

Nov. 24, 1942.

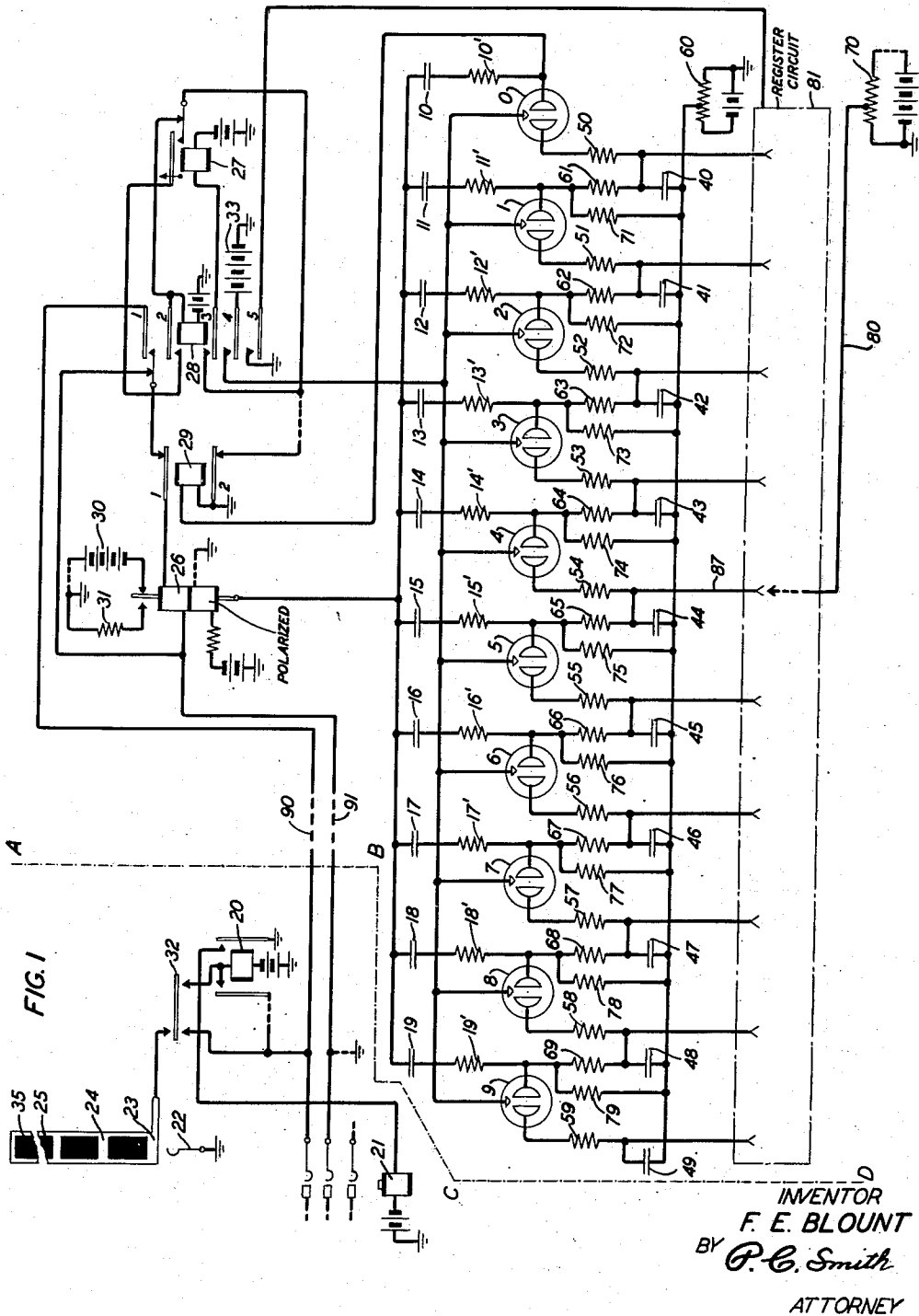
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2,303,016

