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(54) **TELECOMMUNICATION SYSTEMS EMBODYING AUTOMATIC EXCHANGES**

(54) **SYSTEMES DE TELECOMMUNICATION RENFERMAT DES OPERATIONS AUTOMATIQUES**

(57) **Abstract:**

The present invention relates to telecommunication systems embodying automatic exchanges.

In copending Canadian Patent Application Serial No. 620,032, filed September 4, 1951, in the names of A.A. Chubb and M.M. Levy and entitled Telecommunication Systems Embodying Automatic Exchanges, there is described an improved automatic exchange in which a fixed plurality of communication channels is provided. Calling apparatus, responsive to an initial calling signal such as a D.C. signal transmitted when a telephone subscriber lifts a telephone handset prior to dialling the number of another subscriber, selects a free one of these communication channels. Means are provided whereby, in operation, further calling signals, such as dialling impulses, are then applied in the exchange to transmit to the terminal equipment of the called subscriber an identification signal identifying the selected one of the communication channels. Apparatus is provided to identify the channel indicated by the identification signal and to connect the called subscriber to the identified channel.

In copending Canadian Patent Application Serial No. 623,374, filed November 23, 1951, in the name of M.M. Levy and entitled Automatic Exchanges, an automatic exchange is described similar to that described in the aforementioned copending Patent Application Serial No. 620,032. The means described in this patent application for transmitting the signal identifying the seized communication channel differ from those described in this last-mentioned application and comprise a group of low grade channels, one channel for each subscriber on the exchange. It is preferred to use interlaced pulse trains to provide the low grade channels, the identification signal consisting of a coded group of pulses, being transmitted in the low grade channel associated with the called subscriber.

The coded group of pulses is applied to call the called subscriber, and to cause a connection with the communication channel identified by these pulses to be established.

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In order to ensure an adequate speed of operation, however, it may be found necessary to make the pulses in the coded group of a width so small as to cause difficulties in design. These difficulties arise from the fact that the energy contained in the pulses is small.

An object of the present invention is to provide improved apparatus whereby the aforesaid difficulties can be overcome.

According to the present invention, an automatic exchange comprises a number of low grade calling channels equal to the number of stations connected to the exchange, a number of low grade identification channels equal to the number of calling channels, a number of high grade channels substantially less than the number of calling channels, calling apparatus responsive to an initial calling signal from a first station to seize a free one of the high grade channels, a register device responsive to further calling signals from the first station, and representative of the number of a second station, to transmit a calling signal in a predetermined one of the calling channels and an identification signal in a corresponding one of the identification channels, the identification signal being representative of the number of the seized high grade channel, and apparatus adapted in response to the calling and identification signals to connect the terminal equipment of the second station to the identified high grade channel. A low grade channel is a channel having a relatively small bandwidth whereas a high grade channel is a channel having a relatively large bandwidth. When a free high grade channel is seized it is meant that a free high grade channel is found, a connection established therewith and further stations are prevented from using this channel for establishing another call until this channel is released.

After communication has been established the register device may be released for use in making a further call. The maximum number of calls which can be made simultaneously is, therefore, equal to the number of registers provided. This number will, of course, be determined by calculation of the expected load.

The calling, identification, and high grade channels are all preferably provided by interlaced pulse trains. The calling channels may for example be 2,000 in number and the pulses used for each calling channel may have a recurrence frequency of say one pulse per second. The identification channels may be provided by pulses of the same frequency, and the high grade channels may be 100 in number and each one provided by pulses of a recurrence frequency of 8,000 pulses per second. The identification signal may be provided by a coded group of say two pulses.

It will be appreciated that the calling pulse will be much broader than the pulses in the coded group constituting the identification signal. The identification signal does not, however, have to be used to control either calling apparatus or line finders and hence the design difficulties previously referred to are alleviated.

The invention will now be described, by way of example with reference to the accompanying drawings, in which

Figure 1 is a block schematic diagram of one embodiment of the invention,

Figures 2 to 12 are diagrams of parts shown in block form in Figure 1, and

Figure 13 is an explanatory diagram

Figures 14 and 15 are diagrams of further parts shown in block form in Figure 1,

Figure 16 is a further explanatory diagram, and

Figure 17 is a diagram of a gate circuit.

Reffering to Figure 1 this is a block schematic diagram of an automatic exchange suitable for use with 2,000 subscribers. Of the 2,000 subscribers' stations connected to the exchange, one is shown at 10 and another at 11, the station 10 being terminated in the exchange at "sub's line circuit" 12 and the station 11 being terminated at the "sub's line circuit" 13. The "sub's line circuits" will be described later.

The exchange comprises a group of 100 high grade pulse communication channels. This group of channels is provided by means including a pulse generator 14 adapted to generate pulses suitable for combination to provide the 100 channels time-interlaced at a pulse repetition frequency of 8,000 pulses per second in each channel. The 100 channels are terminated by 100 "calling units" respectively of which one is shown at 15. 100 "called units" terminate the other ends of the channels respectively when in use one of the called units being shown at 16. The calling and called units will be described later. Signals between the calling and called units pass through a "GO speech junction" 17, a "~~Return speech~~ junction" 18 or a "Metering and release junction" 19 as the case may be. In the event of a called subscriber being engaged, a "busy signal" is transmitted to the calling subscriber by way of a "busy junction" 20 as will be described later.

For use in establishing calls between subscribers a number of allotters 24 and registers 23 are provided together with a calling junction 25, an identification junction 25' and two further pulse generators 21 and 26, examples of which will be described later.

Assuming the subscriber at station 10 to be calling the subscriber at station 11, the first operation occurs in the sub's line circuit 12. This contains a finder which finds a free calling unit 15. An allotter 24 then comes into operation and allots a register 23 to the calling unit 15.

By means of the allotter and a finder in the register the calling unit found by the sub's line circuit 12 is connected to the allotted register 23 as will be described later. A dialling tone is then automatically transmitted to the calling subscriber.

The output of the pulse generator 21 is in the form of a recurring sequence of twenty pulses which for convenience will be divided into two groups of ten each. The first ten pulses in each sequence will be referred to collectively as the d' pulses and the second ten as the u' pulses. The ten d' pulses will be referred to individually as pulses d'_0 to d'_9 respectively and appear at the terminals Td'_0 to Td'_9 of the generator 21. The ten u' pulses will be referred to individually as pulses u'_0 to u'_9 and appear at terminals Tu'_0 to Tu'_9 of the generator 21.

Each calling unit 15 is connected to one of the terminals Td'_0 to Td'_9 and to one of the terminals Tu'_0 to Tu'_9 of the generator 21, different ones of the calling units being connected to different pairs of the terminals Td' and Tu'. Thus each calling unit is identified by a different pair or d' and u' pulses and, as will be described later, the pair of d' and u' pulses identifying the calling unit seized by a calling subscriber's line circuit is transmitted to the called subscriber's line circuit to identify the high grade channel on which communication is to be established.

When the calling subscriber hears the dialling tone and dials the number of the called subscriber, the dialling pulses are transmitted through the line circuit 12, and the seized calling unit 15 to the allotted register 23. In the register the four sets of dialling pulses are stored on four uniselectors as will be described later. Four groups of ten pulses each, which will be referred to as the M, C, D and U pulses, are applied to the four uniselectors in the register from the pulse generator 26. Thus the uniselectors in the register select one pulse from each of the four groups of recurring pulses applied thereto and it is arranged that these four selected pulses are combined to form a recurring output pulse which occurs in one recurring channel interval in a recurring sequence of 2,000 channel intervals. The sequence may recur for example at the rate of one per second and the 2,000 channels constitute a group of low grade communication channels.

The recurring output pulse to be referred to as the calling pulse from the register is passed to the calling junction and, in addition, is used as a gating pulse and permits the recurring pair of d'u' pulses identified with the seized calling unit to pass to the identification junction 25' only in the low grade channel interval determined by the gating pulse.

The outputs from the calling and identification junctions are applied to all subscriber's line circuits. These circuits have gating pulses applied thereto, however, from the pulse generator 26, the gating pulses applied to each subscriber's line circuit being in the channel whose number corresponds to the subscriber's number on the exchange. Thus the only subscriber's line circuit to respond to a calling pulse appearing at the output of the calling junction is that one whose gating pulse corresponds to the number dialled.

The called subscriber's line circuit then hunts for a free called unit and when a free called unit is found this unit functions, as will be described later, to select appropriate pulses from the output of the generator 14 to enable the called subscriber to establish communication on the channel terminated by the seized calling unit, the selection being determined by the pair of <u>d</u>' <u>u</u>' pulses transmitted through the identification junction.

The automatic exchange shown in Figure 1 will now be described in more detail with reference to Figures 2 to 17. Throughout Figures 2 to 17 all relays and automatic switches are shown in conventional manner the operating windings thereof being referenced with a letter over a figure, the figure indicating the number of relay contacts or banks of switch contacts associated with the winding. The contacts or banks of contacts associated with a winding are given the same letter reference followed by figure, references to different contacts or banks of contacts containing different figures. A contact may also have the same reference letter as its operating winding followed by a further letter or letters. All relays and switches are shown in their unoperated positions.

Referring to Figure 2 this is a circuit diagram of apparatus suitable for use as the sub's line circuits 12 and 13 of Figure 1. The subscriber's line is connected to line terminals LT_1 and LT_2, LT_1 being normally connected to earth through relay contacts K1 and LT_2 being normally connected through relay contacts K2, relay winding L and battery BAT_1 to earth. A uni-selector having six banks of contacts S1 to S6 is operated by a winding S and interruptor Sdm. The automatic interruptor operation may be as described on page 235 of Telephony Volume 2 by J. Atkinson, published by Sir Isaac Pitman & Sons, Ltd. 1950. This work by Atkinson will be hereinafter referred to as Telephony (either Vol I or II) by Atkinson. Each of the banks S1, S2 and S3 has 25 fixed contacts, a first of the contacts being the "home" contact, the next 12 being OUT contacts, and the other 12 being IN contacts.

The banks S1 and S2 are for carrying speech, the wipers thereof being connected to LT_1 and LT_2 respectively, when the apparatus is in use, by relay contacts K1 and K2. Contacts 2 to 13 of S1 are connected to 12 output terminals respectively of which one is shown at $+O_1$, and contacts 14 to 25 are connected to 12 input terminals respectively of which one is shown at $+I_1$. Contacts 2 to 13 of S2 are connected to 12 output terminals of which one is shown at $-O_1$, and contacts 14 to 25 are connected to 12 input terminals of which one is shown at $-I_1$. The bank S3 is used for control purposes, contacts 2 to 13 being connected to 12 output terminals respectively of which one is shown at PO_1, and contacts 14 to 25 being connected at 12 input terminals of which one is shown at PI_1.

Bank S4 has an insulated home contact and a homing arc BC_1. The function of the homing arc is as described on pages 259 and 260 of Telephony Vol II by Atkinson.

Bank S5 has an insulated home contact, an arcuate contact BC_2 extending over the equivalent of contacts 2 to 13 on S1, S2 and S3, and a further arcuate contact BC_3 extending over the equivalent of contacts 14 to 25 on S1, S2 and S3. Contact BC_2 is connected through relay contacts Z2 to earth.

Bank S6 has an insulated home contact, an arcuate contact BC_4 extending over the equivalent of contacts 2 to 13 of S1, S2 and S3, and a further arcuate contact BC_5 extending over the equivalent of contacts 14 to 25 on S1, S2 and S3. Contact BC_5 is connected to an output terminal CS_1.

The home contact on S3 is connected through relay contacts L1 to earth. The wiper of S3 is connected through contacts K3 and L1 to earth through contacts L2, and K4 to contacts Sdm; and through a rectifier W_1 and meter winding M to earth.

The wiper of S4 is connected through contacts L2 to contacts K4 and to the wiper of S5.

The wiper of S6 is connected through relay contacts K7 to the moving contact of contacts K6 which is connected through a rectifier WX2 to a terminal RT, and through a resistor R 202 to a terminal RTX. The fixed contact of relay contacts K6 is connected to an output terminal BJ1. The terminal RT is also connected through resistor R_1, a rectifier WX1, and a resistor R_2 in series to the control grid of a gas-filled triode valve V_1 the control grid being connected to earth through a capacitor CX_1. An input terminal SX1464 is connected through a rectifier W_2 to the junction of the resistor R_1 and rectifier WX1. The cathode lead of the valve V_1 has in series therewith a relay winding Z and the anode of the valve V_1 is connected through relay contacts K5 to the terminal HT+1 of a source (not shown) of D.C. whose negative terminal is earthed. A relay winding K is connected between contacts Sdm and L1.

Referring now to Figure 3 this is a circuit diagram of apparatus suitable for use as the calling unit 15 of Figure 1. It will be assumed that this calling unit is that connected to terminals $+O_1$, $-O_1$ and PO_1 of Figure 2, these terminals also being shown in Figure 3. Terminal + O_1 is connected through relay contacts D1 and one winding of relay A to earth. Terminal $-O_1$ is connected through relay contacts D2, a second winding of relay A and a battery BAT_3 to earth. Terminals + O_1 and - O_1 are also connected through capacitors C_1 and C_2 respectively to a winding MW_1 of a hybrid transformer HY_1 which has a balancing resistor RB. The function of the hybrid transformer and balancing resistor is as described on page 83 Vol I of Telephony by Atkinson.

The winding OW_1 of the hybrid transformer is connected through a capacitor C_3 to the control grid of a pentode valve V_4 whose anode is connected through a load resistor R_3 to the positive terminal HT+2 of a source (not shown) of D.C. whose negative terminal is earthed. The cathode of the valve V_4 is earthed, the screen grid is connected directly to the terminal HT+2, and the suppressor grid is connected through a resistor R_4 to the negative terminal $-GB_1$ of a bias source (not shown) whose positive terminal is earthed. The suppressor grid is also connected through a capacitor C_4 and relay contacts B5 to a terminal GP. The anode of the valve V_4 is connected through a capacitor C_5 to a terminal GSP_1.

Winding IW_1 of the hybrid transformer HY_1 is connected to the output of a low-pass filter FIL_1. One input terminal of the filter is connected to the anode of a pentode valve V_3 and the other to earth through a capacitor C_6 and through a resistor R_5 to the positive terminal HT + 4 of a source of D.C. (not shown). The suppressor grid and cathode of the valve V_3 are connected to earth.

A terminal $RSPO_1$ is connected through a capacitor C_8 to the control grid of a pentode valve V_5 whose cathode is earthed. Negative bias is applied to the control grid of the valve V_5 from the negative terminal $- GB_{20}$ of a bias source (not shown) whose positive terminal is earthed. The anode of the valve V_5 is connected through the primary winding of a transformer XF_1 to the positive terminal HT + 4 of a source (not shown) of D.C. whose negative terminal is earthed. The screen grid of the valve V_5 is connected directly to the terminal HT + 4 and the suppressor grid is connected through a resistor R_6 to the negative terminal $- GB_3$ of a bias source (not shown) whose positive terminal is earthed. The suppressor grid of the valve V_5 is also connected through a capacitor C_9 and the contacts B_5 to the terminal GP.

The transformer XF_1 has two secondary windings S_1XF_1 and S_2XF_1. One terminal of winding S_1XF_1, is connected to the negative terminal $- GB_2$ of a bias source (now shown) and the other terminal is connected through a rectifier W_5, and a resistor R_7 to the control grid of the pentode valve V_3 and is connected through a rectifier W_3 to the negative terminal $- GB_4$ of a bias source (not shown) whose positive terminal is earthed. One terminal of the winding S_2XF_1 is connected to the negative terminal $- GB_4$ and the other terminal of the winding S_2XF_1 is connected through a rectifier W_6 to the control grid of the valve V_3. The terminal $- GB_4$ is also connected to the control grid of V_3 through a rectifier W_4 and a capacitor C_{10} is connected between the control grid of V_3 and earth.

A terminal $ASPO_1$ is connected through a rectifier W_7 and capacitor C_{11} to the control grid of a triode valve V_6 whose cathode is earthed and whose anode is connected through a relay winding D to the positive terminal HT+ 5 of a D.C. source (not shown) whose negative terminal is earthed. The control grid of the valve V_6 is also connected through a rectifier W_8 to the negative terminal $- GB_5$ of a bias source (not shown) whose positive terminal is earthed. The junction of the capacitor C_{11} and the rectifier W_7 is connected to the terminal GP through a resistor R_8.

A relay winding J has one terminal connected to earth through a battery BAT_4. The other terminal of the relay winding J is connected to earth through relay contacts D3, a busbar BUS_1 and relay contacts B4. The busbar is connected through relay contacts E1, one winding of relay E and a battery BAT_5 to earth. A control terminal P_1 is connected either directly to earth or through the other winding of relay E and a battery BAT_6 to earth depending upon the setting of relay contacts B3 and E3. The busbar BUS_1 is connected through relay contacts G1, one winding of a relay G and a battery BAT_7 to earth. The other winding of the relay G has one terminal connected to earth through a battery BAT_8, and has its other terminal connected directly to a terminal BU_1. The busbar is also connected through relay contacts E2 to an output terminal AL.

Terminal HO is connected through relay contacts D5, E4 and A1 to earth. A relay winding B has one terminal connected through contacts A1 to earth and the other through a battery BAT_9 to earth. An output terminal IMP is connected through relay contacts B2 and A1 to earth.

Input terminals Td^1_0 and Tu^1_1 are connected together through resistors R_9 and R_{10} and the junction of these two resistors is connected through relay contacts E6 to an output terminal Rd^1u^1.

Terminal PO_1 is connected through relay contacts B1 to relay contacts D4 which depending upon their setting, provide either an earth connection or a connection to relay contacts J1. The relay contacts J1 provide either an earth connection or a connection through a resistor R_{11} and a battery BAT_{10} to earth.

The cathode of a gas-filled triode valve V_2 is connected to earth through relay contacts A2 and its anode is connected through a relay winding F to the positive terminal HT + 6 of a suitable source (not shown) of D.C. whose negative terminal is earthed. A capacitor C_{12} is normally connected to the positive terminal HT + 7 of a source (not shown) of D.C. whose negative terminal is earthed. The control grid of the valve V_2 is connected to the capacitor C_{12} through a resistor R_{12} and the contacts E5.

A source (not shown) of busy tone is connected to the terminal BT which is connected to the centre winding of the relay A through relay contacts G_2.

A source (not shown) of dialling tone is connected to the terminal DT which is connected through relay contacts F1 to the centre winding of the relay A.

Referring now to Fig.4. this is a circuit diagram of an allotter suitable for use at 24 in Fig. 1. The terminal AL corresponds to the terminal AL of Fig. 3. and is connected through a relay winding ST and a battery BAT_{11} to earth. A uni-selector FD has four banks of contacts FD1, FD2, FD3, and FD4 whose wipers and controlled by automatic stepping apparatus including winding FD and contacts FDdm. The wiper of the bank FD1 is connected through relay contacts ST1, the contacts FDdm, the winding FD, and a battery BAT_{12}, to earth. The junction of the contacts FDdm and the winding FD is connected to earth through relay contacts FK2 and DR4. The fixed contacts of the bank FD1 are connected to output terminals respectively of which one is shown at Q. A terminal R is connected through a relay winding DK and relay contacts ST2 to the moving contact of the bank FD1. The terminal R is also connected through contacts ST3, and DK1 to contacts ST1. The contacts DK1 are also connected through relay winding DR and a battery BAT_{13} to earth.

The bank contacts of the bank FD4 are connected to output terminals respectively of which one is shown at X. The wiper of the bank FD4 is connected through relay contacts DR3, FK1, and DR1 to earth.

The fixed contacts of the bank FD3 are connected to output terminals respectively of which one is shown at P_2. The wiper of the bank FD3 is connected through relay contacts DR2 and one winding of relay FK to earth. One terminal of the other winding of the relay FK is connected through the contacts FK1 and DR1 to earth, and the other terminal thereof is connected through a battery BAT_{14} to earth.

