Potential is supplied to the anode 164 of the shift tube by a circuit which starts at the terminal 165 (Fig. 6), which has a positive potential of 150 volts impressed thereon, and continues over conductor 166, resistor 167 of 250 ohms, point 168, and resistor 169 of 3,000 ohms to the common anode potential supply terminal 170 for the shift tubes. Point 168 in this circuit is connected to ground over a capacitor of 4 microfarads. Terminal 170 is connected to terminal 171 (Fig. 1), to which the anode 164 of the shift tube is connected. As in the case of the anodes of the other tubes of the bank, the potential of the anode will drop to about 15 volts above the potential of the cathode, while the capacitor 158 is charging, and this potential drop will be effective to extinguish any previously conducting tube which derives its anode potential over the resistors 167 and 169 (Fig. 6) in the common anode potential supply circuit for the shift tubes. Since the anodes of the symbol-representing tubes have a different anode potential supply circuit from that of the shift tubes, the firing of the shift tube will be ineffective to extinguish the "0" tube, which is the last symbol-representing tube in the bank to be fired. The "0" tube, therefore, which is conducting at the end of an operation of the tubes of the bank, remains in this condition until the first symbol-representing tube of the next bank is fired.

The sequential and automatic firing of the tubes of a bank always begins with a symbol-representing tube and is initiated by a firing impulse. As explained earlier herein, the control grids of the symbol-representing tubes are electrostatically connected to the firing impulse conductor 130 but are normally sufficiently negatively biased so that a firing impulse impressed on the conductor will not be effective to reduce the bias below its critical point to cause any of the tubes to be fired and rendered conducting. In order that a firing impulse will be effective to fire a tube, the tube must be "primed" by having the normal bias of its grid reduced to such a degree that the firing impulse will be sufficient to carry the bias below the critical value and cause the tube to fire and become conducting; accordingly, the selection of the tube with which the sequential operation of the tubes in the bank is to begin can be effected by the selective "priming" of the tubes. This is accomplished under control of the keys upon which the symbols may be set.

Fig. 1 shows schematically a portion of the row of keys upon which the first symbol to be transmitted may be entered. Only the keys for the digits "1," "2," "8," and "9" are shown, the keys for the digits "3" to "7" inclusive having been omitted to simplify the showing of the bank, inasmuch as the circuits controlled by the omitted keys are similar to the circuits shown and the operation of the keys to selectively prime the tubes can be understood from the circuits shown.

The keys of the bank are normally in an underpressed condition, and when in this position they complete a priming circuit to the "0" tube, which circuit starts at terminal 175, upon which a positive potential of 105 volts is impressed, and continues over potential supply conductor 176, point 177, conductor 178, key-controlled contacts, as 179, in series, and over conductor 180 and resistor 181 of 300,000 ohms to point 112 in the circuit to the control grid 116 of the "0" tube.

When any key of this bank is depressed, it interrupts the priming circuit described above and closes a priming circuit from the potential supply conductor 176 to the control grid of its related symbol-representing tube. The "1" key 182 (Fig. 1) is shown depressed, interrupting the priming circuit to the "0" tube at the point 183 and completing a priming circuit to the control grid 184 of the "1" tube. The priming circuit for control grid 184 extends from point 185 on the potential supply conductor, over contact 179 of the depressed "1" key, conductor 186, and over resistor 187 of 300,000 ohms to point 188 in the circuit to control grid 184.

The application of positive potential by this circuit to the control grid 184 of the "1" tube reduces the negative biasing potential of the control grid 184 almost to its critical point, and, when the firing impulse is impressed on the tubes, the bias of the control grid of the "1" tube will be reduced to within 15 volts negative with respect to the potential of the cathode, and the tube will fire and become conducting. In a similar manner, the closure of a priming circuit to any of the other symbol-representing tubes will select that tube to begin the sequential and automatic firing of the tubes of the bank.

The operation of the symbol-transforming means shown in Fig. 1, by which the burst of impulses corresponding to the first symbol to be transmitted is obtained, will now be explained.

