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

(54) **SYSTEMES DE TELECOMMUNICATION INCORPORANT DES ECHANGES AUTOMATIQUES**

(57) **Abstract:**

The present invention relates to telecommunication systems embodying automatic exchanges. Such systems are commonly used in telephony but may be used in other fields such as for example, telegraphy and remote metering.

In automatic exchange practice it is usual to employ automatic switching apparatus which performs the dual function of routeing a calling signal from a calling subscriber to the called subscriber and subsequently providing the link through which conversation takes place.

A disadvantage of this arrangement arises from the fact that as the same automatic switching apparatus is used for providing the link through which conversations take place, as well as for calling the called subscribers, the major factors determining the quantity of automatic switching apparatus required at an exchange are the number of subscribers, the average number of calls in a given period (the calling rate) and the average duration of conversations. The average time taken to establish a call is a minor factor.

One object of the present invention is to provide an improved automatic exchange in which the average duration of conversation is a minor factor in determining the quantity of automatic switching apparatus required.

According to the present invention an automatic exchange comprises a plurality of communication channels, line terminating apparatus responsive to an initial calling signal from a calling station to select a free one of the said channels, routeing apparatus adapted, in response to dialling signals from the calling station to route to the line terminating apparatus of the called station an identification signal identifying the selected one of the channels, and further apparatus responsive to the channel identification signal to connect the called station to the selected channel.

Other objects and features of the invention will be apparent from the following description of the invention given, by way of example, with reference to the accompanying drawings in which,

Figure 1 is a block schematic diagram of an automatic telephone exchange according to the invention,

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

Figure 13 is an explanatory diagram,

Figure 14 is a circuit diagram of a part shown in block form in Figure 1,

Figures 15 and 16 are explanatory diagrams, and

Figures 17 and 18 are circuit diagrams showing modifications of the arrangements of Figures 3 and 5 respectively.

Referring to Figure 1, this is a block schematic diagram of an automatic telephone exchange 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 in the exchange at "sub's line circuit" 13, to be described later.

The exchange contains 100 communication channels provided by a 100 channel, time-sharing pulse communication arrangement. This arrangement comprises a pulse generator 14 adapted to generate pulses suitable for combination to provide the 100 channels at a pulse repetition frequency of 8,000 c.p.s. as will be described later. The 100 channels are terminated at one end by 100 "calling units" respectively of which one is shown at 15. 100 "called units" are provided for terminating the other ends of the 100 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 evert 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.

In addition to the pulse generator 14 a pulse generator 21 is provided for the purpose of generating pulses suitable for use in routeinga calling signal to the terminal equipment 13 of a called subscriber. For the purpose of routeing the calling signal to the terminal equipment of the called subscriber a router 22 (to be described later) is employed. The router is operated under the control of a register contained in block 23 in Figure 1.

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. An allotter 24 (to be described later) then comes into operation and allots a free register and calling unit finder 23 to the calling unit. The calling unit finder operates to connect the calling unit 15 found by the sub's line circuit 12 to the allotted register 23. A dialling tone is then automatically transmitted to the calling subscriber.

Dialling impulses from the calling subscriber's station are transmitted to the register where they are stored on four uni-selectors (not shown in Figure 1). Pulses are applied from the pulse generator 21 to the uni-selectors which serve to select pulses representative of the four digits dialled. These selected pulses are transmitted, together with pulses representative of the channel number of the free calling unit found by the sub's line circuit 12, to the router 22. The router transmits to the line circuit 13 of the called subscriber 11 a pulse representative of the last digit in the number dialled and the pulses representative of the channel number of the seized calling unit 15.

The line circuit 13, on reception of these pulses, finds a free called unit 16. When the free called unit is seized the pulses representative of the channel number of the seized calling unit are transmitted to a translator 25. The translator contains uni-selectors to be described later which are set to positions dependent upon the characteristics of the received pulses and apply the appropriate speech channel pulses to the called unit from the pulse generator 14 to enable communication to be established between the seized calling and called units, through the GC and RETURN speech junctions 17 and 18. A ringing tone is then automatically transmitted to the called subscriber's station. Signals for controlling the metering of the call and for releasing the register 23 and router 22 are transmitted through the metering and release junction 19.

The automatic exchange shown in Figure 1 will now be described in more detail with reference to Figures 2 to 15. Throughout Figures 2 to 15 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 225 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 to 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 an input terminal RT. This terminal is connected through relay contacts K6 to an output terminal BJ_1 and through resistors R_1 and R_2 in series, to the control grid of a gas-filled triode valve V_1. An input terminal UP_4 is connected through a rectifier W_2 to the junction of resistors R_1 and R_2. 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)

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of D.C. whose negative terminal is earthed. A relay winding K is connected between contacts Sdm and Il.

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.

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 + 3 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 + 5 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 + 5 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 B5 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

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- GB_2 of a bias source (not shown) and the other terminal is connected through a rectifier W_5, a resistor R_7 and the capacitor C_7 to the control grid of the pentode valve V_3. One terminal of the winding S_2XF_1 is connected to the negative terminal - GB_4 of a bias source (not shown) whose positive terminal is earthed, 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 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 $Rd^{1}u^{1}$.

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 are 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.

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 batery 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 rectifier W_9 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.

The terminal P_2 is also connected through relay contacts KF6 to earth. The terminal R is connected through relay contacts

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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 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_{20} to BAT_{23} 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_{24} to earth, and through relay contacts PQ_3 and KF4 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 M1, C1, D1 and U1 are connected through rectifiers W_{10} to W_{13}

respectively to the terminal RO.

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 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 + 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. Terminal PP is connected through relay contacts PQ_2 to earth, and terminal MM is connected through relay contacts PQ4 to earth.

A suitable router (22 Fig.1.) will now be described with reference to Figs. 6 and 7. Referring to Fig.6. this is a block schematic diagram of part of the router, the terminals RO, PP and MM corresponding to the terminals of like reference respectively in Fig.5. The terminal MM is connected through relay contacts RR2, contacts RFdm a uni-selector winding RF and a battery BAT_{26} to earth. The uni-selector RF has two banks RF1 and RF2. The bank contacts of the bank RF1 are connected to the terminals RO of the several registers respectively. The other bank contacts of RF2 are connected to the terminals PP of the several registers respectively and the wiper of RF2 is connected through a relay winding RR and a battery BAT_{27} to earth.

The wiper of bank RF1 is connected through relay contacts RR1 to the input terminals of two gates MG_0 and MG_1. A gating voltage terminal MP_0 is connected to the gate MG_0 and a gating voltage terminal MP_1 is connected to the gate MG_1. These gates will be referred to as the M gates.

The outputs of the M gates are applied to two groups respectively of further gates each group having ten gates. These gates will be referred to as the C gates of which one group is shown at CG_0 to CG_9 connected to the output of the gate MG_1. The gates CG_0 to CG_9 have gating voltage terminals CP_0 to CP_9 respectively.

The outputs of the 20 C gates are applied to 20 groups respectively of further gates which will be referred to as the D gates. One group DG_0 to DG_9 of D gates is shown connected to the output of the C gate CG_4. The D gates DG_0 to DG_9 have gating voltage terminals DP_0

to DP_9 respectively.

The outputs of the 200 D gates are connected to 200 groups of subscriber's line circuits (12 and 13 of Figure 1) each group containing 10 subscriber's line circuits. In Figure 6 one output terminal RT_{13} is shown connected to the output of the D gate DG_6, the subscript 13 in the reference RT_{13} indicating that this terminal is connected to the terminal RT in the subscriber's line circuit 13 of Figure 1. Each of the gates shown in Figure 6 has a terminal T_{32} through which, in operation voltages are applied for closing the gates. The terminals T_{32} of the gates MG_0 and MG_1 are connected through resistors RM_0 and RM_1 respectively to a terminal CLP, the terminals T_{32} of the gates CG_0 to CG_9 are connected through resistors RC_0 to RC_9 respectively to the terminal CLP, and the terminals T_{32} of the gates DG_0 to DG_9 are connected through resistors RD_0 to RD_9 respectively to the terminal CLP.

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Referring now to Figure 7 this is a theoretical circuit diagram of three of the gates shown in block form in Figure 6. The gates shown in Figure 7 are the gates MG_1, CG_4 and DG_6 of Figure 6. The input to the gate MG_1 is applied through a resistor R_{20} to the control grid of a triode valve V_9 whose anode is connected to the positive terminal HT + 9 of a D.C. source (not shown) whose negative terminal is earthed. The cathode of the triode V_9 is connected to earth through a cathode load resistor R_{21}. The terminal MP_1 is connected to the cathode of a diode valve V_{10} whose anode is connected to the input terminal of the gate through a resistor R_{22}, and directly to the control grid of a triode valve V_{11}. The anode of the triode V_{11} is connected to the positive terminal HT + 10 of a source (not shown) of D.C. whose negative terminal is earthed. The cathode of the triode V_{11} is connected to earth through a capacitor C_{16}. The terminal T_{32} of the gate MG_1 is connected through a capacitor C_{17} to the control grid of a triode valve V_{12} whose cathode is earthed. The control grid of the triode V_{12} is also connected through a grid leak R_{23} to the negative terminal $-GB_6$ of a bias source (not shown) whose positive terminal is earthed. The anode of the triode V_{12} is connected to the cathode of the triode V_{11} and to the cathode of a diode valve V_{13} whose anode is connected to the control grid of the triode V_9. The output of the

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gate MG_1 is taken from the cathode of the cathode follower valve V_9.

The gate CG_4 is identical with the gate MG_1 and contains three triode valves V_{14}, V_{15}, V_{16}, two diode valves V_{17} and V_{18}, four resistors R_{24} to R_{27}, two capacitors C_{18} and C_{19}, and a terminal $-GB_7$ which is connected to the negative terminal of a bias source (not shown) whose positive terminal is connected to earth.

The gate DG_6 is also identical with the gate MG_1 and contains three triode valves V_{19}, V_{20} and V_{21}, two diode valves V_{22} and V_{23}, four resistors R_{28} to R_{31}, two capacitors C_{20} and C_{21}, and a terminal $-GB_8$ which is connected to the negative terminal of a bias source (not shown) whose positive terminal is earthed.

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_{28} 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_{22} and C_{23} 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_{24} to the control grid of a pentode valve V_{24} whose cathode is earthed. The anode of the valve V_{24} 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_{25} 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_{24} from a bias terminal $-GB_{21}$. The suppressor grid is connected through a capacitor C_{26} 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_{27} 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 $-GB_9$ 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. whose 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} and a capacitor C_{30} 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 earth and the other terminal thereof is connected through a rectifier W_{17}, a resistor R_{37} and the capacitor C_{30} to the control grid of the pentode V_{27}. The left-hand plate (in the drawing) of the capacitor C_{30} is connected through a rectifier W_{18} and a capacitor C_{31} in parallel to the negative terminal of a bias source (not shown) whose positive terminal is earthed. The centre grid of the pentode V_{27} is connected through a rectifier W_{19} to the terminal $-GB_{13}$.

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

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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_0 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_{30} whose cathode is connected to earth through a bias source GB_{15}. The anode of the valve V_{30} is connected through relay contacts UA1 to one terminal of a relay winding UA one 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 contacts 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_o 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 contact 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'_0 to Tu'_9 and ten terminals Td'_0 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 Fig. 2).

Referring now to Fig. 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'_0 to Tu'_9 are connected through ten rectifiers W_{21} to W_{30} and ten resistors R_{66} to R_{75} respectively to the control grids of the triodes V_{32} to V_{41}. The terminal CS_2 is connected through ten resistors R_{86} to R_{95} to the junctions of the rectifiers and resistors connecting the terminals Tu'_0 to Tu'_9 respectively to the control grids of the triodes V_{32} to V_{41}.

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 ZRD_1. 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'_0 to Td'_9 are connected through ten rectifiers W_{31} to W_{40} and ten resistors R_{76} to R_{85} to the control grids of the valves V_{42} to V_{51} respectively. The terminal CS_2 is connected through ten resistors R_{96} to R_{105} to the junctions respectively of the rectifiers and resistors connecting the terminals Td'_0 to Td'_9 to the control grids of the valves V_{42} to V_{51} respectively.

Referring now to Fig. 10 this is a circuit diagram of an arrangement suitable for use as the GO speech junctions 17 of Fig. 1. The output terminals GSP_1 to GSP_{100} of the 100 calling units respectively (see GSP_1 of Fig. 3) are connected to input terminals GSP_1 to GSP_{100} of the arrangement of Fig. 10. In Fig. 10 only GSP_1 to GSP_{10} 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 inmut pentodes (not shown) are likcwise 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 L_1 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 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 V_{57} 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

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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 now 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 cirmit.

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 oscillator 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 V_{60} 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 wave form 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 multi-

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vibrator 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 suppre or grid is arranged to be sufficient to render th 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_0.

The other 19 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_0, 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 Fig. 12(d) are connected to the control grids thereof respectively.

Thus the pulses appearing at the terminals Td_o to Td_9 are as shown at d_o to d_9 in Fig. 13, and the pulses appearing at the terminals Tu_o to Tu_9 are as shown at u_o to u_9 in Fig. 13.