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The bank contacts of the bank FD2 are connected to output terminals respectively of which one is shown at Y. The wiper of FD2 is connected through the contacts FK1 and DR1 to earth.

Referring now to Fig. 5. this is a theoretical circuit diagram of a suitable register and calling unit finder for use in the arrangement of Fig. 1. The terminals IMP, Rd^1u^1, BU_1, HO, and P_1 correspond to the terminals of the same reference in Fig. 3, and terminals Y, P_2, X, R and Q correspond to those of the same reference in Fig. 4.

The calling unit finder section of the arrangement shown in Fig. 5 comprises a uni-selector CUF having six banks CUF1 to CUF6, whose wipers are driven by an automatic stepping circuit including a battery BAT_{15} connected between earth and one terminal of winding CUF, and contacts CUFdm connected between the other terminal of the winding CUF and the terminal Y. The IMP terminals of several calling units (15 Fig. 1.) are connected to the bank contacts respectively of the bank CUF1 whose wiper is connected through relay contacts H1, a relay winding AA and a battery BAT_{16} to earth. The terminals Rd^1u^1 of the several calling units are connected to the bank contacts of CUF2 respectively whose wiper is connected through a resistor R_{206} and a rectifier WX14 to an output terminal RO. The BU_1 terminals of the several calling units are connected to the bank contacts respectively of CUF3 whose wiper is connected through relay contacts BR1 to earth. The HO terminals of the several calling units are connected to the bank contacts respectively of CUF4 whose wiper is connected through a relay winding H and a battery BAT_{32} to earth. The P_1 terminals of the several calling units are connected to the bank contacts respectively of CUF5 whose wiper is connected to terminal P_2. The bank CUF6 is a homing bank. Each of the banks CUF1 to CUF6 has an insulated home contact.

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The terminal P_3 is also connected through relay contacts KF6 to earth. The terminal R is connected through relay contacts KF6 to earth and through relay contacts KF5 to terminal Q which is also connected through contacts K5 and a battery BAT_{17} to earth. The terminal X is connected through a relay winding KF and battery BAT_{18} to earth, and through relay contacts KF1 and H2 to earth.

A uni-selector ZZ has two banks ZZ1 and ZZ2 whose wipers are driven by an automatic stepping circuit including winding ZZ and contacts ZZdm. The winding ZZ has one terminal connected through a battery BAT_{19} to earth and the other through relay contacts BB1 to earth, and through the contacts ZZdm to the wiper of ZZ2. A capacitor C_{13} and resistor R_{13} are employed to reduce sparking between the contacts ZZdm when in operation. The bank ZZ2 is a homing bank and is connected to earth through a relay contacts KF3.

The register section of Fig.5. comprises four uni-selectors M, C, D and U. The uni-selectors are operated by impulses caused by the operation of relay contacts AA1 as will be described later. The moving contact of AA1 is connected through relay contacts H7 to earth and the fixed contact of AA1 is connected through relay contacts PQ_1 to the wiper of the uni-selector bank ZZ1. The first four bank contacts of ZZ1 are connected to the windings M, C, D and U respectively whose other terminals are connected to earth through batteries BAT_{30} to BAT_{33} respectively. The first four bank contacts of ZZ1 are also connected through contacts Mdm, Cdm, Ddm and Udm to the wipers of the banks M2, C2, D2 and U2 respectively. Each of these banks is a homing bank. The homing arcs of the homing banks M2, C2, D2, and U2 are connected to earth through relay contacts H6, H3, H4 and H5 respectively.

The fifth contact of ZZ1 is connected through a relay winding PQ and a battery BAT_{34} to earth, and through relay contacts PQ_3

and KF_4 in series to earth. A relay winding BB is connected between the fixed contact of AA1 and the negative terminal of a battery BAT_{25} whose positive terminal is earthed.

Each of the banks M1, C1, D1 and U1, has an insulated home contact and ten bank contacts. The ten bank contacts of M1 are connected to terminals MP_1 to MP_9 and MP_0 respectively. The ten bank contacts of C1 are connected to terminals CP_1 to CP_9 and CP_0 respectively. The ten bank contacts of D1 are connected to terminals DP_1 to DP_9 and DP_0 respectively, and those of U1 are connected to terminals UP_1 to UP_9 and UP_0 respectively. The wipers of the banks M_1, C_1, D_1, and U_1 are connected through rectifiers W_{10}, W_{11}, W_{12}, and W_{13} respectively to a busbar BUS2 which is connected through a resistor R_{271} to the positive terminal HT+100 of a source of D.C. (not shown) whose negative terminal is earthed. The busbar BUS2 is also connected through a capacitor C_{100} to the control grid of a triode valve V_{100} whose anode is connected to the terminal HT+100 and whose cathode is connected to earth through a cathode load resistor R_{205}. The control grid of the triode V_{100} is also connected through a resistor R_{272} to the negative terminal $-GB_{104}$ of a bias battery (not shown) whose positive terminal is earthed. The cathode of the triode V_{100} is connected directly to an output terminal RO and through a rectifier WX_{14} to a second output terminal ROX. The terminal ROX is connected through a resistor R_{206} of the wiper of the uni selector bank CUF_2 and thence to the terminal Rd'u'.

An input terminal BJO is connected through a resistor R_{19} and a capacitor C_{13} and resistor R_{13} in series to the control grid of a gas-filled triode V_7. The junction of R_{13} and C_{13} is connected through a resistor R 14 to the positive terminal HT+8 of a source (not shown) of D.C. whose negative terminal is earthed. The cathode of the valve V_7 is connected to earth

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through a resistor R_{15} and the anode of the valve V_7 is connected through relay contacts H8 to the positive terminal HT+9 of a source (not shown) of D.C. whose negative terminal is earthed.

The terminal BJO is also connected through a capacitor C_{14} and a resistor R_{16} to the control grid of a gas-filled triode V_8 whose cathode is earthed. The junction of C_{14} and R_{16} is connected through two resistors R_{17} and R_{18} in series to the cathode of the valve V_7, and the junction of R_{17} and R_{18} is connected to earth through a capacitor C_{15}. The anode of the valve V_8 is connected to the terminal HT+ 9 through a relay winding BR. The junction of the resistor R_{19} and the capacitor C_{13} is connected through a rectifier W_{14} to the wiper of switch bank CUF2.

Referring now to Figures 6 and 7, part of the calling junction 25 of Figure 1 is shown in Figure 6, and Figure 7 shows a further part. Assuming 20 registers to be used the pulses appearing at the output terminals RO of the 20 registers are combined in two groups of ten by means of rectifiers W 120 as shown in Figure 6. The combined pulses in the first group appear across a resistor R227 and those in the second group across a resistor R 228.

The two groups of pulses appearing across the resistors R227 to R228 are applied to the control grids of two pentode valves V_{103} and V_{104} respectively which have a common anode load resister R232. A resistor R 233 and a capacitor C_{104} are for decoupling purposes. The combined outputs from the valves V_{103} and V_{104} appearing across the common load resistor R232 are applied through a capacitor C105 to the control grid of a valve V_{108} whose cathode is connected to earth through a self-biasing circuit comprising a resistor R 234 and a capacitor C_{106}. A rectifier W_{121} and a resistor R 235 are connected in parallel between the control grid of the valve V_{108} and earth and function to render the pulses appearing at the control grid of the valve V_{108} of positive polarity.

The output of the valve V_{108} appearing across a load resistor R_{236} is applied through a capacitor C_{107} and a resistor R_{237} to the control grid of a valve V_{109} which has a cathode load resistor R_{238}. Negative bias is applied through a resistor R_{239} to the control grid of the valve V_{109} from the negative terminal - GB100 of a bias source (not shown) whose positive terminal is earthed. The cathode of the valve V_{109} is connected through a capacitor C_{108} to a terminal TX which is also connected through a resistor R230 to the terminal - GB100.

In Figure 7 the terminal TX is that also shown in Figure 6 and is connected through resistors P 240 to R 249 to the control grids of ten triode valves V_{110} to V_{119} whose cathodes are connected to earth through load resistors R_{250} to R_{259} respectively. The outputs appearing across the cathode load resistors of the ten valves V_{110} to V_{119} are applied to ten groups respectively of triode valves connected as cathode followers. Each of these groups has ten cathode followers and three of the cathode followers in the group connected to the output of the valve V_{114} are shown in Figure 7.

The output voltages appearing at the cathode of the valve V_{114} are applied through a capacitor C_{109} and resistors R260 to R262 to the control grids of three triode valves V_{120}, V_{121} and V_{122} in the group shown. The cathodes of the three valves V_{120} to V_{122} are connected to earth through resistors R 263 to R265 and to three output terminals RT_1, RT_2 and RT_3 respectively. Negative grid bias is applied through a resistor R266 to the control grids of the triodes V_{120} TO V_{122} from the negative terminal $-GB_{101}$ of a bias source (not shown) whose positive terminal is earthed. The anode circuits of all the valves in Figure 7 are decoupled as shown.

The identification junction 35' is identical with the calling junction 35 shown in Figs 6 and 7 the terminals ROX of the several registers replacing the terminals RO in Fig 6 and the output terminals RT being replaced by output terminals RTX of which one is shown in Fig.3.

Referring to Figure 8 this is a theoretical circuit diagram of a suitable called unit (16 Figure 1). In Figure 8 a control terminal PI_2 is connected through relay contacts RB_3 a relay winding RQ and a battery BAT_{38} to earth. The terminal PI_2 is connected to one of the PI terminals of the bank S3 of the uniselector in one of the sub's line circuits (Figure 2). Two terminals $+ I_2$ and $-I_2$ are connected through relay contacts F2 and F3 respectively, and capacitors C_{32} and C_{33} to a winding MW_2 of a hybrid transformer HY_2. An output winding OW_2 of the transformer HY_2 has one terminal earthed and the other terminal thereof is connected through a capacitor C_{34} to the control grid of a pentode valve V_{34} whose cathode is earthed. The anode of the valve V_{34} is connected through a load resistor R_{32} to the positive terminal HT+ 11 of a source (not shown) of D.C. whose negative terminal is earthed. The anode is also connected through a capacitor C_{35} to an output terminal RSP_2, and the screen grid is connected directly to the terminal HT+ 11. Negative bias is applied to the control grid of the valve V_{34} from a bias terminal $-GB_{21}$. The suppressor grid is connected through a capacitor C_{36} to relay contacts CD1, and through a resistor R_{33} to the negative terminal $- GB_8$ of a bias source (not shown) whose positive terminal is earthed.

An input terminal $GSPO_1$ is connected through a capacitor C_{37} to the control grid of a pentode valve V_{25} whose cathode is earthed. The control grid of the pentode V_{25} is also connected through a resistor R_{34} to the negative terminal $-BG_9$ of a bias source (not shown) whose positive terminal is earthed. The anode of the pentode V_{25} is connected through the primary winding of a transformer XF_2 to the positive terminal HT+ 12 of a source (not shown) of D.C. whose negative terminal is earthed. The anode is also connected through a capacitor C_{28} to the control grid of a triode valve V_{26} whose cathode is earthed. The anode of the triode V_{26} is connected through a relay winding RB to the positive terminal HT+13 of a source (not shown) of D.C. negative terminal is earthed. The control grid of the triode V_{26} is connected through a rectifier W_{15} to the negative terminal $-GB_{11}$ of a bias source whose positive terminal is earthed. The screen grid of the pentode V_{25} is connected through a resistor R_{35} to the positive terminal HT+12. The suppressor grid is connected through a resistor R_{36} to the negative terminal $-GB_{10}$ of a bias source (not shown) whose positive terminal is earthed, and through a capacitor C_{29} to the relay contacts CD1.

The transformer XF_2 has two secondary windings S_1XF_2 and S_2XF_2. One terminal of the winding S_1XF_2 is connected to the negative terminal $-GB_{12}$ of a bias source (not shown) whose positive terminal is earthed, and the other terminal thereof is connected through a rectifier W_{16} to the control grid of a pentode valve V_{27} whose cathode is earthed. One terminal of the winding S_2XF_2 is connected to the negative terminal $-GB_{13}$ of a bias source (not shown) whose positive terminal is earthed, and the other terminal of the winding S_2XF_2 is connected through a rectifier W_{17}, and a resistor R_{37} to the control grid of the pentode V_{27}.

A rectifier W_{18} is connected between the terminal $-GB_{12}$ and the left-hand terminal of the winding S_2XF_2 in the drawing.

The primary winding of the transformer XF_2 is tuned by a capacitor C_{30} which is shunted by a resistor R_{194}.

The anode of the pentode V_{27} is connected through the input circuit of a low-pass filter FIL_2 to the positive terminal HT+14 of a source (not shown) of D.C. whose negative terminal is earthed. The screen grid of the pentode V_{27} is connected through a resistor R_{38} to the positive terminal HT+14 and is decoupled by a capacitor C_{32}. One output terminal of the low-pass filter FIL_2 is connected to earth and the other output terminal is connected through the winding IW_2 of the hybrid transformer HY_2 to earth.

The terminal $-I_2$ is normally connected to earth through the relay contacts F3 and a battery BAT_{33}, and the terminal $+I_2$ is normally connected through the relay contacts F2 and through one winding of a relay F to the moving contact of relay contacts RB4. These contacts are normally open and the fixed contact thereof is connected through the secondary winding of a transformer XF_3 to earth. The primary winding of the transformer XF_3 is connected to terminals TR to which ringing current is applied from a suitable source (not shown). The contacts F2 are bridged by a capacitor C_{64}. One terminal of the other winding of relay F is connected through a battery BAT_{29} to earth and the other terminal thereof is connected through relay contacts F1 and RB1 to earth. One winding of a relay RD is connected between the right-hand plate (in the drawing) of the capacitor C_{22} and earth. The other winding of the relay RD has one terminal connected to the right-hand plate of the capacitor C_{23}

and has the other terminal connected through a battery BAT_{30} to earth.

A uniselector ZRU has three banks ZRU1, ZRU2 and ZRU3, each of which has a home contact and bank contacts. The bank ZRU1 has ten bank contacts which are connected to the translator 25 to be described later. The wiper of the bank ZRU1 is connected through a resistor R_{39} to the control grid of a gas-filled triode valve V_{28}. The cathode of the valve V_{28} is connected to the negative terminal of a bias source GB_{14} whose positive terminal is earthed. The anode of the valve V_{28} is connected through relay contacts DA1 to one terminal of a relay winding DA. The other terminal of the winding DA is connected through relay contacts RQ1 and RB2 in parallel to the positive terminal HT+15 of a source (not shown) of D.C. whose negative terminal is earthed.

The bank ZRU2 is a homing bank and has its homing arc BC_6 connected to earth through relay contacts DA2. The wiper of the bank ZRU2 is connected through contacts ZRUdm, operating winding ZRU, a relay winding CD and a battery BAT_{31} in series to earth. The home contact of the bank ZRU2 is connected through relay contacts RQ2 to earth.

The bank ZRU3 has ten bank contacts which are connected to ten terminals Tu_o to Tu_9 respectively. The wiper of the bank ZRU3 is connected through a resistor R_{40} to the fixed contact of contacts CD1.

A uniselector ZRD has three banks ZRD1, ZRD2 and ZRD3, each of which has a home contact and bank contacts. The bank ZRD1 has ten bank contacts which are connected to the translator 25. The wiper of ZRD1 is connected through a resistor R_{41} to the control grid of a gas-filled triode V_{29} whose cathode is connected to earth through a bias source GB_{15}. The anode of the valve V_{29} is connected through relay contacts UA1 to one terminal of a relay winding UA and the other terminal of the winding UA is connected through the relay contacts RQ1 and RB2 to the terminal HT+15.

The bank ZRD2 is a homing bank and the homing arc BC_7 is connected through relay contacts UA2 to earth, and the home contact through RQ2 to earth. The wiper of the bank ZRD2 is connected through the mechanically operated contact ZRDdm, the operating winding ZRD, the relay winding CD and the battery BAT_{31} in series to earth.

The bank ZRD3 has ten bank contacts which are connected to ten terminals Td_0 to Td_9 respectively. The wiper of the bank ZRD3 is connected through a rectifier W_{20} to the fixed contact of contacts CD1.

The moving contact of the contacts CD1 in addition to being connected through the capacitors C_{26} and C_{29} to the suppressor grids of the pentodes V_{24} and V_{25} respectively is connected through a resistor R_{42} to earth and directly to the moving contact of contacts RD1. The fixed contact of contacts RD1 is connected through a resistor R_{43} to earth and through a capacitor C_{33} to the control grid of a triode valve V_{31} whose cathode is earthed. Negative bias is applied through a resistor R_{44} to the control grid of the triode V_{31} from the negative terminal $-GB_{16}$ of a bias source (not shown) whose positive terminal is earthed. The anode of the valve V_{31} is connected through a capacitor C_{34} to an output terminal ASP_1, and through a resistor R_{45} to the positive terminal HT+16 of a source (not shown) of D.C. whose negative terminal is earthed.

The translator 25 is connected through relay contacts RQ3 to the positive terminal HT+17 of a source (not shown) of D.C.

whose negative terminal is earthed. Ten terminals Tu'_o to Tu'_9 and ten terminals Td'_o to Td'_9 are connected to the translator, and a further terminal CS_2 which is connected to the CS terminals in the sub's line circuits (see Figure 2).

Referring now to Figure 9 this is a theoretical circuit diagram of the translator 25. The translator comprises two groups of gas-filled triode valves each group containing ten valves. A first of the groups contains ten triodes V_{32} to V_{41} whose cathodes are connected to earth through resistors R_{46} to R_{55} respectively, and directly to the ten bank contacts respectively of the uniselector bank ZRU_1. The anodes of the triodes V_{32} to V_{41} are connected together and through the relay contacts RQ3 to the terminal $HT+_{17}$. The terminals Tu'_o to Tu'_9 are connected through ten rectifiers W_{21} to W_{30} ten resistors R_{66} to R_{75} and ten rectifiers W_{100} to W_{109} respectively in series to the control grids of the triodes V_{32} to V_{41}. The cathode of a valve V_{101} is connected through ten resistors R_{86} to R_{95} to the junctions of the rectifiers and resistors connecting the terminals Tu'_o to Tu'_9 respectively to the control grids of the triodes V_{32} to V_{41}. The control grids of the triodes V_{32} to V_{41} are connected through capacitors C_{103} to C_{112} and resistors R_{207} to R_{216} respectively to earth.

The second group contains ten triodes V_{42} to V_{51} whose cathodes are earthed through resistors R_{56} to R_{65} respectively. The cathodes of these valves are also connected directly to the ten bank contacts respectively of the uniselector bank ZRD1. The anodes of the valves V_{42} to V_{51} are connected together and through the relay contacts RQ3 to the terminal HT+17. The terminals Td'_o to Td'_9 are connected through ten rectifiers W_{31} to W_{40} ten resistors R76 to R85 and ten rectifiers W_{110} to W_{119} respectively in series to the control grids of the valves V_{42} to V_{51}. The terminal CS_2 is connected through a capacitor C_{101} to the control grid of a valve V_{101} which has a cathode load resistor R_{203}. The cathode of the valve V101 is connected through ten resistors R_{96} to R_{105} to the junctions of the rectifiers W_{31} to W_{40} and resistors R_{76} to R_{85} respectively.

Referring now to Figure 10 this is a circuit diagram of an arrangement suitable for use as the GO speech junctions 17 of Figure 1. The output terminals GSP_1 to GSP_{100} of the 100 calling units respectively (see GSP_1 of Figure 3) are connected to input terminals GSP_1 to GSP_{100} of the arrangement of Figure 10. In Figure 10 only ten of the terminals GSP_1 to GSP_{100} are shown. The input terminals GSP_1 to GSP_{100} are grouped into ten groups of ten terminals each and the ten groups are connected to the control grids of ten pentodes of which five are shown at V_{52} to V_{56}. The terminals GSP_1 to GSP_{10} are connected through rectifiers W_{41} to W_{50} respectively to the control grid of the pentode V_{52}. The other nine groups of input terminals are connected in a like manner to the control grids of the other nine input pentodes respectively. The five pentodes V_{52} to V_{56} have a common cathode resistor R_{106}, and the cathodes of the other five input pentodes (not shown) are likewise provided with a common cathode resistor. The anodes of the five input pentodes V_{52} to V_{56} are connected together as shown and have a common wide band anode load comprising a resistor R_{107}, an inductor L1, and a capacitor C_{35}. A resistor R'_{107} and a capacitor C_{36} are for decoupling purposes. The anode connections of the other five input pentodes are the same as those shown for the pentodes V_{52} to V_{56}.