The key 182 corresponding to the digit "1" has been depressed to interrupt the priming circuit to the "0" tube and complete the priming circuit for the "1" tube. A firing impulse is impressed on the firing impulse conductor 130 and causes the firing of the "1" tube. At the moment the "1" tube is fired, its anode potential will drop because of the resistor 144 and the resistors 136 and 138 in the symbol-representing tube anode potential supply circuit, causing a drop to occur on the conductor 143, terminal 142, and terminal 141 (Fig. 6) of the anode potential supply circuit, which drop is amplified and sharpened to provide an impulse to be sent to the receiving apparatus. The potential of the cathode of the conducting "1" tube will rise and, through the connection between point 105 in its potential supply circuit and the control grid 116 of the "0" tube, will cause the potential of the control grid 116 to rise and reduce the bias below its critical value and cause the "0" tube to fire and become conducting. The potential of the anode of the "0" tube will drop and cause another impulse on conductor 143, terminal 142, and terminal 141 in the anode potential supply circuit, which impulse will also be amplified and sharpened to provide another impulse to be sent to the receiving apparatus, and, in addition, the impulse on conductor 143 will also extinguish the conducting "1" tube. The potential of the cathode of the "0" tube will rise and cause the potential of the grid 159 of the shift tube "Shift" to rise, reducing its bias below its critical value and causing the shift tube to fire and become conducting.

There is a predetermined delay in the potential change on the control grid 159, due to the capacitor 163, which connects the point 161 in this circuit to ground, which delay provides the time interval or spacing between the successive bursts of impulses.

When the shift tube fires, there will be a potential drop in its common anode supply circuit, due to the resistors 167 and 169. However, this drop will not be effective to extinguish the "0" tube, because its anode is included in a different anode potential supply circuit. The potential rise of the cathode 151 of the shift tube is impressed on terminal 189 and is used as a starting impulse for the next bank of tubes to be fired.

It is seen that, during the sequential firing of the tubes of the bank, two impulses will occur on the terminal 141 for controlling the amplifying and sharpening tubes, which amplify and sharpen the impulses before they are sent to the receiving apparatus. After the signal-generating impulses have been provided, an impulse will be impressed on the terminal 189 to cause the firing of the primed tube in the next bank of tubes. Also, it will be noted that, at the end of the operation of the tubes of a bank, the shift tube and the "0" tube will remain conducting. These tubes will be extinguished in a manner to be described later.

Each of the other symbol-transforming banks operates in the same manner as the bank described above. The banks shown in Figs. 2, 3, 4, and 5 generate the impulses which represent the second, third, fourth, and fifth symbols, respectively, and are accordingly numbered "II," "III," "IV," and "V" to indicate the sequence of their operation.

The coordination and interconnections between the various symbol-transforming banks which generate the impulses for the five symbols are as follows:

Each of the negative potential supply conductors 191, 192, 193, and 194 for the banks "II," "III," "IV," and "V" is connected, respectively, to a terminal as 195, 196, 197, and 198, upon which is impressed a negative potential of 150 volts.

The symbol-representing tube anode potential supply conductors 199, 200, 201, and 202 for banks "II," "III," "IV," and "V" have their terminals 203, 204, 205, and 206 connected to the common supply terminal 141 (Fig. 6), so that these supply conductors for all the banks will be connected together at the terminal 141 and from this terminal will be connected over the common resistors 136 and 138 to the source of potential. In this network, the firing of any symbol-representing tube in any bank will cause a potential drop in the supply conductors of all the banks, thus enabling the firing of a tube in any bank to extinguish a previously conducting tube in any other bank; for instance, the "0" tube, which remains conducting when the operation in the first bank is completed, is extinguished by the firing of the first symbol-representing tube in the second bank. This arrangement also enables the firing of a tube in any bank to cause a potential drop at the terminal 141, which drop can be amplified and sharpened and sent as an impulse to the receiving apparatus.

