Sept. 1, 1942. F. R. LAMBERTY ET AL 2,294,464

IMPULSE TRANSMITTER

Filed April 9, 1938 3 Sheets-Sheet 1

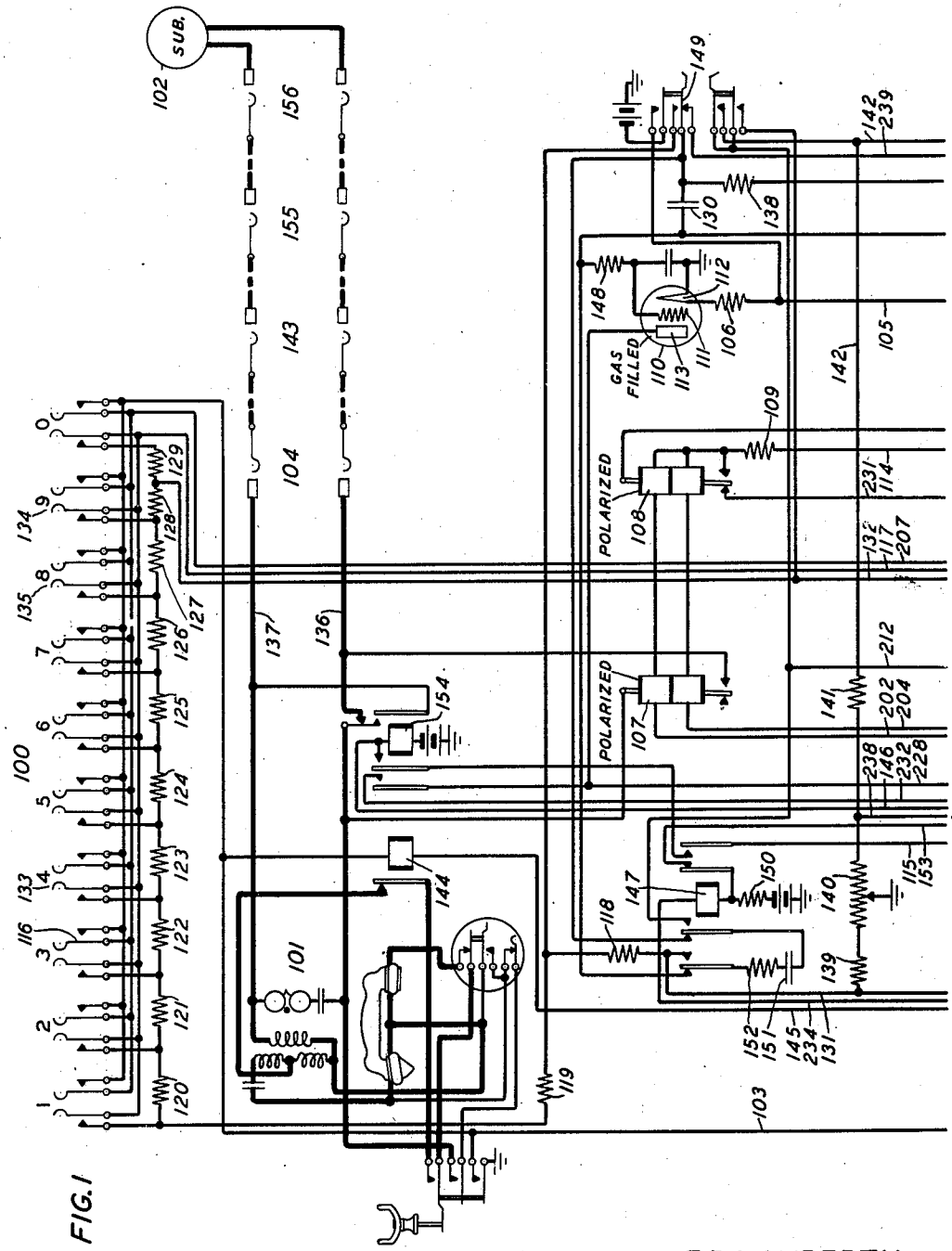

FIG. 1

INVENTORS: F. R. LAMBERTY
G. W. WEAVER

BY P. C. Smith

ATTORNEY

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IMPULSE TRANSMITTER

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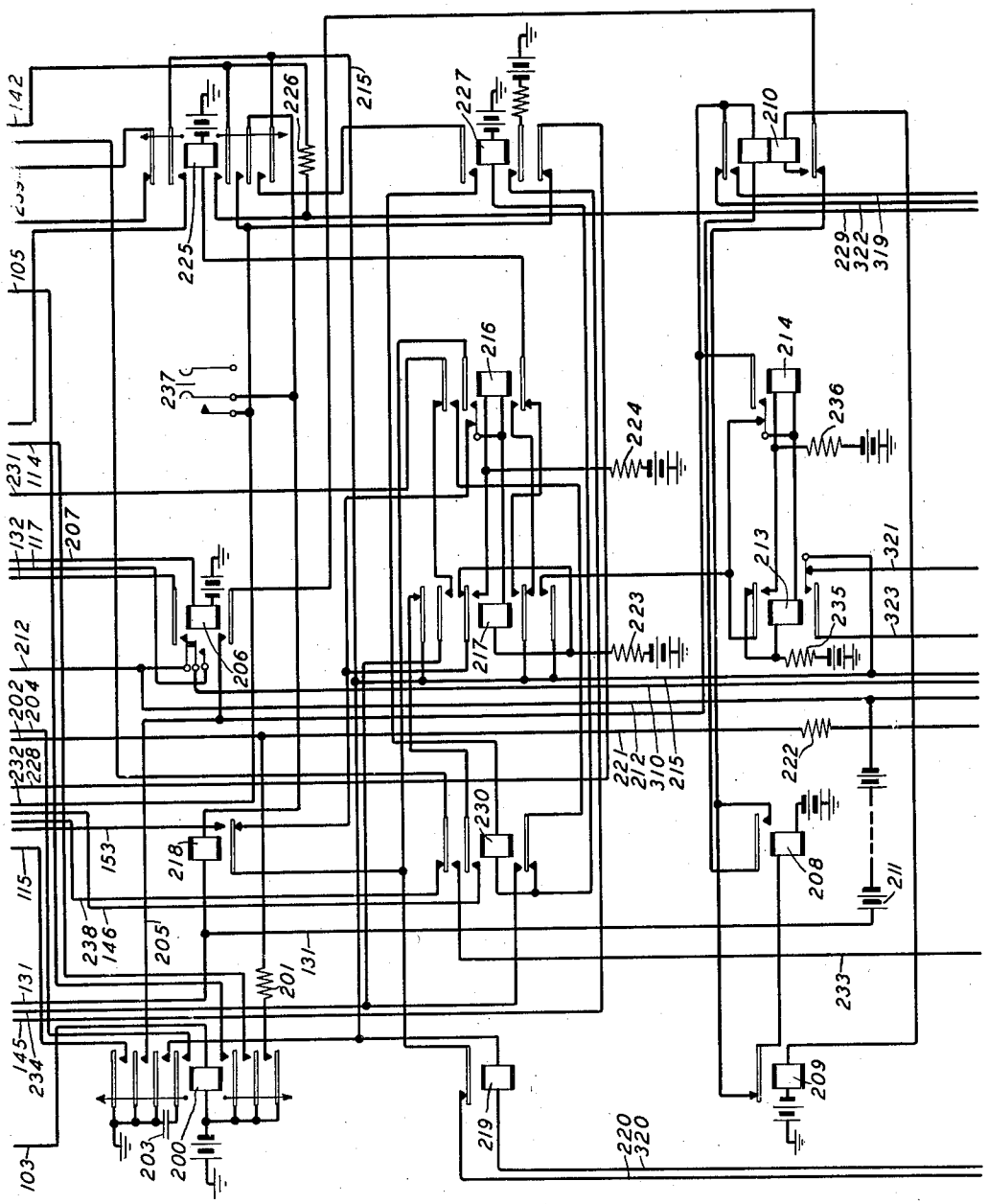