The common anode connection of the five pentodes V_{52} to V_{56} is connected through a capacitor C_{39} to the control grid of a pentode valve V_{57}. The common anode connection of the other

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five input pentodes (not shown) is connected through a capacitor C_{47} to the control grid of a pentode valve V_{58}. The control grid of the pentode V_{57} is connected to earth through a rectifier W_{51} and a resistor R_{108} in parallel, and the control grid of the pentode V_{58} is connected to earth through a rectifier W_{52} and a resistor R_{111} in parallel. The screen grids of the two pentodes V_{57} and V_{58} are connected together and through a resistor R_{110} to the common cathode connection of the two pentodes V_{57} and V_{58}. The suppressor grids of these two pentodes are earthed.

The anodes of the two pentodes V_{57} and V_{58} are connected together and have a common wide band load comprising a resistor R_{112} an inductor L_2 and a capacitor C_{37}. A resistor R_{113} and a capacitor C_{38} are for decoupling purposes, and the junction of R_{113} and C_{38} is connected to the screen grids of the two pentodes V_{57} and V_{58}.

The anodes of the two pentodes V57 and V_{58} are connected through a capacitor C_{40} to the control grid of a pentode valve V_{59}. The control grid of this valve is also connected to earth through a rectifier W_{53} and a resistor R_{114} in parallel. The cathode of the pentode valve V_{59} is connected to earth through a resistor R_{115} and the anode has a wide band load comprising a resistor R_{116} an inductor L_3 and a capacitor C_{41}. A resistor R_{117} and a capacitor C_{42} are for decoupling purposes. The junction of R_{117} and C_{42} is connected to the screen grid of the valve V_{59} and the suppressor grid of the valve V_{59} is earthed.

The anode of the valve V_{59} is connected through a capacitor C_{43} to the control grid of a triode valve V_{60}, the control grid also being connected to earth through a resistor R_{118} and in parallel therewith a rectifier W_{54} and bias source GB_{17} connected in series. The valve V_{60} has a cathode load resistor

R_{119} and the anode thereof is decoupled by means of a resistor R_{120} and a capacitor C_{44}. The load resistor R_{119} is coupled by means of a wide band coupling comprising two capacitors C_{45} and C_{46} and an inductor L_4 to the control grids of three cathode follower valves V_{61} to V_{63}. The control grids of these valves are also connected to earth through a rectifier W_{55} and bias source GB_{18}. The valves V_{61} to V_{63} have cathode load resistors R_{121} to R_{123} respectively and the cathodes are connected to output terminals $GSPO_1$ to $GSPO_3$ respectively.

Although three cathode followers V_{61} to V_{63} have been shown more may be used if desired.

An arrangement as shown in Fig. 10 may also be used as the RETURN speech junction 18 and as the metering and release junction 19 of Fig.1. When used as the RETURN speech junction the terminals GSP_1 to GSP_{100} are replaced by the terminals RSP_1 to RSP_{100} (see RSP_2 Fig. 8), and the terminals $GSPO_1$ to $GSPO_3$ are replaced by the terminals $RSPO_1$ to $RSPO_3$ (see $RSPO_1$ Fig.3). When the arrangement of Fig.10 is used as the metering and release junction the terminals GSP_1 to GSP_{100} are replaced by the terminals ASP_1 to ASP_{100} (see ASP_1 Fig. 8) and the terminals $GSPO_1$ to $GSPO_3$ are replaced by terminals $ASPO_1$ to $ASPO_3$ (see $ASPO_1$ Fig. 3).

Referring new to Fig. 11 this is a circuit diagram of part of the busy junction 20 of Fig. 1. The 2,000 input terminals to the busy junction are grouped in groups of ten and of the 200 groups one is shown at BJ_1 to BJ_{10} in the Figure. These 2,000 terminals are connected to the terminals BJ in the 2,000 sub's line circuits respectively (see BJ_1 in Fig. 2).

Pulses appearing at the terminals BJ_1 to BJ_{10} are combined through resistors R_{124} to R_{143}. The combined outputs of the 200 groups are combined in further groups of ten by means of rectifiers the rectifiers of one group being shown at W_{56} to W_{65}. The outputs of these 20 groups are combined in two further groups of ten each by means of resistors and a see-saw circuit. One of these groups of resistors is shown at R_{145} to R_{154} which are connected to the control grid of a pentode valve V_{52} connected in a see-saw circuit comprising resistors R_{155}, R_{156} and R_{157}. The see-saw circuit functions as described in the M.I.T. Radiation Laboratory Series Vol. 19, Chapter 2, Section 5, 27 et seq, Fig 2.12(a) published by the McGraw Hill Book Company Inc. A resistor R_{179} and a capacitor C_{48} are for decoupling the anode circuit of the valve V_{52}. The cathode and suppressor grid of this valve are connected to earth, the screen grid to the junction of R_{179} and C_{48}, and negative bias for the control grid is supplied from a bias battery through resistors R_{177} and R_{158}. The gain of the see-saw circuit is made substantially unity by appropriate selection of the valves of the resistors in the circuit.

The second see-saw circuit comprises a pentode valve V_{53} connected in a circuit identical with that associated with the valve V_{52}, and comprising resistors R_{160} to R_{164} and a capacitor C_{49}.

The outputs of the two valves V_{52} and V_{53} are combined through two resistors R_{159} and R_{165} and applied to the control grid of a pentode valve V_{54} connected in a further see-saw circuit. The cathode of the pentode is earthed and the anode is coupled to the control grid by means of resistors R_{166}, R_{168}, R_{169} and R_{170}. A resistor R_{167} and a capacitor C_{50} serve to decouple the anode circuit of the valve V_{54}.

The junction of the resistors R_{168} to R_{170} is connected to the control grid of a pentode valve V_{55} which is coupled to a further pentode valve V_{56} by means of a resistor R_{171} which is common to the cathodes of both valves V_{55} and V_{56}.

The anode circuit of the valve V_{56}contains an anode load resistor R_{172} and is decoupled by means of a resistor R_{173} and capacitor C_{54}. The suppressor grids of the valves V_{55} and V_{56} are earthed and their screen grids are connected to the junction of R_{173} with C_{54}.

A capacitor C_{51} serves to connect the anode of the valve V_{56} to the control grid of a triode V_{58}. D.C. restoration of the voltages applied to the control grid of the valve V_{58} is effected by a diode valve V_{57} and a resistor R_{174}. The triode V_{58} has a cathode load R_{175} and acts as a cathode follower the cathode being connected to an output terminal BJO. This terminal is connected to the terminal of like reference in each register (see Fig. 5).

A suitable high frequency pulse generator (14 of Fig.1) will now be described with reference to Fig. 12 (a) to (e). In Fig. 12(a) the output of an ocillator OS_1 is applied to a ringing circuit comprising a pentode valve V_{59} whose anode circuit includes the primary winding of a transformer XF_4. The secondary winding of the transformer XF_4 has a centre tap connected to earth through a resistor R_{181} which is decoupled by a capacitor C_{54}. The lower end of the secondary winding is connected to the cathode of a diode valve V_{60} whose anode is connected through a resistor R_{182} to the positive terminal HT+18 of a source (not shown) of D.C. whose negative terminal is earthed. The anode of the diode V60 is also connected directly to the control grid of a pentode valve V_{61} whose cathode is connected to earth through a bias resistor R_{183} which is decoupled by a capacitor C_{55}.

During the positive half cycles of the voltage at the cathode of the diode V_{60} this diode is non-conducting. Thus the control grid of the valve V_{61} becomes highly positive and anode current of high value flows in the anode circuit of the valve V_{61}.

During negative half-cycles of the voltage at the cathode of the diode V_{60} this diode conducts and it is arranged that the voltage at the control grid of the valve V_{61} falls below the value for anode current cut-off in the valve V_{61}. Thus the wave form of the voltage at the anode of the valve V_{61} is substantially rectangular. The "mark-to-space ratio" of this waveform can be varied by changing the values of R_{181} and R_{183}. A value of 4:1 is used.

The potential variations at the anode of the valve V_{61} are applied through a cathode follower valve V_{62} to a terminal TA.

A diode valve V_{63} and two pentode valves V_{64} and V_{65} function in like manner to provide rectangular pulses of the same frequency but in anti-phase at a terminal TB.

The output of the valve V_{65} is differentiated by a capacitor C_{57} and resistor R_{187} then applied through an inverter comprising a valve V_{66} to a terminal TC.

In Fig.12(b) the input terminal TC which corresponds to the terminal TC in Fig.12(a) is coupled through two diode valves V_{67} and V_{68} to a multivibrator comprising two valves V_{69} and V_{70}. The multivibrator functions in known manner as a frequency divider and provides a division ratio of 5:1. The output voltage of this multivibrator is fed through a cathode follower valve V_{71} to an output terminal TD. The output applied to TD is also differentiated by a capacitor C_{58} and resistor R_{188} and applied to a phase inverter comprising a pentode valve V_{72}.

The output of this phase inverter is fed through two diodes V_{73} and V_{74} to a multivibrator comprising two pentodes V_{75} and

V_{76}. This multivibrator functions as a frequency divider and provides a division ratio of 2:1, and its output is applied through a phase splitter comprising a valve V'_{73} to two terminals TE and TF. The voltage applied to the terminal TF is also differentiated by a capacitor C_{59} and resistor R_{189} and applied through a phase inverter comprising a valve V'_{74}, to a terminal TG.

In Fig.12(c) the terminal TG, which corresponds to the terminal TG of Fig.12(b) is connected to a further multivibrator MV_1 which functions as a frequency divider and provides a division ratio of 5:1. The output of MV_1 is applied through a cathode follower CF_1 to a terminal TH.

In Fig.12(d) the terminal TD corresponds to the terminal TD of Fig.12(b) and is connected to the input of a delay network DL_1 of known kind, which has ten equally spaced taps T_1 to T_{10} respectively, and is terminated by a matched termination R_{184}. The delay of the network DL_1 is made equal to the recurrence period of the pulses applied at the terminal TD from the valve V_{71} of Fig.12(b), and the delay from the input to the first tap T_1 is made equal to the delay between adjacent taps.

The terminal TH in Fig.12(d) corresponds to the terminal TH of Fig.12(c) and is connected to the input end of a delay network DL_2 which has ten equally spaced taps T_{11} to T_{20}. The delay of the network is made equal to the recurrence period of the pulses applied at TH and the delay from the input to the tap T_{11} is made equal to the delay between adjacent taps. The network DL_2 is terminated by a matched termination R_{185}.

The pulse generator is provided with twenty output circuits of which one is shown in Fig.12(e). In Fig.12(e) an input terminal T_1 which corresponds to T_1 in Fig.12(d) is connected to the control grid of a pentode V''_{74}. An input terminal TA which corresponds to TA in Fig.12(a) is connected to the suppressor grid of the pentode V''_{74}. A cathode bias resistor R_{186} decoupled by a capacitor C_{56} provides bias for the pentode and by means of a diode V''_{75} the suppressor grid is kept normally at negative potential as a result of the D.C. restoration action of the diode in response to the positive-going pulses applied at the terminal TA. This negative potential on the suppressor grid is arranged to be sufficient to render the pentode V''_{74} normally non-conducting.

Thus the pentode V''_{74} acts as a gate and a pulse applied to the terminal T_1 passes through the gate only if a pulse is simultaneously applied to the terminal TA.

The output of the valve V''_{74} is applied through a phase inverter V''_{76} and a cathode follower V_{77} to an output terminal Tu_o.

The other nineteen output circuits are identical with that shown in Fig.12(e) and their outputs appear at terminals Tu_1 to Td_9 respectively.

The terminal TA is also connected to the suppressor grids of the gates in the four output circuits connected to the terminals Tu_2, Tu_4, Tu_6 and Tu_8 and the terminals T_3, T_5, T_7 and T_9 are connected to the control grids of those four gates.

The terminal TB of Fig.12(a) is connected to the suppressor grids of the gates in the five output circuits connected to the terminals Tu_1, Tu_3, Tu_5, Tu_7 and Tu_9 and the terminals T_2, T_4, T_6, T_8 and T_{10} are connected to their control grids.

The terminal TE is connected to the suppressor grids of the gates of the five output circuits connected to the terminals Td_o, Td_2, Td_4, Td_6 and Td_8 and the terminals T_{11}, T_{13}, T_{15}, T_{17} and T_{19} are connected to the control grids thereof respectively.

The terminal TF of Fig.12(b) is connected to the suppressor grids of the gates in the remaining five output circuits and the terminals T_{12}, T_{14}, T_{16}, T_{18}, and T_{20} of Figure 12(d) are connected to the control grids thereof respectively.

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Thus the pulses appearing at the terminals Td_o to Td_9 are as shown at $\underline{d_o}$ to $\underline{d_9}$ in Figure 13, and the pulses appearing at the terminals Tu_o to Tu_9 are as shown at u_o to u_9 in Figure 13.

The pulses $\underline{d_o}$ to $\underline{d_9}$ and $\underline{u_o}$ to $\underline{u_9}$ are combined in gates (of which two will be described later) to provide the 100 communication channels. For example the pulses $\underline{d_3}$ are applied to open and close a gate to which the pulses $\underline{u_4}$ are applied to provide channel No.34. Only one of the $\underline{u_4}$ pulses passes through this gate during each $\underline{d_3}$ pulse as will be seen from an examination of Figure 13. 100 $\underline{u}$ pulses occur during each cycle of a $\underline{d}$ pulse and the 100 $\underline{u}$ pulses are gated by the $\underline{d}$ pulses to provide the 100 channels.

The pulse width of the $\underline{u}$ pulses, and hence the channel pulses, is arranged to be about 0.5 u.sec. and the recurrence frequency of the pulses in each channel is arranged to be about 8,000 per second.

Referring to Figure 14 this is a diagram of a suitable pulse generator for use at 21 in Figure 1. The generator shown comprises an oscillator OSC_2 which generates sine waves at a frequency of 200 kc/s. The output of the oscillator OSC_2 is converted into an oscillation of square wave form by a known circuit including a valve V_{123} and the oscillations of square wave form are differentiated by a circuit comprising a capacitor C_{110} and a resistor R_{367}. The narrow pulses resulting from the differentiation are applied to the control grid of a valve V_{124} connected as a cathode follower and the positive-going pulses appearing at the cathode of the valve V_{124} at a frequency of 200,000 p.p.s. are passed to a terminal DT_1.

A first connection is made from the terminal DT_1 to a monostable multi-vibrator MV_{100} which is arranged in known manner to function as a frequency divider providing a division ratio of

4:1. The output of the multi-vibrator MV_{100} is passed to a second mono-stable multi-vibrator MV_{101} which also acts as a frequency divider and provides a division ratio of 5:1. The output pulses from the multi-vibrator MV_{101} which are of a frequency of 10,000 p.p.s. are passed to a terminal DT_2.

A second connection is made from the terminal DT_1 to a system of twenty bistable multi-vibrators of which four are shown at MV_{102}, MV_{103}, MV_{104}, and MV_{105} respectively. The terminal DT_2 is also connected to the system of multi-vibrators MV_{102} to MV_{105}.

The pulses appearing at the terminal DT_2 are arranged to "switch on" the first multi-vibrator MV_{102} in the system of twenty. After 5 micro-seconds however a pulse is applied from the terminal DT_1, which switches off the multi-vibrator MV_{102}. The coupling between the multi-vibrators MV_{102} and MV_{103} is made in accordance with known technique such that when the multi-vibrator MV_{102} is switched off the multi-vibrator MV_{103} is switched on. This process continues until all twenty of the multi-vibrat ors have been switched on and off in turn each one remaining switched on for a period of 5 micro-seconds.

Just as the last multi-vibrator is switched off the next pulse appears at the terminal DT_2 and the whole process is repeated. The twenty output terminals Td'_0 to Tu'_9 are connected to the twenty bistable multi-vibrators respectively.

Referring to Figure 15, this is a block schematic diagram of a suitable pulse generator for use at 26 in Figure 1. The terminal DT_2 is the terminal DT_2 in Figure 14 at which pulses having a recurrence frequency of 10,000 p.p.s. appear, and is connected through two cascaded multi-vibrators MV_{106} and MV_{107} to a terminal DT_3. The multi-vibrators MV_{106} and MV_{107} are arranged to function as frequency dividers providing division ratios of 2:1 and 5:1 respectively whereby an overall division ratio of 10:1 is obtained. Thus the pulses appearing at the terminal DT_3 occur at 1,000 p.p.s. These pulses are fed into a system of ten bi-stable multi-vibrators of which four are shown at MV_{108} to MV_{111}. The pulses appearing at the terminal DT_2 are also applied direct to the multi-vibrators MV_{108} to MV_{111}. It is arranged, as in Figure 14, that a pulse applied to the multi-vibrator MV_{108} switches it on and the next succeeding pulse from the terminal DT_2 direct switches off the multi-vibrator MV_{108}. The multi-vibrator MV_{108} on being switched off switches on the multi-vibrator MV_{109} which is switched off by the next succeeding pulse applied direct from the terminal DT_2. This process is repeated until all ten multi-vibrators in the row have been switched on and off in turn. Thus each of the multi-vibrators is switched on for 100 micro-seconds at a recurrence frequency of 1,000 per second. The output pulses from the ten multi-vibrators are applied to ten output terminals UP_1 to UP_9 and UP_0 respectively which correspond to the terminals of like reference in Figure 5.

The pulses appearing at the terminal DT_3 at the frequency of 1,000 p.p.s. are passed through two further cascaded multi-vibrators MV_{112} and MV_{113} to a terminal DT_4. The multi-vibrators MV_{112} and MV_{113} provide division ratios of 2:1 and 5:1 respectively and hence an overall division ratio of 10:1. Thus the pulses appearing at the terminal DT_4 have a recurrence frequency of 100 p.p.s.

These pulses are applied to a further system of ten multi-vibrators of which four are shown at MV_{114} to MV_{117}. These function in the same manner as the multi-vibrators MV_{108} to MV_{111} and provide ten trains of output pulses at the terminals

DP_1 to DP_9 and DP_o respectively which correspond to the terminals of like reference in Figure 5. The duration of each of these pulses is one millisecond and the pulses in each train occur at a recurrence frequency of 100 p.p.s.

The pulses appearing at the terminal DT_4 are also applied through two cascaded multi-vibrators MV_{118} and MV_{119} to a terminal DT_5. The multi-vibrators MV_{118} and MV_{119} provide a collective division ratio of 10:1 and hence the pulses at the terminal DT_5 recur at 10 p.p.s. These are applied to another system of ten bi-stable multi-vibrators of which four are shown at MV_{120} to MV_{123}. This system functions in the same manner as those already described to provide ten trains of output pulses at the ten output terminals CP_1 to CP_9 and CP_o respectively. The pulses in each of these trains recur at 10 p.p.s. and have a duration of ten milliseconds each.

The pulses appearing at the terminal DT_5 are applied through two cascaded multi-vibrators MV_{124} and MV_{125} to a final system of ten bi-stable multi-vibrators of which four are shown at MV_{126} to MV_{129}. The multi-vibrators MV_{124} and MV_{125} provide a collective division ratio of 10:1 and the final system of multi-vibrators functions in a like manner to those already described to provide ten trains of output pulses at the terminals MP_1 to MP_9 and MP_o respectively. The pulses in these ten trains recur at one p.p.s and each pulse has a duration of 100 milliseconds.