The anodes of the shift tubes of the various banks are all connected to the common anode potential supply circuit by having the terminals 207, 208, 209, and 210 (Figs. 2, 3, 4, and 5), to which they are connected, connected with the terminal 170 (Fig. 6). The potential drop of the anode of any shift tube, as the tube is fired, will cause any previously conducting shift tube to be extinguished, thus enabling the firing of the shift tube for the second bank to extinguish the shift tube of the first bank.

The various banks of tubes are connected for sequential operation by having the firing impulse conductor of a bank connected to the cathode of the shift tube of the bank previously operated. The terminal 189 (Fig. 1) is coupled by capacitor 211 of .001 microfarad to the cathode 151 of the shift tube of the first bank and is also connected to the terminal 212 (Fig. 2), to which the firing impulse conductor 213 of the second bank is connected, so that the potential rise of the cathode 151, as the shift tube is fired, can be impressed on the firing impulse conductor 213 of the second bank to fire any primed symbol-representing tube therein and initiate the sequential firing of the tubes of the second bank. Point 214 on the firing impulse conductor 213 is connected to ground over resistor 215 of 15,000 ohms. The capacitor 211 and the resistor 215 serve to sharpen the firing impulse impressed on firing conductor 213 when the shift tube of the first bank is fired, so that the firing impulse will be effective in the firing of only the primed tube of the sequence. The terminal 216 (Fig. 2), which is electrostatically coupled to the cathode of the shift tube of the second bank, is also connected to the terminal 217 (Fig. 3), to which the firing conductor 218 of the third bank is connected. The terminal 219 (Fig. 3) is connected to the terminal 220 (Fig. 4) to start the sequential operation in the fourth bank, terminal 221 (Fig. 4) is connected to terminal 222 (Fig. 5) to start the sequential operation in the fifth bank after the fourth bank has completed its operation. By means of these connections, the impulses for the five bursts can be formed automatically in succession.

Each of the symbol-transforming banks of tubes has a bank of keys, similar to the bank shown in Fig. 1, for selectively closing priming circuits to the symbol-representing tubes therein.

Impulse amplifying and sharpening means

As explained earlier herein, the signals which are transmitted in the novel communication system are such that variations which might occur in the signal during transmission are not effective to produce erroneous results at the receiving apparatus. In the instant embodiment, the signals which are generated by the symbol-transforming means are sharpened and amplified until they have a much greater amplitude than is necessary for the proper operation of the receiving apparatus, and this allows reasonable variations in the amplitude of the signal to occur during transmission without causing an improper operation of the receiving apparatus.

The means for amplifying and sharpening the impulses before they are sent to the receiving apparatus is shown in Fig. 6 and consists of a pair of vacuum tubes 228 and 229.

Tube 229 has a zero bias and is normally conducting. The anode 230 has positive potential applied thereto from terminal 165, the connection being over point 231, resistor 232 of 250 ohms, points 233 and 234, resistor 235 of 5,000 ohms, and point 236. Point 234 is connected to ground over a stabilizing capacitor of 8 microfarads. Screen grid 237 is connected to terminal 132, to which a positive potential of 105 volts is applied, the connection being over point 238, resistor 239 of 750 ohms, point 240, and resistor 241 of 250 ohms to conductor 133. A stabilizing capacitor 246 of 4 microfarads is connected between point 238 and ground. The cathode 247 and the suppressor grid 248 are connected directly to ground, and the control grid 249 is connected to ground over point 250 and resistor 251 of 10,000 ohms.

Point 250 in the circuit of control grid 237 is coupled over capacitor 252 of 10 micro-microfarads to terminal 141, the potential of which terminal drops to provide a negative impulse each time a symbol-representing tube in any bank is fired. These negative impulses are impressed on the control grid 237 and reduce conduction in tube 229. Since tube 229 is normally conducting, its anode 230 will normally have a positive potential of about 20 volts due to the drop across resistor 235, but, as conduction is reduced in the tube 229, by the negative impulses impressed on the control grid 237, the potential of the anode 230 will rise toward 150 volts and will provide positive impulses which are used to control tube 228.