FIG. 2

INVENTORS F. R. LAMBERTY
G. W. WEAVER

BY P. C. Smith

ATTORNEY

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IMPULSE TRANSMITTER

Filed April 9, 1938 3 Sheets-Sheet 3

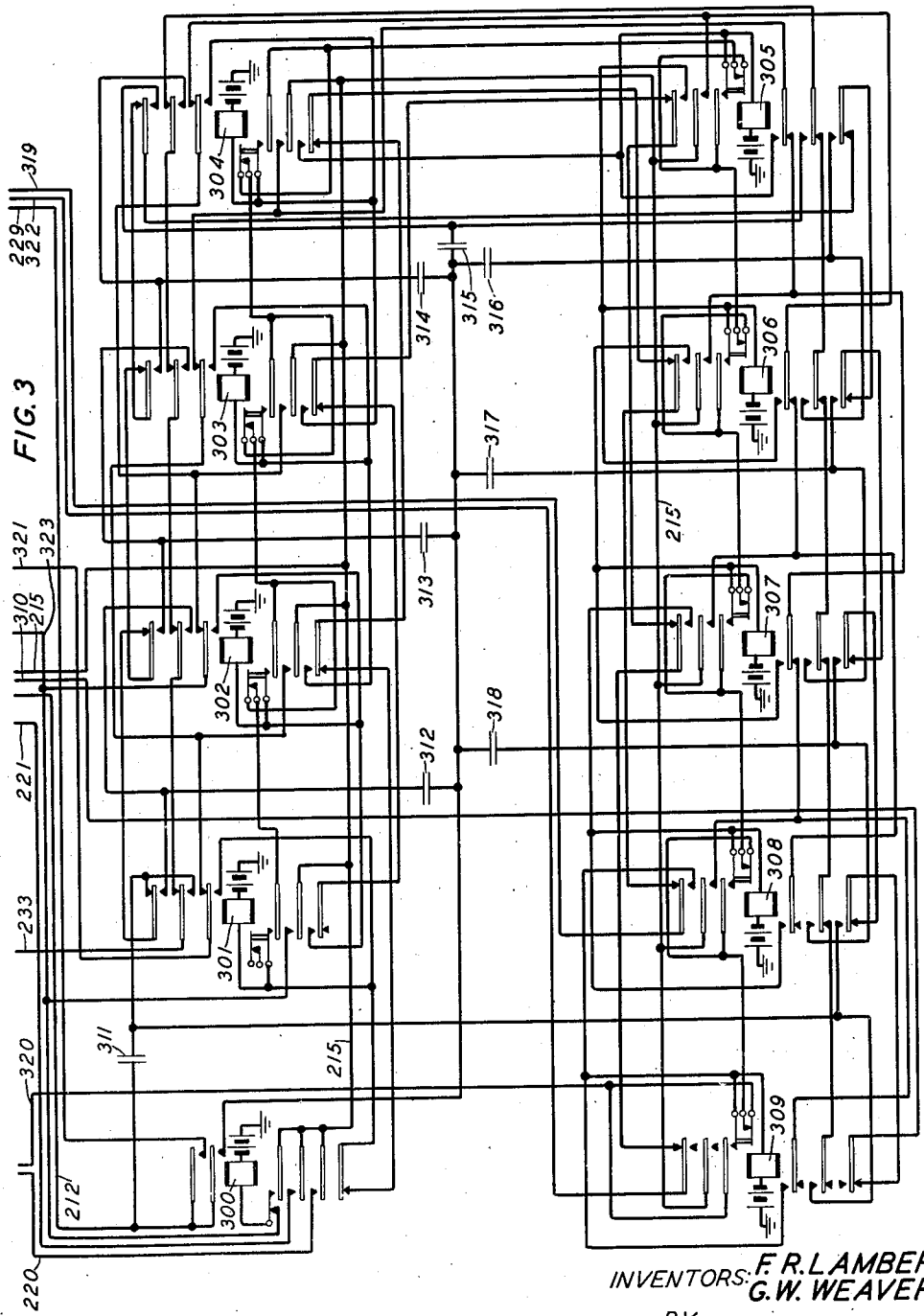

FIG. 3

INVENTORS: F. R. LAMBERTY
G. W. WEAVER

BY P. C. Smith

ATTORNEY

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2,294,464

UNITED STATES PATENT OFFICE

2,294,464

IMPULSE TRANSMITTER

Frederick R. Lamberty, Brooklyn, N. Y., and George W. Weaver, Westwood, N. J., assignors to Bell Telephone Laboratories, Incorporated, New York, N. Y., a corporation of New York

Application April 9, 1938, Serial No. 201,076

12 Claims. (Cl. 177—380)

This invention relates to impulse transmitters and more particularly to keyset controlled senders for transmitting series of impulses for setting selector switches to establish connections to subscribers' lines.

The present invention is of the general type disclosed in Patent No. 2,002,219 granted May 21, 1935 to T. L. Dimond, whereby a subscriber or an operator at a private branch exchange or at a manual board of an automatic exchange system may be keying the digits of a desired line designation on a ten-button keyset cause the registration of such keyed digits in a controlling sender which will then function in accordance with the registered digits to set up connections to the desired line.

It is the object of the invention to simplify such sender circuits by the provision of a single train of relays to serve both as steering relays for successively connecting condenser registers with the keyset and as steering relays for successively connecting the registers with impulse counting equipment during the selection control functioning of the sender and to improve and simplify the impulse counting equipment whereby it may serve not only to control the impulse series transmitted in accordance with digit registrations, but also to measure off delay intervals between the transmission of successive impulse series.

In accordance with the invention it is proposed to employ a group of condensers serving as registers for recording the successive digits keyed and to employ a gas-filled tube controlled successively by the condensers for counting the impulses in each series transmitted by the sender. The condensers are successively connected to the keyset by a train of steering relays which are operated in succession in response to the successive depression and release of keys of the keyset, each condenser being charged to a degree commensurate with the value of the digit being keyed at the time such condenser is associated with the keyset.

Two condenser timed impulsing relays are provided, one of which transmits impulses for the setting of selector switches and the other of which generates impulses for impulse counting. The impulse counting device, as previously stated, comprises a gas-filled tube which is of such a character that it breaks down or becomes conducting when the potential on its control or grid element is raised to a critical value.

For controlling the transmission of series of impulses in accordance with the digits of a keyed line designation registered on the register condensers, the impulse counting device including the tube is successively associated with the condensers by the successive release of operated steering relays. When the impulsing starts for any digit series, a condenser, which will be termed a "bucket" condenser, connected to the grid of the tube, is associated with the register condenser corresponding to the digit being transmitted whereby the potential across the bucket condenser and the serially connected register condenser is raised to the potential of the register condenser.

Associated with the bucket condenser is a further condenser, termed a "dipper" condenser, which under the control of the impulse generating relay is alternately charged to a definite potential and then discharged into the bucket condenser thus raising the potential across the terminals of the bucket condenser by predetermined increments and consequently raising the potential on the grid of the tube by the same increments until such condenser has received sufficient increments to raise the total charge across the bucket condenser and serially connected register condenser to ten increments whereupon the tube will flash and will operate an anode relay to arrest further operation of the pulsing relays, to restore the tube to its normal condition and to prepare circuits for measuring a delay interval before transmitting the next digit series.

During the measuring of a delay interval the bucket condenser is disassociated from any register condenser, but the dipper condenser is alternately charged and discharged into the bucket condenser until the bucket condenser has accumulated a charge equal to the breakdown potential of the tube whereupon the tube will fire to operate the anode relay to terminate the time interval and to prepare the sender circuit for out-pulsing in accordance with the next registered digit.

During out-pulsing for successive digits the operated steering relays are successively released to associate successively charged register condensers with the bucket condenser and the grid of the tube, provision being made to arrest out-pulsing whenever the time interval following the out-pulsing for the last digit keyed and registered on a register condenser has been terminated.

The features of the invention will be more clearly apparent from a consideration of the following detailed description read in connection

with the accompanying drawings which illustrate the employment of the invention at a subscriber's station associated with an automatic telephone exchange system of a type in which the selective operations are controlled by the transmission of series of impulses corresponding to a wanted line designation when it is desired to permit such subscriber to set up connections by keying rather than by dialing digits.

It is to be understood, however, that the invention is not so limited in its use, but may be employed at the operator's position of a private branch exchange system or at an "A" operator's position of an automatic exchange system.

Referring to the drawings:

Fig. 1 shows a calling subscriber's substation circuit and associated keyset, the diagrammatic illustration of a called line and selector switches for establishing a connection from the calling subscriber's line to such called line and a portion of the sender equipment;

Fig. 2 shows further relay equipment of the sender; and

Fig. 3 shows the register condensers and steering relays of the sender.

The complete circuits illustrating the invention will be best visualized by placing Fig. 2 beneath Fig. 1 and Fig. 3 beneath Fig. 2 with the conductors extending to the upper and lower margins thereof in alignment.

The keys of the keyset 100 have digital values of 1 to 0, inclusive, and are of the non-locking type. Steering relays 301 to 309, inclusive, of Fig. 3, serve to connect the digit register condensers 311 to 318, inclusive, one at a time and in rotation to the keys of the keyset 100 at which time each condenser receives a charge corresponding to the digital value of the particular digit keyed and also serve to connect the charged condensers one at a time and in rotation with the bucket condenser 130 associated with the grid or control electrode 111 of the gas-filled tube 110.

It is believed that the invention will be best understood from a detailed description of the establishment of a connection initiated from the substation 101 of a calling line to the called line 102, it being assumed that for this purpose the calling subscriber keys the number 3498.

When the calling subscriber at substation 101 removes the handset from the switchhook cradle, ground is connected over the lower contacts of the cradle contact assembly to conductor 103 thereby completing the operating circuit of relay 200 and applying ground to the outer right contacts of the keys of the keyset 100, and the substation loop is closed through the station line circuit for starting the line finder 104 to search for the calling line in the usual manner. Relay 200 upon operating establishes a circuit from battery, over its inner lower contact, conductor 105 and resistance 106 through the filament 112 of tube 110; establishes a circuit from battery over its lowermost contact, resistance 201, conductor 202, thence in series through the upper windings of pulsing relays 107 and 108, through resistance 109, conductor 114, middle lower contact of relay 200 to battery; establishes a charging circuit for condenser 203 extending from ground, through the condenser, inner upper front contact of relay 200, conductor 204, thence serially through the lower windings of relays 107 and 108, through resistance 109, conductor 114 to battery over the middle lower contact of relay 200, and at its upper three contacts connects holding ground to conductors 115, 205 and 215. Condenser 203 charges in the previously traced circuit and the charging current flowing through the lower windings of pulsing relays 107 and 108 causes their operation at this time to engage their armatures with their left contacts if they are not in engagement therewith.

When the subscriber depresses the No. 3 key 116 to record the first digit of the assumed called line designation, a circuit is established from the battery through the winding of relay 206, conductor 207, right contacts of key 116 to ground on conductor 103 and relay 206 operates establishing a circuit from battery through the winding of relay 208, back contact of relay 209, lower back contact of relay 210, lower contact of relay 206 to ground on conductor 205. Relay 208 operates and locks in a circuit from battery through its winding, back contact of relay 209, front contact of relay 208, upper winding of relay 210 to ground on conductor 205, but relay 210 does not operate in this locking circuit since its upper winding is shunted so long as relay 206 remains operated. Relay 206 also bridges the 135-volt battery 211 across the serially connected resistances 118 to 128, inclusive, of a potential divider associated with the keyset 100 over a circuit extending from the lower terminal of resistance 118 and conductor 131 to the positive terminal of battery 211 and from the negative terminal thereof over conductor 212, the outer upper contact of relay 206, conductor 132 to the junction between resistances 128 and 129. The other junctions between the resistances of the potential divider are connected to the outer left contacts of the keys of the keyset 100.

