April 10, 1934. G. J. KELLEY 1,954,779

ELECTRON TUBE SYSTEM

Filed May 12, 1930 5 Sheets-Sheet 1

Fig. 1.

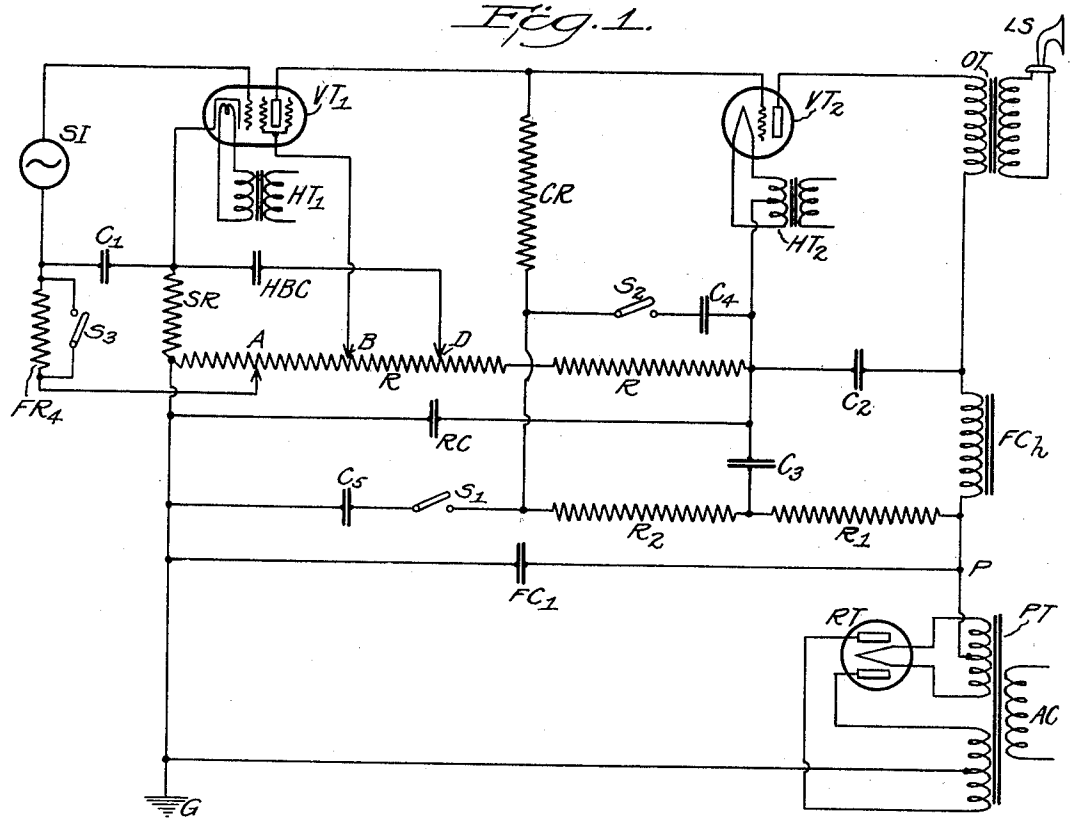
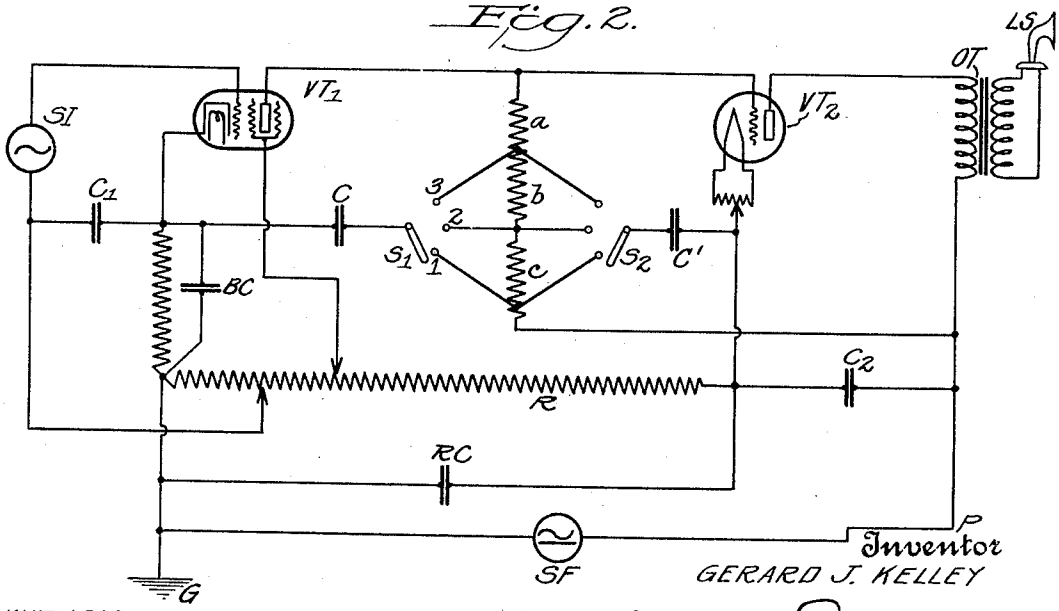


Fig. 2.