Tube 228 is normally non-conducting but is rendered conducting each time a positive potential impulse occurs on the anode 230 of tube 229. Of the elements of tube 228, the anode 253 is connected over point 254 and resistor 255 of 5,000 ohms to point 233 in the circuit previously traced for the anode 230 of tube 229; the screen grid 256 is connected over point 257 to point 240 in the circuit previously traced for the screen grid 237 of tube 229; and the cathode 258 and the suppressor grid 259 are directly connected to ground. Point 257 in the screen grid circuit is coupled to ground over a stabilizing capacitor of 4 microfarads.

Control grid 260 of tube 228 is given a negative bias by being connected to a circuit which starts at terminal 261, upon which a negative potential of 150 volts is impressed, and continues to ground over point 262, resistor 263 of 100,000 ohms, and resistor 264 of 25,000 ohms. The control grid is connected to this circuit over point 265, resistor 266 of 50,000 ohms, point 267, and an adjustable potential-tapping member 268, which cooperates with the resistor 264 to provide the desired negative bias for the control grid. Point 267 is coupled to ground over a stabilizing capacitor of 10 microfarads.

Point 265 in the control grid circuit is electrostatically coupled to point 236 in the anode circuit for tube 229 over a capacitor 269 of 20 micro-microfarads, which coupling enables the positive potential impulses, which occur on point 236 when conduction is reduced in tube 229, to reduce the negative bias on the control grid of tube 228 and render that tube conducting.

Since tube 228 is normally non-conducting, its anode will normally have a positive potential of 150 volts, but this potential is reduced by the drop across resistor 255 each time the tube becomes conducting in response to an impulse impressed on control grid 260, and these potential drops which occur at anode 253 are impressed as output impulses on output terminal 270, point 254 in the anode circuit being connected to terminal 270, which, with terminal 271, forms the output terminals for the sending apparatus.

In the above manner, the negative impulses which are generated by the firing of the symbol-representing tubes are amplified and sharpened for transmission to the receiving apparatus.

Symbol transmission initiating and terminating means

After the symbol-representing keys of the various banks have been set to prime their corresponding symbol-representing tubes, the transmission of these symbols is initiated by a momentary depression of the start key 276 (Fig. 6), which closes the energizing circuit for the starting relay 277; the circuit extends from the terminal 278, upon which may be impressed any desirable positive potential, to the point 279, thence over the contacts 280 closed by the key 276, points 281 and 282, resistor 283 of 2,500 ohms, and over the winding of the starting relay 277 to ground. Point 281 in this circuit is connected to ground over a stabilizing capacitor of .1 microfarad. When the starting relay 277 is energized upon the closure of contact 280 by the start key 276, it closes a holding circuit for itself from terminal 278, point 279, normally closed contacts 284, contacts 285 closed by the starting relay, point 282, and over resistor 283 and the winding of the starting relay 277 to ground. This circuit will mantain the starting relay in energized condition after the starting key has been released and until the normally closed contacts 284 are opened by the energization of the stop relay 286, in a manner to be explained hereinafter, to terminate a transmitting operation.

The starting relay 277 also closes contacts 287 to cause the firing of a start tube 288, which sends an impulse to the firing impulse conductor 130 (Fig. 1) of the first symbol-transforming bank.

Start tube 288 (Fig. 6) is a gaseous electron tube of the type described earlier herein. This tube has its cathode 289 connected to ground over point 290 and resistor 291 of 25,000 ohms. Before the starting relay is energized, the control grid 292 of the start tube is given a negative potential bias of 150 volts by means of a circuit which starts at the terminal 261, upon which is impressed a negative potential of 150 volts, and continues over point 262, conductor 293, resistor 294 of 500,000 ohms, point 295, and resistor 296 of 500,000 ohms to the grid 292. The anode 297 is also given a negative potential of 150 volts before the starting relay is energized, which potential is obtained through a circuit from the point 295 in the grid circuit, over a resistor 298 of 500,000 ohms, point 299, and resistor 300 of 8,000 ohms.