With the No. 3 key 116 depressed and relay 206 operated, potential is applied across the terminals of register condenser 311 from the potential divider. The left terminal of condenser 311 being connected over conductor 212, the upper contacts of relay 206 and conductor 132 to the junction between resistances 128 and 129 and the right terminal of the condenser being connected over the upper back contact of steering relays 301 to 304, inclusive, the lower back contacts of steering relays 305 to 309, inclusive, conductor 310, inner upper contacts of relay 206, conductor 117, left contacts of key 116 to the junction between resistances 121 and 122. Condenser 311 is thus charged to a potential equal to the drop across the resistances 122 to 128, inclusive, or with seven increments of potential.

When the operator releases the depressed key 116 the charging path for condenser 311 is opened at its left contacts and the operating circuit of relay 206 is opened at its right contacts. Relay 206 now releases, opening the shunt around the upper winding of relay 210 which now operates in the locking circuit of relay 208 and establishes a circuit for steering relay 301 which may be traced from battery through the winding of relay 301, thence serially over the lower back contacts of relay 300 and steering relays 302 and 304, serially over the upper back contacts of steering relays 305 and 308, conductor 319, upper front contact of relay 219 to ground on conductor 205. Relay 301 upon operating locks in a circuit from battery through its winding and inner upper front contact, over conductor 321, lower normal contacts of relay 213 to ground on conductor 215; opens at its upper back contact the charging circuit for register condenser 311 previously traced; prepares at its upper front contact the charging circuit for register condenser 312; prepares at its middle upper front

contact a discharge path for condenser 311; closes a shunt around the winding of relay 219 and establishes an operating circuit for off-normal relay 300.

The shunt around the winding of relay 219 may be traced from the right terminal of the winding of relay 219, over conductor 215, lower normal contacts of relay 213, conductor 321, inner upper and inner lower front contacts of relay 301, thence serially through the inner lower normal contacts of relays 302 to 304, inclusive, serially through the inner upper normal contacts of relays 305 to 309, inclusive, conductor 320 to the left terminal of the winding of relay 219. The operating circuit of relay 300 may be traced from battery through the winding and inner lower normal contacts of relay 300, middle lower front contact of relay 301 to ground on conductor 215.

Relay 300 upon operating locks over its inner lower alternate contacts to ground on conductor 215; opens at its lower back contact the initial operating circuit of steering relay 301; connects ground from conductor 215 over its middle lower front contact, conductor 221, through resistance 222 to conductor 202 and thence to the left terminal of the upper winding of pulsing relay 107 for starting the operation of the pulsing relays 107 and 108 as will be presently described and connects battery 211 across the pulsing potential divider comprising resistances 139, 140 and 141, the positive terminal of battery 211 being connected over conductor 131 to the left terminal of resistance 139 and the negative terminal of the battery being connected over conductor 212, the upper contact of relay 300, conductor 229, through resistance 226 and conductor 142 to the right terminal of resistance 141.

Relay 300 also closes circuits for relays 216 and 217 extending from battery through resistance 223, winding of relay 217 and in parallel therewith from battery through resistance 224 and winding of relay 216, thence through the inner upper normal contacts of relay 216, back contact of anode relay 218, back contact of relay 219, conductor 220 and the lower front contact of relay 300 to ground on conductor 215. Relay 216 operates, but the winding of relay 217 being shunted at this time by ground applied over the inner upper normal contacts of relay 216 and over the inner upper back contact of relay 217 to the junction between resistance 223 and the winding of relay 217, does not operate at this time. Relay 216 upon operating locks over its upper inner alternate contacts, back contact of relay 219, conductor 220, lower front contact of relay 300 to ground on conductor 215 and establishes an operating circuit for relay 225 which may be traced from battery through the winding of relay 225, lower front contact of relay 216, lower back contact of relay 217 to ground on conductor 215 for performing functions to be later described.

The subscriber has in the meantime proceeded to depress another key of the keyset 100 to record the second digit of the desired line designation. Since it has been assumed that the second digit was 4, he will depress the No. 4 key 133 whereupon relay 206 will again operate as previously described, and with relays 208 and 210 at the time operated, will establish an operating circuit for relay 209 which circuit may be traced from battery through the winding of relay 209, the lower winding and lower front contact of relay 210, the lower contact of relay 206 to ground on conductor 205. Relay 209 upon operating opens the locking circuit of relay 208 previously traced through the upper winding of relay 210 and relay 208 thereupon releases, but relay 210 is maintained operated over its lower winding in series with the winding of relay 209.

With steering relay 301 operated, the operation of relay 206 now applies potential across the terminals of register condenser 312 from the keyset potential divider, the lower terminal of condenser 312 being connected over the inner upper front contact of relay 300, conductor 212, the upper contacts of relay 206, conductor 132 to the junction between resistances 128 and 129, and the upper terminal of the condenser being connected over the upper front contact of steering relay 301, the upper back contacts of steering relays 302 to 304, inclusive, the lower back contacts of steering relays 305 to 309, inclusive, conductor 310, inner upper contacts of relay 206, conductor 117, left contacts of key 133 to the junction between resistances 122 and 123. Condenser 312 is thus charged to a potential equal to the drop across resistances 123 to 128, inclusive, or with six increments of potential.

When the subscriber releases the depressed key 133, the charging path for condenser 312 is opened at its left contacts and the operating circuit of relay 206 is opened at its right contacts. Relay 206 now releases opening the operating circuit of relay 209 and the locking circuit of relay 210 whereupon these relays release, relay 210 upon releasing establishing an operating circuit for steering relay 302. This circuit may be traced from battery, through the winding of relay 302, the lower front contact of steering relay 301, the lower back contact of steering relay 303, the upper back contacts of steering relays 305, 307 and 309, conductor 322, the upper back contact of relay 210 to ground on conductor 205. Relay 302 upon operating locks in a circuit from battery through its winding and inner upper front contact, middle lower front contact of relay 301 to ground on conductor 215; opens at its upper back contact the charging circuit for register condenser 312 previously traced; prepares at its upper front contact the charging circuit for register condenser 313; prepares at its middle upper front contact a discharge path for condenser 312 and establishes a new shunt around the winding of relay 219 extending as previously traced from the left terminal of relay 219 to the inner lower normal contacts of relay 303, thence over the inner lower and inner upper front contacts of relay 302, middle lower front contact of relay 301, conductor 215 to the right terminal of relay 219, The previously traced shunt of relay 219, established by the operation of relay 301, is now opened at the inner lower contacts of relay 302.

When the subscriber depresses the No. 9 key 134 to record the third digit, assumed to be 9, relay 206 will again operate and with relays 209 and 210 now released, relay 208 operates as described in connection with the recording of the first keyed digit and locks through the upper winding of relay 210, but the winding of relay 210 being shunted, relay 210 does not operate. With steering relay 302 operated, the operation of relay 206 now applies potential across the terminals of register condenser 313 from the keyset potential divider, the lower terminal of condenser 313 being connected over the inner upper front contact of relay 300, conductor 212, the upper contacts of relay 206 and conductor 132 to

the junction between resistances 128 and 129 and the upper terminal of the condenser being connected over the upper front contact of steering relay 302, the upper back contacts of steering relays 303 and 304, the lower back contacts of steering relays 305 to 309, inclusive, conductor 310, inner upper contacts of relay 206, conductor 117, left contacts of key 134 to the junction between resistances 127 and 126. Condenser 313 is thus charged to a potential equal to the drop across resistance 128 or with one increment of potential.

When the operator releases depressed key 134, the charging path for condenser 313 is opened at its left contacts and the operating circuit of relay 206 is opened at its right contacts. Relay 206 now releases removing the shunt from the winding of relay 210 which now operates in the locking circuit of relay 208 and establishes an operating circuit for steering relay 303 which may be traced from battery through the winding of relay 303, the lower front contact of steering relay 302, the lower back contact of relay 304, the upper back contacts of relays 306 and 308, conductor 319, the upper front contact of relay 210 to ground on conductor 205. Relay 303 upon operating locks in a circuit from battery through its winding and inner upper front contact, middle lower front contact of relay 302 to ground on conductor 215; opens at its upper back contact the charging circuit for register condenser 313; prepares at its upper front contact the charging circuit for register condenser 314; prepares at its middle upper front contact the discharge path for condenser 313 and establishes a new shunt around the winding of relay 219, extending as previously traced from the left terminal of relay 219 to the inner lower normal contacts of relay 304, thence over the inner lower and inner upper front contacts of relay 303, the middle lower front contact of relay 302, conductor 215 to the right terminal of relay 219. The previously traced shunt of relay 219, established by the operation of relay 302, is now opened at the inner lower contacts of relay 303.

When the subscriber depresses the No. 8 key 135 to record the fourth digit, assumed to be 8, relay 206 will again operate and with relays 208 and 210 at the time operated, will establish the operating circuit for relay 209 as previously traced. Relay 209 upon operating opens the locking circuit of relay 208 previously traced through the upper winding of relay 210 and relay 208 thereupon releases, but relay 210 is maintained operated over its lower winding in series with the winding of relay 209.

With steering relay 303 operated, the operation of relay 206 now applies potential across the terminals of register condenser 314 from the keyset potential divider, the lower terminal of condenser 314 being connected over the inner upper front contact of relay 306, conductor 212, the upper contacts of relay 206, and conductor 132 to the junction between resistances 128 and 129 and the upper terminal of the condenser being connected over the upper front contact of steering relay 303, the upper back contact of steering relay 304, the lower back contacts of steering relays 305 to 309, inclusive, conductor 310, the inner upper contacts of relay 206, conductor 117, left contacts of key 135 to the junction between resistances 126 and 127. Condenser 314 is thus charged to a potential equal to the drop across resistances 127 and 128, or with two increments of potential.

