

Sept. 23, 1958

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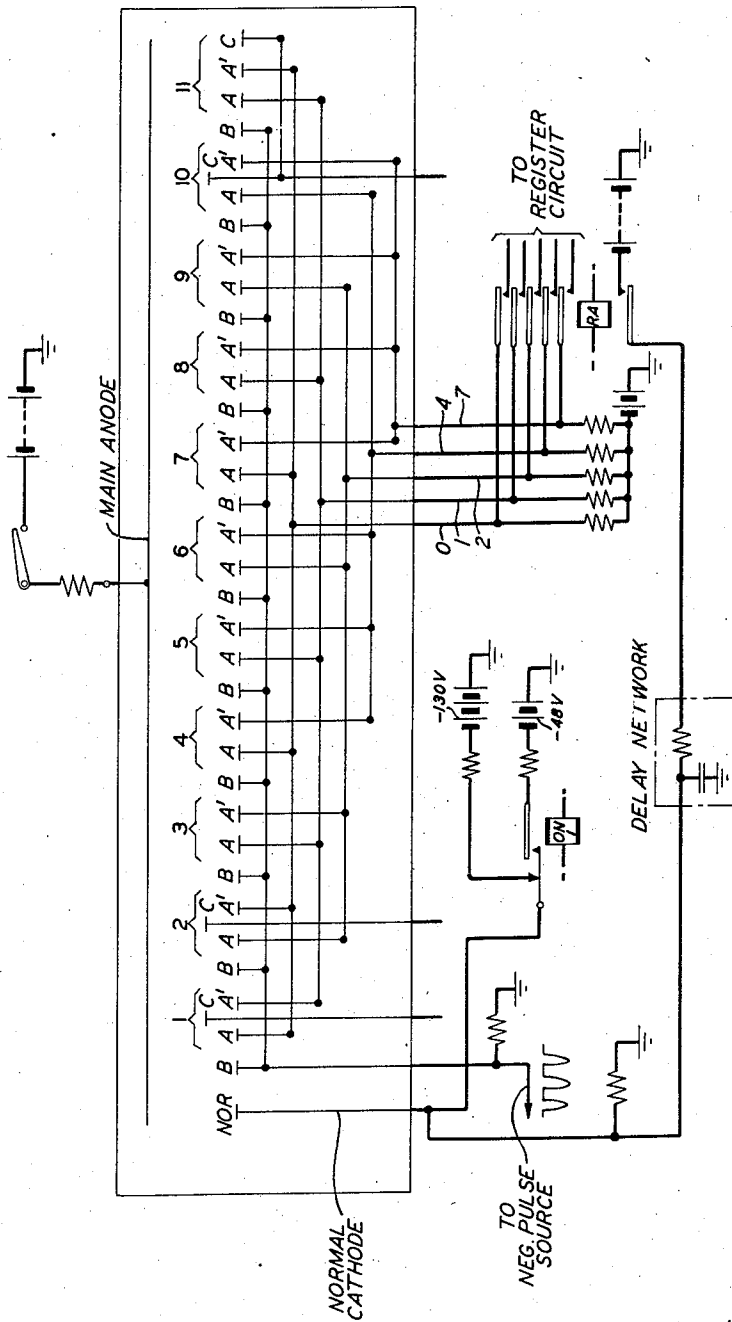
2,853,694

ELECTRON DISCHARGE TUBE CIRCUIT

Filed June 11, 1952

4 Sheets-Sheet 1

FIG. 1



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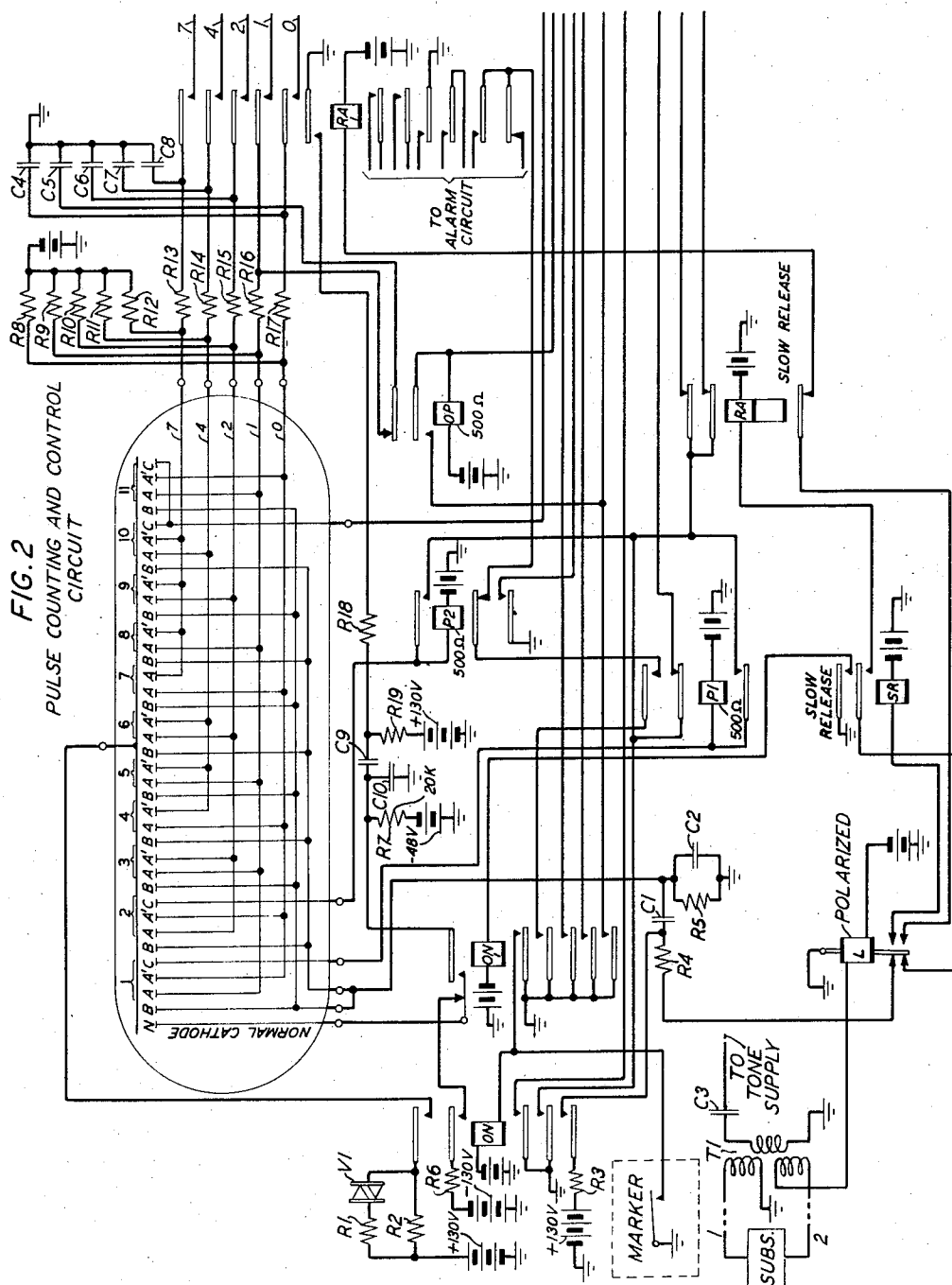
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ELECTRON DISCHARGE TUBE CIRCUIT