When the starting relay 277 closes its contact 287, positive potential is applied to the anode 297 over a circuit which starts at the terminal 165, upon which is impressed a positive potential of 150 volts, and continues over conductor 166, point 301, conductor 302, contacts 287, point 303, resistor 304 of 250 ohms, point 305, conductor 306, point 299, and resistor 300. Point 305 in this circuit is connected to ground over a stabilizing capacitor of .1 microfarad. When the positive potential is applied to the anode 297 by the closing of the contacts 287, the circuit from point 299 to point 295 in the grid circuit causes the positive potential to be applied to the grid 292 and causes its potential to change from 150 volts negative to approximately ground potential. The application of positive potential by the closing of the contacts 287 has caused the anode 297 of the start tube to acquire a positive potential and the grid 292 to become more positive than fifteen volts negative with respect to the cathode 289, which will cause the start tube 288 to fire and become conducting. Point 295 is connected to ground over a capacitor of .5 microfarad, which provides a slight delay in the firing of tube 288 after positive potential has been applied by the closing of contacts 287.

Resistor 291 in the cathode circuit will cause the potential of the cathode 289 to rise sharply when the tube becomes conducting, and this rise is utilized as the firing impulse for the first bank of symbol-transforming tubes. The firing impulse is derived from point 290, which is electrostatically coupled by capacitor 307 of .001 microfarad to the terminal 308, which terminal is connected to the terminal 309 (Fig. 1), to which the firing impulse conductor 130 for the first bank of symbol-transforming tubes is connected. Point 310 (Fig. 1) on the firing conductor 130 is connected to ground over resistor 311 of 15,000 ohms. Capacitor 307 and resistor 311 cooperate to sharpen the firing impulse, enabling the effect of the firing impulse to be removed from the control grids of the other tubes of the bank before the conduction in the previously "primed" tube is effective to cause the next tube in the sequence to be fired and rendered conducting in the normal manner, thus insuring substantially uniform intervals between the impulses of a burst.

After the transmission of the symbols has been initiated, the symbol-transforming banks will be operable one after another in sequence to generate impulses until the shift tube of the fifth bank has fired and become conducting. The potential rise of the cathode of this tube is utilized to fire a stop tube 315 (Fig. 6), which causes the termination of the transmission by energizing the stop relay 286 and thereby opening the holding circuit for the starting relay.

The cathode 316 of the stop tube 315 is at ground potential, being connected to ground over conductor 317. The grid 318 is given a negative biasing potential of approximately 34 volts by being connected to a potential supply circuit which extends from terminal 261, which is supplied with a negative potential of 150 volts, and continues over point 262, conductor 293, point 319, resistor 320 of 500,000 ohms, point 321, resistor 322 of 150,000 ohms to ground over conductor 317. The grid 318 is connected over resistor 323 of 50,000 ohms, point 324, and resistor 325 of 500,000 ohms to the point 321 in the potential supply circuit.

A circuit extends from point 324 over a capacitor 326 of 10 micro-microfarads to the terminal 327, which is connected to the terminal 328 (Fig. 5), to which the cathode of the shift tube is connected. This circuit enables the potential rise of the cathode of the shift tube of the fifth bank to reduce the bias of the grid 318, causing the stop tube to fire and terminate the operation of the sending apparatus.

The anode 329 of the stop tube 315 has positive potential applied thereto when contact 287 is closed by the starting relay. The circuit extends from the terminal 165 and over the contacts 287 to the point 303, as explained above, and then continues over resistor 330 of 500 ohms, point 331, the winding of the stop relay 286, and over resistor 332 of 10,000 ohms to the anode 329. Point 331 in this circuit is connected to ground over a stabilizing capacitor of .1 microfarad. Until the stop tube fires and becomes conducting, there will be no current in the circuit which includes the winding of the stop relay 286; however, as soon as the tube is fired and becomes conducting, current will flow through the winding of the stop relay 286, which will be energized and will open the contacts 284. The contacts 284 will break the holding circuit for the starting relay 277, which will be de-energized and will open contacts 285 and 287. Contact 285 will also interrupt the holding circuit for the starting relay 277 to prevent its re-energization when the contacts 284 close as the stop relay is de-energized. Contacts 287 open the anode circuit for the start and stop tubes, extinguishing these tubes and de-energizing the stop relay.