IMPULSE COUNTING CIRCUIT

Filed June 20, 1941

2 Sheets-Sheet 1



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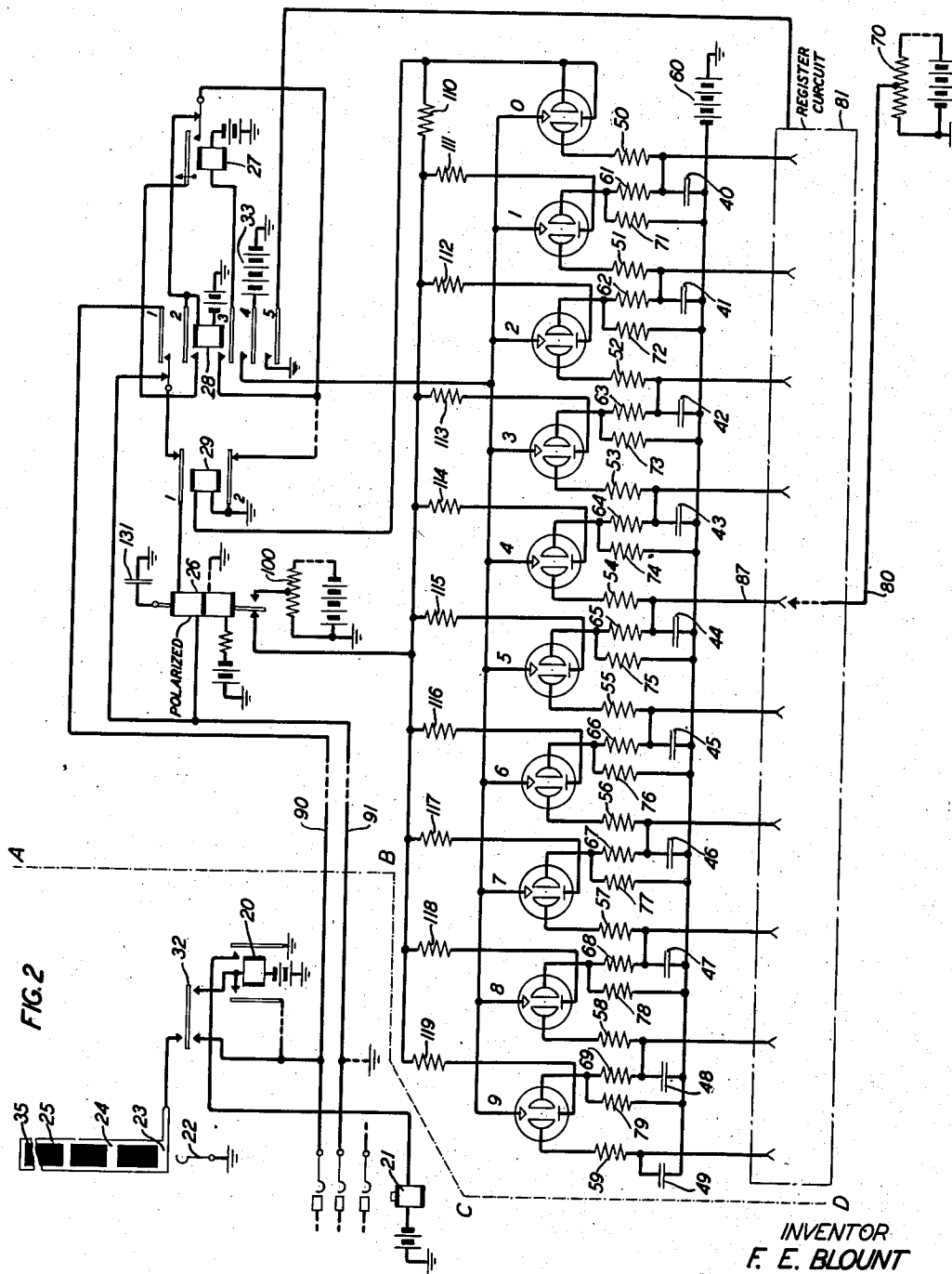
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2 Sheets-Sheet 2



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2,303,016

IMPULSE COUNTING CIRCUIT

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7 Claims. (Cl. 179-16)

This invention relates to telephone systems and more particularly to the utilization in the impulse recording circuits thereof of gaseous discharge or conductor tubes as impulse responsive relays.