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4 Sheets-Sheet 2



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ELECTRON DISCHARGE TUBE CIRCUIT

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4 Sheets-Sheet 3

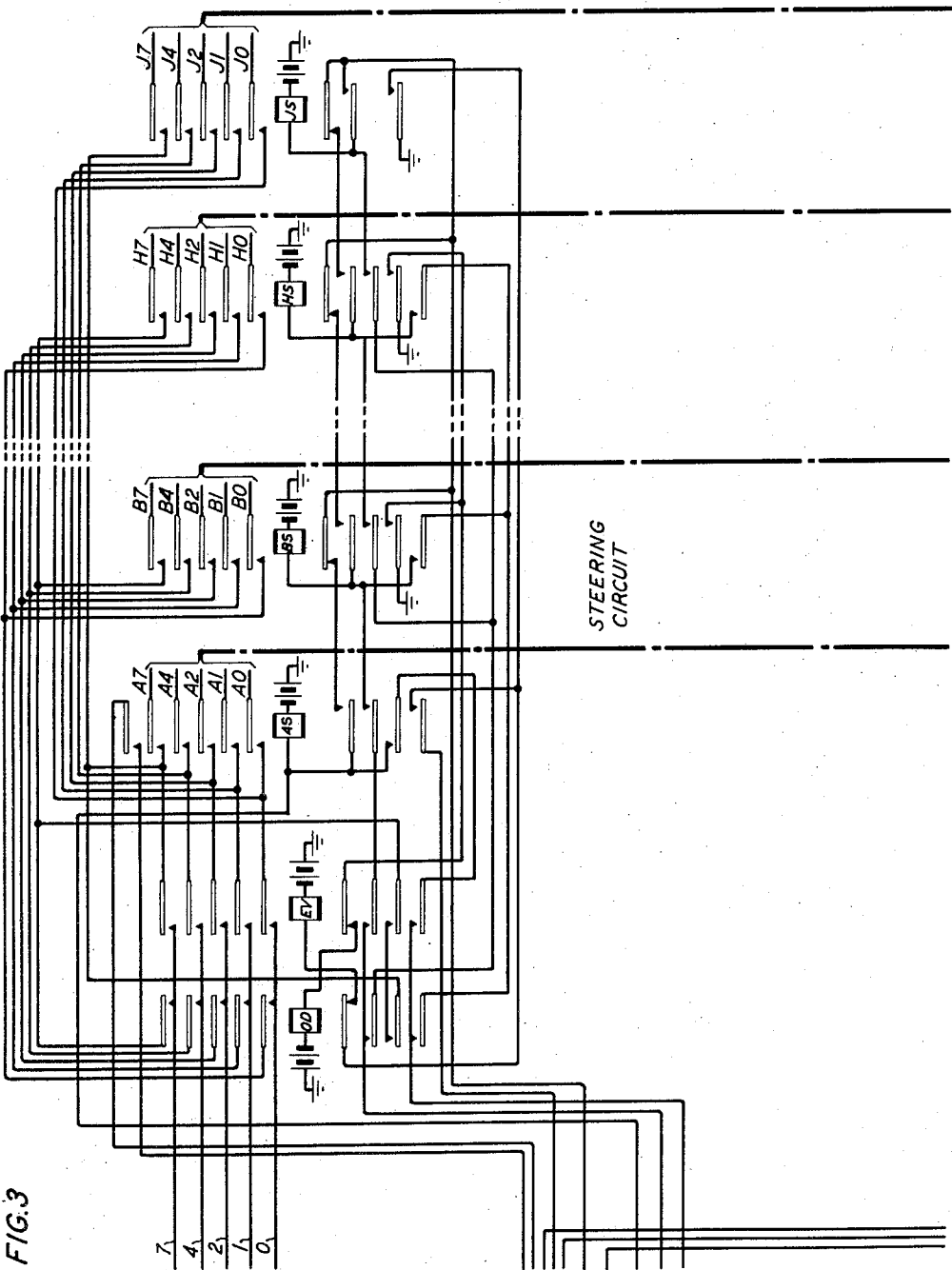


FIG. 3

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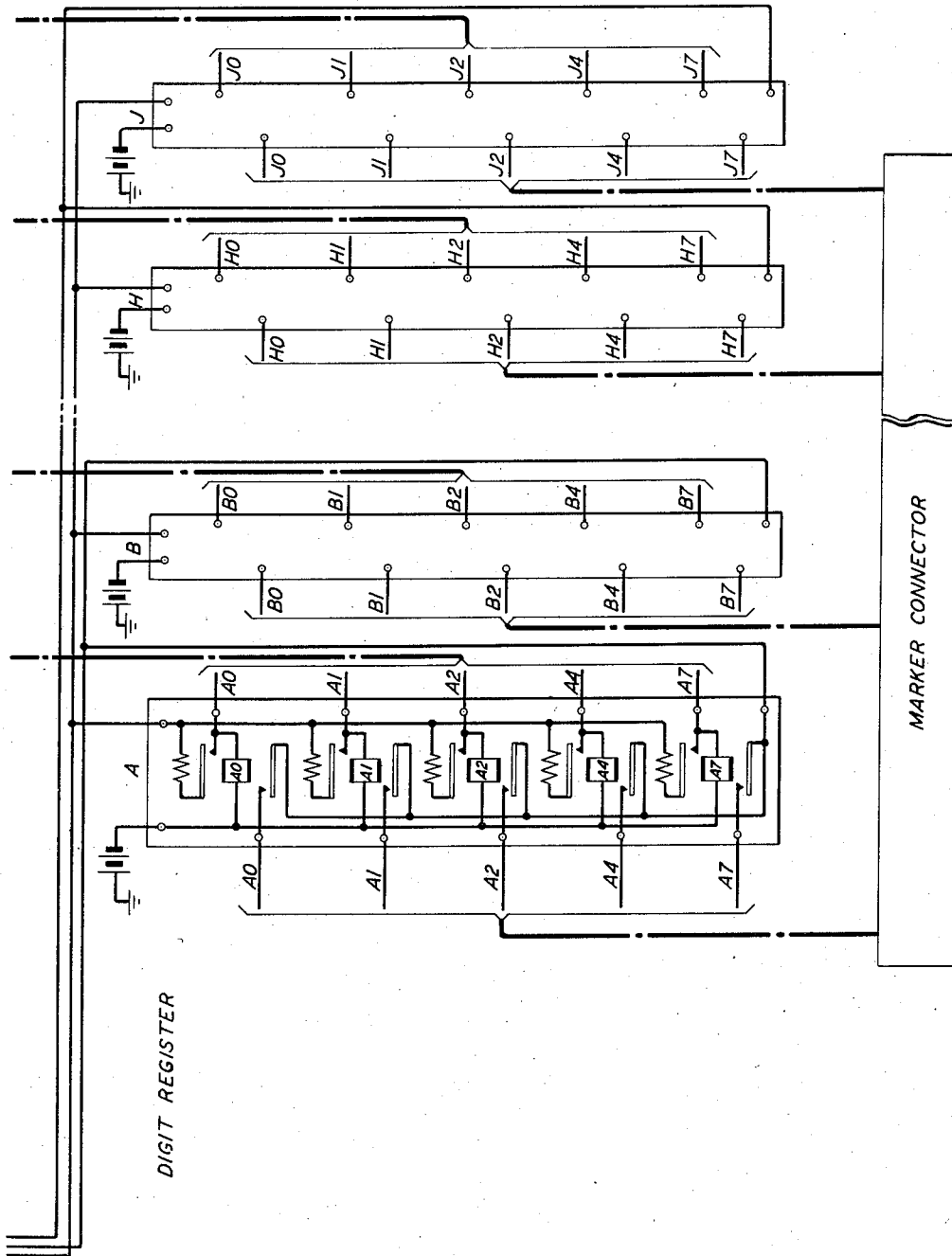
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ELECTRON DISCHARGE TUBE CIRCUIT

Filed June 11, 1952

4 Sheets-Sheet 4



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2,853,694

ELECTRON DISCHARGE TUBE CIRCUIT

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Application June 11, 1952, Serial No. 292,830

4 Claims. (Cl. 340—147)

This invention relates generally to signaling systems and more particularly to arrangements in such systems for detecting, counting and registering signal impulses.

The main object of the invention is to associate a cold cathode multiconductive position gaseous discharge tube with a variable non-linear impedance device common to all of said conductive positions so that the conduction current in the individual conductive positions may be controlled and varied over a greater range than has heretofore been possible.

Another object of the invention is the improvement of gas tube counting and registering circuits.

Another object of the invention is to increase the speed of operation of an impulse counting and registering arrangement suitable for use in a telephone dialing circuit.

Another object of the invention is to use a gaseous discharge tube having a plurality of conductive positions in an impulse counting and registering circuit so as to eliminate the many relays or tubes that have been required in the prior art.

A feature of the invention is the utilization of a cold cathode gaseous discharge stepping tube that has a plurality of cathodes.

Another feature of the invention is the use of a mult cathode gaseous discharge tube for successively counting the groups of pulses that represent the digits of a designated telephone number.

Another feature of the invention is a means for momentarily associating the pulse counting multicathode gaseous discharge tube with successive register means during the interdigital dialing pauses.

A preferred embodiment of the invention is shown in the accompanying drawing in which:

Fig. 1 shows the multiconductive position gaseous counting tube used in a simplified circuit for the purpose of illustrating the basic principles of operation of the tube; and

Figs. 2, 3 and 4 together form a circuit diagram of a preferred exemplary embodiment of the invention.

In present day signaling systems, such as may be used in automatic telephone systems, continuous effort is being made to increase the speed of circuits responsive to dial signals. In the telephone field in particular, continuous effort is expended in attempting to produce circuits which will respond accurately at a more rapid rate to signals such as dial pulses or the like.