The operation of the stop tube, therefore, causes the termination of the operation of the sending apparatus and restores the starting controls to the condition which existed prior to the operation of the start key 276.

Operation

In the operation of the novel communication system, the keys of the sending apparatus are depressed according to the symbols to be sent. The keys, which in the instant embodiment correspond to the digits 1 to 9 inclusive, are effective to prime related tubes in the banks of impulse-generating tubes to control with which tube the sequential firing of the tubes of a bank will begin. In any bank in which no key has been depressed, the "0" tube is automatically selected.

After the keys in the various banks have been depressed to set up the symbols to be transmitted, a start key is operated to initiate the generation of the bursts of impulses. The operation of the start key initiates the sequential firing of the tubes of the first bank to generate the impulses of the first burst, and, when the "0" tube is fired to generate the last impulse of the burst, it causes the shift tube to be fired after a slight delay. The firing of the shift tube initiates the sequential firing of the tubes in the second bank to generate a second burst of impulses, which are separated from the first burst by a space or time interval. In a like manner, the tubes of the third, fourth, and fifth banks of tubes will be operated in succession to produce spaced bursts of impulses containing the desired number of impulses as determined by the setting of the keys of the keyboard. The impulses which are generated by the several banks of tubes form an impulse train containing a plurality of spaced bursts of similar negative impulses having like significance, which impulses are generated at a high rate of speed and are sent out one after another over a single communication channel to the receiving apparatus.

With the values given herein for the resistors and capacitors in the various circuits, the impulses are generated at a rate of about 40 kilocycles, and the time interval between bursts is about 150 micro-seconds.

While the form of the invention shown and described herein is admirably adapted to fulfill the objects primarily stated, it is to be understood that it is not intended to confine the invention to the one form or embodiment disclosed herein, for it is susceptible of embodiment in various forms all coming within the scope of the claims which follow.

What is claimed is:

1. In a communication system having a sending apparatus and a receiving apparatus, the combination of a plurality of groups of electronic devices in the sending apparatus; means connecting the devices of each group so that they will operate and become conducting one after another in sequence; control means to select the device in each of the various groups with which the sequential operation of the devices in that group will commence; means including time delay means for connecting the groups so that the sequential operation of the devices in the groups will take place in one group after another in sequence with a substantially uniform interval of time between the operation of the last device of one group and the operation of the first device of the next group; means to initiate the operation of the selected device in the first of the groups to operate; and means connected to all the devices to produce an impulse each time any of the devices in any group is operated and becomes conducting whereby to provide spaced groups of equal amplitude impulses which have like effect on the receiving apparatus.

2. In a communication system having a sending apparatus and a receiving apparatus, the combination of a plurality of groups of electronic devices in the sending apparatus; means connecting the devices of each group so that they will operate and become conducting one after another in sequence; means to determine in each group the number of devices to be operated, means connecting the groups so that the sequential operation of the devices in the groups will take place in one group after another in sequence, the connecting means including delay means to delay the initiation of the sequential operation of the devices of the next group after the last device of a previous group has operated; means connected to all the devices to produce an impulse each time any of the devices in any group is operated and becomes conducting; means to initiate the sequential operation of the selected number of devices in the first group to be operated; and impulse sharpening and amplifying means, controlled by the means connected to all the devices, for sharpening and amplifying the generated impulses to produce groups of substantially identical impulses having an amplitude sufficiently greater than that necessary to control the receiving apparatus that possible variations which might occur in the impulses during transmission will not cause erroneous results in the reception thereof.