In a machine switching telephone system of the type employing a common sender which controls the setting of selector switches, the sender is provided with registers which are set by series of impulses dialed by a subscriber in accordance with the directory number of a desired line. If the sender is employed in a telephone system of the type using power driven selector switches, for example the panel type, the setting of the switches is controlled in accordance with the setting of the sender registers by impulses transmitted revertively to the sender by the switches during their selective movements. The control circuit, known as the fundamental circuit, has heretofore comprised a control relay in the selector at the time associated with the sender and an impulse responsive or stepping relay in the sender. When the control circuit is established preparatory to setting the switch, both relays are operated by battery and ground usually applied at the switch to the two conductors, respectively, of the fundamental circuit. The operation of the control relay at the switch starts the movement of the brush shaft of the switch, while the operation of the impulse relay in the sender prepares the sender for controlling the amount of the selective movement of the brush shaft of the switch. The switch is provided with a commutator which, as the brush shaft advances, intermittently connects ground to the conductor of the control circuit to which battery is connected, thereby intermittently shunting the impulse relay of the sender. The intermittent operation of the impulse relay controls the successive operation of a train of counting relays the end relay of which, when operated, opening the control circuit to arrest further movement of the brush shaft of the switch. The number of counting relays operated by the impulse relay to control the amount of selective movement of the switch is determined by the setting of the register of the sender which determines at what relay in the train of counting relays the impulse relay is to start the operation of the train.

The present invention provides for the replacement of the usual train of counting relays by a group of gaseous conductor or discharge tubes. The gaseous conductor tube utilized in the present invention is a tube filled with a low pressure

gaseous content which, for purposes of illustration, might be neon, argon, helium, mercury vapor or a combination of gases of this group. The tube has a certain characteristic, namely, that

upon application of a certain difference of potential to its electrodes, its gaseous content will become ionized and thus conducting, but once rendered conducting will remain in this condition of conductivity on a much lower potential. More specifically, the tube contemplated for use in the present invention is a gas-filled device provided with one or more control anodes, a cathode and a main anode. A difference of potential is applied to the cathode and one of the control anodes, the difference being of such a value as to cause ionization of the gap between cathode and control anode whereupon, if a suitable positive potential has been previously applied to the main anode, the ionization of the gas or gases spreads to the gap between the cathode and the main anode to establish the flow of current through the gap and through an external circuit connected between the main anode and cathode.

The invention has for its object the utilization of a plurality of such tubes as impulse registers whereby the number of such registers is reduced and whereby more accurate and faster impulse control may be realized.

The present invention has been illustrated schematically by only so much of a sender circuit and a selector switch circuit as are necessary to a complete understanding of the invention. The type of sender circuit to which the invention applies is disclosed in detail in Patent 1,862,549 granted June 14, 1932, to R. Raymond et al., while a typical selector switch circuit is disclosed in detail in Patent 1,395,977, granted to F. A. Stearn et al. on November 1, 1921.

In the application of the invention to the revertive control of a selector switch, the fundamental or control circuit is established in the well-known manner between the sender and selector switch to be controlled, the control relay of the switch operating and locking over the fundamental circuit and closing the circuit of the updrive magnet of the switch. At the sender, the fundamental circuit is closed through a winding of a polarized stepping relay the armature of which is connected to one side of a group of ten primary condensers. The armature of this relay is adapted to engage a contact connecting with a source of potential for charging said condensers and with another contact which is adapted to close a suitable discharge circuit for said condensers. The

other side of each primary condenser is connected to the cathode of a gaseous conductor tube and to one side of a secondary condenser whose other side is connected to a source of potential. The main anodes of all the tubes are connected together and, through suitably controllable means, to a source of main anode positive potential while the control anode of each tube is connected to the secondary condenser of the previous tube in the chain and to a conductor which extends to the register. Depending upon the setting of the register, a marking potential is then applied to the conductor of whichever tube designates the number of pulses the switching selector must send back to the sender before the fundamental circuit is opened to stop the updrive magnet of said selector.