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ELECTRON TUBE SYSTEM

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Fig. 3.

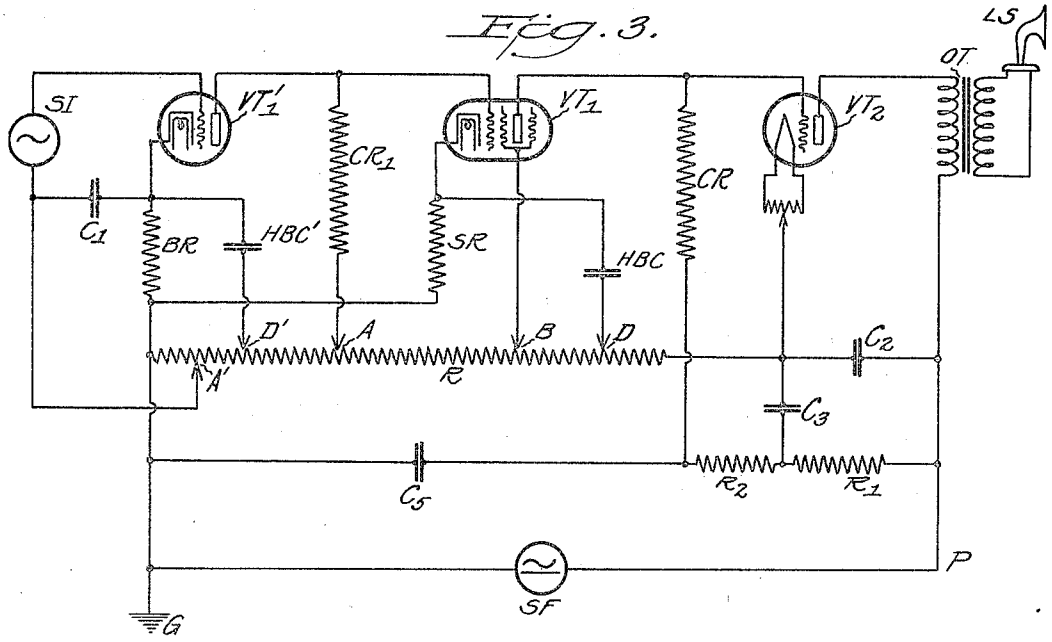
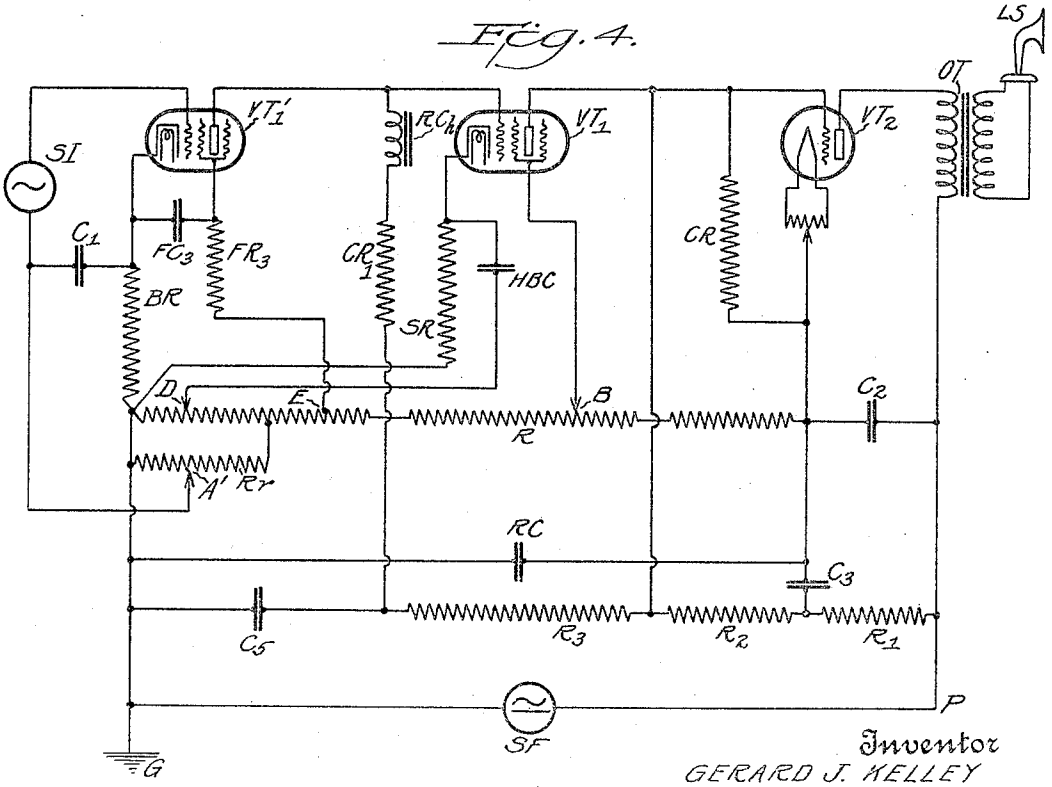


Fig. 4.