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

The pulse width of the *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 now to Fig. 14 this is a schematic diagram of the low frequency pulse generator 21 of Fig. 1. In Fig. 14(a) a low frequency oscillator OS_2 is connected to a limiter LIM_1 which serves to produce square waves. These are differentiated by a capacitor C_{60} and resistor R_{190} and the differentiated voltage is passed to a cathode follower CF_2. This is biased so as to remove the negative-going portions of the differentiated voltage and to pass the positive-going portions to a terminal PA and to a multivibrator MV_2. The multivibrator MV_2 functions as a frequency divider of a division ratio of 2:1 and its output is differentiated by a capacitor C_{61} and a resistor R_{191}. This differentiated voltage is applied through a cathode follower CF_3 to a multivibrator MV_3 which functions as a frequency divider of a division ratio of 5:1. The output of the multivibrator MV_3 is differentiated by a capacitor C_{62} and resistor R_{192} and passed through a cathode follower CF_4 to a multivibrator MV_4 which functions as a frequency divider of a division ratio of 7:1. The output of MV_4 is applied through a terminal PB to a differentiating circuit comprising a capacitor C_{63} and a resistor R_{193} in Fig. 14(b). The differentiated voltage appearing across the resistor R_{193} is applied through a phase inverter PI to an output terminal PC. The terminals PA of Fig. 14(a) are connected together for the purpose of applying re-setting pulses to the multivibrator MV_4.

The pulses appearing at the terminal PB at a recurrence frequency $^1/_{70}$th of that of the pulses appearing at the terminal PA of Fig. 14(a) are applied to an arrangement of 70 bi-stable

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multivibrators (flip-flop circuits) of which two are shown in Fig. 14(c). The terminal PC in Fig. 14(c) is connected to a multivibrator MV_5 and each pulse appearing at the terminal PC operates the multivibrator MV_5. Re-setting pulses are applied to the multivibrator MV_5 from the terminal PA and hence the multivibrator MV_5 remains in its operated condition for only 1/70th of the repetition period of the pulses applied at PC. The resulting pulse from the multivibrator MV_5 is passed through a phase splitter PS_1 to an output terminal MP_1 and to a second bi-stable multivibrator (flip-flop circuit) MV_6. Re-setting pulses for this multivibrator are also applied thereto from the terminal PA. The pulses from the multivibrator MV_6 are fed through a phase splitter PS_2 to an output terminal MP_2 and to the next multivibrator (not shown). The remaining multivibrators are arranged in the same way as those shown in Fig. 14(c) whereby a group of 70 pulses are produced in succession for each pulse applied to the terminal PC.

One such group of 70 pulses is represented in Fig. 15(a). The first ten pulses appear at terminals MP_1 to MP_9 and MP_o respectively (Fig. 15(b)) of which MP_1 and MP_2 are shown in Fig. 14(c). The next ten pulses appear at terminals CP_1 to CP_9 and CP_o respectively, the next ten at terminals DP_1 to DP_9 and DP_o

respectively, the next ten at terminals UP_1 to UP_9 and UP_0 respectively, the next ten at terminals d'_1 to d'_9 and d'_0 respectively and the next ten at terminals u'_1 to u'_9 and u'_0 respectively. The 66th pulse appears at a terminal CLP and the remainder are not used.

As explained in connection with the router (Fig. 6), the sub's line circuits are grouped in groups of ten. The terminals UP_1 to UP_9 and UP_0 of Fig. 15(b) are connected to the UP terminals of the ten sub's line circuits respectively of each group (see UP_4 of Fig. 2).

The terminals MP_1 to MP_9 and MP_0, CP_1 to CP_9 and CP_0, DP_1 to DP_9 and DP_0, UP_1 to UP_9 and UP_0 of Fig. 15(b) are connected to the terminals of like reference in Fig. 5. The terminals MP_1 to MP_9 and MP_0, CP_1 to CP_9 and CP_0 and DP_1 to DP_9 and DP_0 are connected to the terminals of like reference in Fig. 6. The terminal CLP of Fig. 15 (b) is connected to the terminal CLP of Fig. 6. One of the terminals Td'_1 to Td'_9 and Td'_0 and one of the terminals Tu'_1 to Tu'_9 and Tu'_0 are connected to each calling unit (see Td'_0 and Tu'_1 of Fig. 3), different combinations of Td' and Tu' terminals being connected to different calling units. For example, Td'o and Tu'_1 are connected to the calling unit terminating channel No. 1 in the 100 channel communication arrangement (see Fig.3.). Td'_3 and Tu'_6 are connected to the calling unit terminating channel No. 36 and so on, the subscript in the Td' reference representing the number of tens in the channel number and the subscript in the Tu' reference representing the number of units in the channel number.

The terminals Td'_1 to Td'_9 and Td'_0, and the terminals Tu'_1 to Tu'_9 and Tu'_0 of Fig. 15(b) are also connected to the terminals of like reference respectively in the translator (Fig. 9).

It is arranged that each of the low frequency pulses is of about 150 milliseconds duration, and that the recurrence frequency, that is to say the recurrence frequency of the pulses appearing at each output terminal is about 50 p.p.s.

Operation

It will be assumed that the subscriber at the station 10 of Fig. 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 Fig. 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 Fig. 3 (calling unit) it is arranged that when a calling unit is in use the terminal PO thereof (PO_1 in Fig. 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 Fig. 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 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 Fig. 2 will be described later.

Referring now to Fig. 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 contacts D1, through 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 B1 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_0 and u_1 (Fig.13) are therefore applied to the calling unit at Td_0 and Tu_1 from the terminals of like reference in Fig. 12(c). The rectifier W_{66} provides a low impedance path for all of each d_0 pulse applied to the terminal Td_0 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 arranged to be positive-going. The negative bias applied to the suppressor grids 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 capacitor 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 KF5 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 complete 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 CUF, the 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 KF6 remove the earth from the terminal R and earth the terminals P_2 and P_1. The contacts KF3 remove the earth from the homing arc of the uniselector bank ZZ2, and the contacts KF4 prepare an 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 rignt-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 CUF4, 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 $\underline{d'_o}$ and u'_1 are applied to the terminals Td'_o and $\overline{Tu'_1}$ respectively and hence appear at 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 of Fig. 14 are applied to the terminals MP_1 to MP_9 and MP_o respectively of Fig. 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 selector banks M1, C1, D1 and U1 respectively. These pulses are applied through the rectifiers W_{10} to W_{13} respectively to the output terminal RO and the pulses $\underline{d'_o}$ and $\underline{u'_i}$ are applied from the terminal Rd'u' through the selector bank CUF2 and the rectifier W_9 to the terminal RO. Thus the pulses appearing at the terminal RO are in recurring groups each group containing the pulses M_i, C_4, D_6, U_4, $\underline{d'_o}$ and $\underline{u'_i}$, in that order.

After the last digit is dialled the wiper of the bank ZZ1 steps on to the fifth bank contact and hence completes the energising circuit of the relay winding PQ. The contacts PQ1 open and isolate the contacts AA1 from the uniselectors

M, C, D and U. The contacts PQ2 and PQ4 close and apply earths to the terminals PP and MM, and the contacts PQ3 close and hold the winding PQ energised.

Referring now to the diagram of the router shown in Fig. 6. If the router is free, the relay winding RR is de-energised and hence the contacts RR1 are open and the contacts RR2 closed.

The automatic stepping circuit of the uniselector RF is therefore completed from the earthed terminal MM, through the contacts RR2, the mechanically operated contacts RFdm, the operating winding RF and the battery BAT_{26} to earth. The uniselector hunts until the wiper of the bank RF2 reaches the bank contact connected to the earthed terminal PP. The circuit of the relay winding RR is then completed from the earthed terminal PP, through the bank RF2, through the winding RR and through the battery BAT_{27} to earth. The contacts RR1 close connecting the terminal RO to the input of the router, and the contacts RR2 open thus breaking the stepping circuit of the uniselector RF and arresting the motion of the wipers.

The first M_1 pulse to arrive at the terminal RO after the relay contacts RR1 close, causes the gate MG_1 to be opened. This is effected as follows:-

Referring to Fig. 7 the pulses M_1 are applied from the pulse generator of Fig. 14 to the terminal MP_1. The diode V_{10} is arranged to be conducting in the absence of the M_1 pulses and to be insulating during each M_1 pulse. If, therefore pulses other than M_1 pulses appear at the input terminal of the gate MG_1, the diode V_{10} is conducting thereto and hence no appreciable change of current takes place in the triode V_{11}. The charge in the capacitor C_{16} is normally very low and the reactance of this capacitor is made low and hence the control grid of the triode V_9 is substantially short-circuited to earth through the valve V_{13} and the capacitor C_{16}. Any pulses other than M_1 pulses do not, therefore, appreciably affect the anode current of the valve V_9.

When an M_1 pulse appears at the input of the gate, however, the diode V_{10} is non-conducting thereto, the control grid of the valve V_{11} is made positive by the M_1 pulse and hence the capacitor C_{16} receives a charge, the upper plate in the drawing becoming positive. The cathode of the diode V_{13} likewise becomes positive and this valve becomes non-conducting and hence the short-circuit from the control grid of the valve V_9 is removed. The valve V_{12} is made non-conducting by the bias applied to its control grid and hence the charge in the capacitor C_{16} is held and the diode V_{13} remains non-conducting.

The next succeeding C_4 pulse appears, therefore, across the cathode load resistor R_{21}

and hence at the inputs of the C gates connected to the output of the gate MG_1. The gate CG_4 functions in like manner with respect to the C_4 pulses as the M_1 gate functions with respect to the M_1 pulses. Thus the next succeeding D_6 pulse appears at the inputs of the D gates connected to the output of the gate CG_4.

The D gates function in like manner to the M and C gates and hence the gate DG_6 is opened by the next succeeding D_6 pulse.

The remaining pulses of the Group (pulses U_4, d'_o and u'_i in this example) pass therefore to the terminal RT_{13}.

Referring now to Fig. 2, and assuming this to be the line circuit of the called subscriber, the U_4 pulse is applied through the terminal RT and the resistor R_1 to the anode of the rectifier W_2. As the U_4 pulses generated by the low frequency generator (Fig. 14) are also applied at UP_4 the rectifier W_2 is made non-conducting for the duration of the U_4 pulse applied thereto from the terminal RT. This U4 pulse passes therefore through the resistor R_2 to the control grid of the gas-filled triode V1 and strikes this valve. 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 Fig. 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 Fig. 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 BC_2 of the bank S5.

The relay contacts K6 connect the terminal RT to the terminal BJ_1 for a purpose to be described later, and the contacts K7 connect the terminal RT through the uniselector bank S6 to the terminal CS_1.

Referring back to the circuit of the router (Fig. 6) after each group of M, C, D, U, d' and u' pulses has passed therethrough all gates are closed by the application of a pulse to the terminal CLP from the low frequency pulse generator (Fig 14). The M, C and D pulses of the next succeeding group reopen the appropriate gates to allow the U, d' and u' pulses to pass through again. This continues until the relay K of Fig. 2 closes when the next succeeding d' and u' pulses (d'_o and u'_1 in this example) to arrive at the terminal RT are passed 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 Fig. 8 becomes energised, the energising circuit being from earth through the winding RQ, the contacts RB3, the uniselector bank S3 of Fig. 2, the contacts K3 and L1 to earth. Thus the contacts RQ1, RQ2, and RQ3 of Fig. 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 CD1. The relay contacts RQ3 apply H.T. to the translator 25.

Referring to Fig. 9 the d' and u' pulses arriving at the terminal CS_2 from the called subscribers line circuit are applied to the control grids of the valves V_{32} to V_{51} through the resistors R_{86} to R_{105} respectively. The rectifiers W_{21}

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to W40 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'_o and u'i appear at the terminal CS_2 simultaneously with the pulses d'_o and u'_1 applied at the terminals Td'_o and Tu'_i. Thus the rectifiers W_{31} and W_{22} are non-conducting in this example and permit the d'_o and u'_i 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} (Fig. 8) and this valve strikes. Similarly the valve V_{29} (Fig. 8) strikes when the wiper of the bank ZRD1 reaches the bank contact connected to the cathode of the valve V_{42}.

Referring to Fig. 8, when the valves U_{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_o and Tu_i 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 $\underline{u_i}$ 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 $\underline{u_i}$ 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 opening 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 cuffent 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 battery 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 D3.

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. The earths are removed from the contacts PP and MM and the router is released.

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 winding S_2XF_2 has more turns than the winding S_1XF_2 and hence provides a greater output voltage than S_1XF_2. 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 W_{16} 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

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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 V_{27} 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 FIL2 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 $RSPO_1$ of 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

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will now be described. When the called subscriber is engaged, the relay K in his line circuit (Fig. 2) is already energised and the terminal RT is connected through the relay contacts K6 to the terminal BJ_1. Thus the d' and u' pulses arriving at the terminal RT 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 made 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 contacts 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.