When the fundamental circuit is closed between the control relay of the selector and the stepping relay of the sender, the stepping relay operates to cause its armature to close the discharge circuit of the primary condensers whereby the same are discharged. As the brush shaft of the selector switch advances under the control of the updrive magnet, ground is connected to the tip conductor of the fundamental circuit in consequence of which the winding of the stepping relay is short-circuited and the relay is released to cause its armature to complete the charging circuit of the primary condensers. Since, before the closure of the fundamental circuit, a marking potential is assumed to have been applied by the register to the control anode of one of the tubes, the closure of the charging circuit of the primary condensers establishes a difference of potential between the marking voltage and that of the charging circuit which is sufficient to ionize the gap between the cathode and the control anode of the tube to which marking potential has been applied causing the tube to become conducting thereby, first through the gap between the control anode and the cathode and then immediately thereafter through the gap between the cathode and main anode to which positive potential is previously applied through suitable controllable means. The current flow through the cathode-anode circuit of the tube thus rendered conductive charges the second condenser in series with the cathode-electrode circuit to the potential at the cathode thereof, and since this condenser is further connected to the control anode of the succeeding tube, the control anode of such tube is also raised to this potential. The rate at which this secondary condenser is charged is regulated by a series resistance the value of which is such that the voltage of the control anode on the succeeding tube to which it is connected will not rise to a value that will cause ionization in the control anode-cathode circuit of said tube during the time that the primary condensers are still being charged by the release of the stepping relay following the termination of the pulse. This, of course, prevents the operation of more than one tube from a single closure of the primary condenser charging circuit upon the release of the stepping relay. Now when the stepping relay operates on the second pulse, it will discharge all the primary condensers and when it releases at the termination of the second pulse it will recharge them. Since the secondary condenser connected to the control anode of the tube succeeding the one that was rendered conducting on the termination of the first pulse has been raised to a potential the difference between which and that of the primary

condenser associated with it is sufficient to cause ionization of its control anode-cathode gap, said tube will be rendered conducting between this gap and then also in the gap between its main anode and cathode. The current flowing through the cathode-main anode circuit causes the potential of the secondary condenser connected to the control anode of the next tube in the chain to be raised to the cathode potential, thus providing one element of the difference of potential that will cause it to break down on recharging of the primary condensers after the termination of the next pulse. This cycle of operations will be continued until the last tube is operated and the fundamental circuit is opened.

The invention will be more clearly understood by reference to the accompanying drawings in which:

Fig. 1 shows the application to the invention of so-called three-element cold cathode tubes, while

Fig. 2 shows a modification of the invention which makes possible the application of so-called four-element cold cathode tubes.

Referring now to Fig. 1, the apparatus shown to the left of the dotted line A-B-C-D represents schematically in part the apparatus of a selector circuit of the panel type. Since this is well known in the art, only those parts which are necessary for an understanding of the invention are shown, omitted parts being represented by dotted lines. The drawing to the right of the line A-B-C-D shows apparatus arranged in accordance with this invention and is a part of a panel type sender circuit, only those parts which are necessary for an understanding of the invention being shown. The apparatus schematically illustrated in the drawing includes a chain of ten gaseous tubes 0-9, ten primary condensers 10-19, ten secondary condensers 40-49, an interconnecting resistance network for each tube arranged in the manner shown, the fundamental circuit comprising the line relay 20, the polarized stepping relay 26, auxiliary control apparatus in the form of relays 27, 28 and 29, resistance 31 and sources of potential 30, 33, 60 and 70.

Normally the upper winding of stepping relay 26 is short-circuited through the No. 1 normally made continuity contacts of relay 28 and the No. 1 contacts of relay 29 while the armature is kept in engagement with its right contact by means of the biasing circuit established by any suitable means through the lower winding of the relay.

It may be assumed that when the sender is seized the stepping relay 26 has its armature connected to battery 30 and that relays 27, 28 and 29 are normal. When the sender is taken into use, however, any suitable means therein may be utilized for closing the operating circuit of relay 28, from ground on the No. 2 contacts of relay 29 through controllable means (not shown), normally made continuity contacts of relay 27, winding of relay 28 to battery. Relay 28 operates, completes an obvious circuit for relay 27 which operates to lock relay 28 independent of its operating path to its own No. 2 contacts, removes the short circuit from around the upper winding of stepping relay 26 at its No. 1 continuity contacts, applies positive battery 33 through its No. 4 contacts to the main anode of each of the ten tubes 0-9 and, over its No. 5 contacts, applies ground to the register circuit 81 which is only conventionally shown as a rectangle, it being assumed that suitable means

exist therein whereby, in response to any particular setting of such means, conductor 80 which is connected to the source of potential 70 may be connected to the control anode conductor of any one of the ten tubes, such as, for instance, conductor 87 for tube 4.