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ELECTRON TUBE SYSTEM

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Fig. 5.

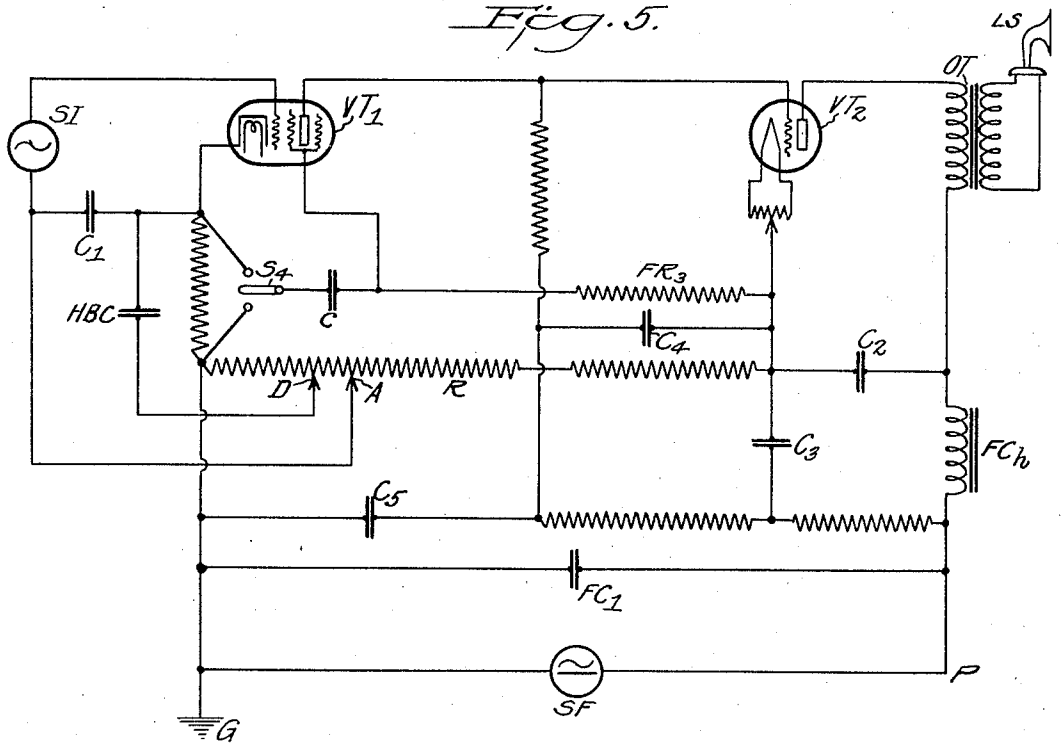
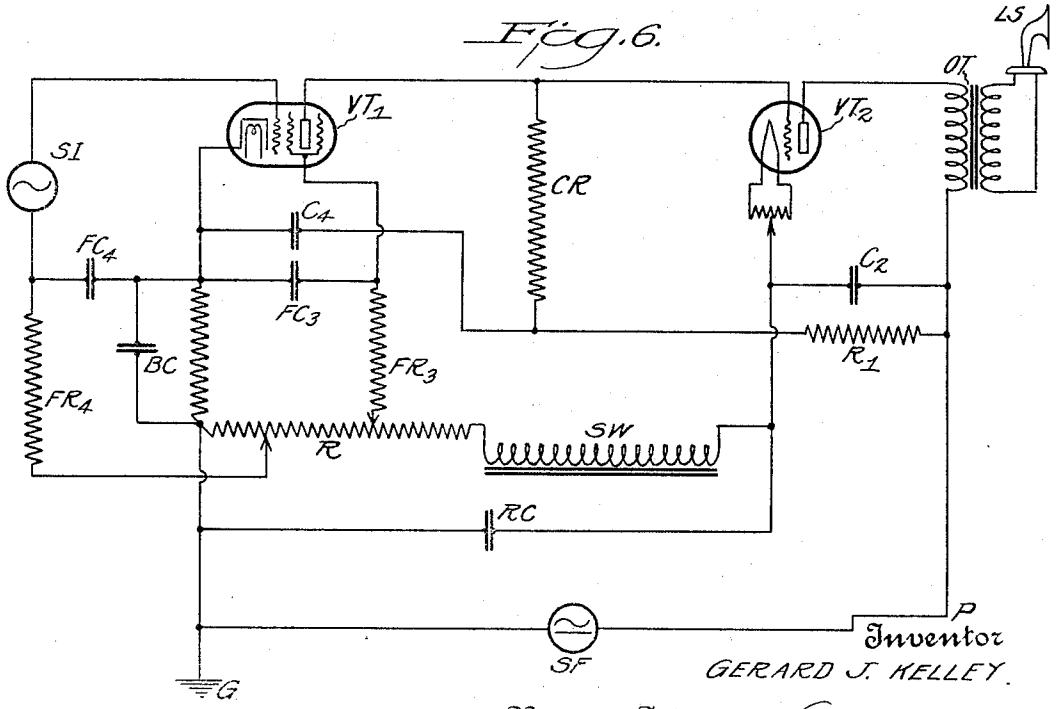


Fig. 6.