A second embodiment of the invention will now be described, in which the apparatus used differs only in some details from that already described.

The low frequency pulses required for use in the second embodiment are the M, C, D and U pulses as used in the first embodiment, and the gate

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closing pulses. In place of the d' and u' pulses, pulses of different durations and frequencies from the d' and u' are used. These pulses will be referred to as d" and u" pulses.

Referring to Fig. 16 this shows five groups of M, C, D and U pulses with four closing pulses CLP between these groups. The u' pulses are replaced by u" pulses of which $u"_1$ to $u"_5$ are shown. Each of the u" pulses occupies an interval of time equal to that occupied by one group of M, C, D and U pulses. The d" pulses occupy an interval of time equal to ten u" pulses and a part of one d" pulse $d"_1$ is shown in Fig. 16.

The high frequency pulse generator is the same as that used in the first embodiment.

The circuit of the calling unit remains as shown in Fig. 3 with the exception of the modification shown in Fig. 17. The interconnection of the terminals Td'_0, Tu'_1 and Rd'u' becomes as shown in Fig. 17. The rectifier W_{67} and resistor R_{196} function in like manner to the rectifier W_{66} and resistor R_{179} associated with the terminals Tu_1 and Td_0 of Fig. 3. Thus the only $Tu"_1$ pulses to reach the terminal Td"u" are those occurring during $Td"_0$ pulses.

The circuit of Fig. 5 is modified as shown in Fig. 18. The pulses appearing at the terminal Rd"u" are applied to render the rectifier W_9 non-conducting. In the absence of a pulse to render the rectifier W_9 non-conducting the outputs from the wipers of the uniselector banks M1, C1, D1 and U1 are dropped across a resistor R_{197}. Thus the only M, C, D and U pulses to reach the terminal RO are those which occur during the gating pulses applied to the terminal Rd"u". These gating pulses are characteristic of the seized calling unit.

The router (Fig. 6) is modified by the removal of the relay RR and the uniselector RF. These are dispensed with in view of the fact that the registers are gated as just described and hence are connected to the router in turn automatically. The only pulses which appear at the output of the router are the U pulses, each U pulse occurring during an interval of time characteristic of the seized calling unit from which it is transmitted.

The called units are as shown in Fig. 8 but the pulses applied to the terminals Tu'_o to Td'_9 of the translator are the pulses $\underline{u''_o}$ to $\underline{d''_9}$ instead of $\underline{u'_o}$ to $\underline{d'_9}$. In addition a circuit is provided to enable only one pulse to pass from the router to the terminal CS_2, whilst a call is being set up. A suitable circuit for this purpose is described in co-pending Canadian Patent Application Serial No. 606,362, filed October 4, 1950, in the name of M.M. Levy and entitled Multi-Channel Communication Systems.

Although arrangements have been described in which the communication channels are provided by interlaced pulse trains it will be understood that any form of communication channels may be used.

Numerous modifications and further embodiments of the invention will be apparent to those skilled in the art.

Features of the arrangement shown in Figure 2 forms the subject of Canadian Patent Application Serial No. 623,170, filed November 19, 1951, in the name of A.A. Chubb and entitled Automatic Telephone Systems. Features of the arrangement shown in Figure 5 forms the subject of Canadian Patent Application Serial No. 620,033, filed September 4, 1951, in the names of A.A. Chubb, R. Mawson and M.M. Levy and entitled Automatic Telephone Exchanges. Features of the arrangements shown in Figures 6 and 7 form the subject of Canadian Patent Application Serial No. 620,038, filed September 4, 1951, in the name of M.M. Levy and entitled Switching Devices. Features of the arrangements shown in Figures 8 and 9 form the subject of Canadian Patent Application Serial No. 626,311, filed February 1, 1952, in the names of A.A. Chubb and M.M. Levy and entitled Automatic Telephone Systems.

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

1. An automatic exchange having a plurality of stations connected thereto each said station being terminated by line terminating equipment in said exchange and having means to transmit an initial calling signal to the exchange to render the exchange responsive to subsequent dialling signals from the station for making a connection with a second station, said exchange including a plurality of communication channels, and said line terminating equipment comprising selector apparatus to select a free one of said channels, said exchange also including means to provide signals identifying the said channels respectively, further selector apparatus by-passing said communication channels, means to apply said dialling signals to said further selector apparatus to select the line terminating equipment of the wanted station indicated by the dialling signals, means to apply the one of said identifying signals characteristic of the selected one of said free channels to said further selector apparatus for transmission to the line terminating equipment of the wanted station, final selector apparatus, and means to apply the last said identifying signal to the final selector apparatus to connect the last said line terminating equipment to the said one of the free

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communication channels.

2. An automatic exchange according to claim 1, wherein the further selector apparatus comprises register means to store said dialling signals, other selector apparatus to select said wanted station and connections to apply said stored signals to operate said further selector apparatus.

3. An automatic exchange according to Claim 1 or Claim 2, wherein the said communication channels are provided by interlaced pulse trains.

4. An automatic exchange according to Claim 1 or Claim 2 wherein the said communication channels are provided by interlaced pulse trains, and said channel identifying signals are provided by further interlaced pulse trains.

5. An automatic exchange having a plurality of stations connected thereto each said station being terminated by line terminating equipment in said exchange and having means to transmit an initial calling signal to the exchange to render the exchange responsive to subsequent dialling signals from said station for making a connection with a second station, said dialling signals constituting pulses which are representative of the number of the second station, said exchange comprising a plurality of communication channels, said line terminating equipment of each of said stations comprising a selector apparatus and

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connections to apply said initial calling signal to said selector apparatus to connect the station originating the initial calling signal to a free one of said channels, register means to store said subsequent dialling signals, connections to apply said dialling signals to said register means, means to generate channel identification signals characteristic of the several channels respectively, means to apply the channel identification signal characteristic of the selected free channel to said register means, apparatus in said register means to combine said stored dialling signals with said channel identification signal to produce a composite signal characteristic of the wanted station and the selected free channel, further selector apparatus, connections to apply said composite signal to said further selector apparatus to select the line terminating equipment of said wanted station and transmit a free channel identifying signal thereto, final selector apparatus, means connecting said final selector apparatus to said channels and means for applying the last said free channel identifying signal thereto to connect the line terminating equipment of the wanted station to said free channel.

6. An automatic exchange according to Claim 5, wherein said channel identifying signals are provided by interlaced recurring pulses of relatively low frequency, means are provided in

said register to reproduce said stored signals in the form of recurring groups of pulses of relatively high frequency and said apparatus to combine said stored dialling signals and said channel identification signal comprises a gate device, means to apply said recurring groups of pulses to the input of the gate device and means to apply the channel identification pulses characteristic of said free channel to control said gate device whereby said composite signal is in the form of a recurring group of pulses which occur only during the periods occupied by the pulses identifying the selected free one of said communication channels.

7. An automatic exchange for a plurality of subscriber stations, each of which has a handset on a rest and which handset when picked up renders effective means to transmit an initial calling signal, said exchange comprising a plurality of communication channels, a plurality of line terminating apparatuses at the exchange, each line terminating apparatus being associated with a different subscriber station, each line terminating apparatus including means responsive to an initial calling signal from its associated subscriber station when the latter has initiated a call to select a free one of said communication channels, routing apparatus by-passing said communication channels and responsive to dialling signals from the calling subscriber station to route

to the line terminating apparatus of the called subscriber station an identification signal identifying a selected one of the channels, and further apparatus responsive to the channel identification signal to connect the called subscriber station to the selected channel.

8. An automatic exchange as set forth in Claim 7 wherein means is included to release the routing apparatus before the call is terminated so that it is free for use in routing other calls.

9. In a communication system a plurality of lines terminating in an exchange, means providing a plurality of communication channels in said exchange available to any of said lines for carrying speech signals, and means for connecting a calling line with a free one of said channels, characterized by the provision of means providing a second plurality of communication channels by-passing the first said channels and extending to the line terminating apparatus of the said lines respectively, means responsive to a calling signal representative of the number of a called subscriber to select the one of the second plurality of communication channels which extends to the line terminating apparatus of the called subscriber and to transmit in the selected one of the second plurality of channels a signal identifying the selected free one of the said communication channels and further means responsive

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to the last said signal to connect the called subscriber's line terminating apparatus to the said free one of the first said plurality of communication channels.

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Fig.1.