If it be assumed that, when the sender is taken into use the register circuit 81 has been set for the digit 4, conductor 80 will be connected through such register to conductor 87 and that indicates to the sender that the distant selector will have to send back a total of five pulses to the sender before the circuit of updrive magnet 21 will be opened by the release of relay 20 consequent to the opening of its circuit in the sender. Assuming, therefore, that the register 81 has been set for the digit 4, that conductor 80 is connected to conductor 87 in consequence thereof, and that, as a result of the operation of relay 28 as above described, the fundamental circuit between the sender and the selector is closed. This circuit may be traced as follows: battery through the selector line relay 20, lower contacts of cam 32, tip conductor 90, No. 1 front contacts of relay 28, No. 1 contacts of relay 29, upper winding of stepping relay 26, ring conductor 91 to ground. Both relays 20 and 26 operate in this circuit. The former closes an obvious circuit for updrive magnet 21 which operates to drive the selector upward, one of whose brushes 22 will engage the commutator 35, while stepping relay 26 operates to cause its armature to engage its left contact, thereby establishing a discharge path for all of the primary condensers 10-19, previously charged when relay 26 was normal.

When brush 22 of the selector has advanced in its upward movement to engage the conducting surface 23 of commutator 35, a locking circuit is established for line relay 20 from ground on said brush, conducting segment 23, left contacts of cam 32, through controlling portions of the selector indicated by the dotted line, left contacts of line relay 20, winding of said relay, to battery. At the same time the locking ground is further applied to the tip conductor 90 thereby establishing a short circuit of the upper winding of stepping relay 26 causing it to release. This release of the stepping relay constitutes the first of the five reveritive pulses which the selector will send back to the sender before the fundamental circuit is opened and the line relay 20 released. With the release of stepping relay 26, a charging circuit is established for the condensers 10-19, said circuit tracing from negative battery 30, right contact and armature of stepping relay 26, corresponding sides of all the condensers 10-19, through their respective series resistances 10'-19', resistance 71-79 in series, respectively, associated with tubes 1-9, to a negative potential determined by the setting of the potentiometer 60. Condenser 10 charges through resistance 10' and the winding of relay 29 to ground. But the capacity of condensers 10-19 is very small and the duration of the charging current through condenser 10 is not long enough to cause the operation of relay 29. The charging current for each of the other condensers, however, is established through resistances 71-79, respectively, to negative potential at potentiometer 60 as before mentioned. The charging current for each of the condensers 11-19 raises the cathode of each of the tubes 0-9 to a potential determined by the value of the resistance network. This potential thus ap-

plied to the cathodes of all the tubes will be ineffective except for tube 4 to the control electrode of which a positive marking potential has been applied from potentiometer 70, over conductors 80 and 87 and resistance 54 to the control electrode thereof. The difference in potential between that applied to the control electrode of tube 4 and that applied to the cathode of said tube during the time that charging current flows through condenser 14 is sufficient to cause ionization of the tube through its control electrode-cathode gap. However, since positive potential from source 33 has been applied to the main anode of all the tubes 0-9, the conductivity of tube 4 through its control electrode-cathode gap immediately causes ionization to spread to the gap between the cathode and the main anode, whereupon a current flow is established in consequence thereof from positive battery 33, No. 4 contacts of relay 28, main anode and cathode of tube 4, resistance 74 to negative potential at 60. This current is also applied through resistance 64 to charge secondary condenser 43 to the potential of the cathode of tube 4 as determined by the current flow through the anode-cathode circuit thereof and, when fully charged, the potential of control electrode of tube 3 is raised to the potential of the cathode of tube 4 via resistances 64 and 53. The value of resistance 64 (as well as the value of the other resistances corresponding to resistance 64 connected to the secondary condensers) should be so determined that condenser 43 does not become fully charged until after the primary condensers have become fully charged. The reason for this is to make certain that the control electrode of tube 3 does not become charged to the full cathode potential of tube 4 until it is certain that no potential is available on the cathode of tube 3. Were it otherwise, tube 3 might be rendered conducting along with tube 4 on the same pulse. Now when the selector has moved upward until brush 22 has passed over conducting segment 23 to the insulating segment immediately contiguous thereto, ground is removed from the tip conductor 90, the shunt is removed around the upper winding of stepping relay 26 and the line relay 20 now holds over the previously established fundamental circuit to ground on the ring conductor 91 while relay 26 reoperates. On the beginning of the second pulse, therefore, the line relay 20 is still operated and stepping relay 26 is reoperated to cause its armature to reestablish the discharge circuit for condensers 10-19 through resistance 31. This discharge path, however, while effective to discharge condensers 10-19 and to thereby restore the cathodes of tubes 0-3 and 5-9 to their previous state of no potential, will in no way affect the charge upon the cathode of tube 4 since the value of the potential thereat is determined by the steady current flowing through the established anode-cathode circuit to source 60. Nor will the discharge of the condensers in any way affect the potential on the control electrode of tube 3 which is derived from the potential of the cathode of tube 4 through which the above-mentioned steady current is flowing. When the selector has advanced to the point where brush 22 has advanced beyond the insulating segment contiguous to segment 23 and in contact with succeeding conducting segment 24, the previously traced locking circuit for the line relay 20 is reestablished, ground is again applied to the tip conductor 90 of the fundamental circuit and