Referring to Figure 16 this shows one of the pulses M_1 which occur at the output terminal MP_1 of Figure 15. During each M_1 pulse ten C pulses (C_1 to C_9 and C_o) occur at the terminals CP_1 to CP_9 and CP_o (Figure 15) respectively. Two of these C pulses are shown at C_1 and C_2. During each C pulse ten D pulses (D_1 to D_9 and D_o) occur at the terminals DP_1 to DP_9 and DP_o respectively (Figure 15). Three trains D_1, D_2 and D_3 of the D pulses are shown. During each D pulse ten U pulses (U_1 to U_9 and U_0) occur at the terminals UP_1 to UP_9 and UP_0 respectively (Figure 15). One train of U_1 pulses is shown in Figure 16.

In addition to what is shown in Figure 15 the pulse generator 26 comprises 2,000 gate circuits (one per subscriber) of which one is shown in Figure 17. The function of these circuits is to provide a recurring sequence of 2,000 gating pulses each of 100 micro-seconds duration, the sequence recurring at the rate of once per second, and the several pulses in each sequence being applied to the 2,000 sub's line circuits respectively.

The circuit shown in Figure 17 is for providing the gating pulses for the sub's line circuit number 1464. The terminal MP_1 of Figure 15 is connected through a rectifier W_{122} and a resistor R268 to the anode of a rectifier W_{123} whose cathode is connected to the terminal CP_4 of Figure 15. The anode of the rectifier W_{123} is connected through a resistor R269 to the anode of a rectifier W_{124} whose cathode is connected to the terminal DP_6 of Figure 15. The anode of the rectifier W_{124} is connected through a resistor R270 to the anode of a rectifier W_{125} and to an output terminal SX1464.

In operation the M_1 pulses pass through the rectifier W_{122} and resistor R268 to the rectifier W_{123} which is normally conducting and provides a low impedance path whereby the M_1 pulses are dropped across the resistor R268. Whenever a C_4 pulse occurs at the terminal CP_4 however the rectifier W_{123} is rendered insulating and hence that part of each M_1 pulse which occurs during a C_4 pulse passes through the resistor R269 to the rectifier W_{124}. The rectifier W_{124} is normally conducting and provides a low impedance path except during the occurrence of D_6 pulses applied from the terminal DP_6. Thus only that part of each M_1 pulse which occurs during both a D_6 and C_4 pulse passes through the resistor R270 to the rectifier W_{125}. This is rendered non-conducting only during the U_4 pulses applied to the terminal UP_4 and hence the only part of each M_1 pulse, in this example, to pass to the output terminal SX1464 is the part which occurs during a U_4 pulse a D_6 pulse and a C_4 pulse.

Operation

It will be assumed that the subscriber at the station 10 of Figure 1 is calling the subscriber at the station 11 and that the number of the station 11 is 1464.

When the subscriber at the station 10 lifts his telephone handset from its rest a connection is automatically made from the terminal LT_1 of Figure 2 through the subscriber's line and telephone set back to the terminal LT_2. Thus a circuit is completed from earth through the battery BAT_1 and the relay winding L back to earth. The relay therefore operates and its contacts L1 and L2 close.

These contacts complete the automatic stepping circuit for the uniselector S, this circuit being from earth through the battery BAT_2, the winding S, mechanically operated contacts Sdm, the relay contacts K4, the relay contacts L2, the wiper and home contact of the bank S3 and the contacts L1 back to earth. The uniselector commences to hunt.

Referring now to Figure 3 (calling unit) it is arranged that when a calling unit is in use the terminal PO thereof (PO_1 in Figure 3) is earthed through contacts B1 as will be described later. When, however, the calling unit is free the contacts B1 are open (as will be described later) and the earth is removed from the terminal PO thereof.

Referring again to Figure 2, so long as the wiper of the bank

S3 is passing over contacts connected to engaged calling units the automatic stepping circuit of the uniselector remains completed through the earthed terminals PO in those units. When, however, a contact connected to a free calling unit is reached the PO terminal thereof is not earthed and hence the automatic stepping circuit is broken and the motion of the wiper arrested.

The relay K is then energised through a circuit comprising the battery BAT_2, the winding S, the contacts Sdm, and the relay contacts L1. The resistance of the relay winding K is made sufficiently high to prevent further operation of the stepping circuit as a result of the current flowing in the circuit of the relay winding K.

Relay contacts K1 to K7 close. Contacts K1 and K2 connect the terminals LT_1 and LT_2 through to the wipers of the uniselector banks S1 and S2. Assuming the wiper of the bank S3 to be arrested on contact PO_1, the wipers of S1 and S2 connect the terminals LT_1 and LT_2 to the terminals $+O_1$ and $-O_1$ respectively.

Whilst this is occurring the circuit in the seized calling unit operates to put an earth on the terminal PO_1 as will be described later.

When the relay contacts K1 and K2 close the relay winding L becomes de-energised and the relay contacts L1 and L2 open. The relay K remains operated however because of the earth applied to the terminal PO_1 by the seized calling unit.

The operation of the remainder of the circuit of Figure 2 will be described later.

Referring now to Figure 3, assuming this to be the seized calling unit current flows from earth through the left hand winding of the relay windings A, through the relay contact D1, through

A

the calling subscriber's line, back through the relay contacts D2, through the right-hand winding A and through the battery BAT_3 to earth. Thus the relay A operates and its contacts A1 and A2 close.

The contacts A2 apply an earth to the cathode of the gas-filled triode V_2, and hence prepare this valve for later operation.

The contacts A1 complete the circuit of the relay winding B the circuit being from earth through the battery BAT_9 through the winding B and the contacts A1 to earth. The relay contacts B_1 to B5 close. The contacts B1 apply an earth to the terminal PO_1. The contacts B2 prepare a circuit for transmitting subsequent dialling impulses to the terminal IMP. The contacts B3 connect the terminal P_1 to the contacts E3 and thence through the left-hand relay winding E to the negative terminal of the battery BAT_6. The contacts B4 put an earth on the busbar BUS_1. The contacts B5 connect the terminal GP to the suppressor grids of the two valves V_4 and V_5.

It is assumed that the seized calling unit terminates channel No. 1. The high-frequency pulses d_o and u_1 (Fig. 13) are therefore applied to the calling unit at Td_o and Tu_1 from the terminals of like reference in Fig. 12(c). The rectifier W66 provides a low impedance path for all of each d_o pulse applied to the terminal Td_o except that part thereof which occurs during a u_1 pulse

The u_1 pulses render the rectifier non-conducting. Thus during the absence of the u_1 pulse the d_o pulse applied to the terminal Td_o is dropped across the resistor R_{179}. During each u_1 pulse coincident with a d_o pulse however, voltage is passed to the terminal GP.

The voltage pulses appearing at the terminal GP are arrnaged to be positive-going. The negative bias applied to the suppressor of the two pentodes V_4 and V_5 is arranged to be sufficient to render these two valves normally non-conducting. The amplitude of the voltage pulses applied to the suppressor grids of the two pentodes V_4 and V_5 from the terminal GP is arranged to be sufficient to overcome the bias and to render these two valves conducting. Thus the valves V_4 and V_5 are gated in channel No. 1, and unmodulated pulses in channel No. 1 are transmitted from the anode of V_4, through the cap acitor C_5 to the terminal GSP_1.

The manner in which a register is allotted to the seized calling unit will now be described. An earth is applied to the terminal AL through the contacts B4, the busbar BUS_1, and the contacts E2.

Referring now to the register and calling unit finder circuit of Figure 5, whenever a register is free an earth is put on to the terminal R through the contacts KF6, and a connection is made from earth through the battery BAT_{17} and the contacts KF_5 to the terminal Q.

Referring to the allotter circuit of Figure 4 the earth on the terminal AL from the seized calling unit completes the energising circuit of the relay ST through the battery BAT_{11}. Thus contacts ST1, ST2 and ST3 close. The automatic stepping circuit of the uniselector FD is completed from earth through the battery BAT_{12}, the winding FD, the mechanically operated contacts FDdm, and the contacts ST1, DK1 and ST3 to the earthed terminal R of a free register. Thus the uniselector commences to hunt.

The contacts ST2 connect the relay winding DK between the earthed terminal R and the wiper of the uniselector bank FD1. When the terminal Q of the free register is reached by the wiper of the bank FD1 the energising circuit of the winding DK is completed through the contacts KF5 (Figure 5) and the battery BAT_{17}.

The contacts DK1 operate and hence break the automatic stepping circuit of the uniselector FD, and complete the energising circuit of the relay winding DR from the earthed terminal R through the contacts ST3 and DK1, the winding DR and the battery BAT_{13}, to earth. Thus the contacts DR1 to DR4 close.

The contacts DR1 complete a circuit from earth, through the contacts DR1, the contacts FK1, the bank FD2, the terminal Y, the mechanically operated contacts CUFdm (Figure 5), the operating winding CUF and the battery BAT_{15} to earth. Thus the uniselector CUF of Figure 5 commences to hunt.

When the wiper of the bank CUF_5 reaches the terminal P_1 connected to the terminal of the same reference in the seized calling unit (Figure 3) a circuit is completed from earth through the battery BAT_6 (Figure 3), the left-hand winding of the relay E, the contacts E3 and B3, the terminal P_1, the uniselector bank CUF5 (Figure 5) the terminal P_2, the uniselector bank FD3 (Figure 4) the contacts DR2 and the left-hand winding of the relay FK. Thus the relay E of Figure 3 and the relay FK of Figure 4 are energised. The contacts FK1 in Figure 4 also completed a circuit from earth through the battery BAT_{14}, the right-hand winding of relay FK, the contacts FK1 and DR1 to earth. This circuit holds the relay FK energised until released as will be described later.

In Figure 4 the contacts FK1 and FK2 close. The contacts FK1 complete a circuit from earth through the contacts DR1, FK1 and DR3, the uniselector bank FD4, the terminal X, the relay winding KF (Figure 5) and a battery BAT_{18} to earth. Thus the relay KF of Figure 5 is energised. The opening of the contacts KF2 arrests the motion of the wipers of the uniselector earth having already been removed from the terminal Y by the operation of the contacts FK1 of Figure 4. The contacts KF5 (Figure 5) disconnect the battery BAT_{17} from the terminal Q. The contacts KF_6 remove the earth from the terminal R and earth the terminals P_2 and P_1. The contacts KF_3 remove the earth from the homing arc of the uniselector bank ZZ2, and the contacts KF4 prepare on earth for the contacts PQ3.

When the earth is removed from the terminal R (Figure 5) and the battery BAT_{17} disconnected from the terminal Q by operation of the relay KF the relay DK of Figure 4 is released. The operation of the contacts DK1 releases the relay DR and the contacts DR1 opening break the energising circuit of the right-hand winding of the relay FK. Referring to Figure 3, when the relay E is energised as previously described the contacts E1 are arranged to close before any other contacts of this relay. A holding circuit is then completed from earth through the contacts B4, the contacts E1, the right-hand winding of the relay E, and the battery BAT_5 to earth. Operation of the contacts E3 earths the terminals P_1 and hence releases the relay FK of Figure 4. Contacts E2 open and remove the earth from the terminal AL. The allotter is, therefore, released and the wipers thereof home to their home contacts.

Until the allotter is released the contacts FK2 and DR4 (Figure 4) serve to hold the uniselector FD.

Referring to Figure 3 the contacts E4 complete a circuit from earth through the contacts A1, E4 and D5 to the terminal HO. The terminal HO of Figure 5 is connected through the uniselector bank OUF4, through the relay winding H and the battery BAT_{32} to earth. The relay H is therefore operated. The contacts H1 to H8 close and the contacts H2 serve to hold the relay winding KF energised, and hence to hold the register connected to the seized calling unit.

The contacts E5 (Figure 3) connect the charged capacitor C_{12} to the control grid of the valve V_2 which, therefore, strikes and energises the relay winding F. The contacts F1 close and hence dialling tone is fed to the calling subscribers line through the windings of the relay A.

The contacts E6 connect the terminals Td'_o and Tu'_1 to the terminal $Rd'_u{}'$. The low frequency pulses <u>d'_o</u> and <u>u'_1</u> are applied to the terminals Td'_o and Tu'_1 respectively and hence appear <u>at</u> the terminal $Rd'_u{}'$.

When the calling subscriber dials the number he requires (1464 in this example) the dialling impulses operate the relay A and hence the contacts A1.

The relay H of Figure 5 is slow acting and hence is not affected by the rapid operation of the contacts A1 of Figure 3. The contacts H1 connect the terminal IMP through the uniselector bank CUF1, the relay winding AA and the battery BAT_{16} to earth. Thus the operation of the contacts A1 of Figure 3 is followed by the contacts AA1 of Figure 5. The contacts H7 earth the moving contact of the contacts AA1 and hence each time the contacts AA1 are closed by a dialling impulse of the first digit a circuit is made from earth through the contacts H7, AA1 and PQ1, the wiper of the uniselector bank ZZ1, the first bank contact of ZZ1, the operating winding M and the battery BAT_{20} to earth. Thus in the present example where the number of impulses in the first digit is one the wiper on the uniselector bank M1 is set to the first bank contact and hence is connected to the terminal MP_1.

The relay BB is slow operating and its contacts BB1 close and open only once for each digit dialled irrespective of the number of impulses in the digit the energising circuit for the winding BB being from earth through the contacts H7 and AA1, the winding BB and the battery BAT_{25} to earth. Thus when the first digit of the wanted number is being dialled the relay contacts BB1 close and remain closed until the dialling impulses for that digit end. The contacts BB1 then open and as a result the wiper of the uniselector bank ZZ1 moves to its second contact.

The dialling impulses of the next digit (4 in this example) are therefore applied to actuate the operating winding of the uniselector C. The wiper of the bank C1 is, therefore, connected through to the terminal CP_4. Likewise the dialling impulses of the third and fourth digits dialled (6 and 4 in this example) are applied to actuate the operating windings of the uniselectors D and U respectively and hence the wipers of the banks D1 and U1 are connected through to the terminals DP_6 and UP_4 respectively.

The pulses M_1 to M_9 and M_o generated by the low frequency pulse generator 26 of Figure 1 are applied to the terminals MP_1 to MP_9 and MP_o respectively of Figure 5. Likewise the pulses C_1 to C_9 and C_o are applied to the terminals CP_1 to CP_9 and CP_o respectively, the pulses D_1 to D_9 and D_o are applied to the terminals DP_1 to DP_9 and DP_o respectively, and the pulses U_1 to U_9 and U_o are applied to the terminals UP_1 to UP_9 and UP_o respectively.

Thus the pulses M_1 C_4 D_6 and U_4 appear at the wipers of the four uniselector banks M_1, C_1, D_1 and U_1 respectively.

The anodes of all the rectifiers W_{10} to W_{13} are connected to the bus-bar BUS_2 which is at positive potential, and hence these rectifiers are normally conducting and provide a low impedance path to earth. When an M_1 pulse occurs this renders the rectifier W_{10} non-conducting but as the remaining rectifiers W_{11} to W_{13} are still conducting the potential of the bus-bar BUS_2 is not altered. Likewise when any C, D or U pulses occur in the absence of other pulses the potential of the bus-bar BUS_2 remains unaltered. When U, D, C and M pulses occur simultaneously however the low impedance path between the bus-bar BUS_2 and earth is removed and the potential of the bus-bar is increased.

In the present example the pulses appearing at the wipers of the uniselector banks M_1, C_1, D_1, and U_1 are the pulses M_1, C_4, D_6, U_4. Thus the bus-bar BUS_2 becomes positive for the duration of each U_4 pulse occurring during $D6$, C_4 and M_1 pulses. The bus-bar BUS_2 remains positive for the duration of the U_4 pulse and this U_4 pulse passes through the capacitor C_{100} to the control grid of the valve V_{100} and hence appears at the cathode valve V_{100} and the output terminal RO. The d' u' pulses applied to the resistor R_{206} from the uniselector bank CUF_2 are normally dropped across the resistor R 206 because of the low impedance path provided through the rectifier WX_{14} and the cathode resistor R_{205} of the triode V_{100}. Whenever the U_4 pulses appears, however, at the terminal RO this pulse renders the rectifier WX_{14} non-conducting whereby the last said low impedance path is broken for the duration of the U_4 pulse and the d' u' pulses occurring during that U_4 pulse interval pass to the output terminal ROX.

The 100 microsecond recurring U_4 pulse appearing at the terminal RO passes through the calling junction 25 of Figure 1 and is applied to the terminal RT in all the subscribers line circuits (Figure 2). Simultaneously with the application of the calling pulse in channel 1464 a gating pulse is applied at the terminal SX1464, in the called subscriber's line circuit and no other, and the calling pulse applied at RT passes through the resistor R_1 and the rectifier WX_1 and charges the capacitor CX1. The voltage is held in the capacitor CX_1 and strikes the tube V_1.

The resulting anode current energises the relay Z and contacts Z1 and Z2 close.

The contacts Z1 complete the energising circuit of the relay L and hence the relay contacts L1 and L2 close. The contacts Z2 earth the contact BC_2 of the uniselector bank S5.

The contacts L1 complete a circuit from earth through the home contact and wiper of the uniselector control bank S3, through the contacts L2, K4 and Sdm, the operating winding and the battery BAT_2 to earth. The uniselector S commences to hunt. The earth on the contact BC_2 of the bank S5 ensures that the uniselector steps over the OUT contacts on the banks S1, S2 and S3 on to the IN contacts.

Referring to Figure 8 (called unit) when the called unit is free the terminal PI_2 is connected through the contacts RB3, the relay winding RQ and the battery BAT_{28} to earth, and hence the terminal PI_2 is of negative potential. When, however, the called unit is engaged the contacts RB_3 are closed (as will be described later) whereby the terminal PI_2 is earthed.

Thus, referring again to Figure 2, the wiper of the bank S3 supplies an earth for the automatic stepping circuit of the uniselector S so long as the wiper is passing over IN contacts connected to engaged called units. When a contact is reached connected to a free called unit, however, the automatic stepping circuit is broken and the motion of the wipers arrested.

The relay K then becomes energised through L1, the earth having been removed from the wiper of S3 and hence from the contacts K4. The contacts K1 and K2 connect the line terminals LT_1 and LT_2 to the seized called unit.

The contacts K3 close and connect the winding K to the wiper of the bank S3.

The contacts K4 open and hence the moving contact of the contacts K4 is disconnected from the moving contact of the contacts L2 and from the wiper of the bank S5.

The contacts K5 open and extinguish the valve V_1 whereby the relay Z becomes de-energised. The contacts Z1 open and de-energise the relay L. The contacts L1 open and remove the direct earth from the relay winding K. The relays Z and L are, however, slow-operating and it is arranged that the earth from the seized called unit is applied to hold the relay K before the contacts L1 open as will be described later. The contacts L2 prepare a homing earth from the bank S4 and the contacts Z2 open and remove the earth from the contact BO_2 of the bank S5.

The relay contacts K6 connect the junction of WX_2 and

R202 to the terminal BJ_1 for a purpose to be described later, and the contacts K7 connect the junction of WX2 and R202 through the uniselector bank S6 to the terminal CS_1.

As soon as the relay K operates, and whilst the relays Z and L are opening, the relay RQ of the seized called unit Figure 8 becomes energised, the energising circuit being from earth through the winding RQ, the contacts RB3, the uniselector bank S3 of Figure 2, the contacts K3 and L1 to earth. Thus the contacts RQ1, RQ2 and RQ3 of Figure 8 close. The contacts RQ1 apply H.T. to the two valves V_{28} and V_{29}. The contacts RQ2 complete the automatic stepping circuits of the uniselectors ZRU and ZRD, and in addition complete the energising circuit of the relay CD. Thus the uniselectors ZRD and ZRU start the hunt, and whilst they are hunting the wipers of the banks ZRD3 and ZRU3 are isolated from the valves V_{24}, V_{25} and V_{31} by the opening of the contacts CD_1. The relay contacts RQ_3 apply HT to the translator 25.