The present invention is herein disclosed as embodied in an automatic telephone system such as is disclosed in the patent to A. J. Busch, 2,585,904 issued February 19, 1952. Busch discloses in detail a cross bar system wherein originating register circuits are used for transmitting dial tone to coin subscribers; for counting the pulses of called digits, for registering the called digits, and for seizing an idle marker circuit for the purpose of having such a marker complete the desired connection. Since the present invention relates solely to pulse counting and registering circuits, only those portions of an originating

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register have been disclosed and described herein. A co-pending application by J. W. Dehn, Serial No. 57,398, filed October 29, 1948, discloses a skeletonized arrangement of the Busch disclosure including an originating register circuit in some detail. The Dehn and Busch disclosures may be referred to for such details, if any, omitted from the present description as may be needed for the incorporation of the present invention into a more complete system.

This invention is not necessarily so limited in its utility that it must be used as a part of an originating register, as it may be utilized in any organization wherein the rapid detection, counting and registering of pulses is required.

The function of an originating register in the cross bar system as disclosed by Busch and Dehn is to receive, detect, count and register the dial pulses transmitted thereto by the dialing action of a calling subscriber. It is the improvement of such counting circuits with which the present invention, in one of its embodiments, finds utility by improving the speed of response in such originating registers, and by simplifying such registers. As may be obtained from the Busch or Dehn disclosure, the general sequence of events during the origination of a call by a subscriber in a cross bar system is as follows:

(1) The calling subscriber lifts his receiver, thereby seizing an idle marker circuit and automatically informing the seized marker that a dial tone connection is desired.

(2) The seized marker tests for and seizes an idle originating register circuit.

(3) The marker interconnects the calling line with the seized originating register circuit over the cross bar switch trains and then the marker releases.

(4) The originating register transmits dial tone to the calling subscriber.

(5) The calling subscriber dials the digits of the called number.

(6) The originating register receives, detects, counts the pulses of each digit, and then registers each digit.

(7) When sufficient digits have been registered therein, the originating register seizes an idle marker circuit and transfers thereto the digits registered along with other items of information pertaining to a call.

(8) After the marker has received all of the information from the originating register, it releases the originating register, completes the call, and releases itself.

Since the present invention is embodied only in the circuits of an originating register, so far as present disclosure is concerned, the subsequent description will only cover items 4, 5 and 6, above. The other items are fully disclosed by Busch and Dehn and are incorporated herein by reference.

Stepping tube

Since the stepping tube used in this invention is relatively new in the art, a brief description concerning its mode of operating is considered appropriate. This tube is of the same general type as shown in the patent to M. A. Townsend, No. 2,575,372, issued November 20, 1951. This patent is cited merely to acquaint one more fully with the construction and operation of the family of tubes of which this tube is a part. The present invention is not to be considered as employing exclusively the tube of the Townsend disclosures.

The stepping tube which performs the counting function for the subscriber's originating register is shown in Fig. 1 of the drawings. With reference to this circuit, it may be observed that the tube has a normal position designated NOR and eleven other positions which permit the counting of any digit 1 to 11. The tube is also provided with a main anode, two A cathodes in each of the

eleven counting positions designated A and A', and an additional cathode in its positions 1, 2, 10 and 11, for performing service functions to be hereinafter explained. Stepping cathodes designated B are interposed between each double set of A cathodes as well as between the NOR cathode and the A cathodes of position "1." All the B cathodes are connected together. The purpose of the B cathodes is to transfer the discharge from a preceding to a succeeding position for each dial pulse received. The twenty-two A cathodes in the ten counting positions are strapped together internally to provide a two-out-of-five code.

When the switch in the anode circuit is closed, positive potential is applied to the main anode and conduction will be initiated between the main anode and the cathode in the normal position designated NOR. The cathode in the normal position has a negative 130-volt battery connected to it, while the cathodes in the other position have merely a negative 48-volt battery connected to them. As a result, the initial conduction will take place in the normal position since the potential difference between the main anode and the NOR cathode is greater than the potential difference between the main anode and the remaining cathodes. A short interval of time after conduction is initiated in the NOR position, relay ON1 operates which removes -130 volts from the NOR cathode and applies -48 volts to it. The negative 48-volt potential is sufficient to sustain an initiated discharge, however, it is unable to effect a discharge initially between a cathode and the anode.

In order to step the tube, it is necessary to apply negative pulses to the common lead connecting the B cathodes. In order for the B cathode at the No. 1 position to seize the discharge from the NOR position, the amplitude of the negative pulses applied to the B cathodes must be greater than the negative potential applied to the NOR cathode. When the negative pulses are applied to the B cathode line the B cathodes will become highly negative and the potential difference between the main anode and the B cathode at the first position will become much greater than the potential difference between the main anode and the NOR cathode. As a result, the discharge path will move to the B cathode of the first position. When the negative pulse terminates, the potential on the B cathode will rise to zero and the discharge will move from the B cathode of the first position to the two A and the one C cathode in the first position. The A and C cathodes will sustain the discharge as they are connected through load resistors to a source of negative potential. The C cathodes are provided for the purpose of performing certain service functions to be explained hereinafter in detail. The associated circuits for these cathodes are not shown in Fig. 1.

When another negative pulse is applied to the B cathodes, a similar action takes place, stepping the discharge from position 1 to position 2. In this manner the count progresses until the digit is fully counted. The tendency of the discharge to move in one direction rather than in the other is governed by the geometry of the cathodes which control the ionization density on the surface of the A cathodes and is greater towards the forward than towards the backward direction.

At the end of each digit or series of pulses, relay RA is operated (by a circuit not shown on Fig 1) and connects the five A cathode leads to relays in associated register circuits. For reasons described hereinafter, only the relays connected to the two A cathode leads over which conduction is taking place will operate.

A short time after relay RA operates the stepping tube is returned to its normal condition by means of the application of a high negative voltage pulse to the normal cathode which transfers the conduction back to this position of the tube. This negative pulse is originated by the negative battery on the lower contact on the RA relay and is applied through a suitable delay network so that relays

in the register circuit will have a sufficient time to operate before the tube will return to its normal position.