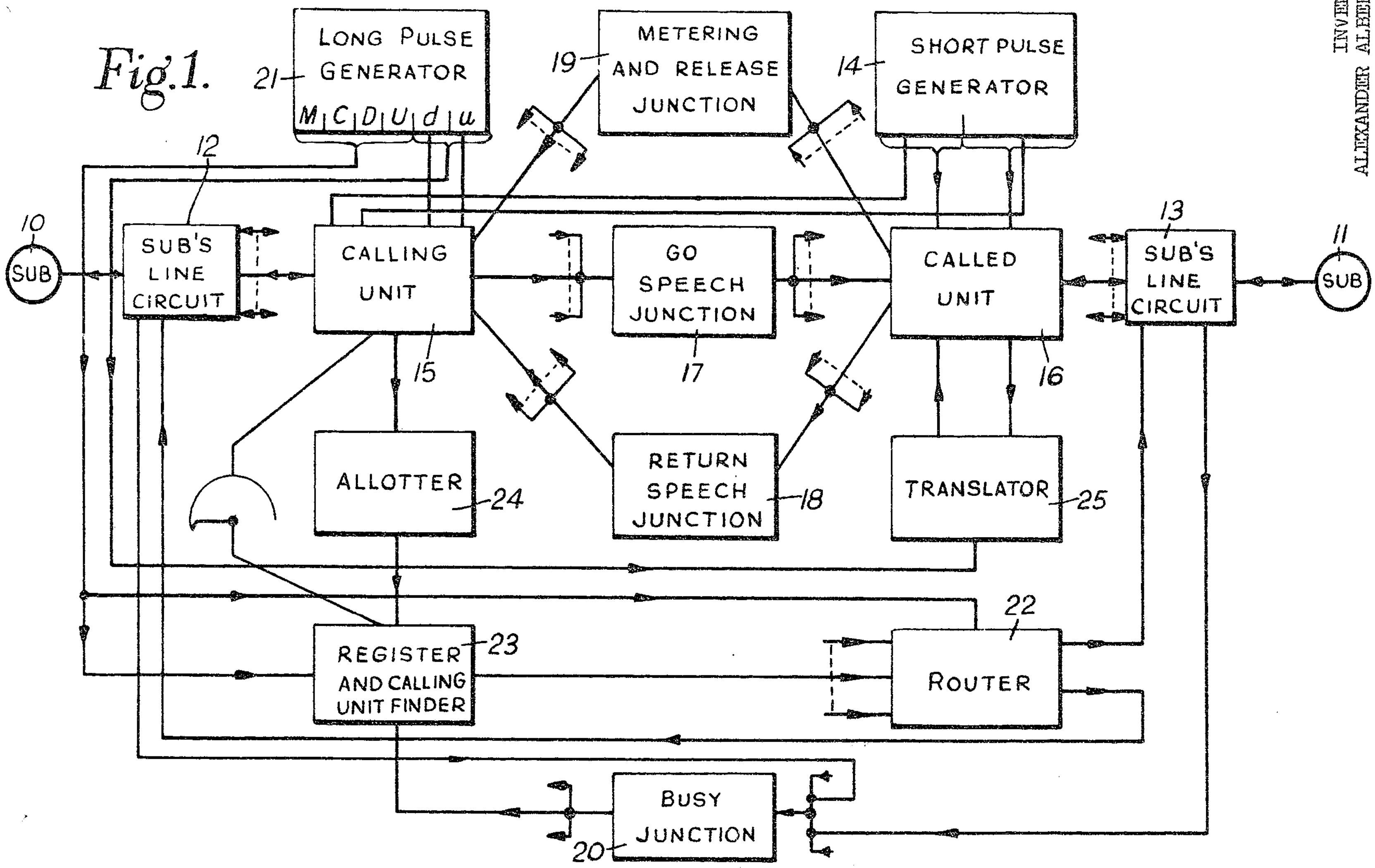

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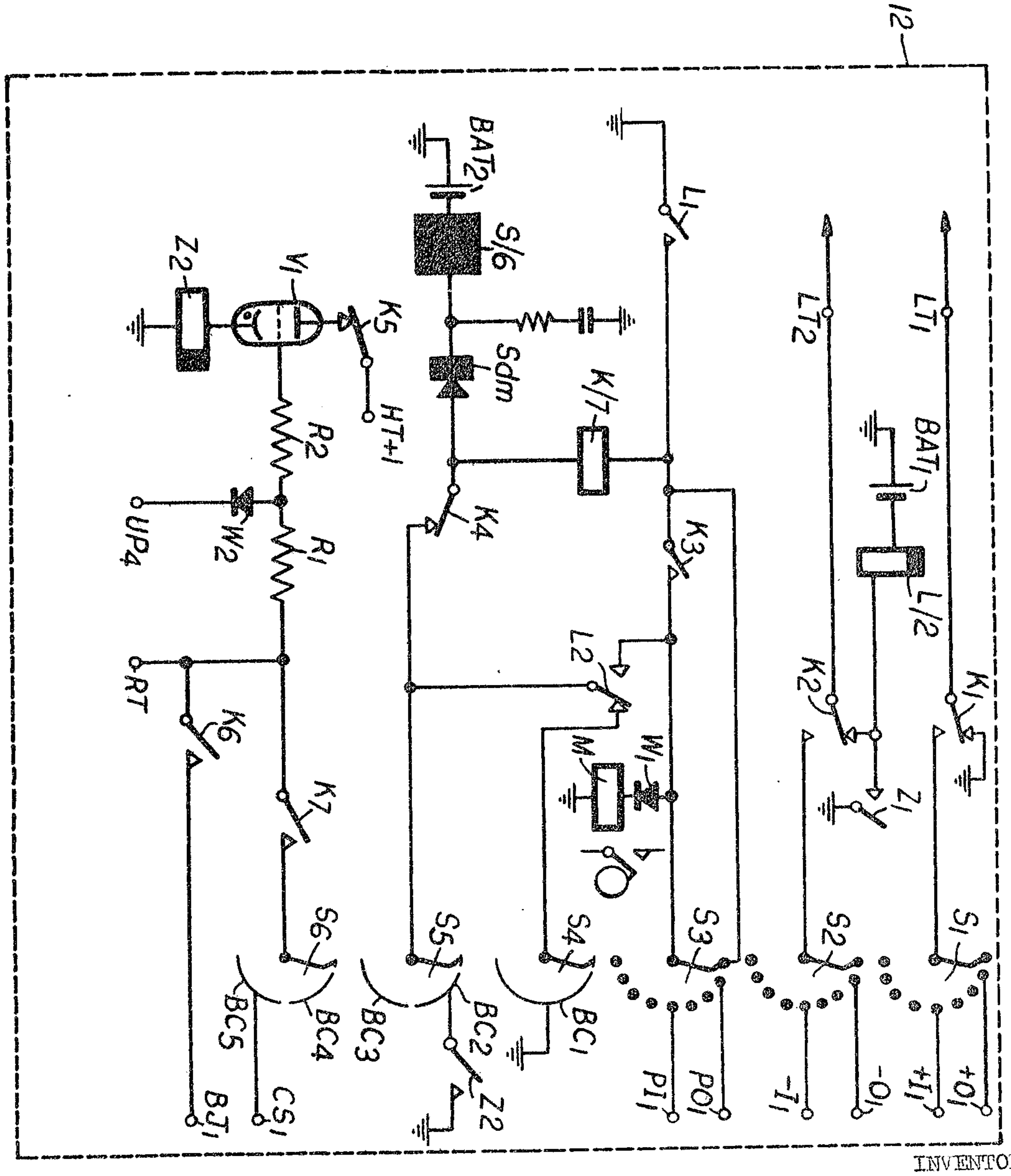
Fig. 2.



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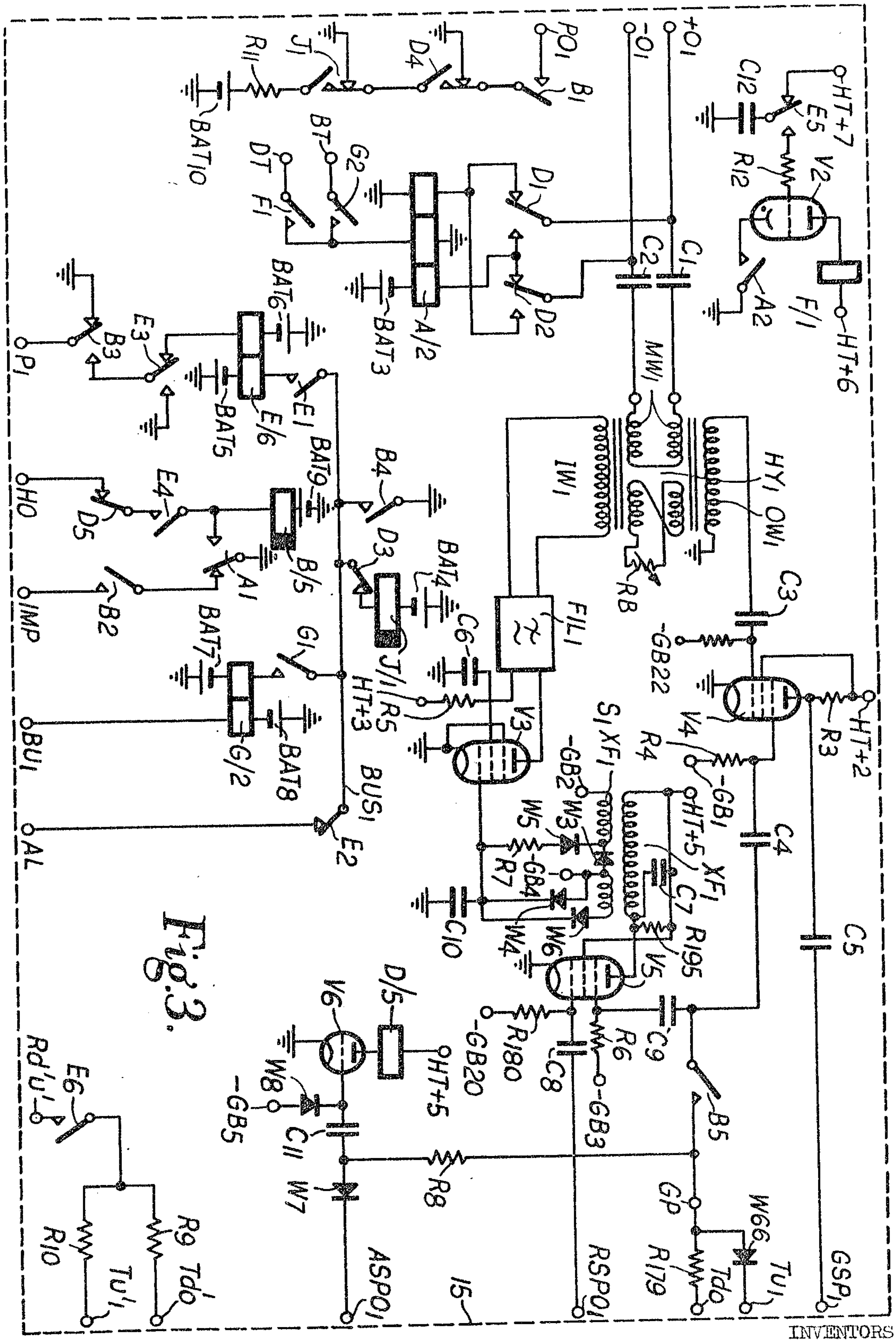

Fig. 3.

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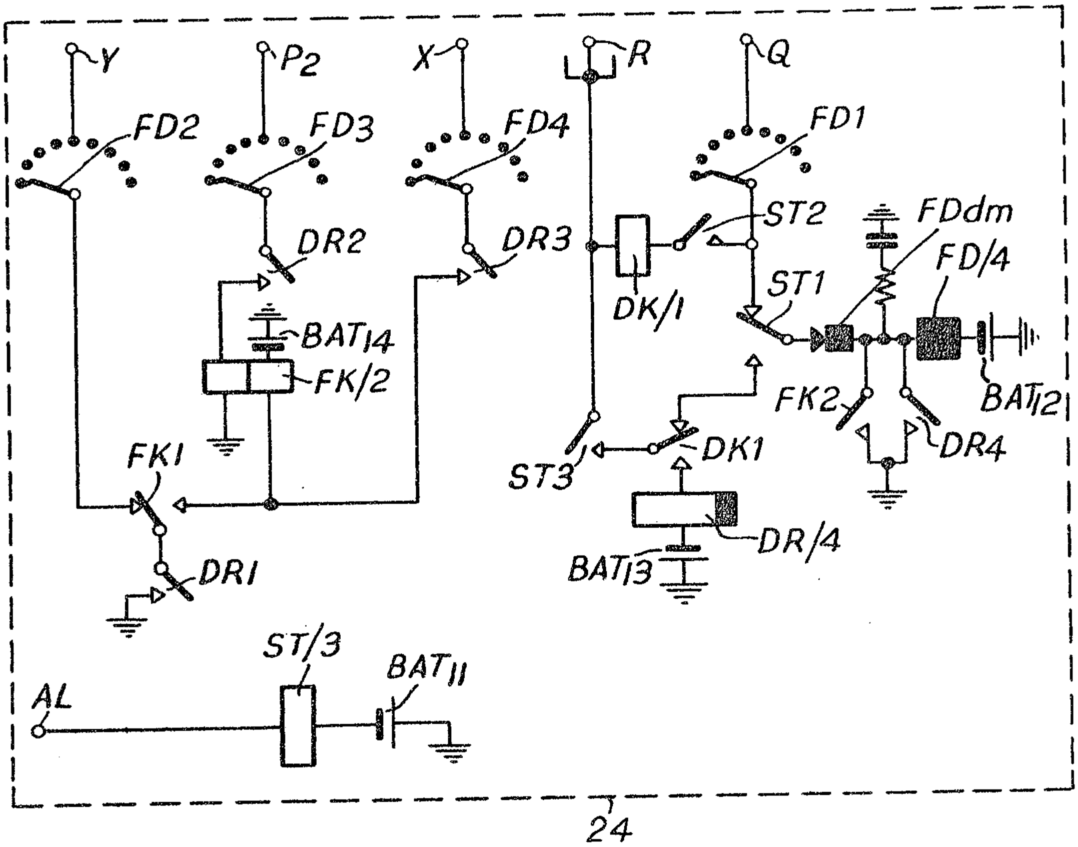
Fig.4.



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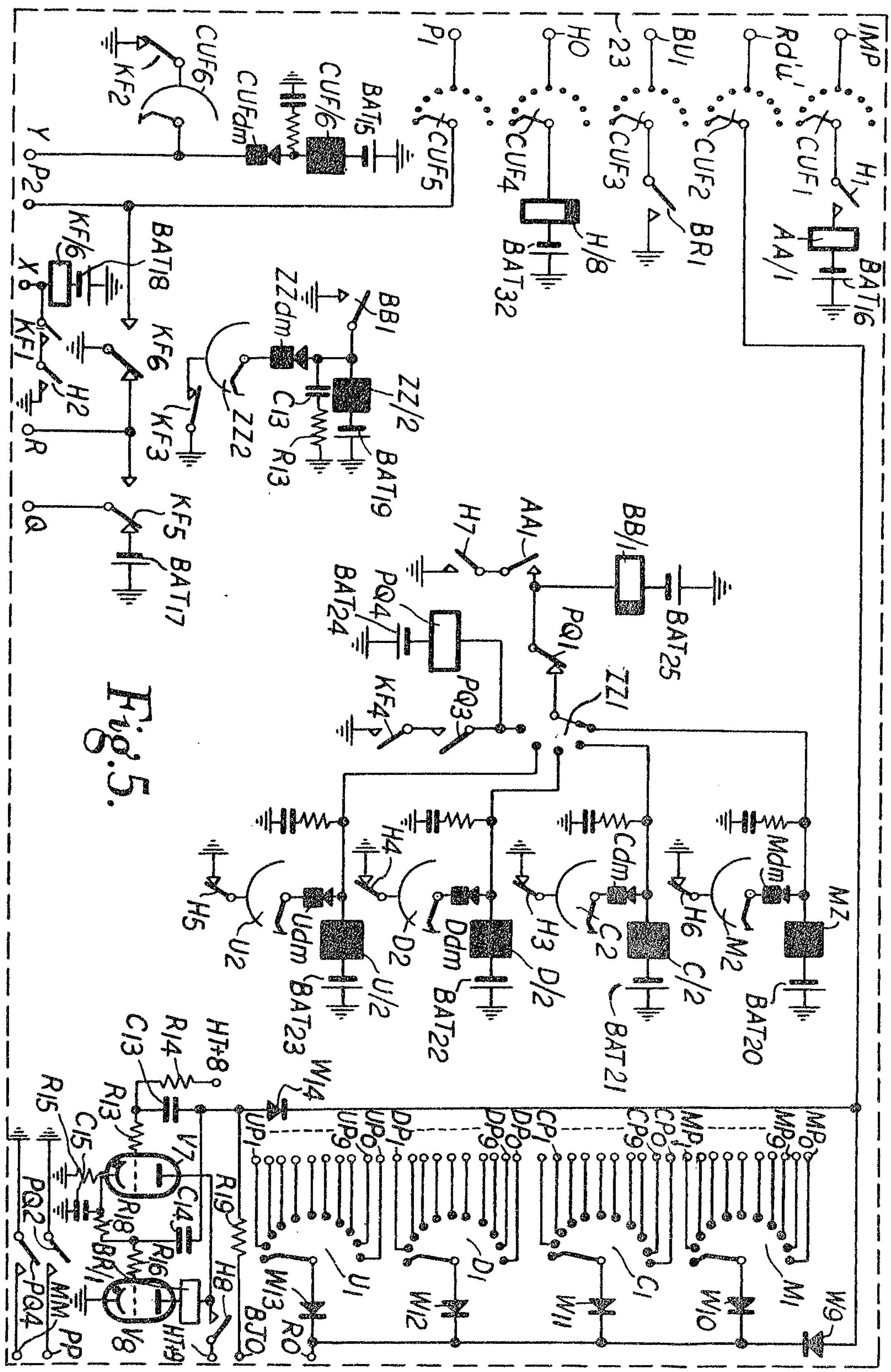

Fig. 5.