Referring again to Figure 2 the <u>d'</u> <u>u'</u> pulses applied to the terminals RTX are normally dropped across the resistor R_{202}, a low impedance path being provided through the rectifier WX_2. When, however, the calling pulses appear at the terminal RT they render the rectifier WX_2 non-conducting for the duration of each calling pulse. Thus the low impedance path is broken and the <u>d'</u> <u>u'</u> pulses appearing during each calling pulse in the channel 1464 pass through the relay contacts K_7 to the wiper of the uniselector bank S_6 and pass through the arcuate contact BC_5 to the output terminal CS_1.

Referring to Figure 9 the <u>d'</u> and <u>u'</u> pulses arriving the terminal CS_2 from the called subscribers line circuit pass to the control grid of the valve V_{101} and hence appear at the cathode of the valve V_{101}. From there the pulses are applied to the control grids of the valves V_{32} to V_{51} through the resistors R_{86} to R_{105} and pulse lengthening circuits comprising the rectifiers W_{100} to W_{119} and capacitors C_{103} to C_{122}. The rectifiers W_{21} to W_{40} are, however, conducting to these pulses except the rectifiers to which d' and u' pulses are applied from the terminals Tu'o to Td'_9 simultaneously with the d' and u' pulses arriving at the terminal CS_2. In this example the pulses d'_0 and u'_1 appear at the terminal CS_2 simultaneously with the pulses d'_0 and u'_1 applied at the terminals Td'_0 and Tu'_1. Thus the rectifiers W_{31} and W_{22} are non-conducting in this example and permit the d'_0 and u'_1 pulses applied to the terminal CS'_2 to pass to the control grids of the valves V_{42} and V_{33} respectively. These two valves strike and hence their cathodes become positive.

When the wiper of the bank ZRU1 reaches the bank contact connected to the cathode of the valve V_{33} the positive potential appears at the control grid of the valve V_{28} (Figure 8) and this valve strikes. Similarly the valve V_{29} (Figure 8) strikes when the wiper of the bank ZRD1 reaches the bank contact connected to the cathode of the valve V_{42}.

Referring to Figure 8, when the valves V_{28} and V_{29} strike the relays DA and UA become energised by the anode circuits of these two valves. Thus the contacts DA1, DA2, UA1 and UA2 are operated. The contacts DA1 hold the relay DA and extinguish the valve V_{28} and the contacts DA_2 break the automatic stepping circuit of the uniselector ZRU. The contacts UA1 hold the relay UA and extinguish the valve V_{29}, and the contacts UA2 break the automatic stepping circuit of the uniselector ZRD.

Thus the wipers of the banks ZRD3 and ZRU3 are arrested on the bank contacts connected to the terminals Td_c and Tu_1 respectively. The pulses d_o and u, are applied to these terminals respectively from the high frequency pulse generator. In the absence of a $\underline{d_o}$ pulse the rectifier W_{20} is conducting and hence the $\underline{u_1}$ pulses are dropped across the resistor R_{40}. The occurrence of a $\underline{d_o}$ pulse renders the rectifier W_{20} non-conducting and hence the $\underline{u_1}$ pulse occurring during each d_o pulse passes to the contacts CD1 that is to say pulses in channel No. 1. These contacts close simultaneously with the open ng of the automatic stepping circuit of the selectors and the pulses in channel No. 1 pass to the suppressor grids of the valves V_{24} and V_{25}.

Thus unmodulated pulses of anode current flow in the valves V_{24} and V_{25} which are arranged to be normally non-conducting by the bias applied thereto from the terminals $-GB_8$ and $-GB_{10}$ respectively. The pulses passed by the valve V_{25} are applied through the capacitor C_{28} to the control grid of the valve V_{26}. Thus, pulses of anode current flow in this valve which is arranged to be normally non-conducting by the bias applied thereto from the terminal $-GB_{11}$. Thus the relay RB becomes energised and the contacts RB1 and RB4 thereof are operated.

The contacts RB3 put an earth on the terminal PI_2 and hence hold the relay K of Fig. 2 it being arranged that the contacts RB3 close about 1/2 second before the contacts L1 of Fig.2 open. The contacts RB2 close and hold the relays DA and UA when the relay RQ becomes de-energised on the operation of the contacts RB3.

The contacts RB4 close and apply ringing voltage from the transformer XF_3 to the called subscriber's station. When the called subscriber answers the relay F becomes energised, the energising circuit being from earth through the battery BAT_{33} the contacts F3, the called subscriber's line, the contacts F2, the relay winding F, the contacts RB4 and the secondary winding of the transformer XF3 back to earth. The contacts RB1 and F1 hold the relay F.

The relay RD then becomes energised, the energising circuit being from earth through the batterty BAT_{30}, one winding of the relay RD, the contacts F3, the called subscriber's line the contacts F2 and the other winding of the relay RD back to earth.

The contacts Rd1 then apply the pulses in channel No.1 through the valve V_{31} to the terminal ASP_1 and thence through the metering and release junction (19 Fig. 1) to the terminal $ASPO_1$ of Fig. 3 (calling unit). The rectifier W_7 is rendered non-conducting thereby and permits the pulses in channel No. 1 from the terminal GP to appear at the control grid of the valve V_6. This valve then passes pulses of anode current through the relay winding D which becomes energised.

The contacts D1 and D2 operate and reverse the polarity of the terminals $+O_1$ and $-O_1$. This is for signalling purposes as described on page 278 of Telephony Vol II by Atkinson. The contacts D4 apply a pulse of current to the terminal PO_1 from the battery BAT_{10}, the relay contacts J1 being operated after the contacts D4 on de-energisation of the slow operating relay J by the opening of the contacts

The pulse of current applied to the terminal PO_1 operates the meter M of Fig. 2 to record the establishment of the call.

The contacts D5 (Fig.3) open and hence remove the earth from the terminal HO. Thus the relay H of Fig. 5 becomes de-energised. The contacts H2 open and hence the relay KF is de-energised, and thus the register is released and the uniselector CUF homes.

Speech voltages from the calling subscriber's station are transmitted through the transformer HY_1 to the control grid of the valve V_4 and there amplitude-modulate the pulses in channel No. 1 applied to the terminal GSP_1. These amplitude-modulated pulses pass through the GO speech junction to the called units.

Referring to Fig. 8 all pulses from the terminal $GSPO_1$ of the GO speech junction are passed to the control grid of the pentode V_{25} which is gated by channel No. 1 pulses as previously described. Thus only the pulses in channel No. 1 pass to the transformer XF_2.

The primary winding is tuned by the capacitor C_{30} to a periodicity of approximately twice the width of the pulses applied thereto from the valve V_{25}, and is heavily damped by the resistor R_{194}. The w inding S_2XF_2 has more turns than the winding S_2XF_1 and hence provides a greater output voltage than S_2XF_1. The terminal $-GB_{13}$ is arranged to be about five volts less negative than the terminal $-GB_{12}$.

Assuming the charge in the capacitor C_{31} to be such that the potential of the upper plate thereof in the drawing is between that of $-GB_{13}$ and $-GB_{12}$, the rectifiers W16 to W_{19} are non-conducting. When a pulse arrives at the primary winding of the transformer XF_2 from the valve V_{25} the leading edge of the pulse shock excites the transformer. The first, and negative, half-cycle of the free oscillation is applied to the anode of W_{16} which, therefore, remains non-conducting, and to the cathode of W_{17} which becomes conducting and hence C_{31} discharges through R_{37} and W_{17} until the potential of its upper plate in the drawing equals the potential of the terminal $-GB_{12}$. Any further negative excursion at the cathode of W_{17} is damped by W_{18}. Simultaneously W_{19} becomes conducting and as a result the capacitor C_{31} discharges further and its upper plate is left at a potential somewhat below that of the terminal $-GB_{12}$.

Just as this negative half-cycle ends, the lagging edge of the pulse arrives and again the transformer XF_2 is shock-excited but this time in the opposite sense. The first, and positive, half-cycle of this second free oscillation has no effect on W_{17} and W_{18}. The capacitor C_{31} is charged, however, through W_{16} to a value dependent upon the amplitude of the pulse applied to the transformer XF_2, and lying between the potentials of the terminals $-GB_{12}$ and $-GB_{13}$.

The damping provided by the resistor R_{194} is arranged to be sufficient to prevent subsequent half-cycles from affecting the charge in the capacitor C_{31}.

Thus the capacitor C_{31} presents relatively broad pulses to the valve V27 in response to relatively narrow pulses passed by the valve V_{25}, the amplitude of the broad pulses being dependent upon the amplitude of the narrow pulses.

The broad amplitude-modulated pulses are demodulated by being passed through the low-pass filter FIL_2 and the speech voltages are passed through the transformer HY_2, the capacitors C_{22} and C_{23}, the contacts F2 and F3, and the called subscriber's line circuit to the called subscriber's line.

Speech voltages from the called subscriber are passed through his line circuit, and the hybrid transformer HY_2 to the control grid of the pentode V_{24}. Here they serve to amplitude-modulate the pulses (in channel No. 1) applied from the anode of V_{24} to the terminal RSP_2. These pulses are applied through the RETURN speech junction to the terminal $RSPO_1$ to Fig. 3 and thence to the control grid of the pentode V_5 which is gated by pulses in channel No. 1 applied to the suppressor grid from the terminal GP.

The transformer XF_1 in the anode circuit of the valve V_5, together with the capacitors C_7 and C_{10}, the resistors R_7 and R_{195}, and the rectifiers W_3 to W_6, function in the same manner as the transformer XF_2, capacitors C_{30} and C_{31}, resistors R_{37} and R_{194}, and rectifiers W_{16} to W_{19} of Fig. 8, to broaden the pulses passed by the valve V_5.

The broadened, amplitude-modulated pulses are passed through the valve V_3 and are demodulated by a low-pass Filter FIL_1. The speech voltages are applied through the transformer HY_1 and the calling subscribers line circuit to the calling subscriber's line.

The operation of the arrangement shown when a called subscriber is already engaged will now be described. When the called subscriber is engaged, the relay K in his line circuit (Fig.2) is already energised and the junction of WX2 and R_{202} is connected through the relay contacts K6 to the terminal BJ_1. Thus the d' and u' pulses arriving at the terminal RTX in the channel intervals of channel No. 1464 in the present example are transmitted to the terminal BJ_1

and thence through the Busy junction to the terminal BJO in the register (Fig.5) allotted to the calling subscriber.

Thus these pulses coincide with the d' and u' pulses applied from the terminal Rd'u' to the rectifier W_{14} which is rendered non-conducting thereby. Thus the d' and u' pulses applied to the terminal BJO pass through the capacitors C_{13} and C_{14} to the control grids of the valves V_7 and V_8. The d' pulse serves to strike the valve V_7 whose cathode potential rises. The rise in potential at the cathode of the valve V_7 is transmitted to the control grid of the valve V_8 but is arranged to be insufficient to strike V_8. The u' pulse applied to the control grid of V_8 is arranged to provide sufficient extra potential to strike V_8. The relay BR is, therefore, energised. The contacts BR1 close and hence earth the terminal BU_1. Referring to Fig. 3, when the terminal BU_1 is earthed the relay G becomes energised. The contacts G1 hold the relay G and the contacts G2 apply the busy tone to the calling subscribers line through the relay windings A and the calling subscriber's line circuit.

When a call is ended and the calling subscriber replaces his handset on its rest, the energising circuit for the relay A (Fig.3) is broken. The relay contacts A1 return to the position shown thus de-energising the relay B. The contacts B1 remove the earth from the terminal PO_1. Thus the relay K (Fig.2) becomes de-energised, and the uniselector S homes. The calling unit is released and all relays return to their unoperated condition.

Thus the pulses arriving in channel No. 1 in this example at the terminal $GSPO_1$ of Fig. 8 cease and hence the relay RB becomes de-energised. The contracts RB3 open, and the earth is removed from the terminal PI_2. Thus the relay K in the called subscriber's line circuit is released and the uniselector in this line circuit homes. The contacts RB1 open and release the relay F (Fig.8). The contacts RB2 open and release the relays DA and UA. Thus the contacts DA2 and UA2 close and the uniselectors ZRU and ZRD home. The called unit is then ready for use in making another call.

The embodiments of the invention in which an exclusive property or privilege is claimed are defined as follows:

1. An automatic exchange comprising a first group of low grade communication channels, a second group of low grade communication channels, a plurality of line terminating units which are connected to individual ones of a plurality of station associated with the exchange, each of said line terminating units having an individual one of said first group of low grade communication channels and an individual one of said second group of low grade communication channels identified therewith, a group of high grade communication channels, the number of communication channels in said group of high grade communication channels being less than the number of line terminating units in said plurality of line terminating units, first apparatus which seizes a free one of said high grade communication channels in response to an initial calling signal from a line terminating unit of said plurality of line terminating units and connects that line terminating unit thereto, that calling signal originating from a calling station of said plurality of stations, connected to that line terminating unit, further apparatus which transmits a calling signal and an identification signal to that one of said plurality of line terminating units to which a called station of said plurality of stations is connected, in response to further signals from the line terminating unit to which the calling station is connected, these further signals being representative of the identity of the called station, the calling signal transmitted

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by said further apparatus being transmitted to the line terminating unit to which the called station is connected in that one of said first group of low grade communication channels which is identified with that line terminating unit, and the identification signal transmitted by said further apparatus identifying that one of said high grade communication channels seized by said first apparatus and being transmitted to the line terminating unit to which the called station is connected in that one of said second group of low grade communication channels which is identified with that line terminating unit, and additional apparatus which, in response to the calling signal and identification signal received by the line terminating unit to which the called station is connected, connects that line terminating unit to that one of said high grade communication channels which is identified by that identification signal.

2. An automatic exchange according to Claim 1, wherein said first group of low grade communication channels is constituted by a group of time division multiplex pulse communication channels.

3. An automatic exchange according to Claim 1 or Claim 2 wherein said second group of low grade communication channels is constituted by a group of time division multiplex pulse communication channels.

4. An automatic exchange according to Claim 1 wherein said first group of low grade communication channels and said second group of low grade communication channels are each constituted by a group of pulse signals

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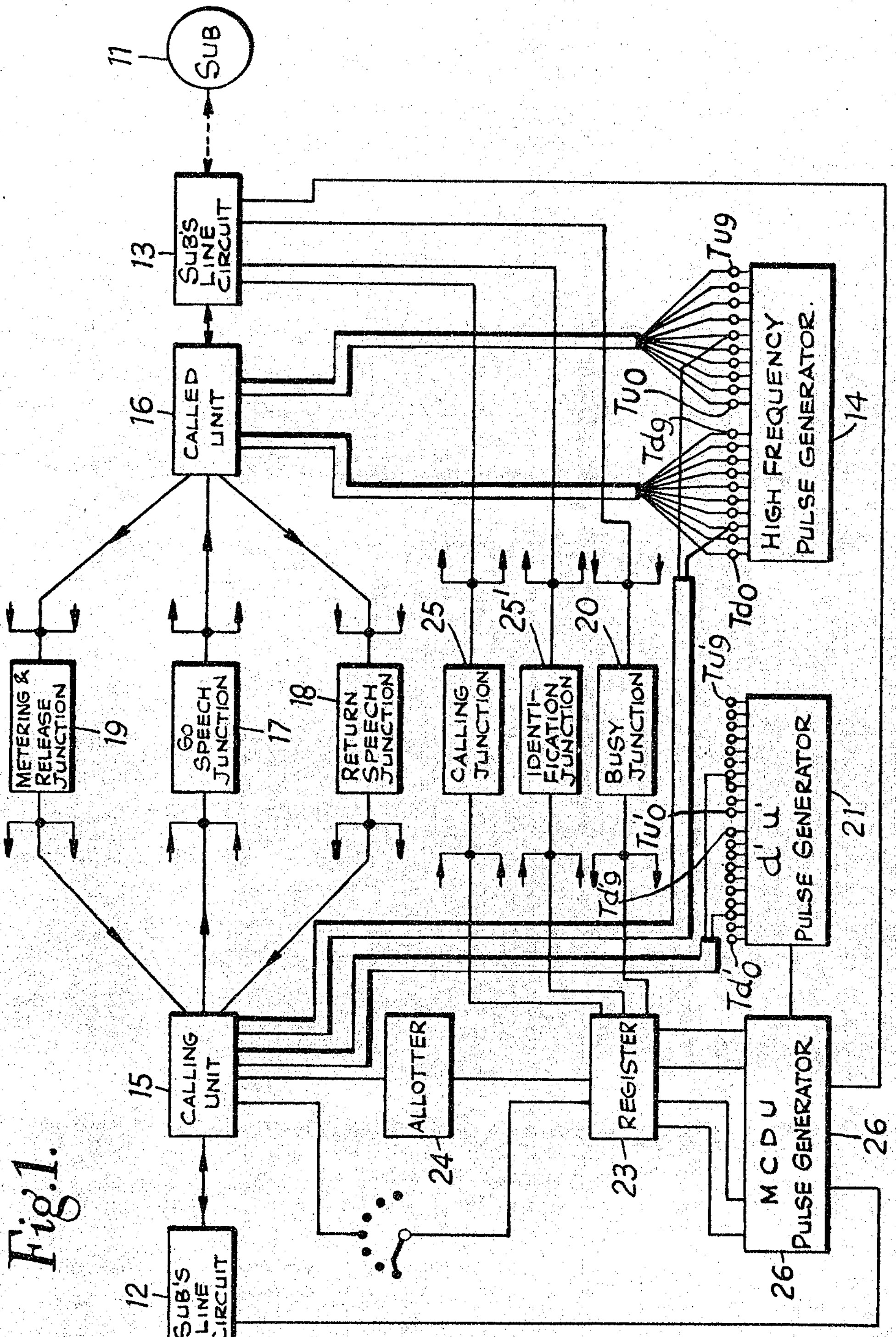
combined in time division multiplex, and wherein, for each of said line terminating units, pulses of the two pulse signals that constitute the two low grade communication channels, one from each of the first and second groups of low grade communication channels, that are identified with that line terminating unit, have the same pulse recurrence frequency and the same positions in time.

5. An automatic exchange according to any one of Claims 1, 2 or 4 wherein said group of high grade communication channels is constituted by a group of time division multiplex pulse communication channels.

A

Fig.1.