It should be fully appreciated that Fig. 1 is a highly simplified drawing and is used merely to illustrate the basic features and principles of operation of the stepping tube used in applicant's invention. The circuits utilized in Fig. 1 are similarly extremely simplified and are shown only in a diagrammatic sense to better illustrate the principles of operation of the tube and are not necessarily even related to the more complex circuit shown in Figs. 2, 3 and 4 which, when taken together, illustrate a preferred exemplary embodiment of applicant's invention.

Circuit description

Fig. 2 shows in detail a circuit that detects and counts the pulses sent over a subscriber's line. Fig. 4 shows in detail a circuit that will register and store the digits counted by the apparatus shown in Fig. 2. Fig. 3 shows in detail a circuit that will connect the output of the counting tube of Fig. 2 to successive registers of Fig. 4. The digit representative of the number of pulses in the first digit counted will be stored in the column of register relays designated A0 . . . A7. The second digit dialed will be stored in the column of relays designated B0 . . . B7. The dotted lines connecting the relays of the B column with those of the H column indicates that five or more columns of register relays may be inserted between the B and the H columns of register relays. After the B column of register relays each succeeding column will successively register and store the succeeding digits that are dialed. The last digit dialed will be stored in the register relays of the J column. It should be remembered this showing is merely exemplary and that there could be as many columns of register relays in Fig. 3 as may be desired.

When the marker seizes an idle originating register circuit as is partly disclosed in Figs. 2, 3 and 4, the off-normal relay ON is operated by a ground in the marker which is represented by a dotted rectangle in Fig. 2. Relay ON, upon operating, prepares the register circuit for the operation as follows:

- (1) Connects +130 volts to the anode of the stepping tube by means of a network consisting of resistors R1 and R2 and varistor V1.
- (2) Connects +130 volts through the R3 resistor to the C1 capacitor, thus partly charging this capacitor.
- (3) Connects ground to the steering and digit register circuits.

(4) Connects -130 volts through resistor R6 to the N normalizing cathode of the tube. With +130 volts on the anode and -130 volts on the N cathode, the stepping tube will break down and sustain a discharge between the main anode and the N cathode.

After seizure by a marker of an idle originating register circuit as outlined above, the marker effects interconnections over the cross bar switch train between the seized register and the calling line, thereby connecting the ring and tip conductors 1 and 2 of the register to the calling line loop. The circuit comprising transformer T1 and condenser C3 provides a means of impressing dial tone on the subscriber's line at the proper time. The tone supply circuit, not shown, impresses dial tone at the proper time on the series circuit comprising condenser C3 and the primary of transformer T1. T1, in turn, impresses the dial tone onto the subscriber's line.

After the marker connects the register of Figs. 2, 3, and 4 to the calling line, relay L is operated by a circuit extending from ground on the upper winding of transformer T1, through the subscriber's line, through the lower secondary winding of transformer T1, and back to battery through the L relay winding.

When relay L operates, it operates slow release relay SR which, in turn, operates relay ON1. The operation of the ON1 relay connects ground to various parts of the circuit, disconnects the negative 130-volt battery supply

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from the N cathode of the stepping tube, and connects a negative 48-volt battery through resistor R7 to the N cathode. The operation of relay L also operates relay RA1.

The L relay repeats the dial pulses received over the subscriber's line in response to the dialing action of the subscriber. When the first pulse from the subscriber's dialing is received, the L relay releases thereby causing the slow release RA relay to operate and relay RA1 to release. Relay RA, being of the slow release type, will remain operated during the pulsing period of the L relay. This will keep relay RA1 released until relay RA releases during the interdigital periods or at the termination of dialing. The release of the L relay also connects a ground to condenser C1 through resistor R4. This causes condenser C1 to discharge through resistor RL1 to a ground on the contacts of the L relay, thereby applying a negative drive pulse to the B cathodes of the stepping tube. The conduction in the tube now moves from the N cathode to the B cathode interposed between the normal cathode and the A cathodes of the first position since the potential difference between the main anode and the B cathode is now much greater than the potential difference between the main anode and the N cathode. As the charge on condenser C1 dissipates, the potential on the B cathodes will rise and the discharge will move to the A cathodes of the first position. The discharge will spread to the C cathode of the first position at the same time it spreads to the A cathodes of this position. As stated before, the discharge has a tendency to move in a forward direction rather than in a backward one because of the geometry of the cathodes which control the ionization density on the surface of the cathodes and thereby assure the forward direction of discharge travel.

The discharge to the C cathode of the first position causes relay P1 to operate which locks to an off-normal ground furnished by the ON relay and grounds the C cathode of the first position. The purpose of the P1 relay is to perform certain functions which are hereinafter explained in greater detail. The tube at this time is discharged to its first position thereby indicating that one pulse has been received.

When the L relay reoperates due to the reclosure of the subscriber's dial after the first pulse, it removes ground from the C1 condenser, thereby allowing it to recharge through R3 and prepare the circuit for the reception of the next pulse. A positive pulse is impressed on the B cathodes during the charging time of C1 but it serves no useful function.

When the L relay releases on the reception of the second dial pulse, a negative pulse from C1 will again be applied to the B cathode lead which will advance the discharge in the stepping tube to the cathodes of the second position. The current flowing through the C cathode of the second position will operate relay P2, which will lock to a ground furnished by the relay ON. The tube is now conducting in its second position, thereby indicating that two pulses have been received. Finally, when the digit is fully counted and all the pulses have been received, the L relay will remain operated, and the stepping tube will be conducting in the position representative of the number of pulses in the digit dialed.

As the L relay remains operated after the last pulse has been received, slow release relay RA will release, which in turn will cause relay RA1 to reoperate. If it were to be assumed that eight pulses were in the first digit, the stepping tube would now be conducting in position 8 and current would be flowing over cathode leads 7 and 1. The cathode current flowing over cathode leads 7 and 1 will cause an IR drop in resistors R12 and R9 which terminate on a negative 48-volt battery. This IR drop due to the cathode current will raise the potential on the cathode side of resistors R12 and R9 from -48 volts to approximately 0 volts. The potential on the cathode side of resistors R8, R10 and R11, which

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are connected to cathode leads over which no current is flowing, will be at the potential of the negative battery since there will be no IR drop in these resistors at this time. Correspondingly, condensers C8 and C5 will be discharged to a potential of 0 volts since they are connected to cathode leads 7 and 1, respectively. Conversely, condensers C4, C6 and C7, which are connected to cathode leads over which no current is flowing, will be charged to the potential of the negative 48-volt battery.