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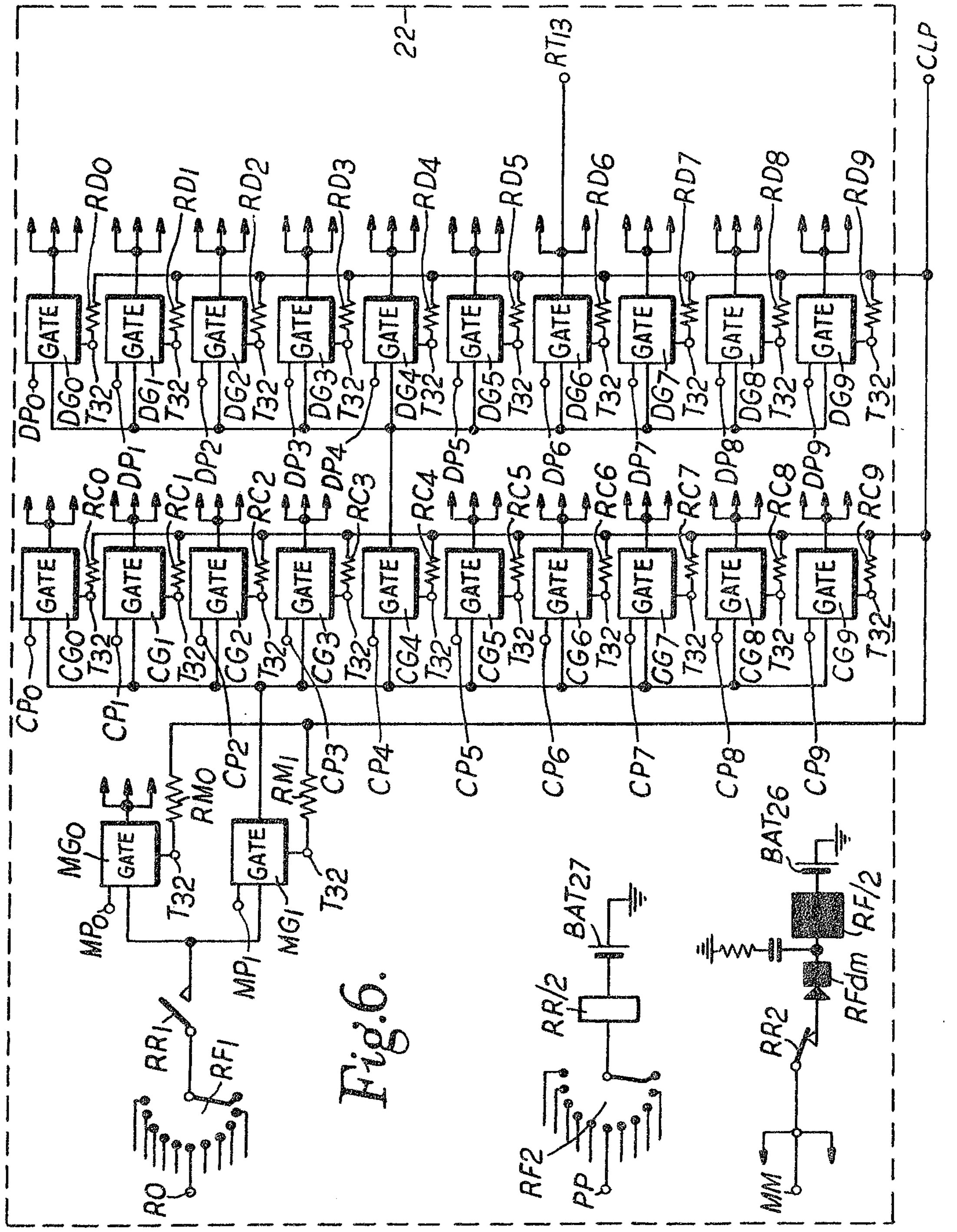

Fig.6.

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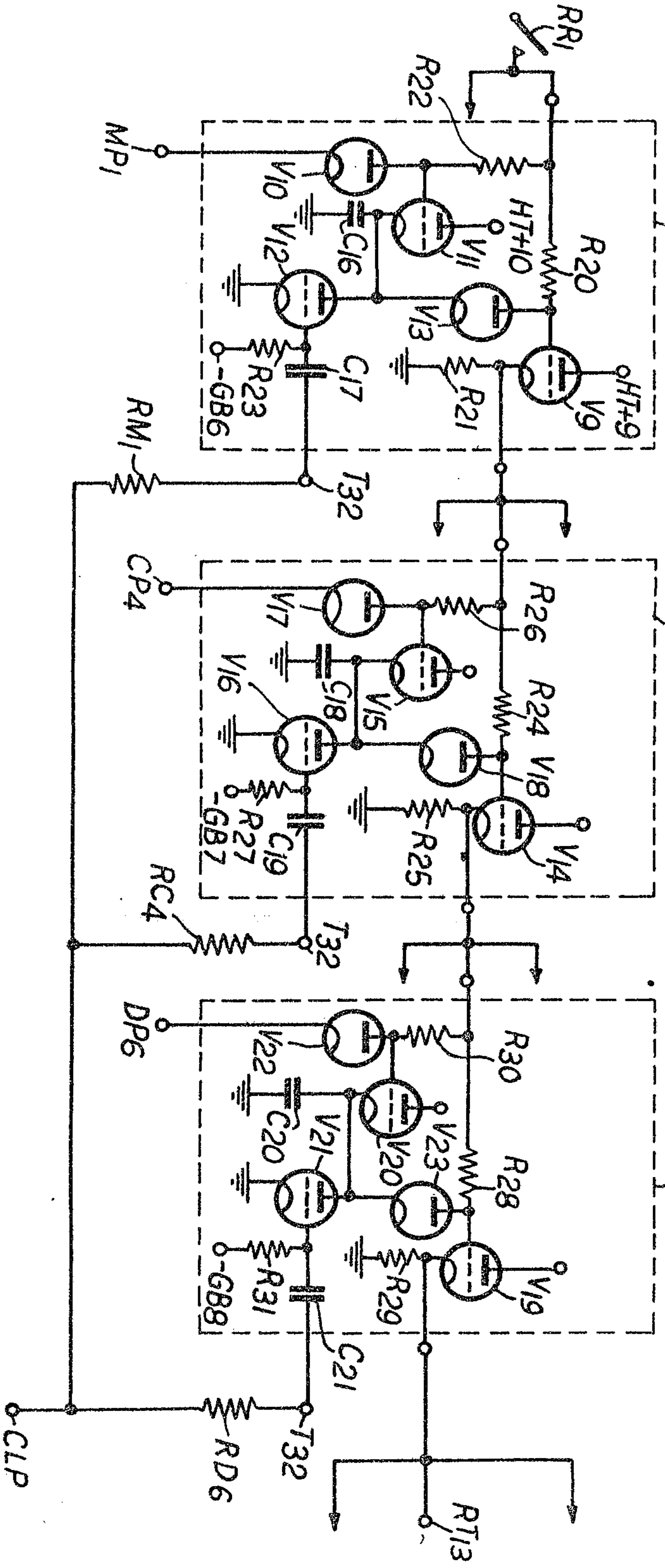

Fig. 7.

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Fig. 8.