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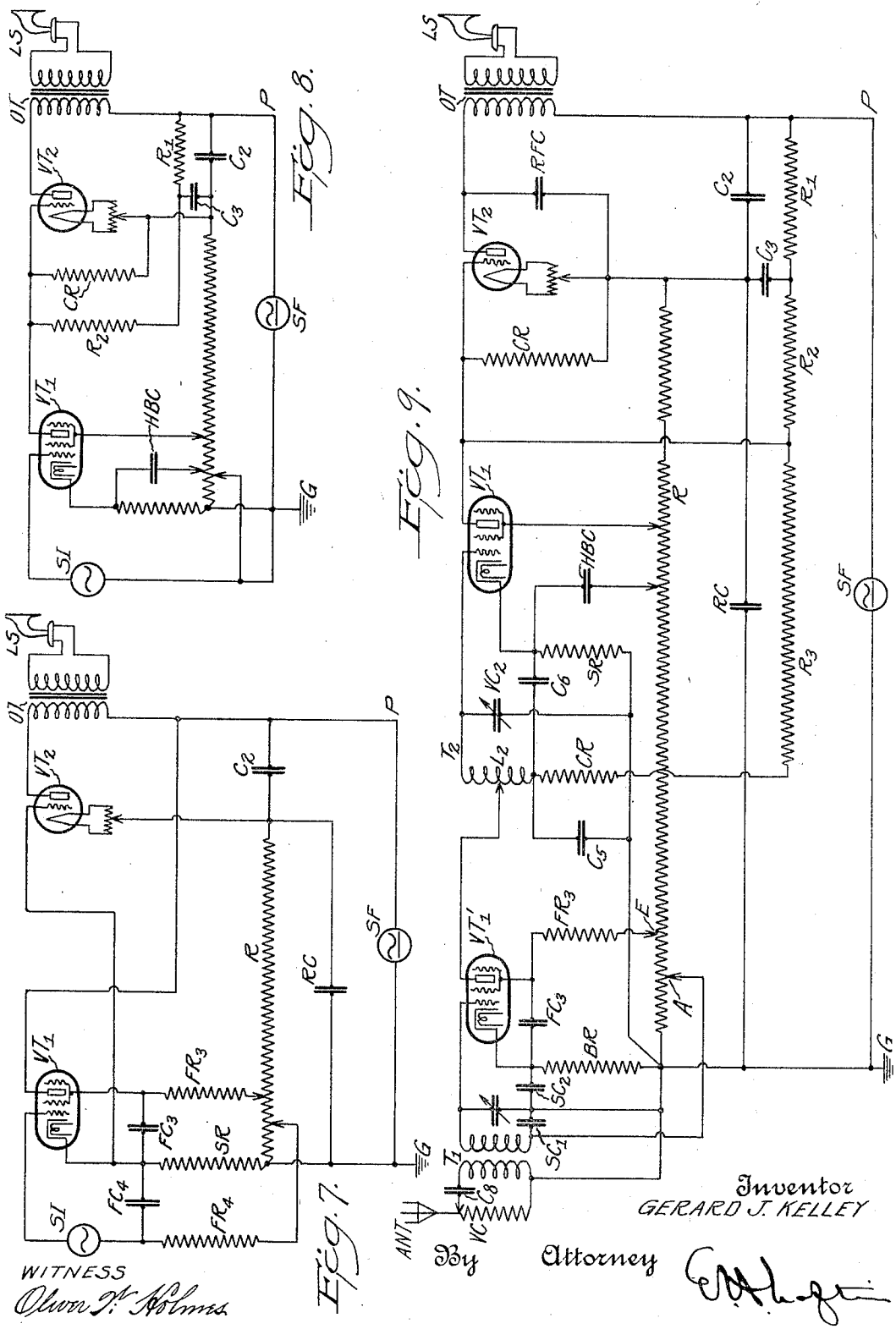
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ELECTRON TUBE SYSTEM