Relay AS operated with the operation of relay ON from a ground supplied by relay ON through a break contact on relay P1. Relay AS operated locks through its own contacts and through the lower contacts of relay BS unoperated to a ground furnished by a pair of lower make contacts of relay ON1. The operation of relay P2 during the dialing time operated relay EV over by the following circuit: a lower break contact of relay OD, a lower make contact of relay AS, to a ground supplied by a lower make contact of relay P2.

When relay RA1 reoperates at the termination of dialing, the cathode leads will be closed through the contacts of relays RA1, EV and AS to the correspondingly numbered relays in the A column of register relays. Register relays A0, A2 and A4 which are connected to the non-conducting cathodes, will not operate at this time since they have a negative battery connected to both sides of their windings. The negative battery connected on their left winding terminals is supplied by an obvious circuit shown on Fig. 4, while the negative battery connected to their right winding terminals is supplied by the same battery that furnishes the negative potential to the cathodes of the stepping tube. Register relays A1 and A7, which are connected to the conducting cathodes, operate because they have a negative battery terminal connected to their left winding terminal while their right winding terminals are connected through the contacts of relays AS, EV and RA1 to condensers C8 and C5 which are discharged at this time to a potential of approximately 0 volts. Condensers C8 and C5 will charge through relays A7 and A1 to the negative battery on the left winding terminals of these relays. This charging current flowing through relays A7 and A1 will cause them to operate and then lock to a ground furnished by relay ON. Relays A1 and A7 operated indicate that the number 8 was the first digit dialed.

Resistors R13 and R17 are inserted for the purpose of preventing oscillation between adjacent cathodes, and for isolating condensers C4 through C8 from resistors R8 through R12 so that no interaction between these two elements will take place.

As relay RA1 operates at the end of the reception of the pulses representing the first digit, it causes a negative pulse to be applied to the normal cathode of the stepping tube thereby resetting it. This negative pulse is supplied by the network consisting of resistor R7, resistor R18, resistor R19 and condensers C9 and C10. The action of this network is as follows: under normal conditions with relays ON1 operated and relay RA1 unoperated, condenser C10 charges to a negative 48-volt potential through resistor R7; condenser C9 assumes a charge of +130 volts on its right-hand plate and -48 volts on its left-hand plate; as relay RA1 operates it effectively places the right-hand plate of condenser C9 at ground through low valued resistance R18; this changes the potential across the C9 condenser from 178 volts to 48 volts and the current flow introduced by this voltage change of 130 volts produces a voltage drop of 130 volts across the resistor R7 which makes the left-hand condenser plate at -178 volts with respect to ground. Condenser C10 is of the proper value so that it will have to be fully charged before the negative pulse will be applied to the normal cathode, thereby resetting the tube; this will provide a time delay sufficiently long to allow the register relays to operate before the tube is reset.

Since the stepping tube is again conducting in its normal position, it is now ready for the reception of the next series of pulses which will constitute the second digit. After the first digit has been counted and registered in the A column of register relays, the steering circuit shown on Fig. 3 operates relays which will disconnect the A column of register relays from the counting circuit of Fig. 2 and connect the B column of register relays to the counting circuit.

When relay RA released at the end of the reception of the pulses of the first digit, relay BS was operated by a circuit which consists of a pair of lower make contacts on relay AS, a pair of lower make contacts on relay EV, and a pair of upper break contacts on relay RA, to a ground furnished by relay ON.

Relay BS operated locks to a ground supplied by relay ON through a pair of lower break contacts of relay HS. The operation of relay BS removes one holding path from relay AS, however relay AS remains operated via a second holding path which consists of a pair of its lower make contacts through a lower pair of make contacts on relay EV, to a pair of upper break contacts on relay RA, to a ground furnished by relay ON. Relay AS will release when relay RA operates upon the initiation of the dialing of the second digit.

Relay L responds as the pulses of the second digit are received in response to the subscriber's dialing. Relay RA will operate on the first release of relay L and, being of the slow release type, will remain operated during the reception of pulses for the second digit. The operation of relay RA will break the holding path for relay AS thereby causing its release, which in turn will cause the release of relay EV. The release of relay EV will close a circuit for the operation of relay OD through a pair of lower break contacts of relay EV to a ground on the lower make contacts of relay BS. The operation of relay RA will also cause the release of relay RA1 which will disconnect the counting circuit of Fig. 2 from the steering circuit of Fig. 3. This relay will not reoperate until relay RA releases at the termination of the dialing of the second digit.

As the L relay releases and reoperates in response to the pulses representing the second digit, the stepping tube will step to the position representative of the number of pulses received for the second digit. This action of the stepping tube and its associated circuit is similar to that already described for the pulses of the first digit.

Relay L will remain operated after the dialing of the second digit is completed and will cause the release of slow release relay RA, which in turn will cause the reoperation of relay RA1. Upon the operation of relay RA1, the counting circuit of Fig. 2 will be connected through relays OD and BS to column B of the register relays. The number representing the second digit dialed will be entered into the B column of register relays via the two conducting cathode leads.

The release of relay RA after the second digit is dialed will also close a path to operate relay HS which will lock to a ground supplied by relay ON1 through the contacts of relay JS. Relay HS operated will provide a holding ground for relay OD which is already operated at this time. Relay BS will remain operated until the first release of relay L on the reception of the first pulse of the third digit. The release of relay L at this time will effect the operation of relay RA which in turn will interrupt the holding path for relay BS, thereby causing its release.