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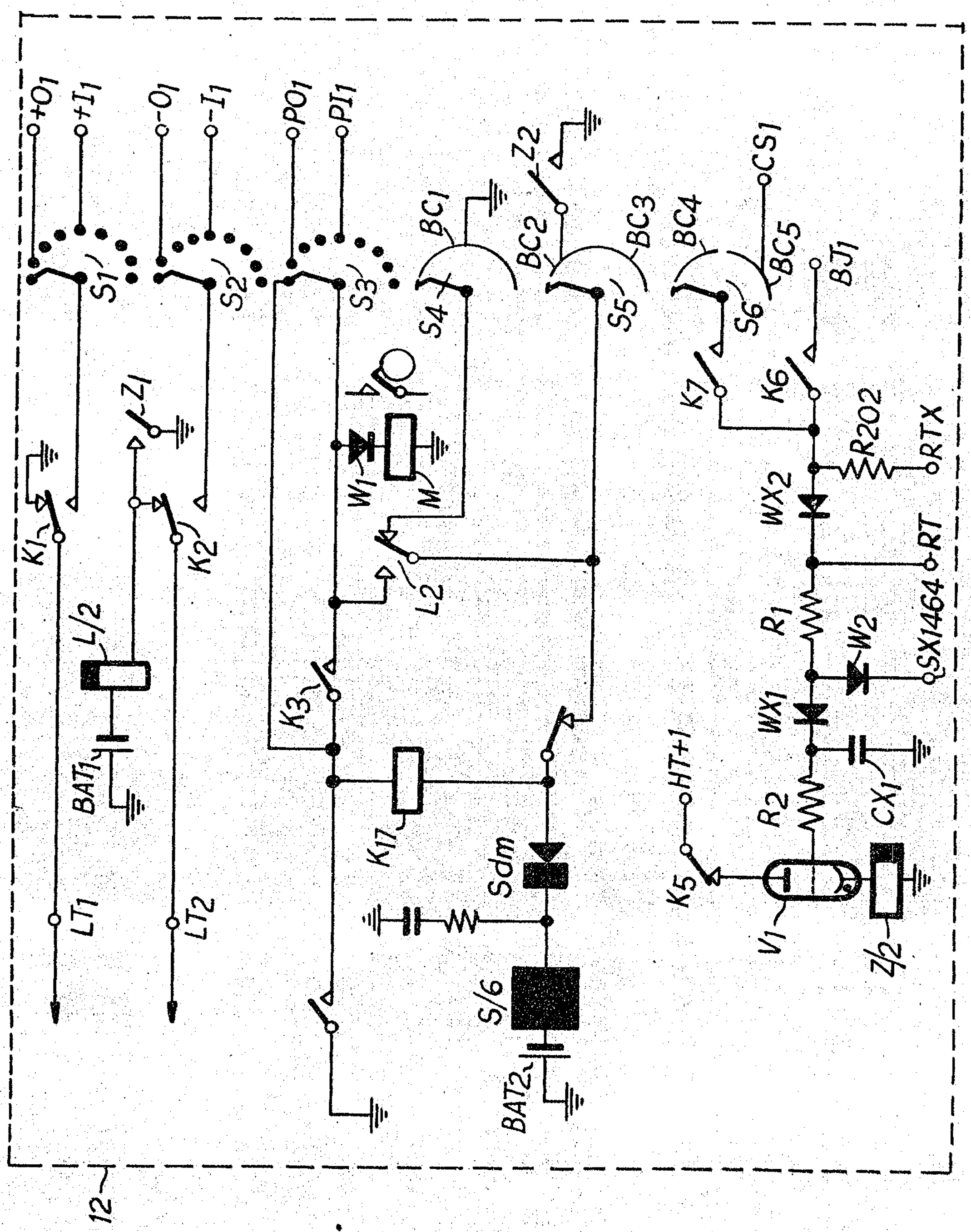

Fig.2.

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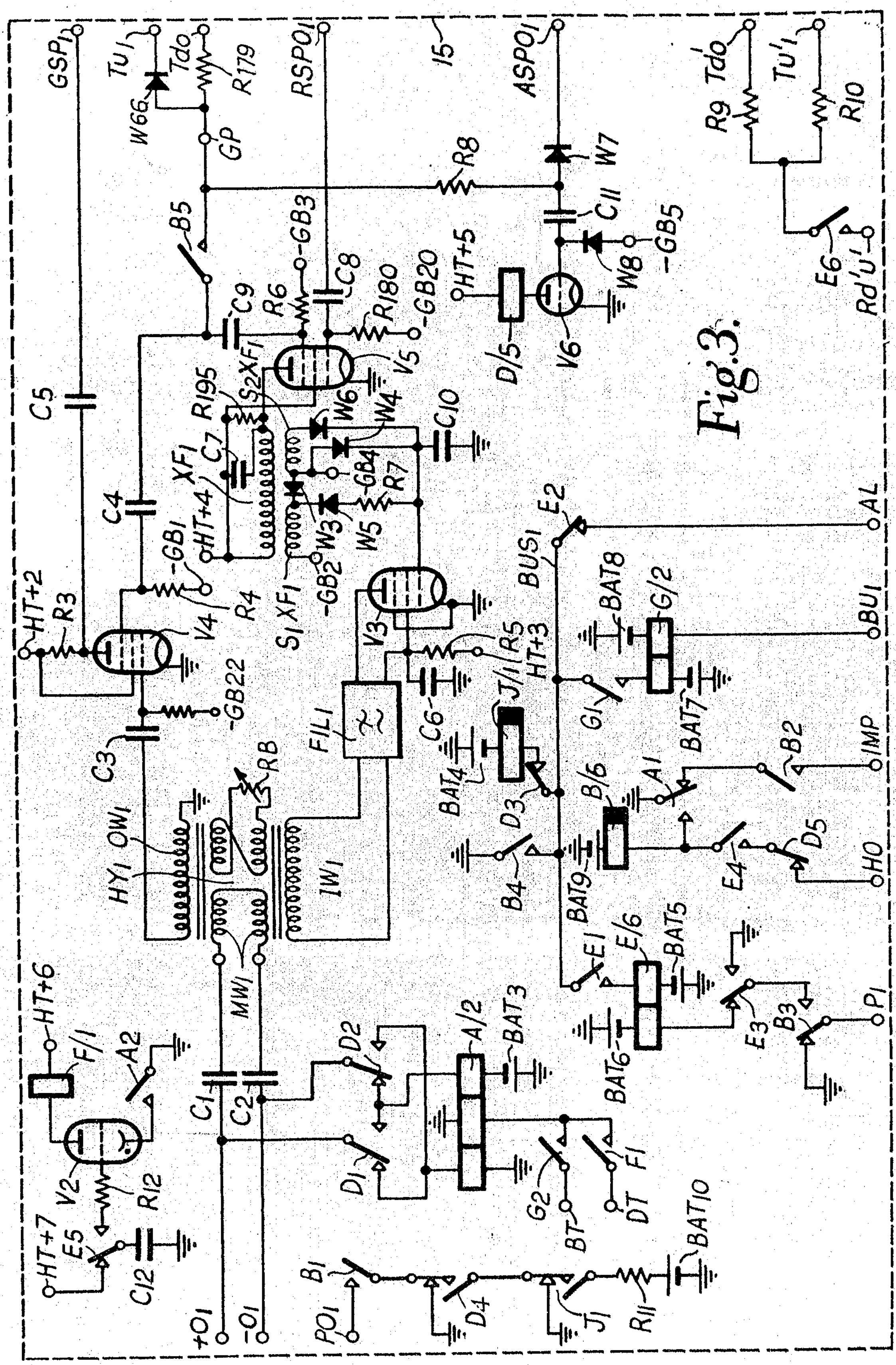

Fig. 3.

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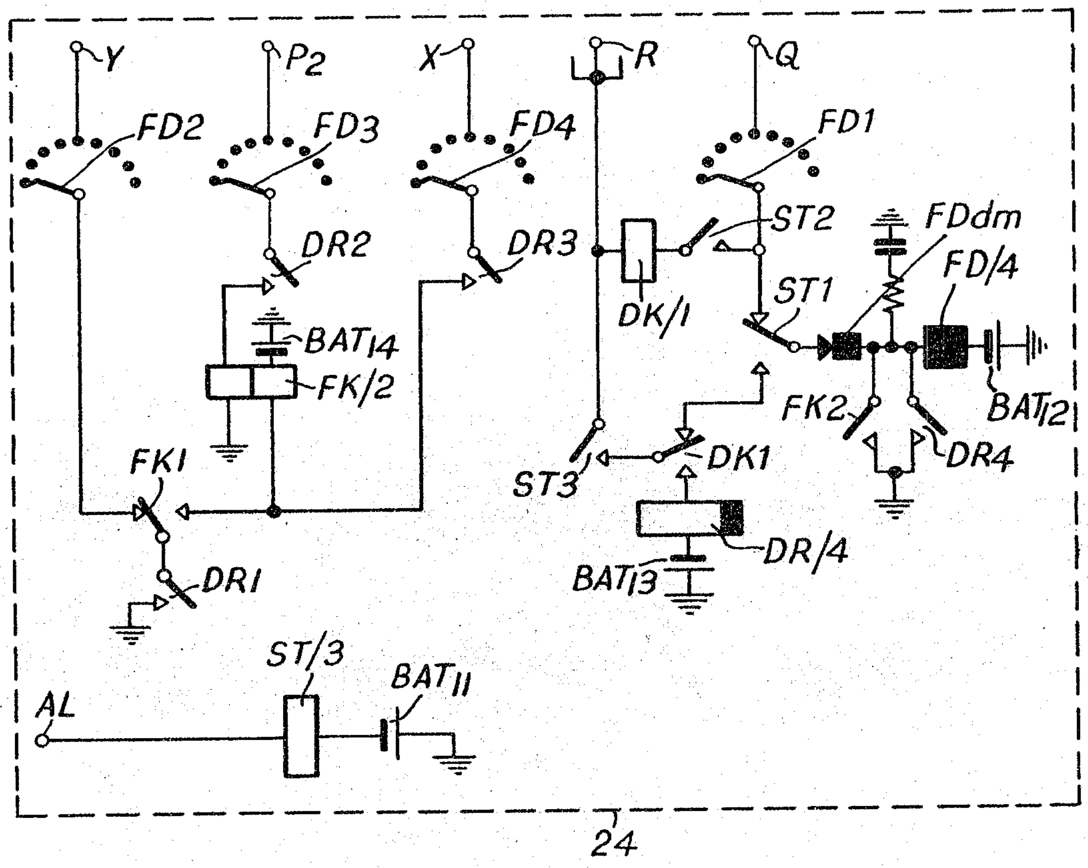
Fig.4.



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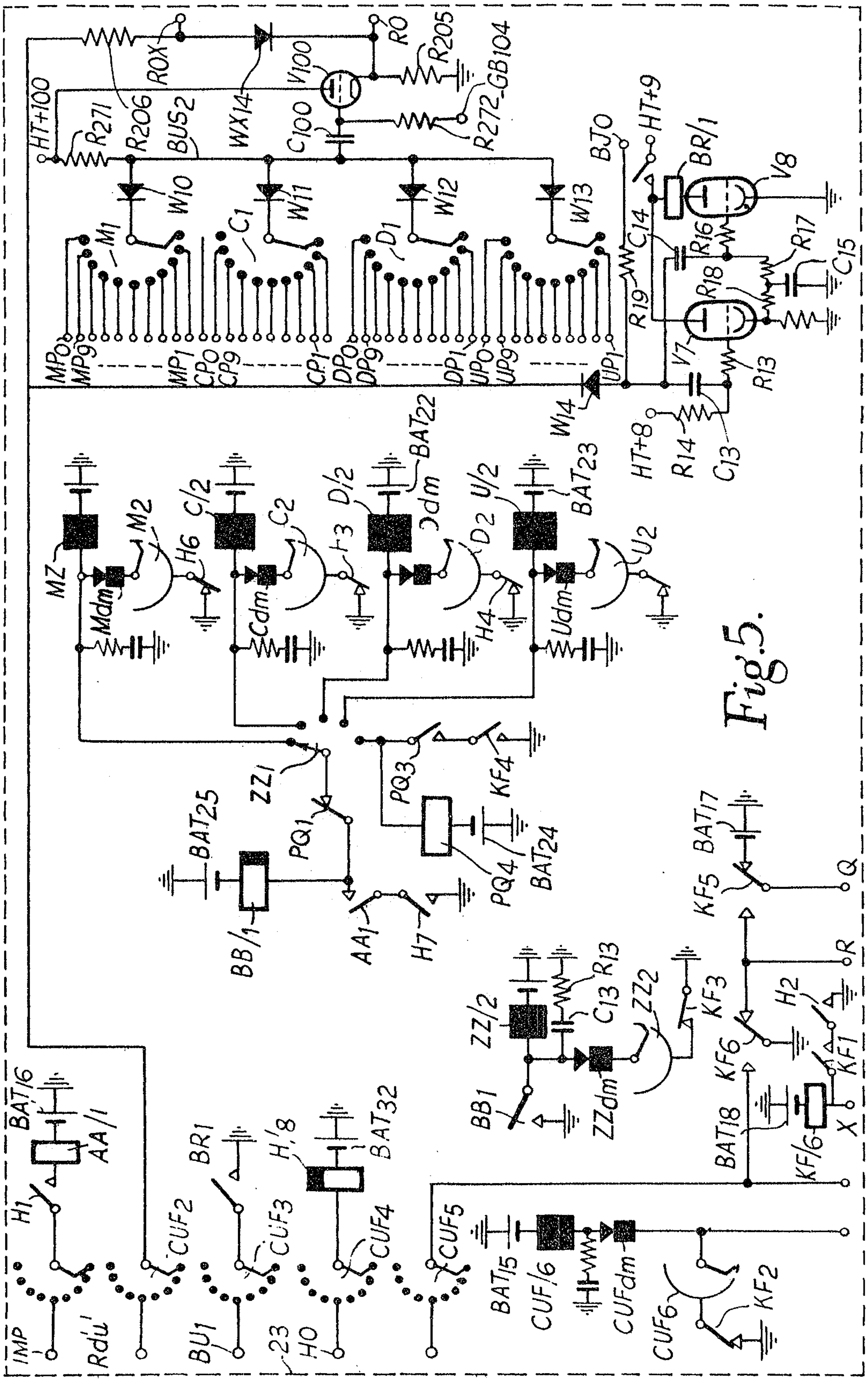

Fig.5.

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Fig.6.

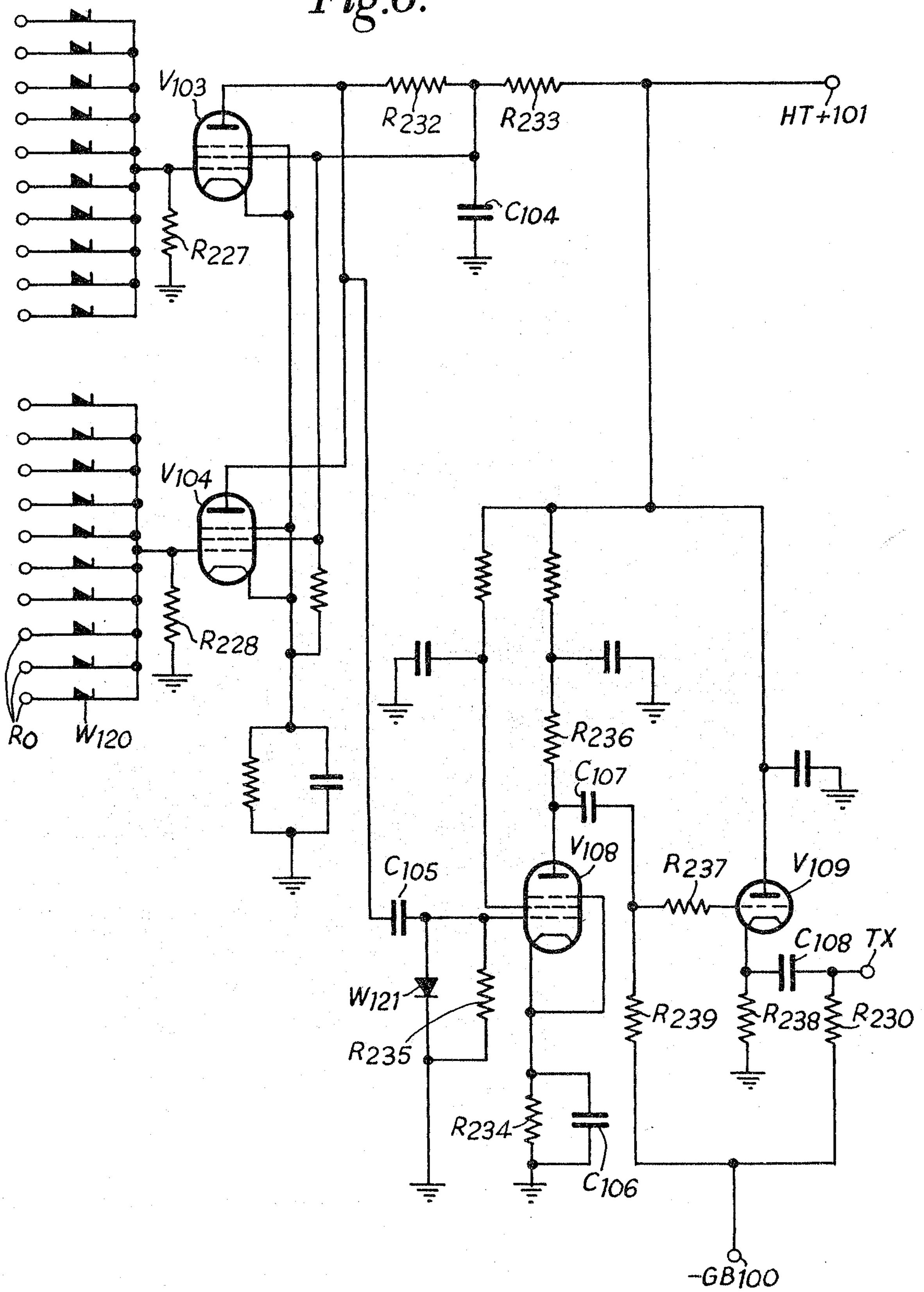

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Fig. 7.

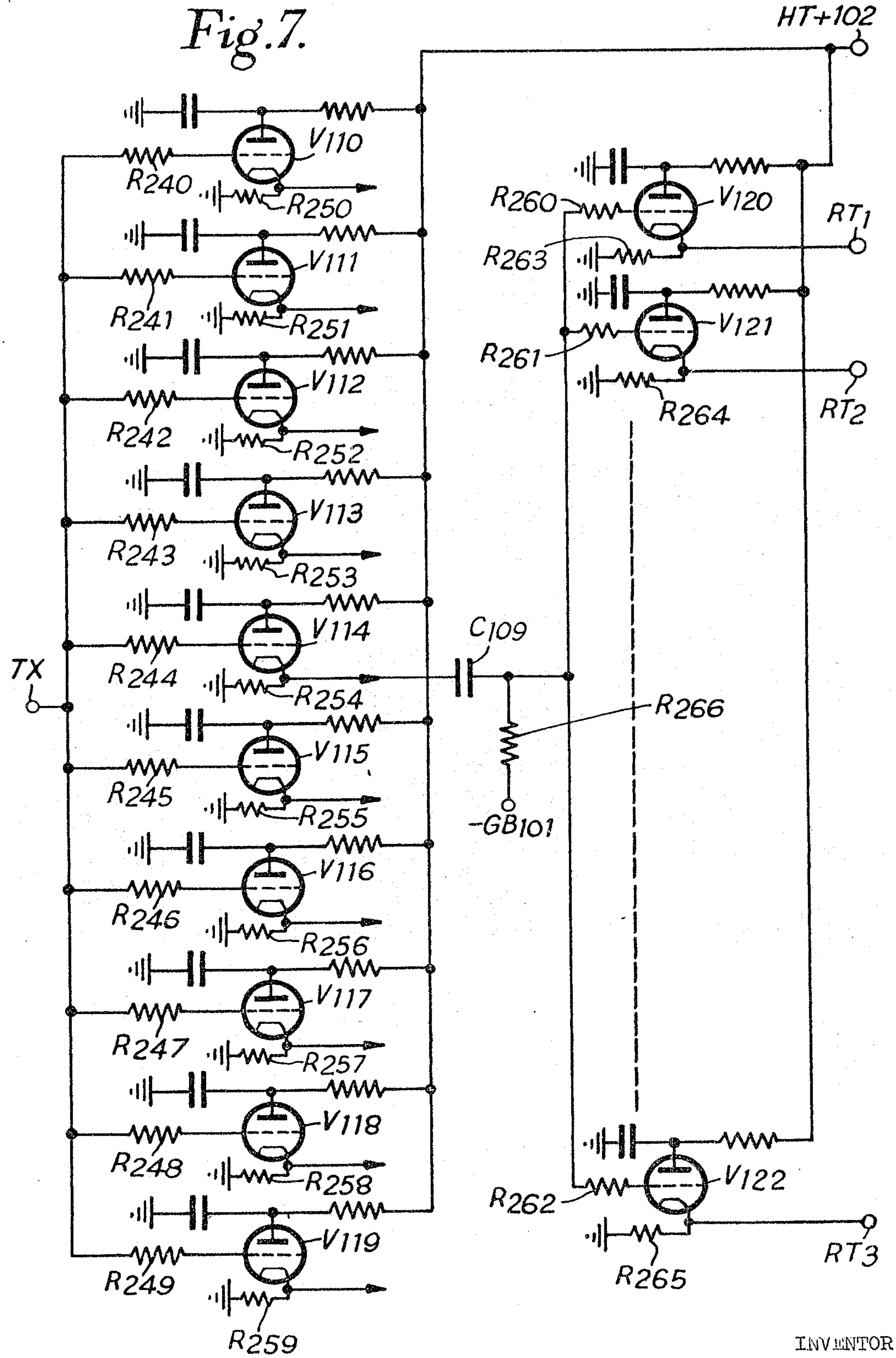

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Fig. 8.