When the subscriber releases the depressed key 135 the charging path for condenser 314 is opened at its left contacts and the operating circuit of relay 206 is opened at its right contacts. Relay 206 now releases opening the operating circuit of relay 209 and the locking circuit of relay 210 whereupon these relays release, relay 210 upon releasing establishing an operating circuit for steering relay 304 which may be traced from battery through the winding of relay 304, the lower front contact of steering relay 303, the upper back contacts of steering relays 305, 307 and 309, conductor 322, the upper back contact of relay 210 to ground on conductor 205. Relay 304 upon operating locks in a circuit from battery through its winding and inner upper front contact, middle lower front contact of relay 303 to ground on conductor 215; opens at its upper back contact the charging circuit for register condenser 314; prepares at its upper front contacts the charging circuit for register condenser 315; prepares at its middle upper front contact a discharge path for condenser 314 and establishes a new shunt around the winding of relay 219 extending as previously traced from the left terminal of relay 219 to the inner upper normal contacts of relay 305, thence over the inner front contacts of relay 304, the middle lower front contact of relay 303 and conductor 215 to the right terminal of relay 219. The previously traced shunt of relay 219, established by the operation of relay 303, is now opened at the inner lower contacts of relay 304.

It will be noted from the foregoing description that relays 208, 209 and 210 function in response to the operation and release of relay 206 in such a manner that relay 210 is operated following the termination of keying of each odd digit and is released following the termination of keying of each even digit.

All of the digits of the assumed line number have now been registered by the charged condition of condensers 311 to 314, inclusive. In the meantime and as soon as the first keyed digit was recorded as indicated by the operation of steering relay 301, off-normal relay 300, relay 216 and relay 225, outpulsing for the first digit was initiated. When relay 300 operated and connected ground through resistance 222 to the left terminal of the winding of pulsing relay 107, an energizing circuit through the upper windings of relays 107 and 108 and resistance 109 was completed over conductor 114 and a contact of relay 200 to battery and the pulsing relays thereupon operated their armatures into engagement with their right contacts. With relay 225 now operated ground is connected from conductor 215 over the upper front contact of relay 225 to the armature of relay 108 and a discharge path for condenser 203 is established from ground on the armature of relay 108 over its right contact, through the lower windings of relays 107 and 108, conductor 204, the inner upper contact of relay 200, through condenser 203 to ground and condenser 203 discharges thereover. At the same time ground applied over the armature and right contact of relay 108 through the upper windings of relays 107 and 108, over conductor 202, resistance 222, conductor 221 and the middle lower contact of relay 300 to ground on conductor 215, short-circuits the upper windings of relays 107 and 108. With their upper windings shirt-circuited, the discharge current from condenser 203 energizes the lower windings of relays 107 and 108 in such a direction as to cause these relays

to move their armatures into engagement with their left contacts.

When the armature of relay 108 leaves its right contact the shunt around the upper windings of relays 107 and 108 is opened and these windings again energize and the previously traced charging circuit for condenser 203 is again established. Since relays 107 and 108 are differentially wound, the flux set up by the energization of their upper windings is opposed by the flux set up by the charging current for condenser 203 flowing through their lower windings. When the charging current through the lower windings decays, however, the upper windings take control and relays 107 and 108 move their armatures into engagement with their right contacts. In this manner relays 107 and 108 continue to operate their armatures from their right to their left contacts at a rate determined by the charging and discharging times of condenser 203, or at a rate determined by the best conditions for the transmission of selector setting impulses.

Relay 225 upon operating in addition to controlling the operation of the pulsing relays 107 and 108, opens at its upper back contact a discharge circuit through resistance 138 for bucket condenser 130; closes a shunt over its inner lower front contact around resistance 226; connects the positive terminal of battery 211 through the winding of anode relay 218, the middle lower front contact of relay 225, the lower back contact of relay 227 and conductor 228 to the anode 113 of tube 110 and connects the potential divider comprising resistances 139, 140 and 141 without the inclusion of resistance 226 in series across the terminals of battery 211, the left terminal of resistance 139 being connected over conductor 131 to the positive terminal of battery 211 and the right terminal of resistance 141 being connected over conductor 142, the inner lower contact of relay 225, conductor 229, the upper contact of relay 300, conductor 212 to the negative terminal of battery 211.

Upon the first operation of the armature of pulsing relay 107 to the right a shunt is established around the right normal contacts of relay 154 and when relay 107 again operates its armature to the left this shunt is opened, but without effect since relay 154 has not yet operated and consequently the line loop extending over conductors 136 and 137 to the line relay (not shown) of the first selector 143 is not interrupted to cause the vertical stepping of the first selector. When pulsing relay 108 first engages its armature with its left contact following the operation of relays 216 and 225, a circuit is established for operating relay 227 which may be traced from battery through the winding of relay 227, the lower back contact of relay 230, the upper front contact of relay 216, conductor 231, the left contact of pulsing relay 108, the upper front contact of relay 225 to ground on conductor 215. Relay 227 upon operating locks over a circuit in series with the winding of relay 230, the upper front contact of relay 227, the lower front contact of relay 225, to ground on conductor 215, but relay 230 does not operate in this locking circuit so long as pulsing relay 108 holds its armature on its left contact. Relay 227 also closes a circuit for relay 144 extending from ground on conductor 103 through the winding of relay 144, conductor 145, over the lower front contact of relay 227 to battery and relay 144 operates to open the receiver circuit at the substation during impulsing.

When relays 107 and 108 again engage their armatures with their right contacts, the shunt around the winding of relay 230 is opened by relay 108 and relay 230 operates in the locking circuit of relay 227 and establishes the operating circuit of relay 154 which may be traced from battery, through the winding of relay 154, conductor 146, inner upper front contact of relay 230, upper back contact of relay 217 to ground on conductor 215. Relay 154 upon operating opens the shunt around the contacts of pulsing relay 107 and establishes an impulsing loop from tip conductor 137, over the right alternate contacts of relay 154, the right contact of pulsing relay 107 to ring conductor 136 preparatory to impulsing and at its outer left contacts establishes a new circuit for applying positive potential to the anode 113 of the tube 110 replacing the circuit previously traced over the back contact of relay 227. This circuit extends from the positive terminal of battery 211, through the winding of relay 218, the middle lower contact of relay 225, conductor 232, outer left contacts of relay 154 to the anode 113.

With relay 230 operated a circuit is established from the grid 111 of the tube, through resistance 148, bucket condenser 130, normal contacts of key 149, conductor 239, upper front contact of relay 230, conductor 233, the middle upper front contact of steering relay 301, condenser 311, upper contact of relay 300, conductor 229, inner lower front contact of relay 225, conductor 142, resistances 141 and 140 of the pulsing potential divider to the adjustable ground whereby the discharged bucket condenser is connected in series with the register condenser 311 assumed to be charged with seven increments of potential.

On the next operation of the armatures of pulsing relays 107 and 108 into engagement with their left contacts, relay 107 opens the out-pulsing loop to transmit one impulse to the first selector switch 143 and relay 108 establishes a circuit from ground on its armature, over its left contact, conductor 231, the upper front contact of relay 216, the lower front contact of relay 230, conductor 234, winding of secondary pulsing relay 147 and resistance 150 to battery. Relay 147 operates and at its right front contact establishes a holding circuit for relay 154 extending from battery through the winding and inner left front contact of relay 154, right front contact of relay 147 to ground on conductor 115 and at its left front contacts establishes a charging circuit for dipper condenser 151 extending from the positive terminal of battery 211, over conductor 131, the outer left front contact of relay 147, resistance 152, condenser 151, the inner left front contact of relay 147, conductor 212 to the negative terminal of battery 211. Condenser 151 is of such capacity that it now charges to a potential substantially equal to one increment of the potential previously applied during the keying operation across the terminals of register condenser 311.

As soon as pulsing relays 107 and 108 again move their armatures to the right, relay 107 again closes the out-pulsing loop to terminate the first transmitted impulse and relay 108 opens the operating circuit of secondary pulsing relay 147 which releases, opening the charging circuit of dipper condenser 151 and connecting the dipper condenser over its left front contacts in parallel with bucket condenser 130. Condenser 151 now discharges into condenser 130, raising the potential thereof by one increment. Upon

successive operations of the armatures of pulsing relays 107 and 108 first to the left and then to the right, the out-pulsing loop is opened and closed and secondary pulsing relay 147 is operated and released to charge dipper condenser 151 and to discharge it into bucket condenser 130. After relay 107 has thus opened and then closed the out-pulsing loop three times and relay 108 has operated and then released pulsing relay 147 three times, three increments of potential will have been applied to bucket condenser 130 at which time the total potential across the terminals of condensers 130 and 311 will be ten increments. This total potential applied to the grid 111 of tube 110 will cause the tube to break down establishing a discharge path for condensers 130 and 311 through the tube extending from the grounded cathode 112 to the grid 111, through resistance 148, condenser 130, thence as traced through register condenser 311, over the upper contact of relay 300, conductor 229, inner lower contact of relay 225, conductor 142, through resistances 141 and 140 of the potential divider to ground and establishing a conducting path through the tube from the cathode to the anode. This latter circuit may be traced from ground over the cathode-anode path of the tube, thence as traced through the winding of anode relay 218 to the positive terminal of battery 211 and from the negative terminal of battery, conductor 212, upper contacts of relay 300, conductor 229, inner lower contact of relay 225, conductor 142, resistance 141 to ground at the adjustable point on resistance 140.