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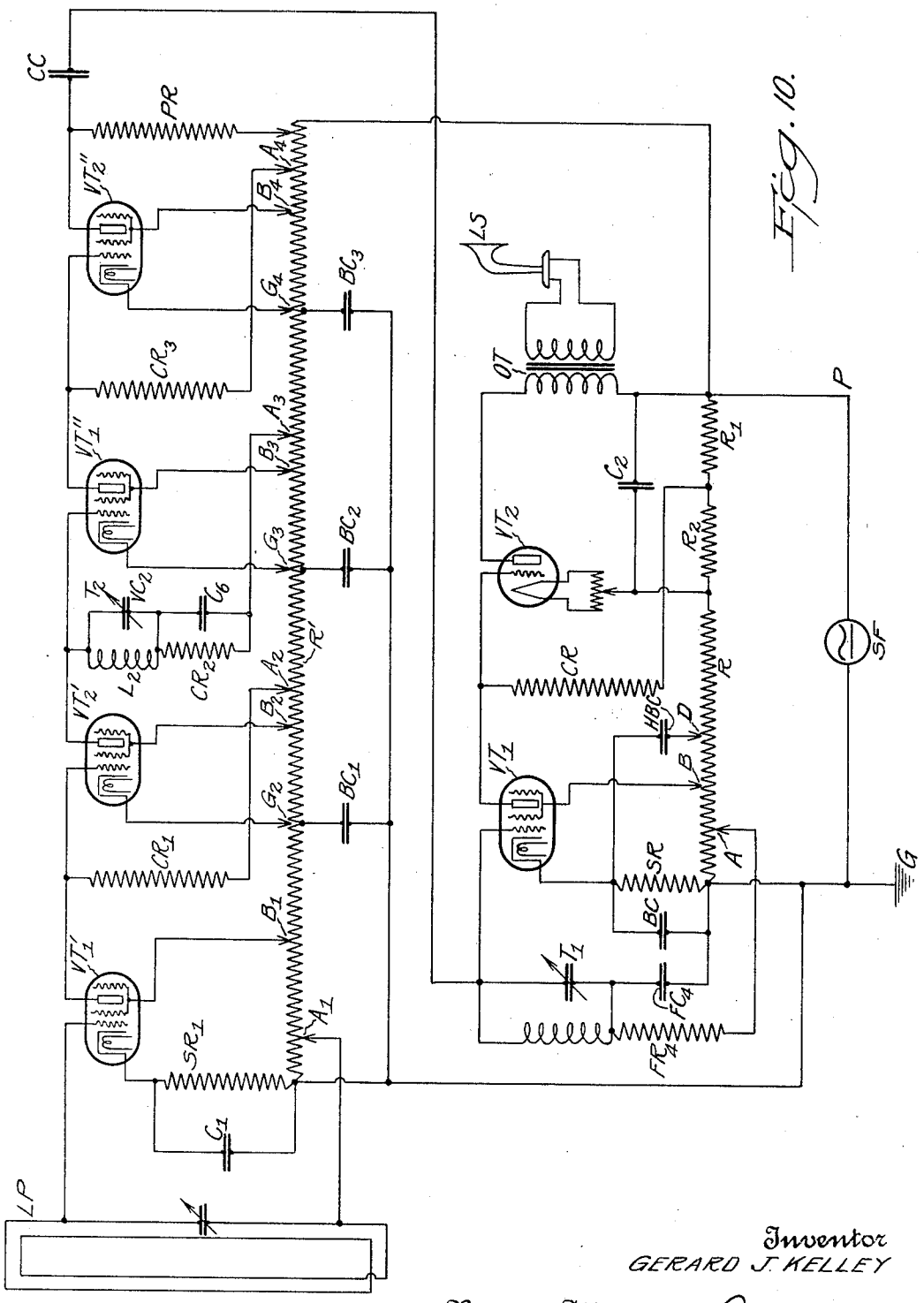


Fig. 10.

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1,954,779

ELECTRON TUBE SYSTEM

Gerard J. Kelley, New York, N. Y., assignor, by mesne assignments, to Radio Corporation of America, New York, N. Y., a corporation of Delaware

Application May 12, 1930, Serial No. 451,562

11 Claims. (Cl. 179—171)

The present invention relates to electron tube systems, and is a continuation in part of my copending application Serial No. 429,956, filed February 20, 1930.

An object of my invention is the control of signal current effects within a direct coupled tube system so as to produce a high order of radio or audio frequency amplification throughout the system.

Another object of my invention is to so regulate and apportion the signal current effects with respect to direct current effects that abnormally high coefficients of amplification may be obtained, while maintaining faithful reproduction of the signals to be amplified.

Other objects of my invention will become apparent as the description of my invention is developed with reference to the accompanying drawings in which

Fig. 1 diagrammatically illustrates one adaptation of the features of my invention,

Fig. 2 diagrammatically illustrates certain features embodied in Fig. 1,

Fig. 3 diagrammatically illustrates a three tube modification of the direct coupled tube system of Fig. 1,

Fig. 4 diagrammatically illustrates a modification of the circuit arrangement of Fig. 3 and involves certain humbucking features,

Fig. 5 diagrammatically illustrates a modification of the energization system of Fig. 1,

Fig. 6 diagrammatically illustrates a modification of the circuit arrangement of Fig. 5,

Fig. 7 diagrammatically illustrates a modification of the energization and signal current system of Fig. 6,

Fig. 8 diagrammatically illustrates a modification of the energization and signal current system of Fig. 12 of my copending application hereinbefore referred to,

Fig. 9 diagrammatically illustrates a modification of the circuit arrangement of Fig. 4, and

Fig. 10 diagrammatically illustrates the circuit arrangement of a complete radio receiving system embodying certain of the features disclosed in my copending application hereinbefore referred to in combination with certain of the features described with reference to the foregoing figures.