stepping relay 26 is again released, at which time its armature will engage its right contact and again complete a charging circuit for condensers 10—19. Since tube 4 is now conducting and since its cathode potential is applied to the control electrode of tube 3, the charging current through condenser 13 is applied to the cathode of tube 3 and the difference of potential between that on its control electrode (which is at the same potential as the cathode of tube 4) and that applied to its cathode through resistance 13' from the charging current flowing through condenser 13, is sufficient to cause ionization of its control electrode-cathode gap whereupon the tube is immediately rendered conductive through its main anode and cathode gap to establish a current flow from positive potential source 33, main anode and cathode of tube 3, resistance 73 to negative source of potential 60. The potential on the cathode determined by this current is now applied to charge condenser 42 through resistance 63, and after it is fully charged to the potential of the cathode the same is immediately applied to the control electrode of tube 2 via resistance 52. When the selector has advanced so that brush 22 is in contact with the insulating segment immediately above conducting segment 24, ground is disconnected from conductor 90, stepping relay 26 again reoperates in series with line relay 20, the selector moves the equivalent of another step and stepping relay 26 again establishes the discharge circuit for condensers 10—19 via resistance 31.

It is obvious that the above operations will be repeated for tubes 2, 1 and 0 on each operation and release, respectively, of the stepping relay 26. When tube 0 operates in response to the fifth pulse transmitted from the selector, the anode-cathode circuit is closed through relay 29 so that current flowing through said anode-cathode circuit includes the winding of relay 29, causing said relay to operate. At its No. 1 contacts, it opens the fundamental circuit in consequence of which the line relay 20 of the distant selector will release as soon as brush 22 has passed beyond the conducting segment which caused the release of stepping relay 26 and the operation of relay 29 in consequence thereof, while at its No. 2 contacts relay 29 opens the circuit of relay 27 which, in turn, releases relay 28 thereby removing positive source of potential 33 from the main anodes of the tubes causing tubes 0—4, inclusive, to be restored to their non-conducting condition.

The opening of the fundamental circuit causes the release of relay 20 which, in turn, opens the circuit of updrive magnet 21 and causes the selector to come to rest, it having taken five steps as determined by the number of conducting segments traversed by brush 22 in its upward movement before it was brought to rest.

It is obvious that the above operations may be repeated for successive digit registrations which may be recorded in the register circuit 81, in consequence of which the conductor 80 may be connected to the control electrode of any one of the tubes 0—9 depending upon the number of pulses which have to be counted by the sender before opening the fundamental circuit, it being assumed, of course, that for each selective operation relays 28 and 27 are operated in advance by means controlled by the sender and that the connection of ground to the register circuit over the No. 5 contacts of relay 28 supplies the signal for resetting the register 81 to the next digit

registration for which counting will have to be done.