Relay 218 operates, establishing a circuit from the junction between the winding of secondary pulsing relay and resistance 150 over the right back contact of relay 147, conductor 153, front contact of relay 218, back contact of relay 219, conductor 220, lower front contact of relay 300 to ground on conductor 215 to shunt the winding of relay 147 and thus prevent its further operation on subsequent closures of the left contact of pulsing relay 108 and, at its back contact opens the shunt previously traced around the winding of relay 217. Relay 217 now operates, opens at its upper back contact the circuit of relay 154 which thereupon releases to shunt the pulsing contacts of pulsing relay 107 thereby rendering the further operation of pulsing relay 107 ineffective to transmit impulses to the first selector 143; at its lower back contact opens the circuit of relay 225 which then releases and closes a circuit for relays 214 and 213 in parallel extending from battery through resistance 235, winding of relay 213 and from battery through resistance 236, winding of relay 214, thence over the normal contacts of relay 214, lower front contact of relay 217 to ground on conductor 215.

Relay 214 operates over the previously traced circuit and locks over its alternate contacts to ground on conductor 205, but relay 213 being shunted by ground applied from conductor 215 over the lower contacts of relay 217 and its own upper back contact to the junction between its winding and resistance 235, does not operate so long as relay 217 remains operated. Relay 225 upon releasing closes at its upper back contact the resistance shunt around bucket condenser 130 to fully discharge the condenser; at its upper front contact removes ground from the armature of pulsing relay 108 thereby arresting the further operation of pulsing relays 107 and 108; at its inner lower contact removes the shunt from resistance 226; at its middle lower contact opens the cathode-anode circuit through the tube thereby extinguishing the tube and releasing anode relay 218 and at its lower contact opening the locking circuits of relays 227 and 230 which thereupon release. Relay 227 upon releasing in turn releases relay 144 to again close the substation receiver circuit.

Relay 218 upon releasing removes the shunt from the winding of secondary pulsing relay 147 and at its back contact establishes a shunt circuit for shunting down relay 216, which circuit may be traced from ground on conductor 220, back contact of relay 219, back contact of relay 218, inner upper front contact of relay 217 to the junction between the winding of relay 216 and resistance 224. Relay 216 now releases closing a holding circuit for relay 217 extending from battery through resistance 223, winding of relay 217, inner upper normal contacts of relay 216, back contact of relay 213, back contact of relay 219 to ground on conductor 220. With relay 217 operated an operating circuit for relay 225 is reestablished from battery through the winding of relay 225, lower back contact of relay 216, inner lower front contact of relay 217 to ground on conductor 215. Relay 225 upon operating again removes the shunt from bucket condenser 130, connects ground to the armature of pulsing relay 108 to cause relays 107 and 108 to again operate intermittently as previously described, reconnects the positive terminal battery 211 through the winding of anode relay 218 to the anode of tube 110 and again shunts resistance 226.

As soon as pulsing relay 108 engages its left contact a circuit is established from ground on the armature thereof over the left contact, conductor 231, the upper back contact of relay 216, the upper front contact of relay 217, conductor 234, through the winding of relay 147 and resistance 150 to battery and relay 147 operates to close the previously traced charging circuit for dipper condenser 151. On the next operation of the armature of pulsing relay 108 to its right contact, relay 147 releases and as previously described, connects the dipper condenser 151 in a discharging path to bucket condenser 130. As relay 108 continues to operate, the dipper condenser 151 is alternately charged and discharged into condenser 130 until the potential across condenser 130 reaches the breakdown potential of tube 110 whereupon the tube fires establishing a discharge path for condenser 130 from ground on the cathode 112, through the tube to the grid 111, thence through resistance 148, condenser 130, normal contacts of key 149, conductor 239, upper back contact of relay 230, conductor 238, through resistance 140 to ground and establishing the cathode-anode circuit through the tube thereby reoperating the anode relay 218. The time required to raise the potential on the grid of tube 110 to the breakdown point thus measures a sufficient delay interval to give the first selector 143 time to perform its trunk hunting function. During this interval due to the fact that relay 154 is not operated, the repeated operation of pulsing relay 107 is without effect.

When anode relay 218 operates, it again shunts relay 147 in its non-operated position and opens the locking circuit of relay 217 which thereupon releases, opening at its lower contact the shunt around the winding of relay 213 thereby permitting the operation of relay 213 and opening the circuit of relay 225 which thereupon releases.

Relay 225 upon releasing reestablishes the discharge shunt around condenser 130, removes ground from the armature of pulsing relay 108 to arrest the operation of pulsing relays 107 and 108 and opens the cathode-anode circuit through tube 110 to extingush the tube and to releane anode relay 218.

Relay 218 upon releasing removes the shunt from the winding of the secondary pulsing relay 147 and establishes a circuit for reoperating relay 216 which may be traced from ground on conductor 220, back contact of relay 219, back contact of relay 218, normal contacts and winding of relay 216, through resistance 224 to battery. With relay 216 operated and relay 217 released the previously traced operating circuit for relay 225 is established and relay 225 reoperates to remove the shunt from condenser 130, to restart the operation of pulsing relays 107 and 108 and to connect the positive terminal of battery 211 through the winding of anode relay 218 to the anode of the tube. Upon the first engagement of the armature of pulsing relay 108 with its left contact, with relays 216 and 225 now operated, the circuit of relay 227 is established from battry, through the winding of relay 227, lower back contact of relay 230, upper front contact of relay 216, conductor 231, left contact of relay 108, upper front contact of relay 225 to ground on conductor 215 and relay 227 operates, again establishing the operating circuit of relay 144 and closing a previously traced locking circuit for itself extending through the winding of relay 230. Relay 230 operates in this locking circuit as soon as pulsing relay 108 opens its left contact, causing the reoperation of relay 154 which thereupon renders the pulsing contacts of pulsing relay 107 effective for transmitting impulses to the second selector switch 155.

Relay 213 upon operating opens at its lower transfer contacts the locking circuit of steering relay 301 which thereupon releases and establishes a new holding circuit for steering relay 302 to replace the holding circuit therefor previously traced over the middle lower front contact of steering relay 301. The new holding circuit for relay 302 may be traced from battery through the winding and inner upper front contact of relay 302, conductor 323, lower alternate contacts of relay 213 to ground on conductor 215. The release of steering relay 301 disconnects the register condenser 311 from the impulse counting device and associates register condenser 312 therewith.

With relay 230 operated a circuit is established from the grid 111 of the tube through resistance 148, condenser 130, normal contacts of key 149, conductor 239, upper front contact of relay 230, conductor 233, the upper middle back contact of steering relay 301, the upper middle front contact of steering relay 302, condenser 312, upper contacts of relay 300, conductor 229, inner lower front contact of relay 225, conductor 142, resistances 141 and 140 to ground at resistance 140 whereby condensers 130 and 312 are connected in series.

On the next operation of the armatures of pulsing relays 107 and 108 to the left, relay 107 opens the out-pulsing loop to transmit one impulse to the second selector 155 and relay 108 establishes the circuit previously traced over the upper front contact of relay 216, the lower front contact of relay 230 and conductor 234 for operating the secondary pulsing relay 147 which closes the charging circuit of dipper condenser 151. On the next operation of the armatures of relays 107 and 108 to the right, relay 107 recloses the out-pulsing loop to terminate the first transmitted impulse and relay 108 opens the circuit of relay 147 which now releases and connects condenser 151 into a discharge path through the condenser 130. Upon successive operations of the armatures of pulsing relays 107 and 108 first to the left and then to the right, the out-pulsing loop is opened and closed and relay 147 is operated and released to charge condenser 151 and to discharge it into condenser 130. After relay 107 has thus opened and then closed the out-pulsing loop four times and relay 108 has operated and released relay 147 four times, four increments of potential will have been applied to condenser 130 at which time the total potential across the terminals of condensers 130 and 312 will be ten increments, since it was assumed that condenser 312 was charged with six increments. This total potential applied to grid 111 of the tube will cause the tube to break down establishing a discharge path for condensers 130 and 312 across the cathode and grid as previously described and establishing a conducting path through the tube from the cathode to the anode as previously traced over which the anode relay 218 is operated.

Relay 218 upon operating again shunts relay 147 in its non-operated position and at its back contact opens the shunt around the winding of relay 217. Relay 217 now operates opening at its upper back contact the circuit of relay 154 which thereupon releases to shunt the pulsing contacts of pulsing relay 107 thereby rendering the further operation of pulsing relay 107 ineffective to transmit impulses to the second selector. At its lower back contact relay 217 also opens the circuit of relay 225 which then releases, and connects ground from conductor 215 over its lower front contact, the upper front contact of relay 213 to the junction between resistance 236 and the winding of relay 214 whereupon relay 214 is shunted and releases.

Relay 225 upon releasing closes the discharge shunt around condenser 130 to fully discharge it, removes ground from the armature of pulsing relay 108 to arrest further operation of pulsing relays 107 and 108, opens the cathode-anode circuit through the tube thereby extinguishing the tube and releasing anode relay 218 and opens the locking circuits of relays 227 and 230 which thereupon release. Relay 227 upon releasing in turn releases relay 144. Relay 218 upon releasing removes the shunt from the winding of pulsing relay 147 and at its back contact establishes a shunt circuit for shunting down relay 216 as hereinbefore traced. With relay 216 released, relay 217 is locked operated in the circuit previously traced over the back contact of anode relay 218 and relay 225 is again operated over the previously traced circuit extending over the lower back contact of relay 216 and the inner lower front contact of relay 217.

Relay 225 upon reoperating removes the shunt from condenser 130; connects ground to the armature of pulsing relay 108 to cause relays 107 and 108 to again operate intermittently and reconnects the positive terminal of battery 211 through the winding of anode relay 218 to the anode of the tube. As soon as pulsing relay 108 engages its left contact, with relay 216 released and relay 217 operated, relay 147 is operated to close the previously traced charging circuit for dipper condenser 151. On

the next operation of the armature of relay 108 to the right, relay 147 releases and as previously described, connects the dipper condenser 151 in a discharging path to the bucket condenser 130. As relay 108 continues to operate, the dipper condenser 151 is alternately charged and discharged into condenser 130 until the potential across condenser 130 reaches the breakdown potential of tube 110 whereupon the tube fires establishing a discharge path for condenser 130 from the cathode 112 to the grid 111 as previously traced and establishing the cathode-anode circuit through the tube for reoperating the anode relay 218. The time required to raise the potential on the grid of the tube to the breakdown point thus measures a sufficient delay interval to give the second selector 155 time to perform its trunk hunting function. During this time, due to the fact that relay 154 is not operated, the repeated operation of pulsing relay 107 is without effect.