3. In a communication system having a sending apparatus and a receiving apparatus, the combination of a plurality of groups of gaseous electron tubes in the sending apparatus; means connecting the tubes of each group so that they will be fired and rendered conducting one after another automatically in sequence; control means to select the number of tubes to be operated in each group according to the data to be transmitted; means connecting the groups so that the sequential firing of the tubes in the groups will take place in one group after another in sequence, the connections between groups including timing means which delays the initiation of the sequential operation of the tubes of the next group for a predetermined time; means to initiate the sequential operation of the tubes of the first group of tubes to be operated; means connected to all the tubes to produce an impulse each time any of the tubes in any group is fired and becomes conducting; and impulse sharpening and amplifying means, controlled by the means connected to all the tubes, for sharpening and amplifying the generated impulses to produce spaced groups of equal amplitude impulses which have like effect on the receiving apparatus.

4. In an apparatus of the class described, the combination of a plurality of banks of electronic devices; means connecting the electronic devices of each bank so that they will operate and become conducting automatically one after the other in sequence after any electronic device of the bank has been operated; means enabling each electronic device to generate an impulse when it becomes conducting; a plurality of banks of manipulative devices, one bank related to each bank of electronic devices; means controlled by the manipulative devices for selecting the electronic device in each bank with which the sequential operation is to begin; means to cause the selected electronic device in the first bank to be operated, to operate and initiate the automatic operation of the electronic devices succeeding the selected electronic device in the sequence in that bank; means to connect the banks of electronic devices for sequential operation, including a connection from the last electronic device in the sequence in one bank to the electronic devices of the next bank to be operated, said connection including delaying means, whereby the operation of the last electronic device in the sequence in one bank will cause the selected electronic device in the next bank to be operated and initiate the automatic operation of

the electronic devices in the next bank after a predetermined delay or pause; and impulse sharpening and amplifying means to sharpen and amplify the impulses generated by the various banks to provide groups of substantially identical impulses.

5. In an apparatus of the class described, the combination of a bank of electronic devices; means connecting the electronic devices in a chain sequence so that they will operate and become conducting automatically one after another in sequence toward one end of the chain after any electronic device in the chain has been rendered conducting to initiate the sequential operation of the electronic devices; a plurality of manipulative devices; means for selecting a predetermined one of said electronic devices to initiate the sequential operation of the electronic devices when none of the manipulative devices has been operated; means rendered operable by the manipulative devices, when operated, to select other of the electronic devices to initiate the sequential operation of the electronic devices; any manipulative device, when operated to select one of the other of the electronic devices, being operable to disable the means for selecting said predetermined one of the electronic devices; and means to cause the selected electronic device of the bank to become conducting and initiate the automatic sequential operation of the electronic devices in the bank.

6. In a device of the class described, the combination of a plurality of gaseous electron tubes, each tube containing an anode, a cathode, and a control grid; means to supply positive potential to the anodes of the tubes; separate negative potential supply means for the cathode of each tube, said separate supply means including resistors to cause the potential of the cathode of a tube to rise when that tube becomes conducting; means for supplying negative potential bias to the control grids and for connecting the tubes for automatic operation one after another in sequence, said last-mentioned means consisting of circuits extending from the cathode potential supply means for any of the various tubes to the control grid of the next tube to be operated in the sequence, said circuits supplying normal negative bias to the control grids and enabling the potential rise of the cathode of a tube in the sequence to reduce the bias of the control grid of the next tube in the sequence to cause the automatic sequential firing of the tubes in the bank after any tube in the bank has been fired and rendered conducting; means to impress a starting impulse on the control grids of the tubes, said starting impulse being ineffective to overcome the normal negative bias on the control grids but being effective to cause the firing of only the tube which has had the bias on its control grid reduced and thereby has been selected to initiate the sequential firing of the tubes; means normally reducing the bias on the control grid of one of said tubes; normally inoperative means for reducing the bias on other of said tubes; and a plurality of manipulative means for disabling the means for reducing the bias on said one tube and for selectively rendering one or another of the normally inoperative means operative to thereby select one of said other tubes to initiate the sequential operation instead of said one tube.

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