Referring to Fig. 1, VT_1 and VT_2 designate two electron tubes in direct coupled cascade relation having a signal input circuit SI and an output circuit which may consist of an output transformer OT and a loud speaking device LS or other type of indicator. The input circuit may consist of any type of instrumentality developing an alternating current potential or fluctuating direct current potential.

VT_1 and VT_2 are four element and three element electron tubes respectively the cathodes of which are energized through heating current transformers HT_1 and HT_2. The plate of the tube VT_2 is connected through a filter choke coil FCh to the positive terminal P of a rectifier system including a rectifier tube RT energized from a power transformer PT. The cathode of tube VT_2 is connected through a resistance R to the negative terminal G of the rectifier system. The output of the rectifier is shunted by a filter condenser FC_1.

The cathode of tube VT_1 is connected to the terminal G through a stabilizing resistance SR, the grid and screen grid being returned to points A and B on the resistance R, all of which structure has been described in detail in my copending application hereinbefore referred to.

In this instance, however, I have provided a filter resistance FR_4, in the grid circuit of tube VT_1 which may be shorted out by a switch S_3 depending upon whether it is desired to have or remove any signal current regeneration within the system.

In the arrangement of Fig. 1, I connect the plate of tube VT_1 and the grid of tube VT_2 to the terminal P of the rectifier system through a coupling resistance CR and two series resistances R_1 and R_2. The condenser C_2 serves both as a filter condenser and as signal current condenser for the output circuit of tube VT_2. The condenser C_3 serves as a filter condenser in conjunction with the resistance R_1 completing the signal input circuit for the tube VT_2, and it also completes the signal output circuit of tube VT_1.

When the switches S_1 and S_2 are open as shown signal current flowing in the plate circuit of tube VT_1 developes signal current potentials across both the resistances CR and R_2, the total potential being impressed upon the input circuit of tube VT_2. If now the switch S_1 is closed the plate circuit of tube VT_1 is closed through the condenser C_5. The impedance input circuit of tube VT_2 remains the same, however, the resultant action being similar to a step-down auto-transformer. If, however, the switch S_2 is closed the plate circuit of the tube VT_1 and the grid-circuit of tube VT_2 are simultaneously completed through the condenser C_4, the signal currents in the plate circuit of tube VT_1 developing potentials only across the resistance CR and these same potentials being applied to the input circuit of tube VT_2.

The functions of these condensers are more fully explained with reference to Fig. 2 in which the resistances CR, R_2 and R_1 of Fig. 1 are designated *a*, *b*, *c*. With the switches S_1 and S_2 open the signal current path from the plate to the cathode of tube VT_1 is through resistances, *a*, *b*, *c*, and condensers, C_2, RC, and BC. The impedance to signal current in the input circuit of tube VT_2 is the resistance of *a*, *b*, *c* and the condenser C_2.

If the arm of switch S_1 is moved across contacts 1, 2, and 3 the impedance of the coupling between tubes may be changed. When on contact 1 the impedance of the condenser C is substituted for the impedance of the series condensers RC and BC in the plate circuit of tube VT_1. When the arm of switch S_1 is moved to contact 2 the impedance of the section *c* is removed, thus reducing the coupling between tubes to that of the sections *a* and *b*. When the arm of switch S_1 is moved to contact 3 the section *a* is the only coupling between tubes VT_1 and VT_2. The condenser C acts simultaneously to reduce the impedance in both the output circuit of the tube VT_1 and the input circuit of tube VT_2 because the combination of condensers BC and RC maintains the cathode of tubes VT_1 and VT_2 at substantially the same signal current potential. However, if either condenser BC or RC has substantial impedance to signal currents a condenser C_1 and switch S_2 must be provided if it is desired to equalize the signal current impedance in the two circuits.

Referring to Fig. 3, I have modified the circuit arrangement of Fig. 1 to include a tube VT'_1. Herein I have shown the cathode of tube VT'_1 connected to the terminal G of the source SF through a bias resistance B*r*, the grid of this tube being returned to the point A' on the resistance R which is shunted to the cathode through a condenser C_1. The plate of tube VT'_1 and the grid of tube VT_1 are returned to a point A on the resistance R. For the tube VT'_1 I have also provided a hum bucking condenser HBC' connected between the cathode and the variable tap D' on the resistance R.