When anode relay 218 operates it again shunts relay 147 in its non-operated position and opens the locking circuit of relay 217 which thereupon releases, opening at its lower contacts the locking circuit of relay 213 which thereupon releases, and opening the circuit of relay 225 which also releases. Relay 225 upon releasing establishes the shunt around condenser 130 to fully discharge it, removes ground from the armature of pulsing relay 108 to arrest the further operation of pulsing relays 107 and 108 and opens the cathode-anode circuit of the tube thereby extinguishing the tube and releasing anode relay 218.

Relay 218 upon releasing removes the shunt from the winding of pulsing relay 147 and establishes the previously traced circuit for reoperating relay 216. With relay 216 operated and relay 217 released the previously traced circuit is established for relay 225 which reoperates to remove the shunt from condenser 130, to start the intermittent operation of pulsing relays 107 and 108 and to reconnect the positive terminal of battery 211 through the winding of anode relay 218 to the anode of the tube. Upon the first engagement of the armature of pulsing relay 108 with its left contact, with relays 216 and 225 now operated, relay 227 is reoperated, locks through the winding of relay 230 as previously described and reestablishes the previously traced operating circuit for relay 144. Relay 230 operates in the locking circuit of relay 227 upon the next opening of the left contact of pulsing relay 108, causing the reoperation of relay 154 which thereupon renders the pulsing contacts of pulsing relay 107 effective for transmitting impulses to the connector switch 156.

Relay 213 upon releasing opens at its transfer contacts the locking circuit of steering relay 302 which thereupon releases and establishes a new holding circuit for steering relay 303 to replace the holding circuit therefor previously traced over the middle lower front contact of steering relay 302. The new holding circuit for relay 303 may be traced from battery, through the winding and inner upper front contact thereof, inner upper back contact of steering relay 301, conductor 321, lower normal contacts of relay 213 to ground on conductor 215. The release of steering relay 302 disconnects the register condenser 312 from the impulse counting device and associates register condenser 313 therewith.

With relay 230 operated a circuit is established from the grid 111 of the tube, through resistance 148, condenser 130, normal contacts of key 149, conductor 239, upper front contact of relay 230, conductor 233, the upper middle back contacts of steering relays 301 and 302, the upper middle front contact of steering relay 303, condenser 313, upper contacts of relay 309, conductor 229, inner lower front contact of relay 225, conductor 142, resistances 141 and 140 to ground whereby condensers 130 and 313 are connected in series.

On the next operation of the armatures of pulsing relays 107 and 108 to the left, relay 107 opens the out-pulsing loop to transmit an impulse to step the connector switch 156 one step vertically and relay 108 establishes the circuit previously traced over the upper front contact of relay 216 and the lower front contact of relay 230 for operating the pulsing relay 147 which closes the charging circuit of dipper condenser 151. On the next operation of the armatures of relays 107 and 108 to the right, relay 107 recloses the out-pulsing loop terminating the first impulse transmitted to connector 156, and relay 108 opens the circuit of relay 147 which now releases and connects condenser 151 into a discharge path through condenser 130. Upon successive operations of the armatures of pulsing relays 107 and 108, first to the left and then to the right, the out-pulsing loop is opened and closed and relay 147 is operated and released to charge condenser 151 and to discharge it into condenser 130. After relay 107 has thus opened and then closed the out-pulsing loop nine times and relay 108 has operated and released relay 147 nine times, nine increments of potential will have been applied to condenser 130 at which time the total potential across the terminals of condensers 130 and 313 will be ten increments, since it was assumed that condenser 313 was charged with one increment of potential. This total potential applied to grid 111 of the tube will cause the tube to break down establishing a discharge path for condensers 130 and 313 across the cathode and grid, as prevously described, and establishing a conducting path through the tube from the cathode to the anode as previously traced, over which the anode relay 218 is operated.

Relay 218 upon operating again shunts relay 147 in its non-operated position and at its back contact opens the shunt around the winding of relay 217. Relay 217 now operates, opening at its back contact the circuit of relay 154 which thereupon releases to shunt the pulsing contacts of pulsing relay 107 thereby rendering the further operation of pulsing relay 107 ineffective to transmit impulses to the connector 156, at its lower back contact opening the circuit of relay 225 which then releases, and connecting ground from conductor 215 over its lower front contact, the normal contacts and winding of relay 214, through resistance 236 to battery, whereupon relay 214 operates.

Relay 225 upon releasing closes the discharge shunt around condenser 130 to fully discharge it, removes ground from the armature of pulsing relay 108 to arrest further operation of pulsing relays 107 and 108, opens the cathode-anode circuit through the tube thereby extinguishing the tube and releasing the anode relay 218, and opens the locking circuit of relays 227 and 230 which thereupon release. Relay 227 upon releasngi in turn releases relay 144. Relay 218 upon releasing removes the shunt from the wind-

ing of pulsing relay 147 and at its back contact establishes a shunt circuit for shunting down relay 216 as hereinbefore traced. With relay 216 released, relay 217 is locked operated in the circuit previously traced over the back contact of anode relay 218 and relay 225 is again operated over the previously traced circuit extending over the lower back contact of relay 216 and the inner lower front contact of relay 217.

Relay 225 upon reoperating removes the shunt from condenser 130, connects ground to the armature of pulsing relay 108 to cause relays 107 and 108 to again operate intermittently and reconnects the positive terminal of battery 211 through the winding of anode relay 218 to the anode of the tube. As soon as pulsing relay 108 engages its left contact with relay 216 released and relay 217 operated, relay 147 is operated to close the previously traced charging circuit for dipper condenser 151. On the next operation of the armature of relay 108 to the right, relay 147 releases and as previously described, connects the dipper condenser 151 in a discharge path to the bucket condenser 130. As relay 108 continues to operate, the dipper condenser 151 is alternately charged and discharged into condenser 130 until the potential across condenser 130 reaches the breakdown potential of the tube whereupon the tube fires, establishing the previously traced discharging path for condenser 130 through the tube from the cathode to the grid and establishing the cathode-anode circuit to the tube for reoperating the anode relay 218. A time interval has thus been measured. During this time interval, due to the fact that relay 154 is not operated, the repeated operation of pulsing relay 107 is without effect.

When anode relay 218 operates it again shunts relay 147 in its non-operated position and opens the locking circuit of relay 217 which thereupon releases, opening at its lower contact the shunt around the winding of relay 213 which thereupon operates, and opening the circuit of relay 225 which also releases. Relay 225 upon releasing reestablishes the discharge shunt for condenser 130, removes ground from the armature of pulsing relay 108 to arrest the further operation of pulsing relays 107 and 108 and opens the cathode-anode circuit of the tube thereby extinguishing the tube and releasing the anode relay 218.

Relay 218 upon releasing removes the shunt from the winding of pulsing relay 147 and establishes the previously traced circuit for reoperating relay 216. With relay 216 operated and relay 217 released a previously traced circuit is established for relay 225 which reoperates, removes the shunt from condenser 130, starts the intermittent operation of pulsing relays 107 and 108 and reconnects the positive terminal of battery 211 through the winding of anode relay 218 to the anode of the tube. Upon the first engagement of the armature of pulsing relay 108 with its left contact, with relays 216 and 225 now operated, relay 227 is operated locking through the winding of relay 230 and reestablishes the circuit of relay 144. Relay 230 operates in the locking circuit of relay 227 as soon as pulsing relay 108 opens its left contact, causing the reoperation of relay 154 which thereupon renders the pulsing contacts of pulsing relay 107 effective for transmitting impulses to step the connector 156 in a rotary direction.

Relay 213 upon operating opens at its transfer contacts the locking circuit of steering relay 303 which thereupon releases and establishes a new holding circuit for steering relay 304 to replace the holding circuit therefor previously traced over the middle lower front contact of steering relay 303. The new holding circuit of relay 304 may be traced from battery through the winding and inner upper front contact thereof, inner upper back contact of steering relay 302, conductor 323, alternate contacts of relay 213 to ground on conductor 215. The release of steering relay 303 disconnects the register condenser 313 from the impulse counting device and associates register condenser 314 therewith.

With relay 230 operated a circuit is established from the grid 111 of tube 110, through resistance 148, condenser 130, normal contacts of key 149, conductor 239, upper front contact of relay 230, conductor 233, the upper middle back contacts of steering relays 301 to 303, inclusive, the upper middle front contact of steering relay 304, condenser 314, upper contacts of relay 300, conductor 229, inner lower front contact of relay 225, conductor 142, resistances 141 and 140 to ground whereby condensers 130 and 314 are connected in series.

On the next operation of the armatures of pulsing relays 107 and 108 to the left, relay 107 opens the out-pulsing loop to transmit an impulse to step the connector switch 156 one step in a rotary direction and relay 108 establishes the circuit previously traced over the upper front contact of relay 216 and the lower front contact of relay 230 for operating the pulsing relay 147 which closes the charging circuit of dipper condenser 151. On the next operation of the armatures of relays 107 and 108 to the right, relay 107 closes the out-pulsing loop to terminate the first impulse and relay 108 opens the circuit of relay 147 which now releases and connects condenser 151 into a discharge path through condenser 130. Upon successive operations of the armatures of pulsing relays 107 and 108, first to the left and then to the right, the out-pulsing loop is opened and closed and relay 147 is operated and released to charge condenser 151 and to discharge it into condenser 130. After relay 107 has thus opened and closed the out-pulsing loop eight times and relay 108 has operated and released relay 147 eight times, eight increments of potential will have been applied to condenser 130 at which time the total potential across the terminals of condensers 130 and 314 will be ten increments, since it was assumed that condenser 314 was charged with two increments of potential. This total potential applied to grid 111 of the tube will cause the tube to break down establishing a discharge path for condensers 130 and 314 across the cathode and grid as previously described and establishing a conducting path through the tube from the cathode to the anode as previously traced, over which the anode relay 218 is operated.