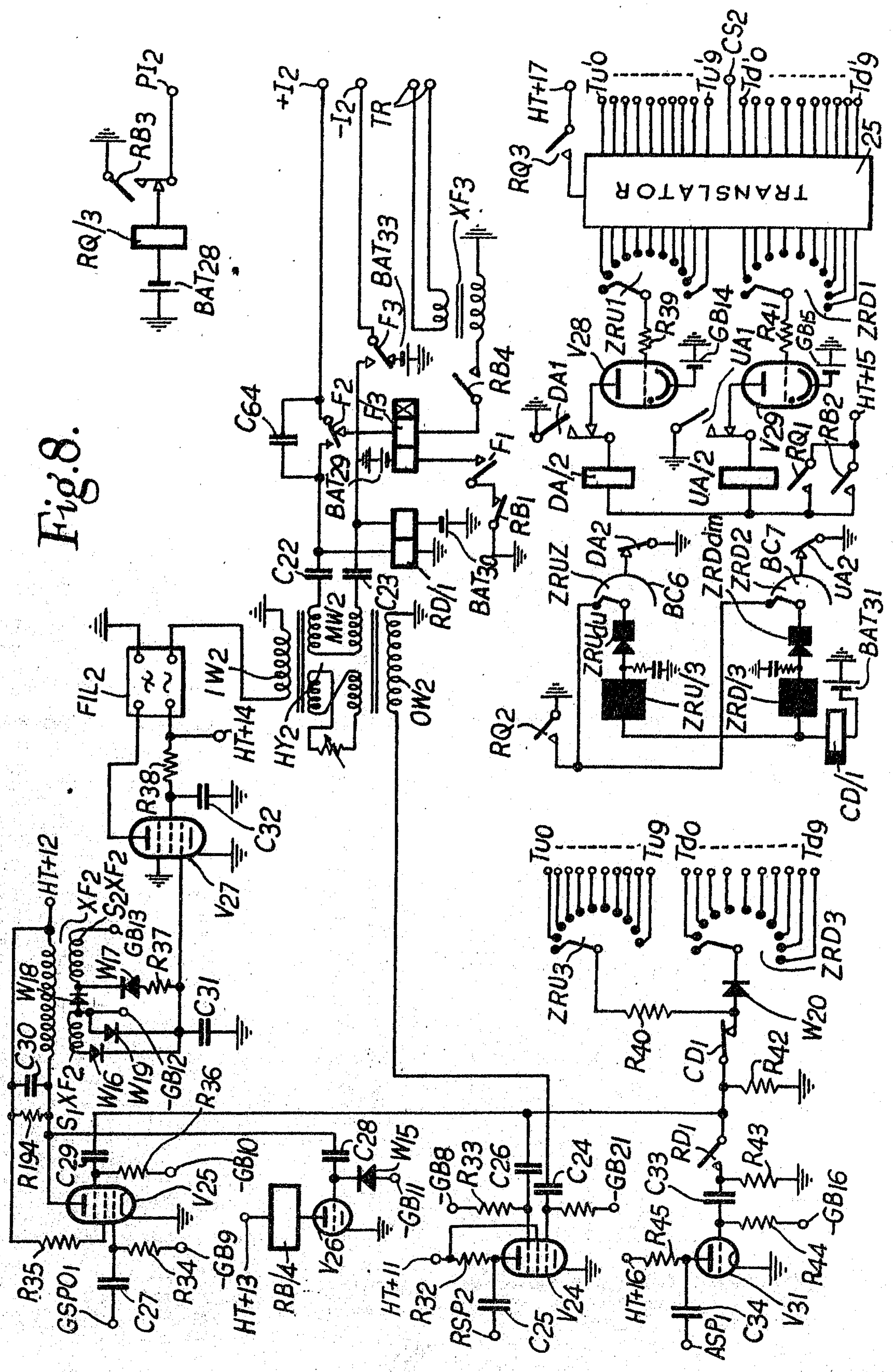

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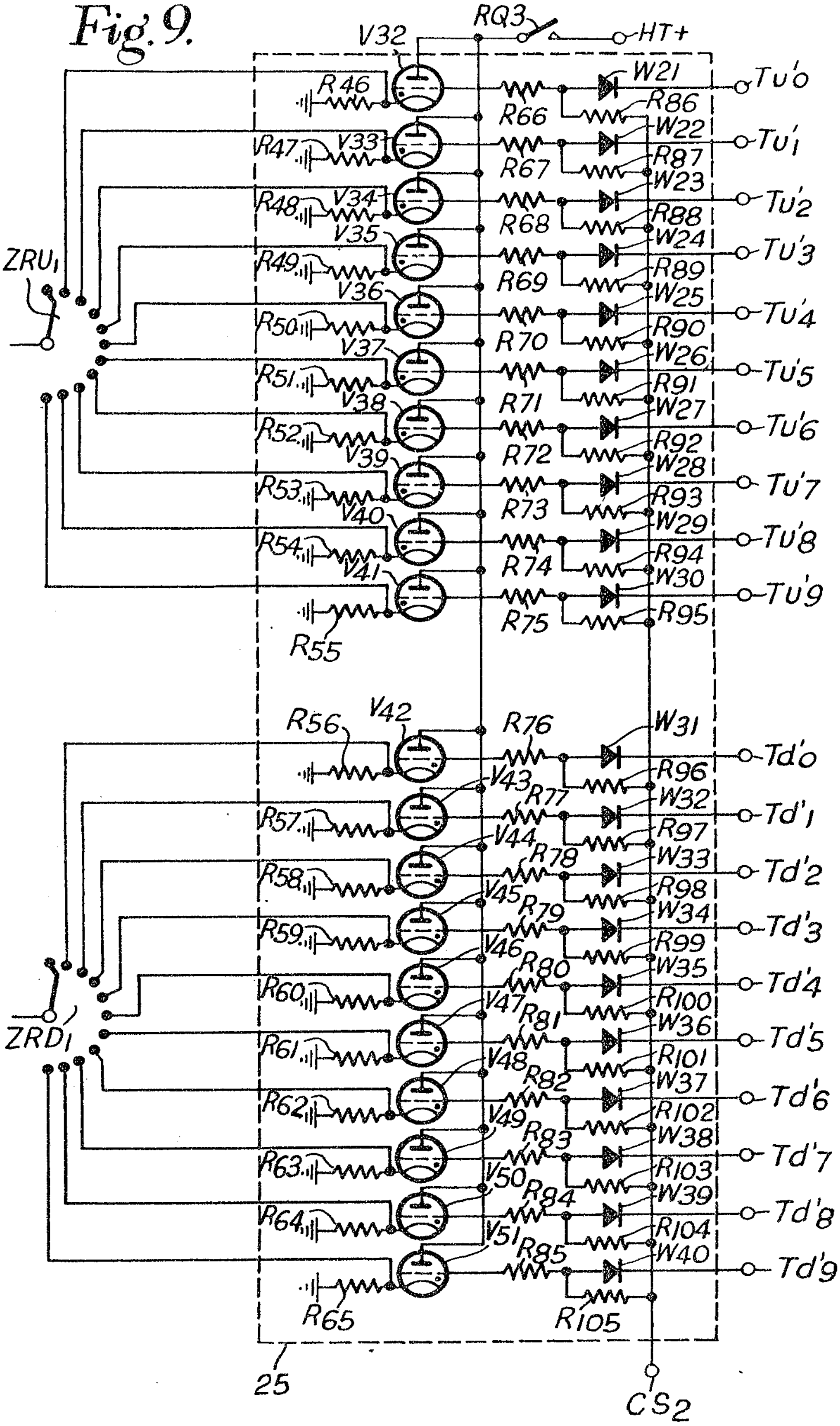
Fig. 9.



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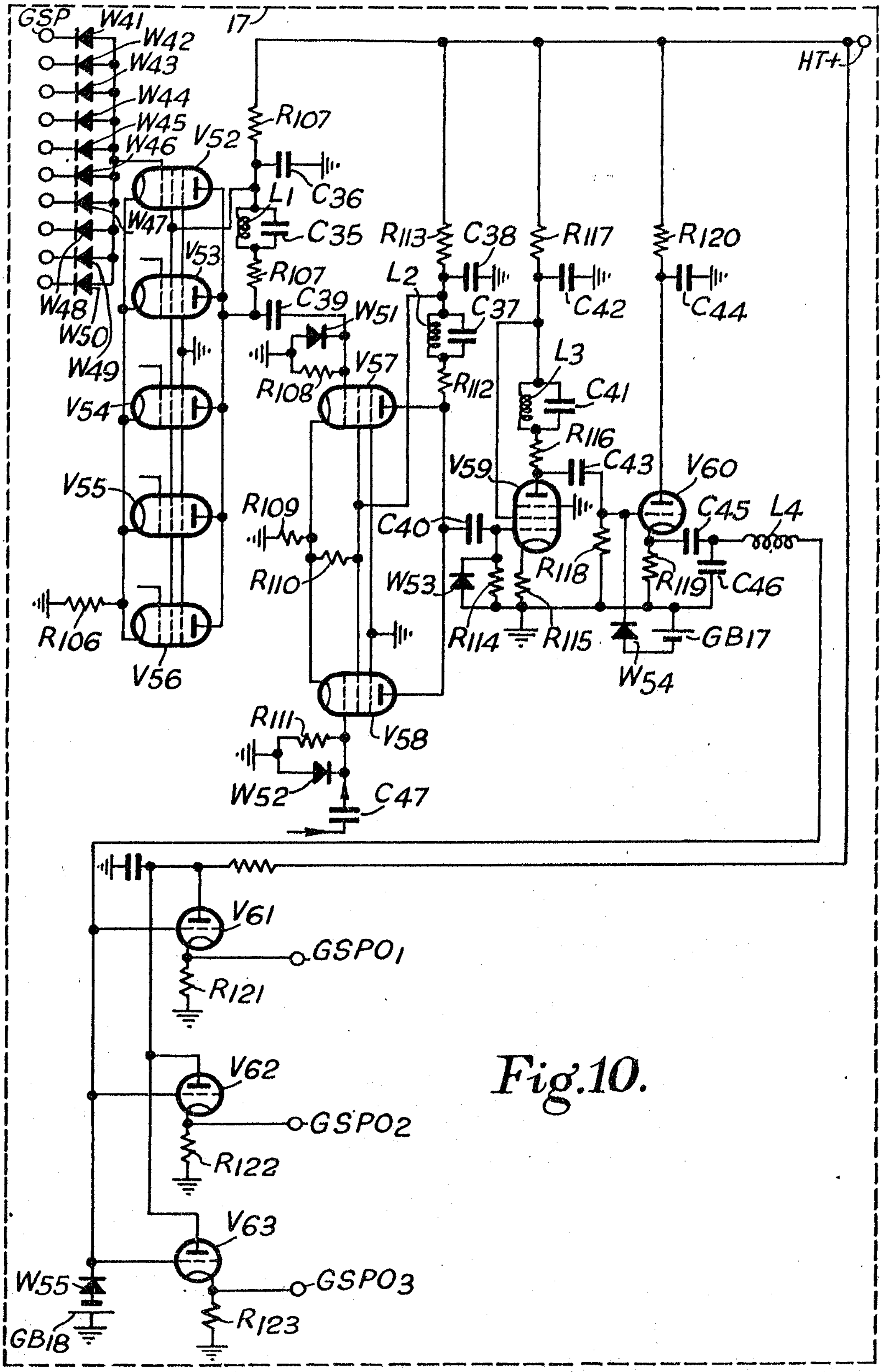

Fig.10.

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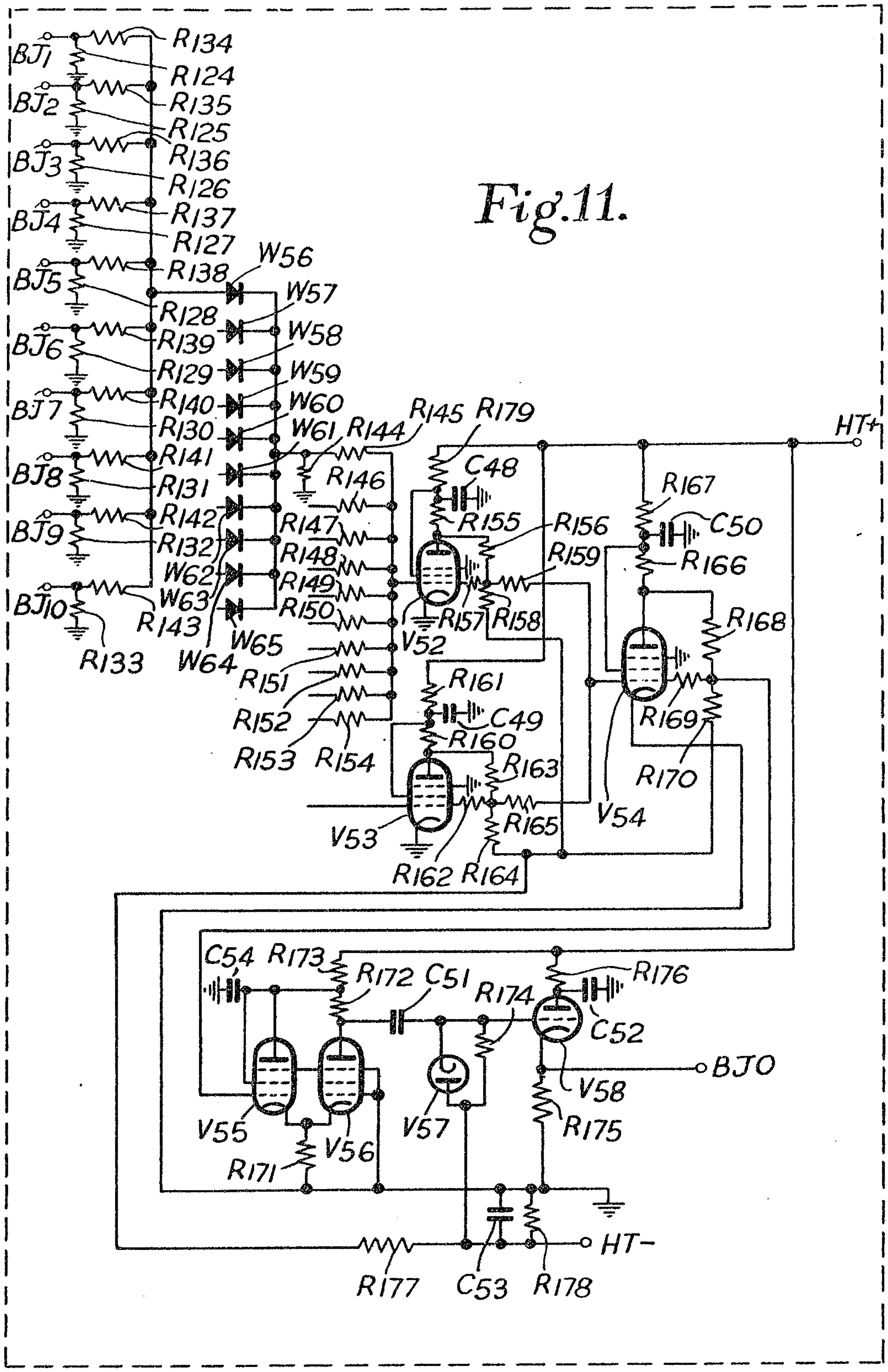

Fig.11.

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Fig.12(a).

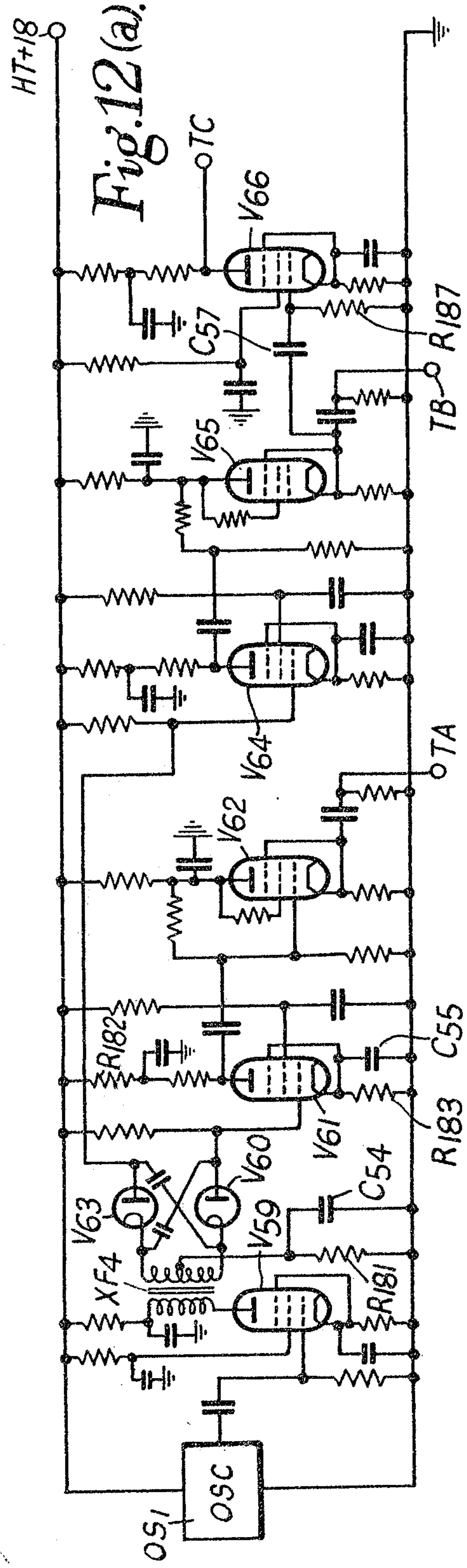
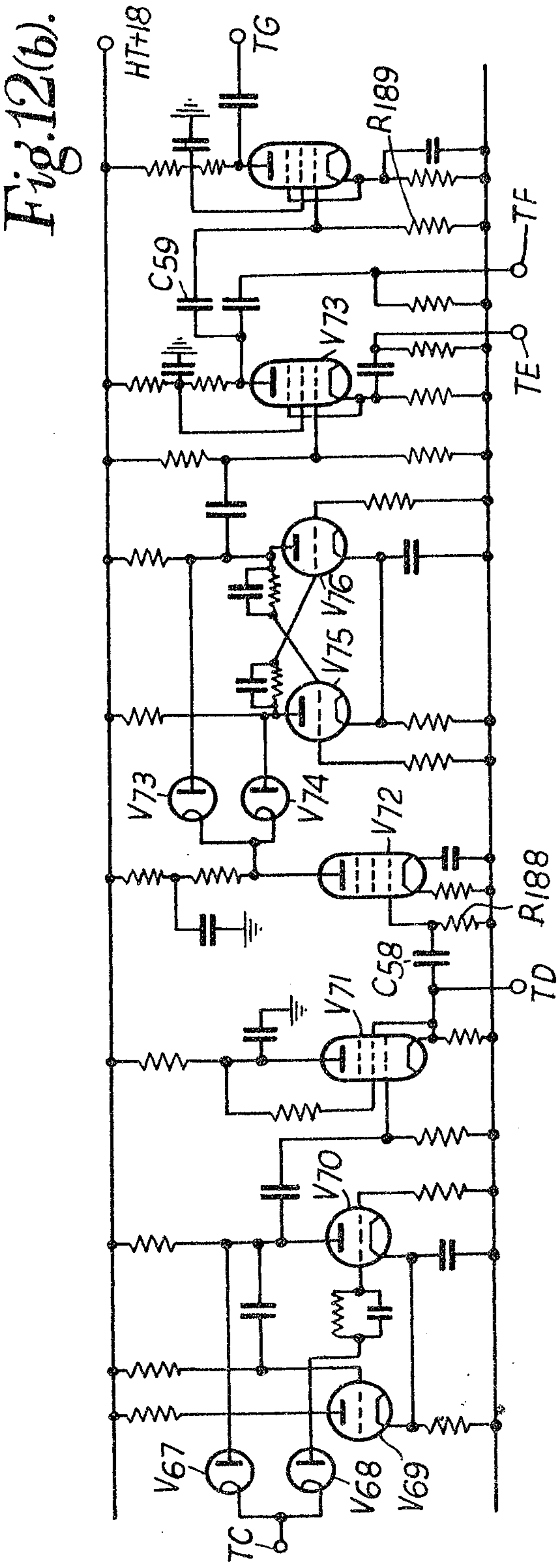