In Fig. 4 I have modified the circuit arrangement of Fig. 3 to utilize a screen-grid tube VT'_1. Herein I have returned the grid of tube VT'_1 to a point A' on a resistance R*r*, the resistance R*r* being of a very high value and functioning in conjunction with the condenser C_1 as a filter resistance similar to the function of the resistance FR_4 of Fig. 1. The screen grid of tube VT'_1, I have returned to the point E on the resistance R through a filter resistance FR_3 which is shunted to the cathode by means of a filter condenser FC_3. The plate of tube VT'_1 and the grid of tube VT, I have connected to the terminal P of the source SF through a radio frequency choke coil RC*h*, a coupling resistance CR_1 and resistances R_3, R_2 and R_1, the junction between the resistances CR_1 and R_3 being shunted to ground by the condenser C_5.

In the input circuit of tube VT_2 I have made the following change. The plate of tube VT_1 and the grid of tube VT_2 I have connected to the terminal P of the source SF through the resistances R_2 and R_1, and have also connected the plate of tube VT_1 and the grid of tube VT_2 to the center-tap of the filament of the tube VT_2 through a resistance CR. In other respects the connections are the same as in the circuit arrangement of Fig. 3.

In operating with this change of connection in the grid circuit of tube VT_2 I obtain a remarkable phenomenon which has the effect of substantially doubling the effective output ability (wattage) of the system over that normally understood to be possessed thereby. For example, in using a well-known commercial power amplifier tube at VT_2 rated to give about 1½ watts of undistorted output with specified rated energizing potentials, I find that with the same rated potentials and the special connections of Fig. 4, I obtain undistorted output energy at the rate of substantially 3 watts.

In Fig. 5 I have shown the feature of filtration of the screen grid circuit as applied to the tube VT_1 of the circuit arrangement of Fig. 1. Herein I have shown the screen grid of tube VT_1 energized through the filter resistance FR_3 from the potential developed across the resistance R. The value of the resistance FR_3 is dependent upon the point along the resistance R from which the potential is taken for the screen grid. The screen grid is shunted either to ground or to the cathode of the tube VT_1 by means of a condenser C, the only change noticeable in the operation required being a shifting of the point D on the resistance R' to which the hum bucking condenser HBC is returned.

In Fig. 6 I have shown a modification of the circuit arrangement of Fig. 5 wherein I have employed a grid filter comprising filter resistance FR_4 and filter condenser FC_4, a screen-grid filter comprising filter resistance FR_3 and condenser FC_3. I have further utilized the choking action of the speaker field winding SW in conjunction with the condenser RC to filter hum from the resistance R. I have found that the connection of the condenser C_4 from the junction between the resistances CR and R_1 and the cathode of tube VT_1 serves to adequately reduce the hum of the system to a value below audibility without the use of the hum bucking condenser HBC described with reference to the foregoing figures.

In Fig. 7 I have shown a peculiar utilization of a feature of the circuit arrangement of Fig. 5. If the by-pass condenser HBC of Fig. 5 is omitted there will develop a signal current potential across the stabilizing resistance SR so that the grid of tube VT_2 may be directly connected to the cathode of the tube VT_1, the plate thereof being connected to the terminal P of the source SF, the resistance SR serving as the coupling resistance between tubes VT_1 and VT_2.

In Fig. 8 I have shown the feature of the combination of resistances CR, R_2, R_1 and the condenser C_3 incorporated in a two tube direct coupled system. The effect of this combination in the output wattage of a two tube system as shown in this figure is even more noticeable than when utilized in the three tube system, the operation of which was described with reference to Fig. 4.

In Fig. 9 I have shown the circuit arrangement of Fig. 4 modified in such a manner that tube VT'_1 functions primarily as a radio frequency amplifier, the input for the system comprising a tunable transfer circuit T_1 energized from an Antenna A*nt*, through a volume control system comprising an antenna resistance and a condenser C_3. In this arrangement I have replaced the radio frequency choke coil RC*h* of Fig. 4 with a tunable circuit T_2 comprising an inductance L_2 and a variable condenser VC_2 connected in the manner shown, and have connected the condenser C_5 between the junction between the inductance L_2 and ground. In this arrangement the bias for the tube VT_1 is determined by the

proportioning of the resistances SR, CR, R_3, R_2, and R_1 as in the arrangement of Fig. 4. The signal input for tube VT_1 however is determined by the impedance of the tuned circuit T_2 to currents of signal frequency, the input circuit to the cathode of tube VT_1 being closed through a condenser C_6. The variable connection between the plate of tube VT'_1 and the inductance L_2 functions in the same manner as the variable tap on an auto-transformer to vary the coupling between the tubes VT'_1 and VT_1. Between the plate of tube VT_2 and the cathode I have connected a radio frequency by-pass condenser RFC to shunt radio frequency currents away from the output transformer OT. This condenser, while helpful, is not essential to the operation of the circuit arrangement illustrated in this figure.

In Fig. 10, I have shown a direct coupled tube system functioning as a radio frequency amplifier system and a direct coupled tube system functioning as a detector amplifier system connected in cascade and energized from a common source of fluctuating unidirectional current SF. Across the terminals P and G of the source SF I have connected the primary of the output transformer OT, the anode to cathode path of tube VT_2 and the resistance R. In shunt to the anode to cathode path of tube VT_2 I have connected two high resistances R_1 and R_2, and have energized the grid of tube VT_2 and the plate of tube VT_1 by connecting the same through the coupling resistance CR. The tube VT_1 is otherwise energized in the manner described with reference to the foregoing figures, the tunable input circuit T_1 thereof being provided with a filter system including filter resistance FR_4 and filter condenser FC_4 as previously described with reference to Fig. 6 hereof.