The reception, detection and counting of pulses representative of additional digits will be similar to the action explained for the first two digits. Whereas the first digit was registered column A of the register relay circuit, and the second digit was registered column B of the register relay circuit, additional digits will be represented and stored in the additional columns of register relays indicated on Fig. 4. The next to the last digit

would be stored in column H while the last digit would be stored in column J. It should be remembered however that this showing is merely exemplary since as many columns of register relays may be provided as there are digits to be stored. After the dialing is completed and all the digits representing the called telephone number have been entered into the register circuit of Fig. 4, the marker operates and receives the information from the register circuit on a two-out-of-five code basis. The marker then disconnects the calling line from the circuit of Fig. 2, effects the release of the equipment shown in Figs. 2, 3, and 4, and takes further action to complete the call.

Relay P1 which is operated from the cathode C in the first position of the stepping tube is provided to furnish certain holding grounds to the other parts of the circuit at the proper time and to perform certain service functions, the circuits of which are not shown herein.

Relay P2 which is operated from the C cathode in the second position of the stepping tube is provided to furnish certain holding and operating grounds to other parts of the circuit at the proper time and to perform certain service functions not shown herein. One of the service functions performed by relay P2 is to ring in an alarm in case the first digit does not consist of a number greater than 1. Since no telephone number begins with the digit 1, such a situation would be indicative of the fact that some special situation exists. Relay P2 in conjunction with relay P1 acts to detect this abnormal condition and to initiate the dissemination of the necessary alarm indication.

Relay OP is operated by the C cathodes in positions 10 and 11 of the tube and is furnished to perform the necessary service functions should the digit 0 be dialed on the first digit or should a greater number of pulses than 10 be received as representative of the first digit. Since no telephone number begins with 0, it is evident that if the first digit dialed is 0 some special situation exists, such as the subscribed wishes to converse with the operator. It should be noticed that the circuit that connects relay OP to the C cathodes in positions 10 and 11 is wired through the make contacts of relay AS. Since relay AS is operated only during the reception and registering of the pulses of the first digit, relay OP and its associated circuits will be inoperative during the reception of the remaining digits since relay AS will be released at this time. Thus relay OP will allow the entering of the digit "0" into any column of register relays other than column A. The operation of relay OP also opens a circuit to condenser C5 so that the register circuit of column A will not have the digit 0 entered into it should the stepping tube receive that number of pulses as representative of the first digit.

The eleventh position in the stepping tube is furnished to detect the trouble condition that would occur should an alternating voltage ever be permanently applied to the B cathodes. This condition would occur should an alternating-current power line ever become shorted to the B cathode line. In case of a trouble of this nature, the tube would step to position 11 and operate relay OP. This alarm condition would be detected by the operator and reported to the proper maintenance authority.

In designing equipment for use in the telephone industry, it is necessary that such equipment shall be long lived so that telephone rates may be kept as low as possible. In keeping with this general objective, it is necessary that the stepping tube shall have as long a life as is possible. In practice, it has been found that the life of such stepping tubes can usually be measured by the life of the normal cathode, since by far the greater percentage of time that the tube conducts, the conduction takes place between the main anode and the normal cathode. Expressed in another way, the counting time of the tube is very short compared to the time the tube

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conducts in its normal position while waiting for the reception of impulses. It is therefore obvious that if the stepping tube is to be long lived that the normal cathode should be as long lived as possible. Long normal cathode life can be accomplished by keeping the conduction current for the normal cathode to as low a value as is possible with reliable performance. The normal cathode current can be lowered by inserting a resistor, such as R7, in the cathode circuit, however the value of resistance that can be inserted in the cathode branch of the circuit to limit the normal cathode current is limited because the IR drop of such a resistor cannot be greater than that value which would cause the normal cathode to assume a potential differential of any more than 5 volts with respect to an adjacent cathode. Should the voltage gradient between cathodes exceed 5 volts, the performance of the tube will become unreliable. It is therefore obvious that sufficient resistance cannot be inserted in the normal cathode leg of the circuit to limit the cathode current to that low value which is necessary for a maximum cathode life and hence maximum tube life. Accordingly, the value of resistor R7 is limited to that value of resistance whose IR drop would place the potential of the normal cathode no more than 5 volts positive with respect to the other cathodes in the tube.

If the tube cathode currents were uniform and equal for all stepping positions of the tube, it is obvious that the value of resistance R2 could be adjusted to such a value that would limit the cathode current for the normal position to the desired low value that is consistent with maximum cathode life and tube life. Resistor R1 and varistor V1 could also be eliminated. Unfortunately, however, the tube current is not uniform and equal in all positions of the stepping tube since the cathode currents will vary in accordance with the resistance of the external cathode circuit. Another requirement of the stepping tube is that relays P1, P2 and OP, which are associated with the C cathodes in positions 1, 2, 10 and 11, respectively, must operate as rapidly as possible so that the rate of stepping for the tube may be kept at a high figure. If the value of resistance R2 were high enough so that it would limit the normal cathode current to the desired low value, then when the discharge in the tube stepped to positions 1, 2, 10 or 11, the resulting value of tube current would be so low that the operate time of relays P1, P2 and OP would be so great that the stepping rate of the tube would be lowered to a value which would make it commercially undesirable. On the other hand, if resistor R2 were lowered to that value of resistance which would provide a current that would operate relays P1, P2 and OP as soon as possible when the tube is conducting in positions 1, 2, 10 or 11, the resulting current through the normal cathode would be so high that the normal cathode life and hence the tube life would be considerably shortened.

Therefore, a problem arose whereby it is necessary to provide a varying current through the tube depending upon which position the conduction is taking place. The solution of this problem was reached by inserting the series combination of resistor R1 and varistor V1 in parallel with resistor R2. The varistor changes its impedance as the external circuit resistance is changed and thereby provides a means of producing a varying tube current. The resultant arrangement gives a tube current for the normal cathode that is low and therefore conducive to long cathode life. In the positions 1, 2, 10 and 11 where it is necessary to provide a maximum of current to operate relays as soon as possible, the tube current is increased to the desired value. This phenomenon is due to the nature and characteristics of the varistor V1.