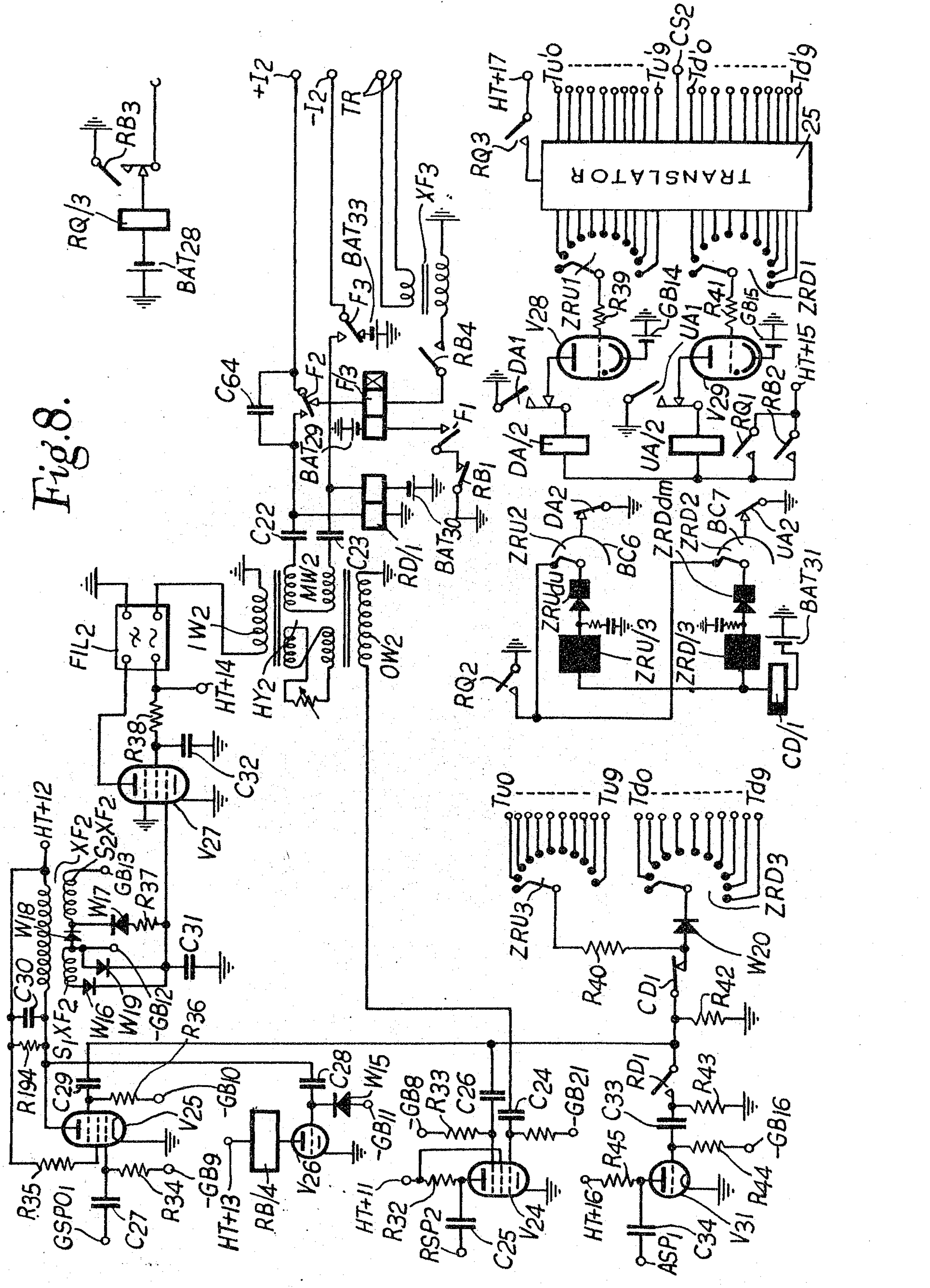

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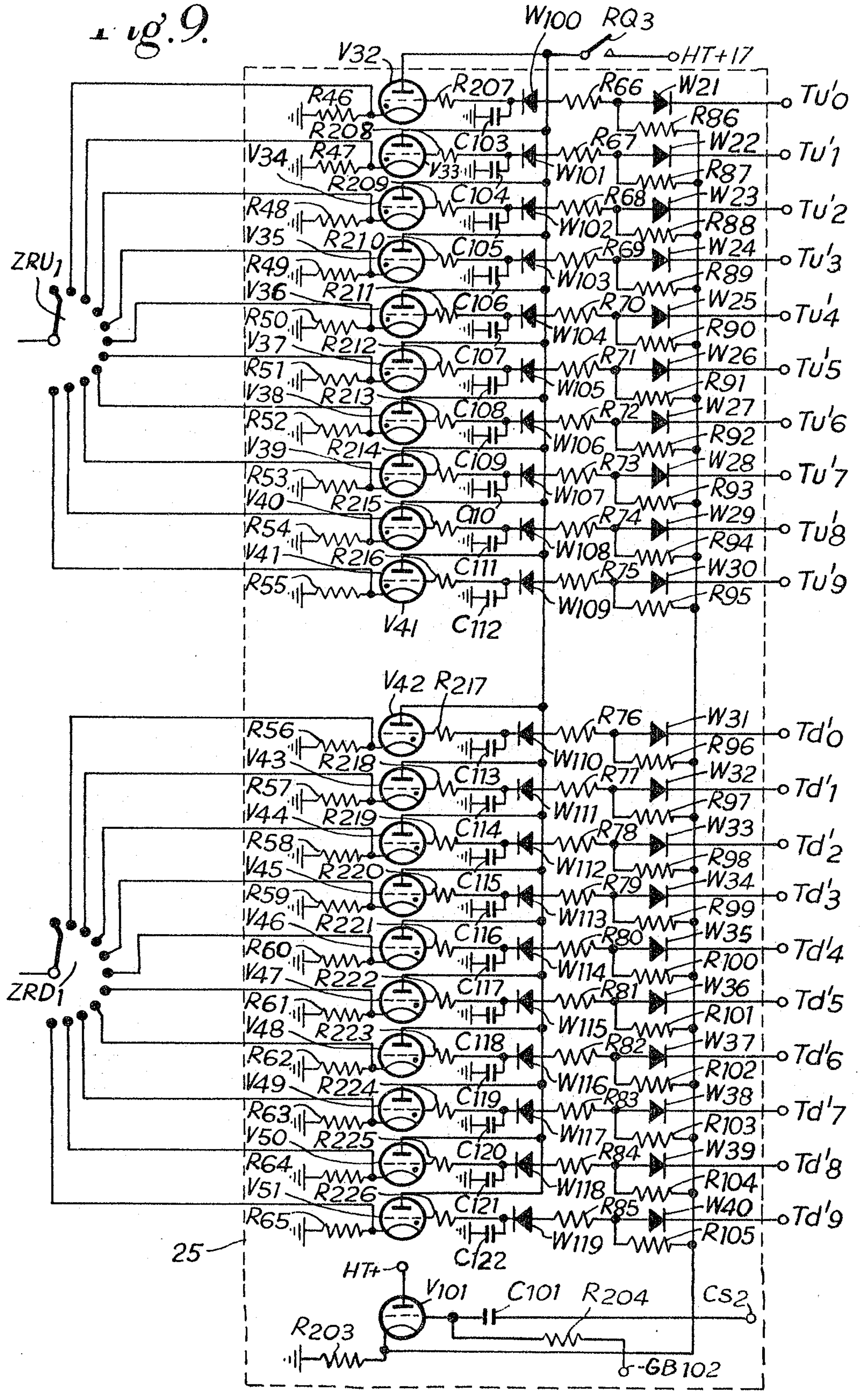
Fig. 9.



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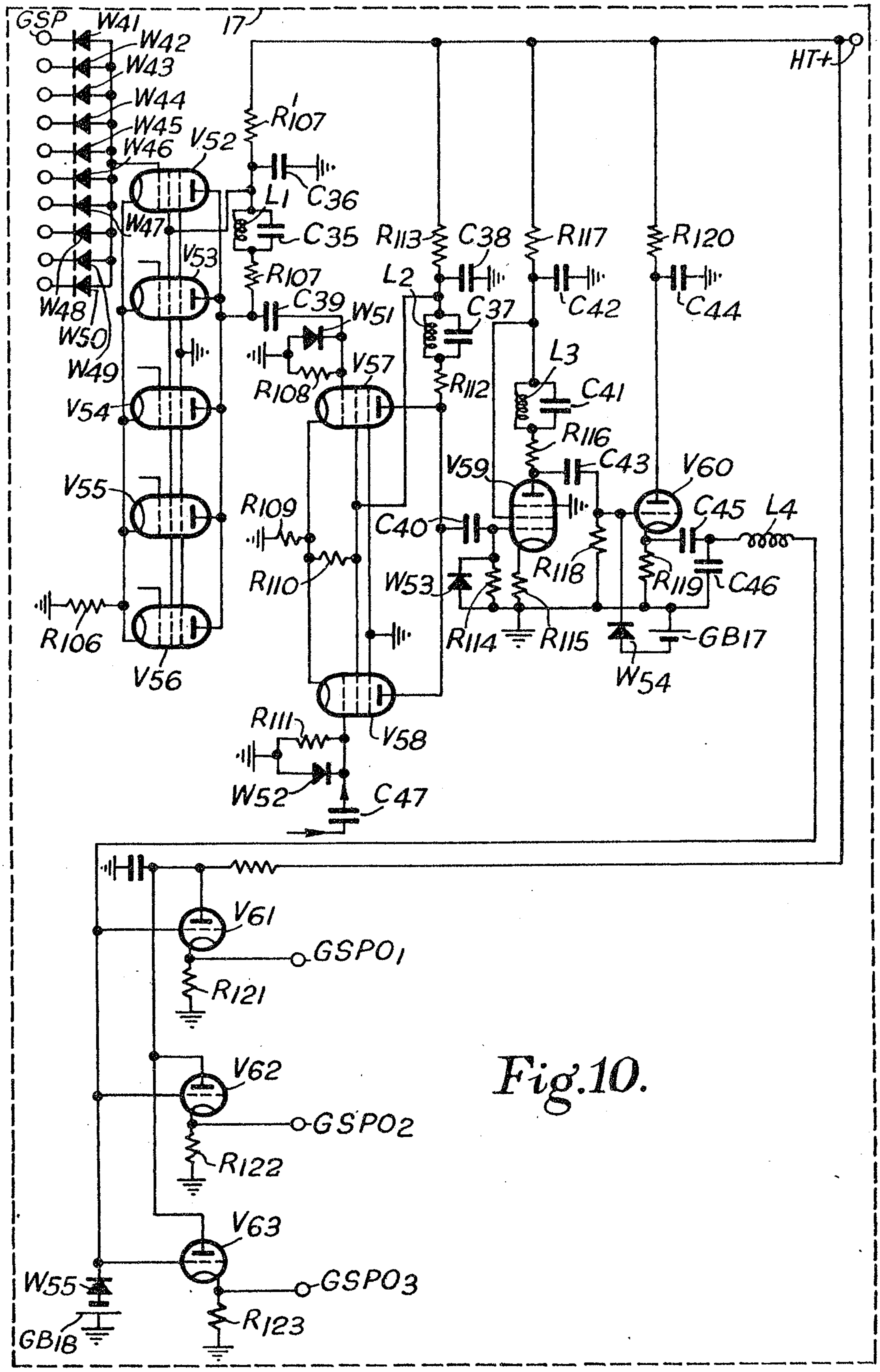

Fig.10.

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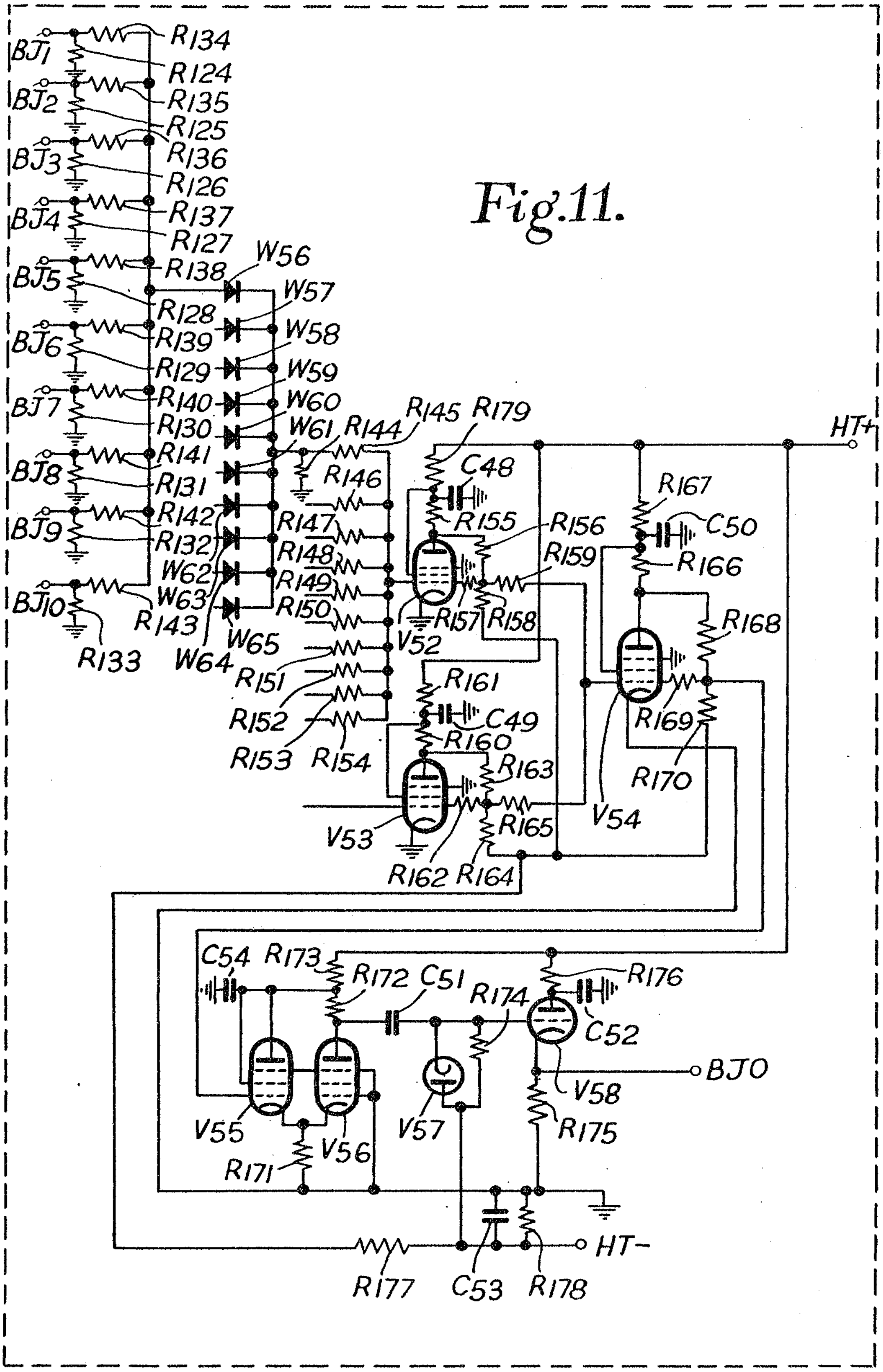
Fig.11.



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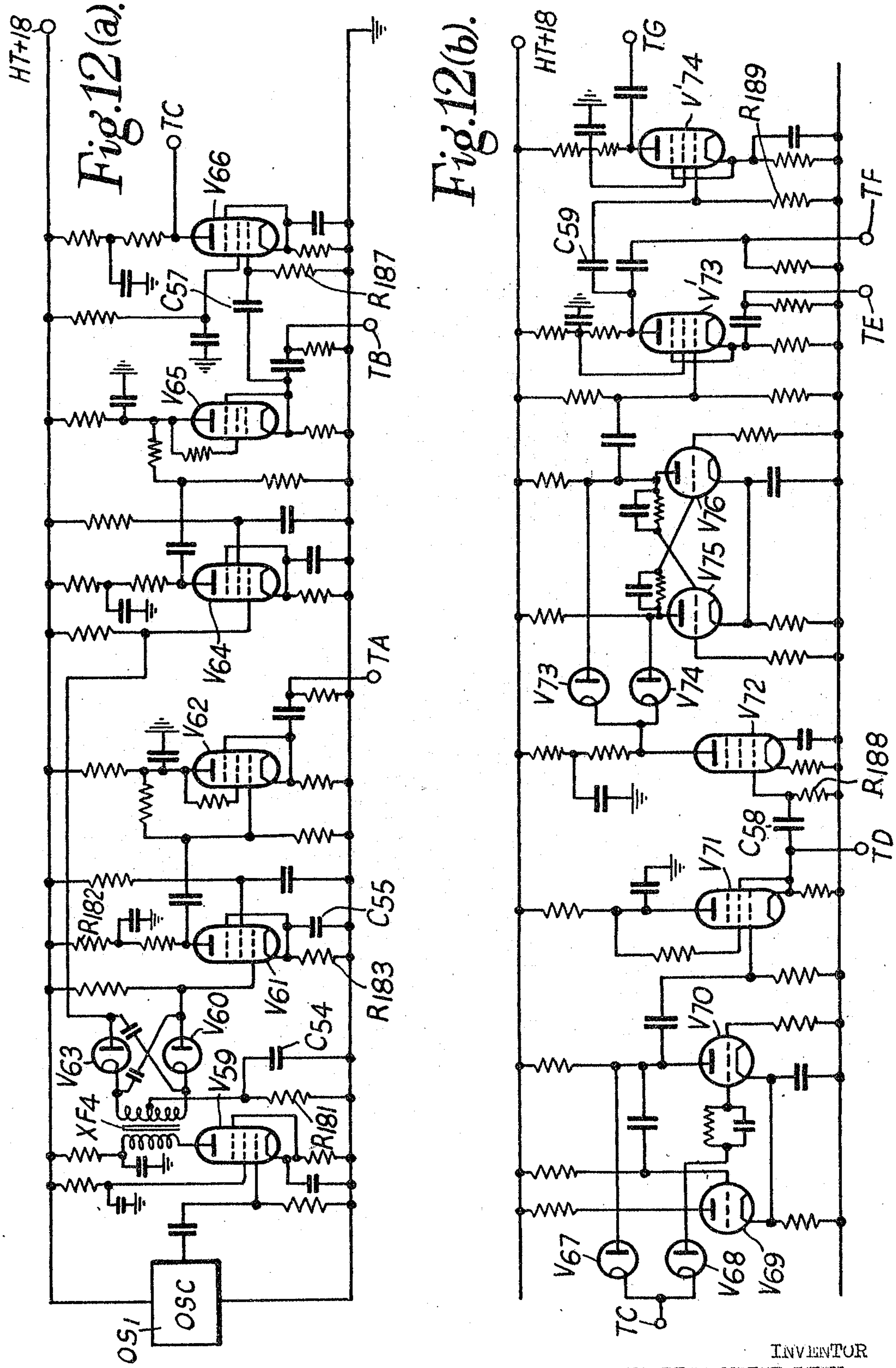

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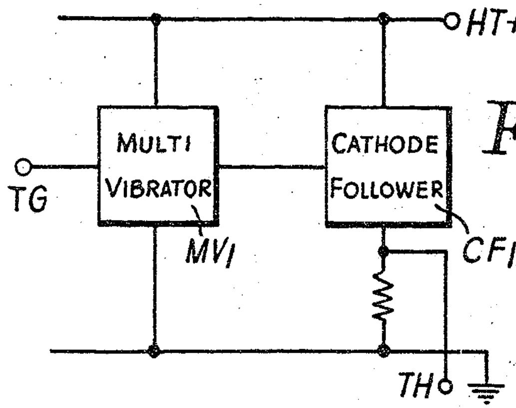


Fig.12(c).