Relay 218 upon operating again shunts relay 147 in its non-operated position and at its back contact opens the shunt around the winding of relay 217. Relay 217 now operates opening at its upper back contact the circuit of relay 154 which thereupon releases to shunt the pulsing contacts of pulsing relay 107 thereby rendering the further operation of pulsing relay 107 ineffective to transmit impulses to the connector 156, at its lower back contact opening the circuit of relay 225 which then releases and connecting ground from conductor 215 over its lower front contact, the upper front contact of relay 213 to the junction between resistance 236 and the winding of relay

214 whereupon relay 214 is shunted and releases.

Relay 225 upon releasing closes the discharge shunt around condenser 130 to fully discharge it, removes ground from the armature of pulsing relay 108 to arrest further operation of pulsing relays 107 and 108, opens the cathode-anode circuit through the tube thereby extinguishing the tube and releasing anode relay 218 and opens the locking circuits of relays 227 and 230 which thereupon release. Relay 227 upon releasing in turn releases relay 144. Relay 218 upon releasing removes the shunt from the winding of pulsing relay 147 and at its back contact establishes a shunt around the winding of relay 216 as previously traced whereupon relay 216 releases. With relay 216 released, relay 217 is locked operated in the circuit previously traced over the back contact of relay 218 and relay 225 is again operated over the previously traced circuit extending over the lower back contact of relay 216 and the inner lower front contact of relay 217.

Relay 225 upon operating removes the shunt from condenser 130, again starts the operation of pulsing relays 107 and 108 and reconnects the positive terminal of battery 211 through the winding of anode relay 218 to the anode of the tube. As soon as pulsing relay 108 engages its left contact, with relay 216 released and relay 217 operated, relay 147 is operated to close the previously traced charging circuit for dipper condenser 151. On the next operation of the armature of relay 108 to the right, relay 147 releases and as previously described, connects condenser 151 in a discharge path to condenser 130. As relay 108 continues to operate, condenser 151 is alternately charged and discharged into condenser 130 until the potential across condenser 130 reaches the breakdown potential of tube 110 whereupon the tube fires establishing the previously traced discharge path for condenser 130 through the tube from the cathode to the grid, and establishing the cathode-anode circuit through the tube for reoperating the anode relay 218. A time interval has thus been measured. During this time interval, due to the fact that relay 154 is not operated, the repeated operation of pulsing relay 107 is without effect.

Since the connector switch 156 has now been set upon the terminals of the wanted line 102, the connector proceeds to test the line for its busy or idle condition, to return a busy signal if the line is busy, or to apply ringing current if the line is idle. If the line is found to be idle and the called subscriber responds, the ringing current is cut off and a talking circuit is established from the calling substation 101 to the called line 102.

When anode relay 218 operates it again shunts relay 147 in its non-operated position and opens the locking circuit of relay 217 which thereupon releases opening at its lower contact the locking circuit of relay 213 which thereupon releases, and opening the circuit of relay 225 which also releases. Relay 225 upon releasing reestablishes the discharge shunt for condenser 130, arrests the further operation of pulsing relays 107 and 108 and opens the cathode-anode circuit of the tube thereby extinguishing the tube and releasing anode relay 218.

Relay 213 upon releasing opens at its transfer contacts one locking circuit of steering relay 304 which may be traced from battery through the winding and inner upper front contact of relay 304, inner upper back contact of steering relay 302, conductor 323, contacts of relay 213 to ground on conductor 215 and, since it was assumed that only four digits were keyed by the subscriber and steering relay 305 has not therefore operated, there is now no effective shunt around the winding of relay 219 and relay 219 therefore operates over a circuit extending from battery through the winding and inner lower front contact of steering relay 304, thence as traced over the inner upper normal contacts of steering relays 305 to 309, inclusive, conductor 320, winding of relay 219 to ground on conductor 215. At its contacts relay 219 upon operating removes ground from the armature of anode relay 218 whereby relay 218 upon releasing is ineffective to cause the reoperation of relays 216 and 225 and the further operation of pulsing relays 107 and 108.

When the calling subscriber returns his handset to the cradle, ground is removed from conductor 103 thereby releasing start relay 200 which then removes ground from conductor 215 thereby releasing any operated relays of the sender, in this case, steering relay 304, off-normal relay 300 and relay 219.

Had the subscriber delayed keying after having keyed the first digit, at which time only steering relay 301 has operated and locked under the control of the lower normal contacts of relay 213, off-normal relay 300 has operated and locked and the winding of relay 219 is shunted over the lower normal contacts of relay 213, the inner upper front contact of relay 301, the inner lower normal contacts of steering relays 302 to 304, inclusive, the inner upper normal contacts of steering relays 305 to 309, inclusive, and conductor 320; then as soon as impulsing for the first digit registered in condenser register 311 has been completed and the following time interval has been measured, relay 213 is operated as previously described. With no other steering relay yet operated, the operation of relay 213 now opens the shunt around the winding of relay 219 whereupon relay 219 operates in series with steering relay 301 in a circuit from battery through the winding and inner lower front contact of relay 301, thence over normal contacts of the remaining steering relays, conductor 320, winding of relay 219 to ground on conductor 215. Relay 219 upon operating removes ground from the armature of anode relay 219 to prevent the operation of relays 214 and 225 whereby the transmission of further impulses is prevented.

When the next digit is keyed and steering relay 302 operates, the winding of relay 219 is again short-circuited over conductor 215, the middle lower front contact of relay 301, the inner front contacts of relay 302 and thence as traced to conductor 320, and relay 219 releases whereupon the out-pulsing functions of the sender are resumed in the manner previously described. A similar condition occurs at any time that the sender has pulsed out all the digits keyed by the subscriber.

From the foregoing description it will be apparent that the pairs of relays 216, 217 and 213, 214 act as counting relays, relay 216 operating prior to the out-pulsing of any digit series, relay 217 operating at the end of out-pulsing, relay 216 releasing prior to the beginning of the succeeding time interval and relay 217 releasing at the end of the time interval. Relay 214 operates at the end of out-pulsing for each odd digit series, relay 213 operates at the end of the following time interval, relay 214 releases at the end of the out-pulsing for each even digit series and relay 213 releases at the end of the following time interval.

It is to be noted that eight condenser registers 311 to 318, inclusive, are disclosed and that if a line designation comprises more than eight digits, steering relay 308 will be operated following the charging of register condenser 318 for the eighth digit keyed upon the release of the depressed key and will lock up and prepare a charging circuit for register condenser 311. This condenser which was employed to register the first digit keyed will by this time have determined the out-pulsing for the first digit and have become discharged. If then the subscriber keys a ninth digit, the operation of relay 206, with relay 210 not operated will, as previously described, cause the operation of relay 208 and will apply potential across the terminals of register condenser 311 from the keyset potential divider, the left terminal of condenser 311 being connected over the upper front contact of relay 300, conductor 212, the upper contacts of relay 206, conductor 132 to the junction between resistances 128 and 129 and the right terminal of condenser 311 being connected over the lower front contact of steering relay 308, the lower back contact of steering relay 309, conductor 310, inner upper contacts of relay 206, conductor 117, left contact of the key depressed for the ninth digit to a junction between two resistances of the keyset potential divider whereby condenser 311 will be charged to a potential determined by the digital value of the depressed key.

When the subscriber releases the depressed key, the charging path for condenser 311 is opened and relay 206 is released whereupon relay 210 operates in the locking circuit of relay 208, as previously described, and establishes a circuit for steering relay 309 which may be traced from battery, through the winding of relay 309, the upper front contact of relay 308, conductor 319, upper front contact of relay 210 to ground on conductor 205. Relay 309 upon operating locks in a circuit from battery through its winding and inner lower front contact, middle upper front contact of relay 308 to ground on conductor 215, opens at its lower back contact the charging circuit for register condenser 311 previously traced, prepares at its middle lower front contact the discharge path for condenser 311 and establishes a new shunt around the winding of relay 219 extending, as previously traced, from the left terminal of relay 219, over conductor 320, inner front contacts of relay 309, middle upper front contact of relay 308, conductor 215 to the right terminal of relay 219. No provision is made for registering more than nine digits although it will be apparent that the circuits might readily be arranged to do so.

The provision for enabling the registration of nine digits has particular utility when the circuits are installed on a subscriber's line of a private branch exchange. In such an installation the subscriber would key a first digit to obtain access to a trunk outgoing to a central office and would then wait before keying the digits of the directory number of a desired subscriber's line until after a dialing tone has been received from the central office. The establishment of the connection to the central office restores the first register condenser 311 to its discharged or normal condition as previously described. Having received the dial tone from the central office the subscriber would then proceed to key the digits of the desired line designation which might comprise seven digits to reach the subscriber's line and an eighth digit to indicate the desired party on the line should the desired subscriber be located on a party line. The first seven digits of the line number would be registered on condensers 312 to 318 inclusive and the eighth digit would be registered on condenser 311 as previously described.

Should it be found necessary to replace the tube or found desirable to check the adjustment of the tube in use, the key 149 is first operated. The operation of the key will connect battery over its upper alternate contacts to the filament circuit of the tube and will connect both the keyset potential divider and the pulsing potential divider across the terminals of battery 211. The left end of the keyset potential divider is connected over conductor 131 to the positive terminal of battery 211 and the junction between resistances 128 and 129 of this potential divider is connected over the lower alternate contacts of key 149 and thence over conductor 212 to the negative terminal of battery 211. The left end of the pulsing potential divider is connected over conductor 134 to the positive terminal of battery 211, the negative terminal of which is connected over conductor 212, the next-to-lower alternate contacts of key 149 and conductor 142 to the right terminal of the pulsing potential divider. At its inner upper alternate contacts key 149 connects the grid of tube 110 through resistance 148, over the upper back contacts of relay 225 and resistance 136 to a test point on the keyset potential divider between resistances 119 and 118.