Fig.12(b).



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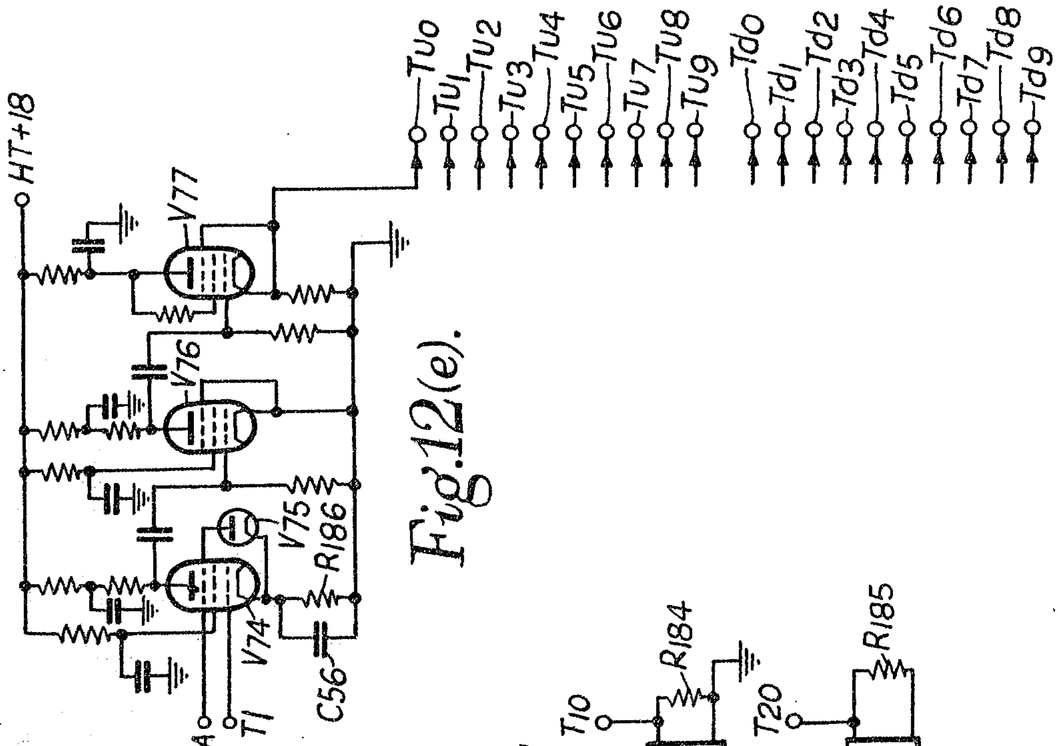

Fig.12(e).

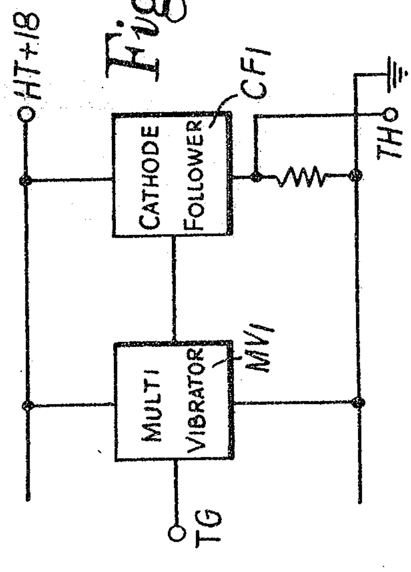

Fig.12(c).

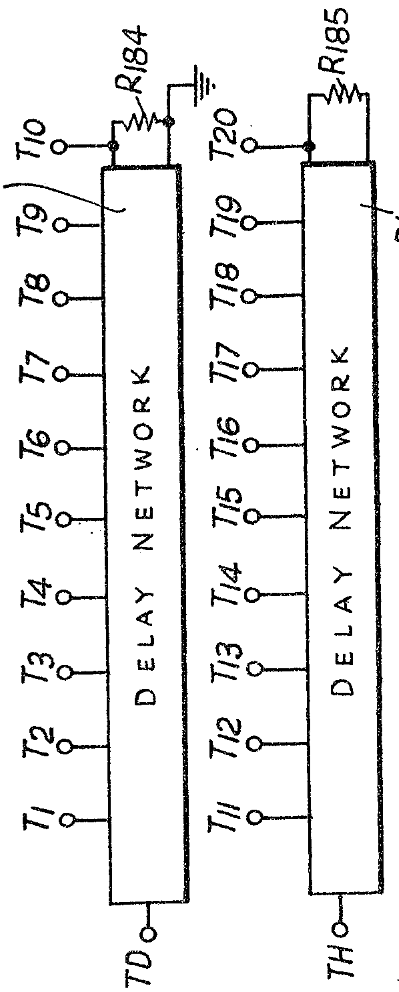

Fig.12(d).

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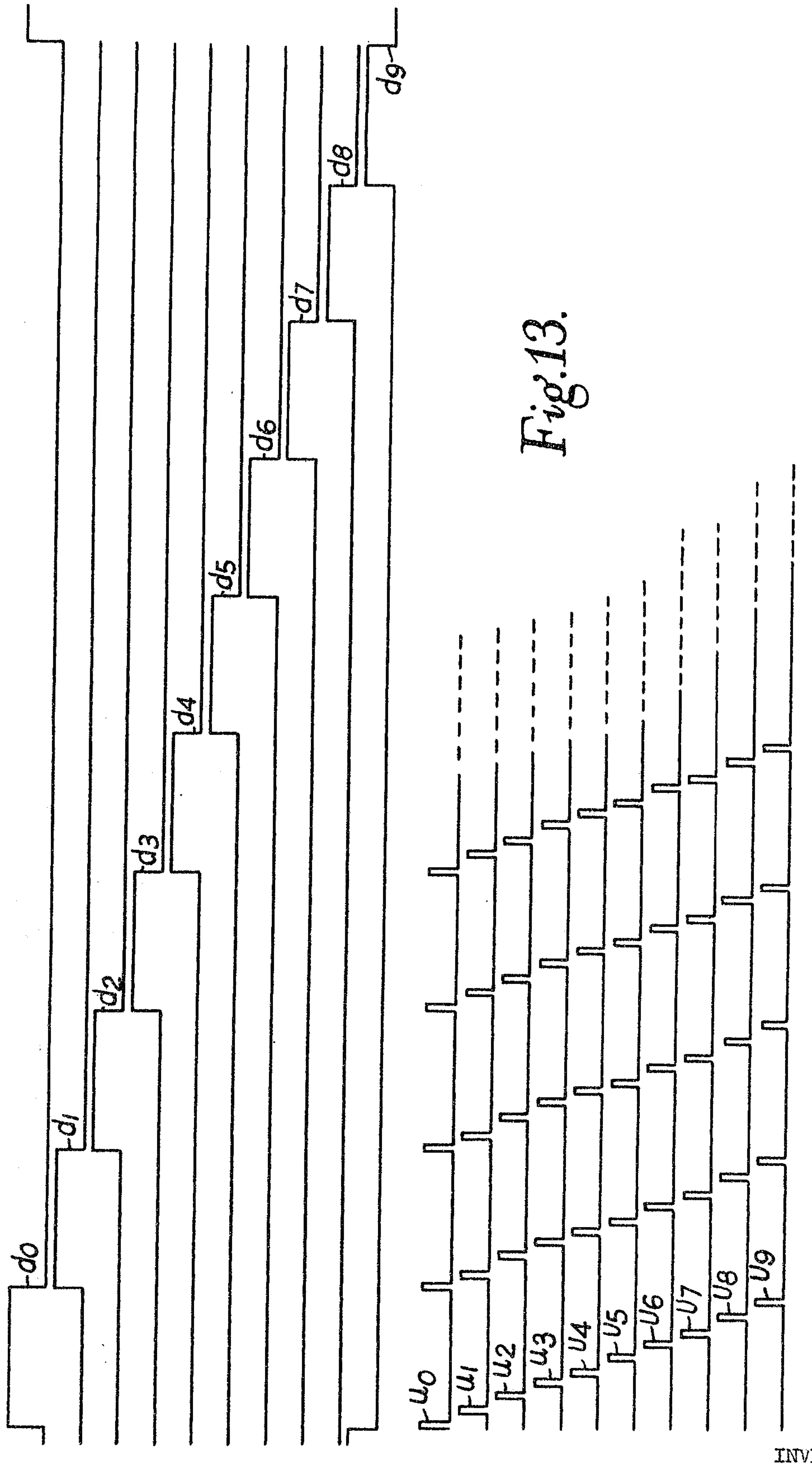

Fig.13.

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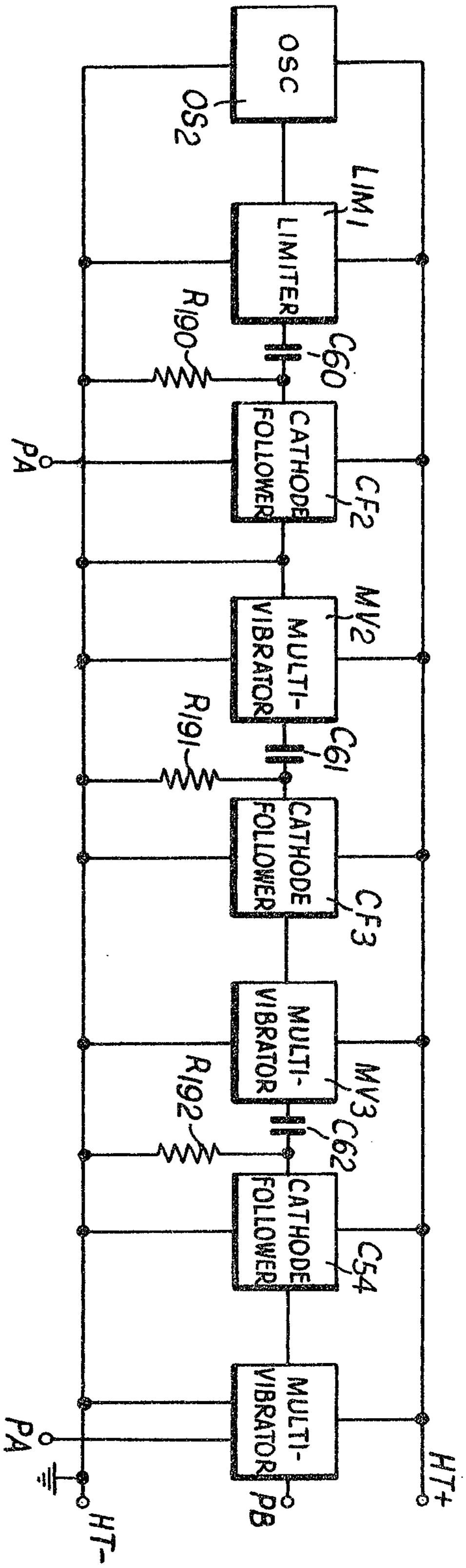

Fig. 14(a).