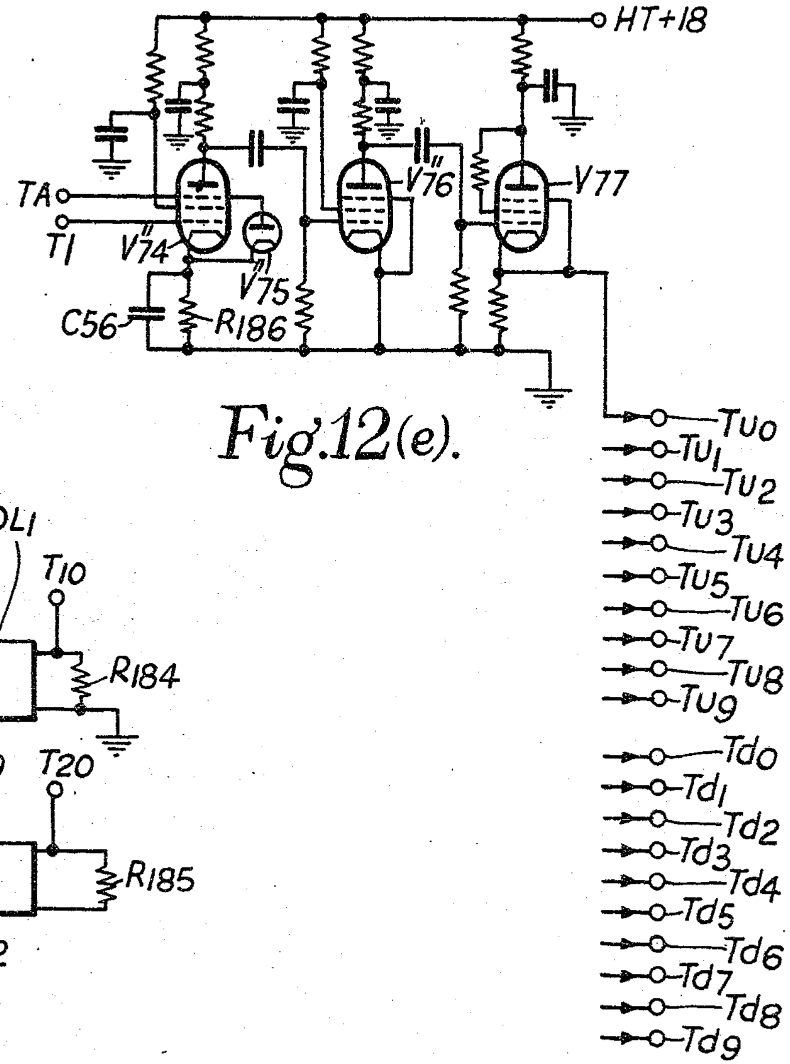
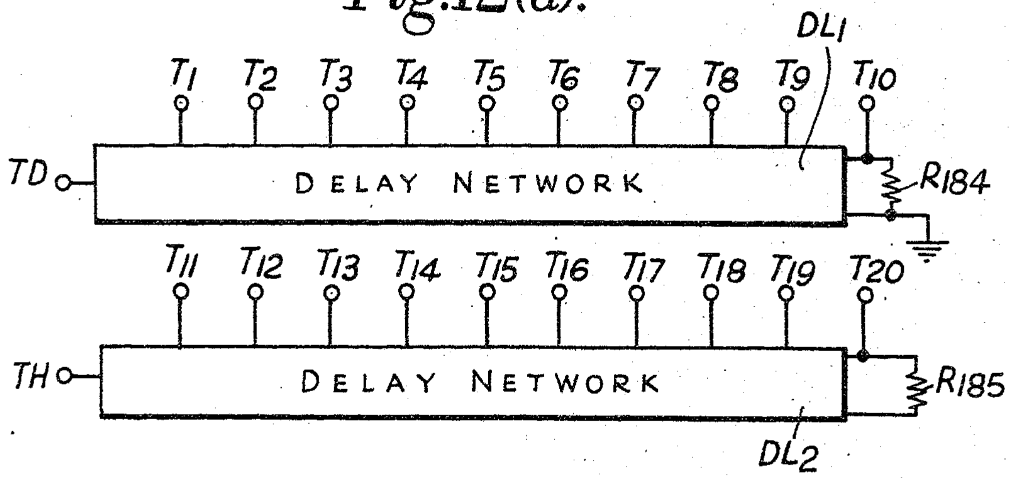


Fig.12(e).

Fig.12(d).



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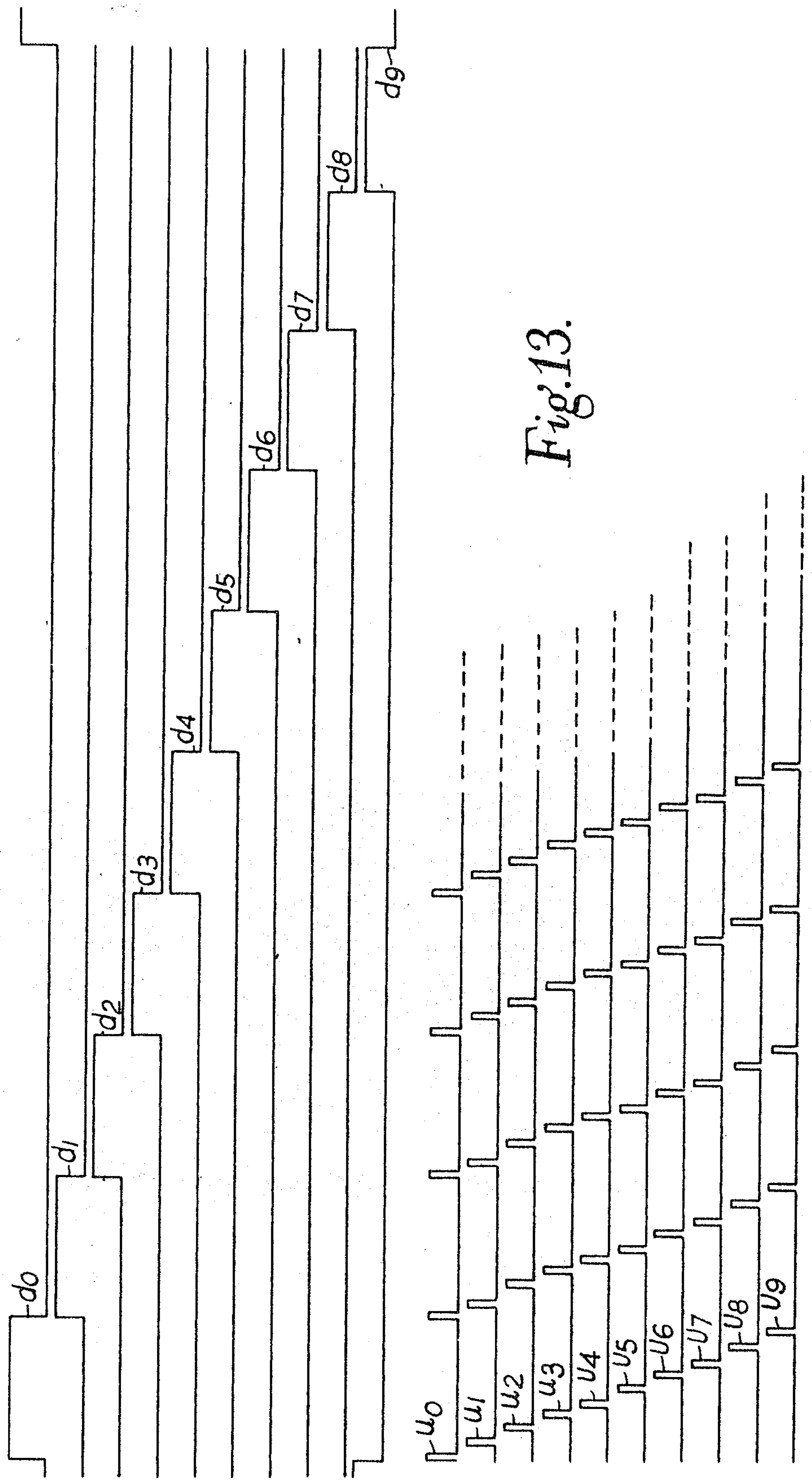

Fig. 13.

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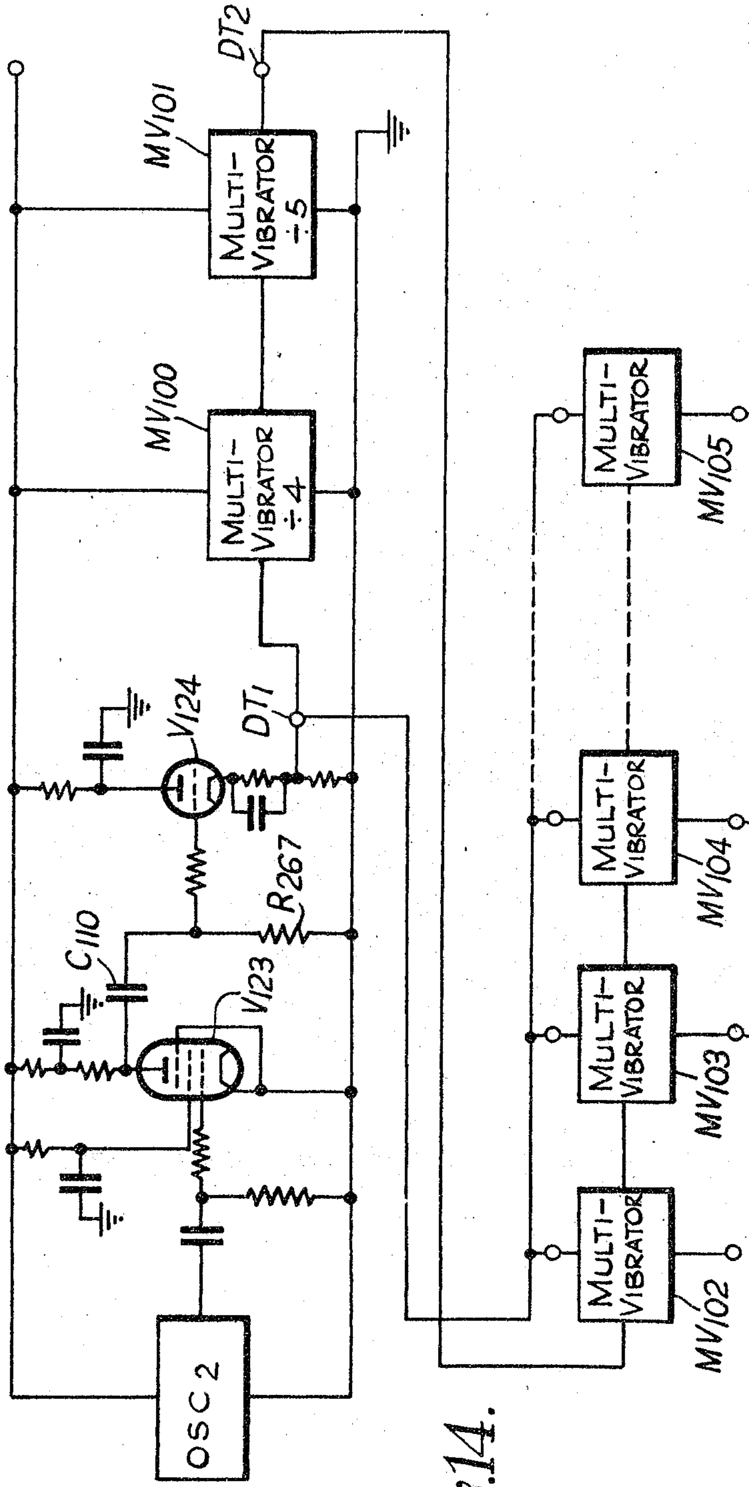

Fig.14.

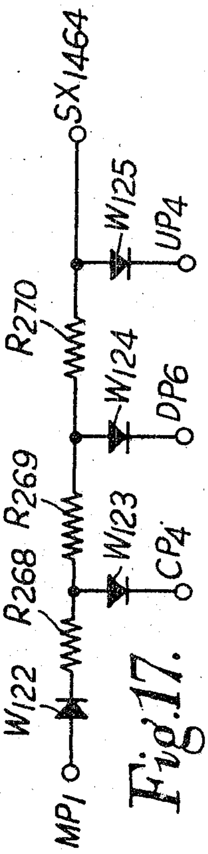

Fig.17.

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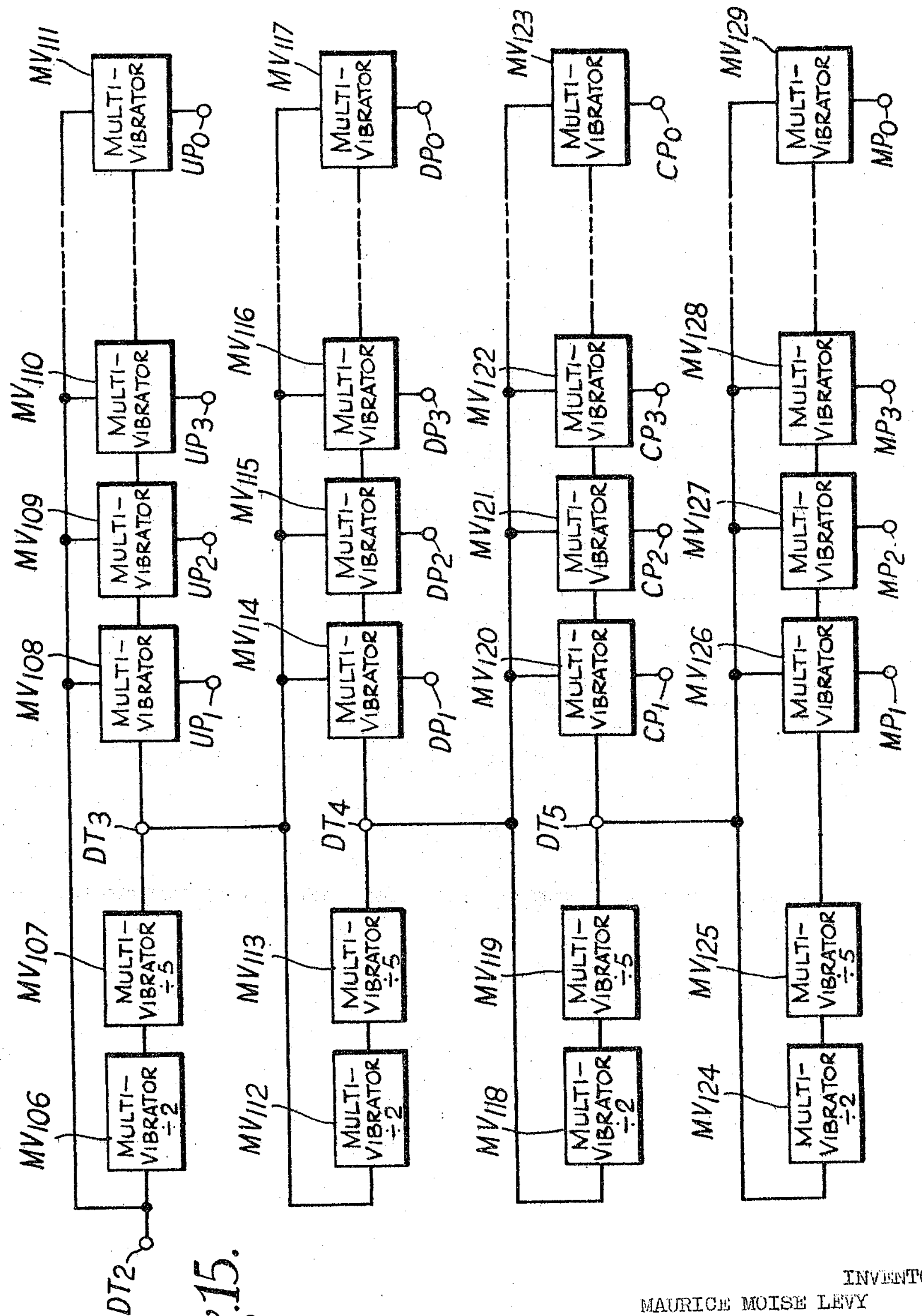

Fig.15.

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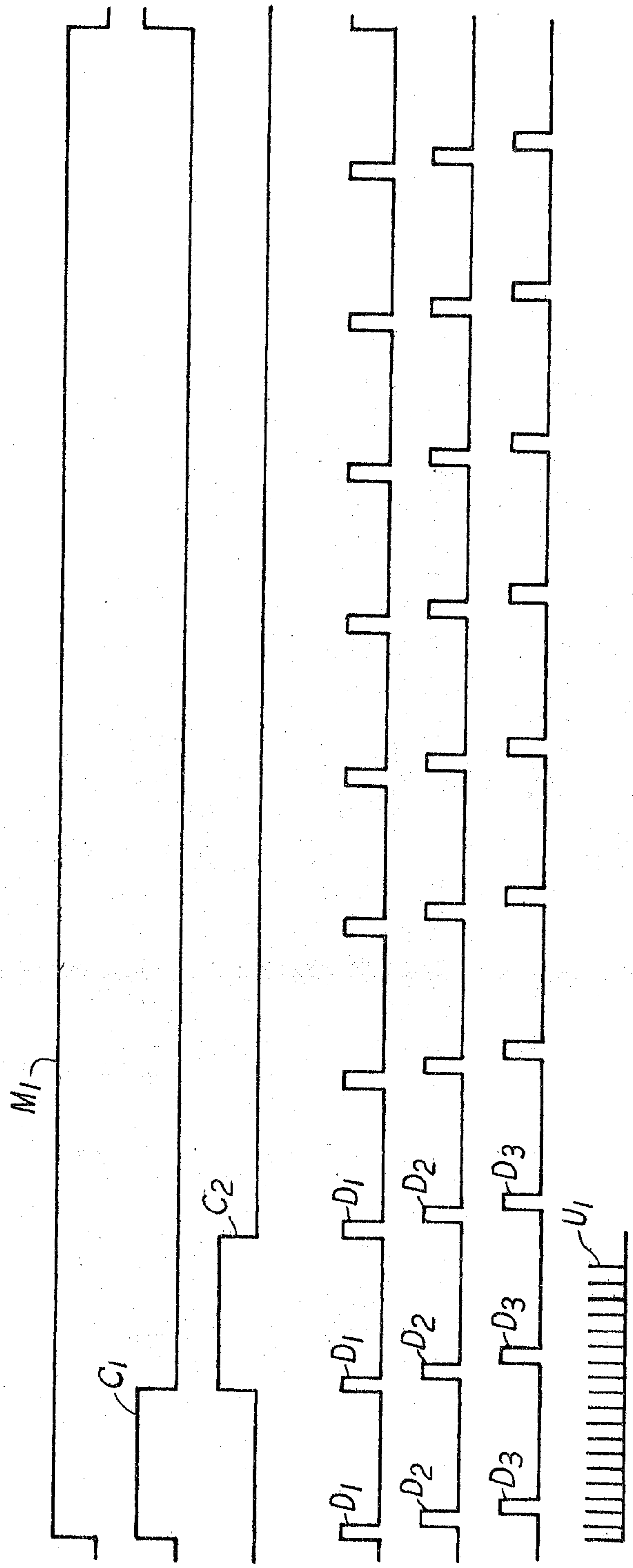
Fig.16.



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