After the key 149 has been operated for at least one second, test key 237 is operated thus connecting the positive terminal of battery 211 through the winding of anode relay 218, contacts of key 237, back contact of relay 227 and conductor 228 to the anode of the tube. The potential applied to the grid should fire the tube and if the tube is thus conducting it will be indicated by the operation of anode relay 218 or by the blue glow within the tube. It may then be extinguished by releasing key 237. If the tube is not conducting, the adjusting point on resistance 140 of the pulsing potential divider should be moved until the tube becomes conducting. The correct adjustment will be a point at which a minimum variation in the potential divider will distinguish between the operation and non-operation of the tube with the key 237 operated. When the adjustment is completed both keys 149 and 237 are released.

What is claimed is:

1. In combination, a gaseous conductor device having a definite breakdown potential, a first condenser, means for placing a variable charge on said condenser, a second condenser, means for connecting said condensers in series in a path across the terminals of said device, a third condenser, a charging circuit for said third condenser, and means for charging said second condenser in steps by connecting said third condenser alternately into said charging circuit and in parallel with said second condenser, said device becoming conducting when the sum of the charges on said first and second condensers reaches the breakdown potential of said device.

2. In combination, a gaseous conductor device having a definite breakdown potential, a first condenser, means including a keyset for placing a charge on said condenser commensurate with the digital value of the operated key of said keyset, a second condenser, means for connecting said condensers in series in a path across the terminals of said device, a third condenser, a

charging circuit for said third condenser, and means for charging said second condenser in steps by connecting said third condenser alternately into said charging circuit and in parallel with said second condenser, said device becoming conducting when the sum of the charges on said first and second condensers reaches the breakdown potential of said device.

3. In combination, a first condenser serving as a digit register, means including a keyset for placing a charge on said condenser commensurate with the digital value of the operated key of said keyset, means for generating impulses, an impulse counting means comprising a gaseous conductor device having a definite breakdown potential, a second condenser, means for connecting said condensers in series in a path across the terminals of said device, a third condenser, a charging circuit for said third condenser, means controlled by said impulse generating means for charging said second condenser in steps by connecting said third condenser alternately into said charging circuit and in parallel with said second condenser, said device becoming conducting when the sum of the charges on said first and second condensers reaches the breakdown potential of said device, and means responsive when said device becomes conducting for arresting the operation of said impulse generating means.

4. In combination, a group of first condensers serving as digit registers, a keyset, a group of stearing relays, means for successively operating said relays, means operated by the successive operation of said relays to successively connect said condensers with said keyset, means controlled by said keyset for placing a charge on each of said condensers when associated therewith in accordance with the digital value of an operated key, means for generating series of impulses, an impulse counting means comprising a gaseous conductor device having a definite breakdown potential, a second condenser, a third condenser, a charging circuit for said third condenser, and means controlled by said impulse generating means for charging said second condenser in steps by connecting said third condenser alternately into said charging circuit and in parallel with said second condenser, means for successively releasing said relays, means operated by the successive release of said relays to successively connect said first condensers in series with said second condenser in a path across the terminals of said device, said device becoming conducting when the sum of the charges on the second condenser and on the first condenser at the time connected in series therewith reaches the breakdown potential of said device, and means controlled by said device when it becomes conducting for terminating the impulse series then being generated.

5. In combination, a group of first condensers serving as digit registers, a keyset, a group of steering relays, means for successively operating said relays, means operated by the successive operation of said relays to successively connect said condensers with said keyset, means controlled by said keyset for placing a charge on each of said condensers when associated therewith in accordance with the digital value of an operated key, means for generating series of impulses, an impulse counting means comprising a gaseous conductor device having a definite breakdown potential, a second condenser, a third condenser, a charging circuit for said third condenser, and means controlled by said impulse generating means for charging said second condenser in steps by connecting said third condenser alternately into said charging circuit and in parallel with said second condenser, means responsive to the operation of the first of said steering relays for connecting the first of said register condensers in series with said second condenser across the terminals of said device and for starting said impulse generating means, said device becoming conducting when the sum of the charges on said first condenser and said second condenser reaches the breakdown potential of said device, means controlled by said device when it becomes conducting for restoring said impulse counting device and for releasing said first steering relay and means operated by the release of said first relay to associate the next register condenser with said counting means, said counting means functioning in this manner to successively associate said register condensers therewith until all of said register condensers are fully discharged and said impulse generating means has generated series of impulses in accordance with the charged condition of all of said register condensers.

6. In combination, a group of first condensers serving as digit registers, a keyset, means operable to successively connect said condensers with said keyset, means controlled by said keyset for placing a charge on each of said condensers when associated therewith in accordance with the digital value of the operated key, means for generating series of impulses, an impulse counting means comprising a gaseous conductor device having a definite breakdown potential, a second condenser, a third condenser, and means controlled by said impulse generating means for charging said second condenser in steps by alternately charging said third condenser and discharging it into said second condenser, means operable to successively connect said first condensers in series with said second condenser in a path across the terminals of said device, said device becoming conducting when the sum of the charges on the second condenser and on the first condenser at the time connected in series therewith reaches the breakdown potential of said device, means controlled by said device when it becomes conducting for terminating the impulse series then being generated, and means for operating said counting means to measure a delay interval following the generation of each series of impulses.

7. In combination, a group of first condensers serving as digit registers, a keyset, means operable to successively connect said condensers with said keyset, means controlled by said keyset for placing a charge on each of said condensers when associated therewith in accordance with the digital value of an operated key, means for generating series of impulses, an impulse counting means comprising a gaseous conductor device having an adjustable breakdown potential, a second condenser, a third condenser, and means controlled by said impulse generating means for charging said second condenser in steps by alternately charging said third condenser and discharging it into said second condenser, means operable to connect each one of said first condensers in series with said second condenser and said second condenser alone in alternation in a path across the terminals of said device, said first condensers being successively connected to said second condenser, means for changing the breakdown potential of said device at such time as said second condenser only is connected across the

terminals thereof, and means controlled by said device whenever it becomes conducting for arresting the operation of said impulse generating means.

8. In combination, a group of first condensers serving as digit registers, a keyset, means operable to successively connect said condensers with said keyset, means controlled by said keyset for placing a charge on each of said condensers when associated therewith in accordance with the digital value of an operated key, means for generating impulses, impulse counting means operable to alternately count series of impulses commensurate with the values of registered digits and to count series of impulses to measure interposed delay intervals, said counting means comprising a gaseous conductor device, a potential divider for varying the biasing potential of said device, a second condenser, a third condenser, and means controlled by said impulse generating means for charging said second condenser in steps by alternately charging said third condenser and discharging it into said second condenser, means operable to connect said first condensers in succession in series with said second condenser across the terminals of said device during the counting of digit impulse series whereby said device becomes conducting to terminate the counting of any impulse series when the total potential across the second condenser and the associated first condenser reaches the critical breakdown potential of said device, and means for connecting said second condenser only across the terminals of said device during the counting of impulses for a delay interval whereby said device becomes conducting to terminate the counting for the delay interval when the potential across said second condenser reaches the critical breakdown potential of said device.

9. In combination, a first condenser serving as a digit register, means including a keyset for placing a charge on said condenser commensurate with the digital value of the operated key of said keyset, means for generating impulses, an impulse counting means operable first to count a series of impulses commensurate with the value of the registered digit and then to count a series of impulses to measure a delay interval comprising a gas-filled tube having an anode, a cathode and a grid, a potential divider for varying the biasing potential on the grid of said tube, a second condenser, a third condenser, and means controlled by said impulse generating means for charging said second condenser in steps by alternately charging said third condenser and discharging it into said second condenser, means operative to start said impulse generating means and to connect said first condenser in series with said second condenser across the cathode-grid path through said tube to one point on said potential divider whereby said tube is caused to become conducting when the sum of the charges on said first and second condensers reaches the critical breakdown potential of said tube, an anode relay operable over the cathode-anode path through said tube when said tube becomes conducting to arrest the operation of said impulse generating means and to extinguish said tube, means controlled by said latter means to restart said impulse generating means and to connect said second condenser across the cathode-grid path through said tube to another point on said potential divider whereby said tube is again caused to become conducting when the charge on said second condenser reaches the critical breakdown potential of said tube, said anode relay then again operating to arrest the operation of said impulse generating means.

10. In a register in which a digit is recorded as a quantity of charge on a condenser, means for determining the value of the recorded digit comprising, means for connecting a potential in series with said condenser and varying the value of said potential in substantially uniform steps, the number of steps required to cause the effective total potential to arrive at a predetermined value thus being a measure of the charge on the condenser and hence characteristic of the digit recorded.

11. In combination, two condensers, means for charging the first of said condensers to any of a plurality of different values, means for charging the second of said condensers in substantially uniform steps, a discharge path, means for connecting said two condensers in series in said discharge path after each of said steps, means preventing the discharge of said condensers over said path until said second condenser has been charged to a value complementary to the value of the charge upon said first condenser, and means operated by the discharge of said condensers over said path when said second condenser has been charged to said complementary value.

12. In combination, two condensers, means for charging the first of said condensers to any of a plurality of different values, means for charging the second of said condensers in steps and, after each step, testing the effective total potential of said two condensers in series, means substantially preventing any variation in the amount of charge on said first condenser during each of said testing operations if said effective total potential is below a predetermined value, and means operated when the effective total potential of the two condensers in series reaches said predetermined value.

FREDERICK R. LAMBERTY.
GEORGE W. WEAVER.