As will be recalled, a varistor is a non-linear impedance element which has the characteristics that its resistance decreases at a rapid rate as the voltage across its

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terminals increases. If the voltage across a varistor were doubled, its resultant resistance would not be halved but instead, it would be some small fraction much smaller than the value of one-half, all depending upon the characteristics of an individual varistor. For instance, it would be possible to design a varistor that as the voltage across its terminals is doubled, its corresponding resistance would be decreased by the value of one-quarter. In the normal position of the tube, the value of resistor R7 together with the non-linear characteristics of varistor V1 limit the tube current to the low value desired for long tube life. In practice, the value of R7 has been found to be about 20,000 ohms. This value provides the proper tube current and also insures that the potential of the normal cathode does not rise to a positive value greater than -40 volts. In positions 1, 2, 10 and 11 the relays P1, P2 and OP each have a resistance of 500 ohms. This decreases the resistance in the cathode circuit by a factor of 20,000/500 or 40. However, due to the non-linear characteristics of varistor V1, the lowering of the resistance in its external circuit by a factor of 40 will result in an increased circuit current not of 40 times but of a much greater value, possibly 80 or 100 times.

The value of resistance R2 and the characteristics of varistor V1 are chosen and designed respectively so that the varied currents that are desired in the different conductive positions of the tube are actually achieved. Resistor R1 is a current-limiting resistor inserted in series with varistor V1 to prevent the varistors burning out due to the increased current through it should a short appear in any one part of the circuit.

From the foregoing description, it can be appreciated that the present invention permits pulses to be detected, counted and registered at a more rapid rate than heretofore known. It is to be understood that the hereinbefore described arrangements are but illustrative of the application of the principles of the invention. Numerous other arrangements may be devised by those skilled in the art without departing from the spirit and scope of the invention.

What is claimed is:

1. In a signaling system, an impulse responsive means, a gas discharge tube having a plurality of distinct conductive positions therein, means controlled by said responsive means in response to impulses received to advance the conductive path in said gas tube step by step from position to position, a common anode operatively associated with all of said conductive positions, a variable impedance connected to said common anode, a separate cathode in each conductive position of said tube, additional cathodes in some of said conductive positions, a plurality of fixed value impedance elements some of which have different impedance magnitudes from the others, each of said cathodes being connected to one of said fixed value impedance elements, said variable common impedance being effective to vary the magnitude of its own impedance in response to the variation of tube currents caused by said separate fixed value impedance elements as said conductive path in said tube is advanced from position to position, registering means, and means operative upon the cessation of impulses for selectively operating said registering means in accordance with the position of the conductive path in said tube.

2. In a signaling system, an impulse responsive means, a gaseous discharge tube having a plurality of distinctive conductive positions, means for causing the conductive path in said tube to advance step by step from position to position in response to the reception of a series of impulses by said impulse responsive means, a first electrode common to all of said conductive positions, a plurality of second electrodes with each of said conductive positions having at least one of said second electrodes exclusively and operatively associated therewith, a plurality of fixed value impedance elements with some of said impedance elements being of a different impedance value

than others of said elements, each of said second electrodes being connected to one of said fixed value impedance elements, a variable impedance element connected to said first electrode, said variable impedance element being effective to vary the magnitude of its own impedance in response to the variation in tube currents caused by said different fixed value impedance elements as the conductive path in said tube steps from position to position, registering means, means operative upon the cessation of a series of impulses for connecting said gaseous discharge tube to said register means whereby said register means are selectively operated in accordance with the final conductive position established in said tube.

3. In a signaling system, an impulse responsive relay, a gas stepping tube having a plurality of distinctive conductive positions therein, contacts controlled by said impulse responsive relay in response to a series of impulses received by said relay to advance the conductive path in said tube step by step from position to position therein, an anode common to all of said conductive positions, a variable load impedance connected to said anode, a plurality of cathodes in said tube with each of said conductive positions having at least one of said cathodes exclusively and operatively associated therewith, a plurality of fixed value impedance elements of different impedance magnitudes, each of said cathodes being connected to one of said fixed value impedance elements, said variable impedance being effective to increase the magnitude of its own impedance in response to the decrease in tube current caused as the conductive path in said tube steps to a conductive position associated with a fixed value impedance element of a relatively high impedance magnitude, said variable impedance also being effective to lower the magnitude of its own impedance in response to the increase in tube current caused as the conductive path in said tube steps to a conductive position associated with a fixed value impedance element of a relatively low impedance magnitude, a register, means operative upon the cessation of a group of impulses for connecting said cathodes to said register whereby said register is selectively operated in accordance with the final conductive position established in said tube.

4. In combination, a source of potential of a first

polarity, a switching device, a variable impedance having a negative resistance characteristic whereby its impedance is lowered in response to an increased current flow therethrough and is raised in response to a decreased current flow therethrough, said variable impedance interconnecting said source of potential and said switching device, a source of potential of opposite polarity from said first-named source of potential, a plurality of fixed value impedance elements some of which have a different impedance value from the others and each of whose one side is connected to said source of potential of opposite polarity and each of whose other side is connected to said switching device, means operable to cause said switching device to interconnect said variable impedance successively with each of said fixed value impedances to cause a current to flow through said variable impedance in response to each interconnection with the instantaneous magnitude of said current being determined in part by the instantaneous impedance value of said variable impedance and the impedance value of the fixed value impedance to which said variable impedance is then connected, the negative resistance characteristic of said variable impedance and the instantaneous current therethrough being effective to cause said variable impedance to increase the value of its own impedance as it is connected to an impedance element of relatively high magnitude and to decrease the value of its own impedance as it is connected to an impedance element of relatively low magnitude.

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