The circuit of Fig. 2 is substantially similar to that of Fig. 1 except that the tubes used are four-element tubes each of which is provided with a control cathode and a control anode, while instead of using ten primary condensers, one for each tube, one single condenser 131 is used in parallel with ten separate resistances 110—119, one connected to the control cathode of each of the tubes 0—9 respectively. The operations are also similar except for the fact that the condenser 131 charges and discharges in the reverse manner in which condensers 10—19 charged and discharged in the circuit of Fig. 1. That is, prior to the closing of the fundamental circuit, condenser 131 is in a discharged condition and when the circuit is closed, said condenser is charged from the potential supplied through potentiometer 100, right contacts and armature of relay 26, condenser 131 to ground. The charge placed thereon depends, of course, upon the setting of the potentiometer 100 which may be adjusted to provide the required potential necessary to operate the tubes as shown below. When brush 22 of the selector advances to conducting segment 23 and stepping relay 26 is released in consequence thereof, the armature of said relay is caused to engage its left contacts and a discharge path for the condenser will be established, using its potential to break down whichever tube has had marking potential applied to its control anode by the register 81. Thus, if it is assumed that the setting of register 81 calls for five pulses and, as described previously for Fig. 1, conductor 80 is connected to conductor 87, a marking potential is applied to the control electrode of tube 4 so that when stepping relay 26 releases, the potential from condenser 131 is applied via resistance 114 to the control cathode of tube 4. The difference in potential between that applied by condenser 131 to the control cathode of tube 4 via resistance 114 and that applied by source 70 to the control anode of said tube is sufficient to cause ionization of the tube in the gap extending between the control electrode and the control cathode whereupon ionization immediately spreads to the main anode to which positive potential from source 33 is applied through the No. 4 contacts of relay 28 and the cathode to which negative potential 60 is applied through resistance 74. A main anode-cathode circuit results therefrom the current of which charges condenser 43 at the rate determined by the value of resistance 64. When fully charged, the control anode of tube 3 is immediately raised to the potential of the cathode of tube 4. The operations from here on are then repeated for each pulse until tube 0 is rendered conducting, at which time relay 29 operates to open the fundamental circuit.

While I have described my invention and the means for utilizing the same in connection with its specific application to a pulse counting circuit for controlling the movement of a selector, it is to be understood that various other applications and embodiments thereof may be made by those skilled in the art without departing from the spirit of the invention as defined within the scope of the appended claims. For instance, either pulsing circuit may be used for counting pulses generated from the dial of a subscriber's telephone station or from the dial of an operator's position. For, in both of these cases, relay 26 may assume one position when the dial loop is closed

and another position when the dial loop is opened, and since a pulse constitutes an open position of the line followed by a closed position of said line, it is obvious that relay 26 will follow dial pulses so generated, the same being registered by the tubes operating in the manner described. The pulse series could always begin at a tube to which the marking potential is permanently applied, and could be ended by relay means responsive at the termination of the series to operate relay 29 to reset the circuit for the next series of pulses.

What is claimed is:

1. A pulse counting circuit comprising a source of pulses, a plurality of electronic devices, means for applying a potential to an electrode of a predetermined one of said devices, means responsive to a pulse from said pulse source for rendering said predetermined device conducting, means responsive to the conductivity of said predetermined device for applying a potential to an electrode of the next one of said devices whereby upon the succeeding pulse said next device is rendered conducting, and means responsive to the conductivity of one of said devices for rendering said source of pulses ineffective.

2. A pulse counting circuit comprising a source of pulses, a plurality of electronic devices, means for applying a potential to an electrode of a predetermined one of said devices, means responsive to a pulse from said pulse source for rendering said predetermined device conducting, means responsive to the conductivity of said predetermined device for applying a potential to an electrode of the next one of said devices subsequent to the termination of said pulse whereby upon the succeeding pulse said next device is rendered conducting, and means responsive to the conductivity of one of said devices for rendering said source of pulses ineffective.

3. In a telephone system, an impulsing device, an impulse responsive device, a control circuit extending from said impulsing device to said responsive device, and an impulse counting circuit responsive thereto comprising a plurality of gaseous conductor tubes each having a control electrode, a main anode and cathode, means for applying a positive potential to the main anode of all said tubes, a source of negative potential applied to the cathodes of all said tubes, means for applying a source of potential to the control anode of a predetermined one of said tubes, means responsive to said impulse responsive device for applying a second source of potential to the cathode of said tube whereby the difference of potential between said two sources applied to the cathode and said source applied to the control electrode of said tube renders said tube conducting, and means responsive to the conductivity of said tube for applying a potential derived from the current flowing through the cathode-anode circuit of said conducting tube to the control electrode of the succeeding tube.

4. In a telephone system, an impulsing device, an impulse responsive device, a control circuit extending from said impulsing device to said responsive device, and an impulse counting circuit comprising a plurality of gaseous conductor tubes each having a control electrode, a main anode and a cathode, means for applying a positive potential to the main anodes of all of said tubes, a source of negative potential applied to the cathodes of all said tubes, means for applying a source of potential to the control anode of a predetermined one of said tubes, a primary condenser

connected to the cathode of each tube, means responsive to said impulse responsive device for applying a charging current to all of said primary condensers whereby a breakdown potential is applied to the cathode of the tube having a potential connected to its control electrode and whereby said tube is rendered conducting through its anode-cathode circuit completed by the positive potential connected to its main anode and the negative potential connected to its cathode, and means responsive to the conductivity of said tube for applying a potential derived from the current through said cathode-anode circuit to the control electrode of the succeeding tube.