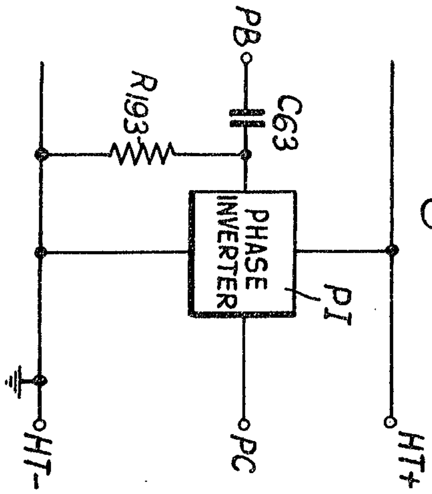

Fig. 14(b).

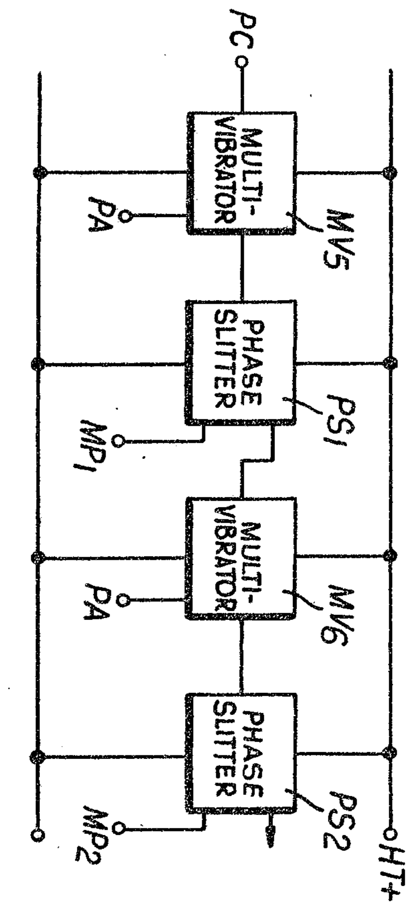

Fig. 14(c).

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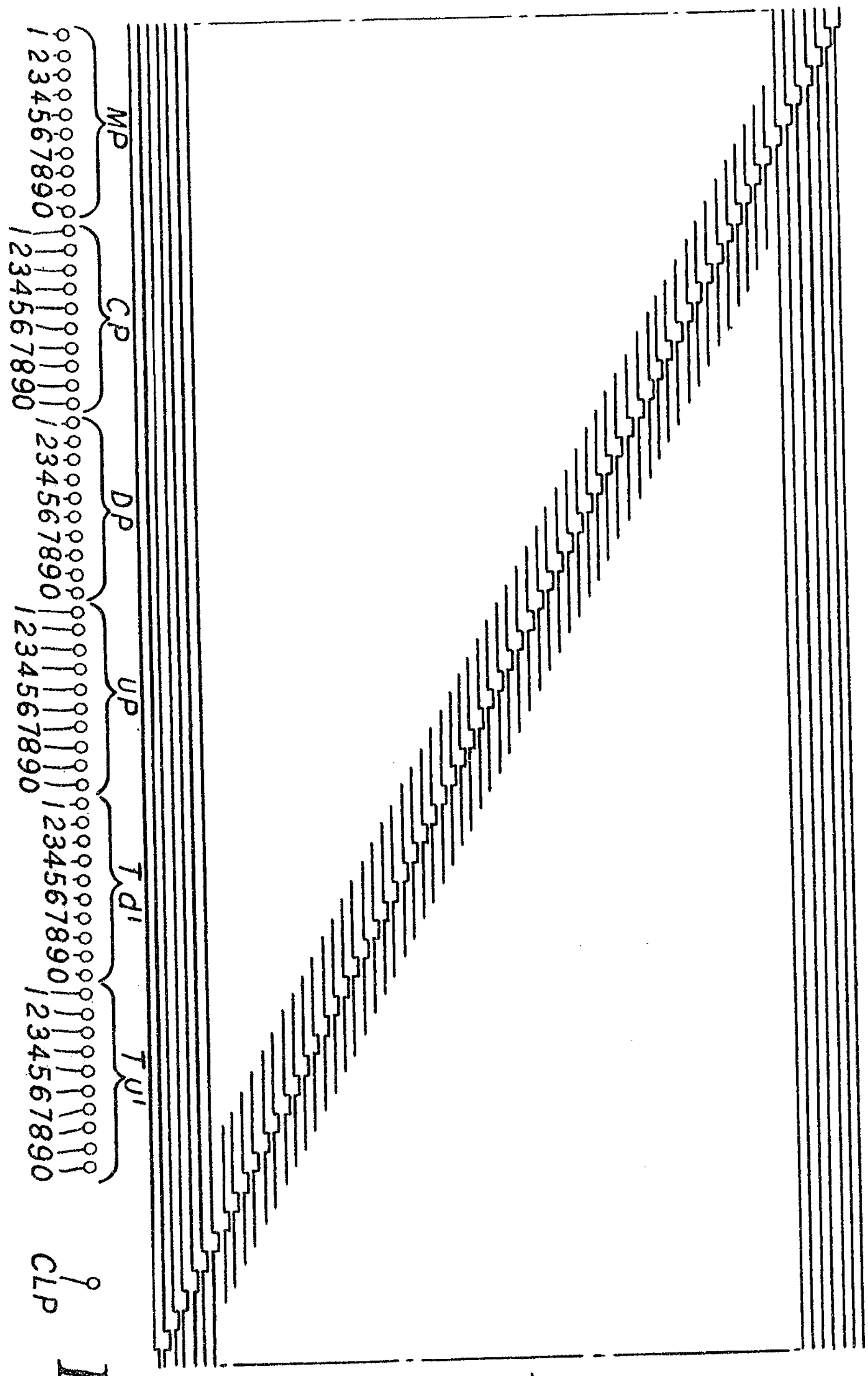

Fig.15(a).

Fig.15(b).

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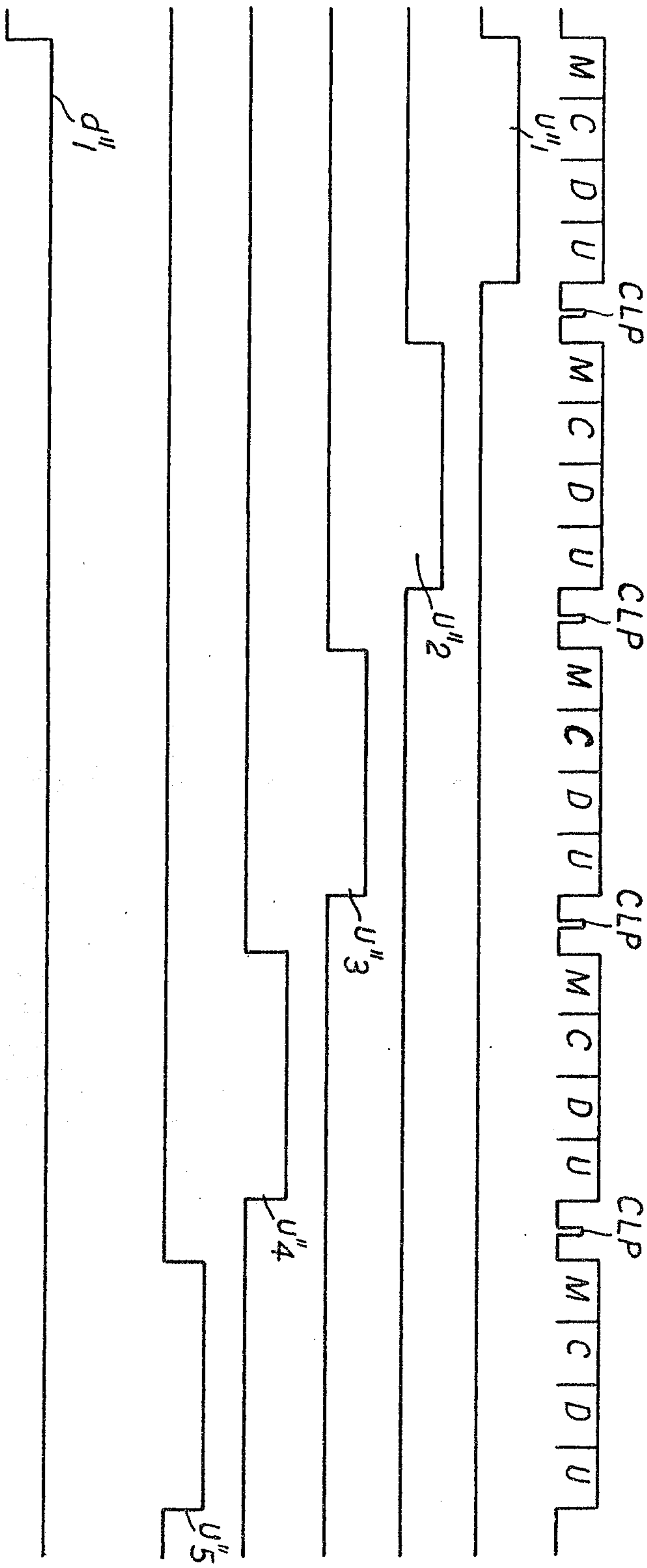

Fig. 16.

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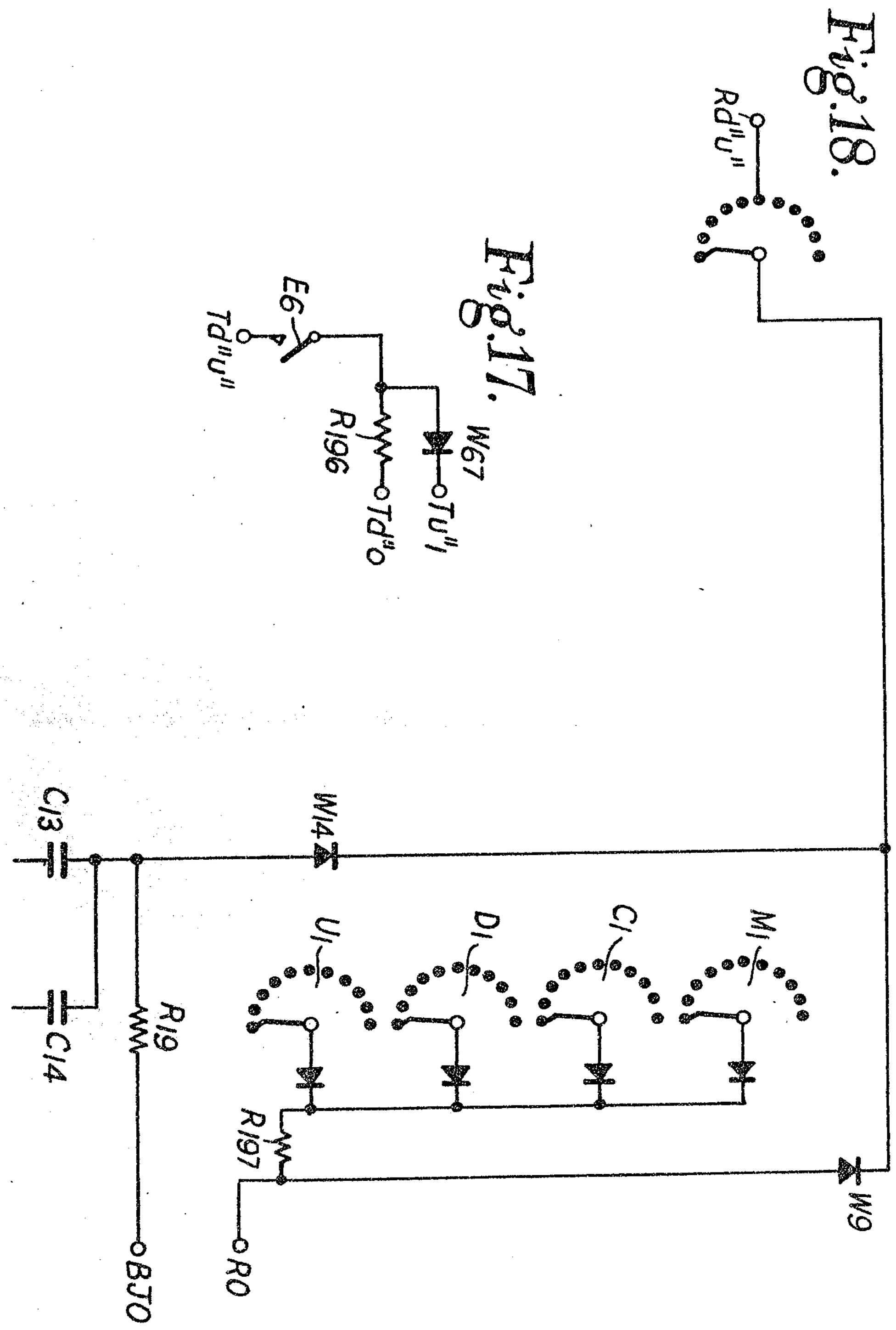

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