5. In a telephone system, an impulsing device, an impulse responsive device, a control circuit extending from said impulsing device to said responsive device, and an impulse counting circuit comprising a plurality of gaseous conductor tubes each having a control electrode, a main anode and a cathode, means for applying a positive potential to the main anodes of all said tubes, a source of negative potential applied to the cathodes of all said tubes, means for applying a source of potential to the control anode of any one of said tubes, a primary condenser for each tube, a secondary condenser for each tube, a resistance network for each tube by which the associated primary condenser is connected through a resistance to the cathode of the associated tube and by which the secondary condenser is connected through a resistance to said cathode and through another resistance to the control electrode of the succeeding tube, means responsive to said impulse device for closing a charging circuit to all of said primary condensers whereby a breakdown potential difference is effected between the potential applied to the control electrode of one of said tubes and the potential applied to the cathode thereof in consequence of the charging current through the primary condenser individual to said tube, and whereby the current produced by the conductivity of said tube through the cathode-anode circuit completed by the source of positive potential applied to its main anode and the source of negative potential applied to its cathode will charge the secondary condenser connected to the control electrode of the succeeding tube and thereafter to raise said electrode to the same potential as the cathode of the conducting tube, means responsive to said impulse responsive device for discharging said primary condensers, said previously mentioned means for charging said primary condensers being thereafter again responsive to said impulse responsive device to re-establish the charging circuit through said primary condensers whereby a breakdown potential difference is effected between the potential applied to the control electrode of said succeeding tube from the cathode of the preceding conducting tube and the potential applied to the cathode thereof in consequence of the charging current through the primary condensers individual to said succeeding tube.

6. In a telephone system, an impulsing circuit, an impulse responsive device, a control circuit extending from said impulsing device to said responsive device, and an impulse counting circuit comprising a plurality of gaseous conductor tubes each having a control anode, a control cathode, a main anode and a main cathode, means for applying a positive potential to the main anodes of all of said tubes, a source of negative potential applied to the main cathodes of all of said tubes, means for applying a source of potential to the

control anode of a predetermined one of said tubes, a condenser, means for charging said condenser, means responsive to said impulse responsive device for raising the potential of the control cathode of whichever tube has a source of potential connected to its control anode to the potential of said condenser whereby the difference in potential between control anode and cathode will ionize the tube and render it conducting through the main anode and main cathode circuit completed by said positive and negative sources of potential respectively applied thereto, and means responsive to the current flowing through said circuit for applying to the control anode of the succeeding tube the potential to which the cathode of the conducting tube is raised by said current.

7. In a telephone system, an impulsing device, an impulse responsive device, a control circuit extending from said impulsing device to said responsive device, an impulse counting circuit comprising a plurality of gaseous conductor tubes each having a control anode, a control cathode, a main anode and a main cathode, means for applying a positive potential to the main anodes of all said tubes, a source of negative potential applied to the main cathodes of all said tubes, means for applying a source of potential to the control anode of a predetermined one of said tubes, a condenser for each tube, a resistance network for each tube whereby a condenser is connected to the main cathode of one tube through a resistance and the control electrode of the succeeding tube through another resistance, a resistance

connected to the control cathode of each tube, another condenser, means responsive to the unoperated condition of said impulse responsive device for charging said first condenser, means responsive to said impulse responsive device for connecting said charged condenser to said resistances connected to the control cathodes of said tubes whereby said cathodes are raised to the potential of said condenser and whereby the difference between said potential and that applied to the control anode of one of said tubes will cause said tube to ionize and become conducting through its main anode and main cathode circuit completed by said positive and negative sources of potential respectively applied thereto and whereby the current flowing through said circuit will charge said other condenser connected to the main cathode of said tube and to the control anode of the succeeding tube to the potential of said main cathode and thereafter to raise said control electrode to the same potential as said main cathode, said previously mentioned means responsive to the unoperated condition of said impulse responsive device for charging said other condenser being again effective at the termination of a pulse to charge said condenser whereby upon the operation of said impulse responsive device the potential to which said condenser is charged is applied to the control cathode of the succeeding tube to effect its ionization in combination with the potential applied to its control anode from the cathode of the preceding tube.

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