Across the terminals G and P of the source SF I have connected a potentiometer R' from which I have energized a four stage direct coupled tube system VT'_1, VT'_2, VT''_1, VT''_2 by connecting the cathode of tube VT'_1 to the terminal G of the source SF through a stabilizing resistance SR_1 which is shunted by a signal current condenser C_1, and connecting the cathodes of tubes VT'_2, VT''_1, VT''_2 and directly to the points G_2, G_3 and G_4 of the potentiometer R', each of these points being by-passed to ground by condensers BC_1, BC_2 and BC_3 respectively, and the remaining electrodes as follows: The grid of tube VT'_1 is connected through a tunable input circuit, such as a loop LP, to the point A_1 on the resistance R', the resultant voltages between the cathode of tube VT'_1 and the point A_1 on the resistance R' stabilizes the four tube direct coupled system in the same manner as the voltages between the cathode of tube VT_1 and the point A on the resistance R stabilize the two tube direct coupled system as has been described in detail with reference to Fig. 5 in my copending application hereinbefore referred to. The screen grids of tubes VT'_1, VT'_2, VT''_1 and VT''_2 are respectively connected to points B_1, B_2, B_3 and B_4 on the potentiometer R' of proper voltage with respect to the points G, G_2, G_3 and G_4. The plate of tube VT'_1 and the grid of tube VT'_2 are returned to the point A_2 on the potentiometer R' through the coupling resistance CR_1. The plate of tube VT'_2 and the grid of tube VT''_1 are returned to the point A_3 on the potentiometer R' through a coupling circuit including inductance L_2, condenser VC_2, resistance CR_2 and condenser C_6 as hereinbefore described with reference to Fig. 9. The plate of tube VT''_1 and the grid of tube VT''_2 are connected to the point A_4 on the potentiometer R'. The plate of tube VT''_2 is connected to the terminal P of the source SF through a plate resistance PR, and coupled to the grid of tube VT_1 through a coupling condenser CC.

The operation of this circuit arrangement is as follows: The input circuit LP selectively impresses signal currents voltages upon the grid of tube VT'_1.

The tube VT'_1 amplifies these signals and aperiodically impresses them on the grid circuit of tube VT'_2 by means of the coupling resistance CR_1. The tube VT'_2 further amplifies the signals and selectively impresses them on the grid circuit of tube VT''_1 through the tuned circuit T_2. The tube VT''_1 further amplifies these signals and aperiodically impresses them on the grid circuit of tube VT''_2 by means of the coupling resistance CR_3. The tube VT''_2 further amplifies the signals and develops signal current potentials across the resistance PR which potentials are resonantly abstracted from this resistance by the tuned circuit T_1 coupled thereto through the condenser CC. The tubes VT_1 and VT_2 then detect and amplify the amplified high frequency currents in the manner fully set forth in copending application of Sidney Y. White, Serial No. 318,754, filed July 29, 1929.

While I have illustrated and described my invention as embodied in certain specific circuit arrangements it is to be understood that various modifications thereof may be made without departing from the spirit of my invention as defined by the claims appended hereto.

Having thus described my invention, what I claim is:

1. In an electron tube system, the combination of a plurality of electron tubes direct coupled in cascade through a common impedance element and means for varying the effective value of said impedance with respect to signal currents while maintaining the value of said impedance constant with respect to direct currents flowing therethrough, said means consisting of a condenser variably connected between selected points on said impedance and the cathode of one of said tubes.

2. In an electron tube system, the combination of a plurality of electron tubes direct coupled in cascade through a common impedance element and means for varying the effective value of said impedance with respect to signal currents while maintaining the value of said impedance constant with respect to direct currents flowing therethrough, said means consisting of a condenser variably connected between selected points on said impedance and the cathode of the tube containing said impedance within its plate circuit.

3. In an electron tube system, the combination of a plurality of electron tubes direct coupled in cascade through a common impedance element and means for varying the effective value of said impedance with respect to signal currents while maintaining the value of said impedance constant with respect to direct currents flowing therethrough, said means consisting of a condenser variably connected between selected points on said impedance and the cathode of the tube containing said impedance within its grid circuit.

4. In an electron tube system, the combination of a plurality of electron tubes direct coupled in cascade through a common impedance element and means for varying the effective

value of said impedance with respect to signal currents while maintaining the value of said impedance constant with respect to direct currents flowing therethrough, said means consisting of condensers variably connected between selected points on said impedance and the cathodes of each of the tubes containing said impedance within their circuits.

5. In an electron tube system, the combination of a plurality of tubes direct coupled in cascade, a source of current for energizing the electrodes of said tubes, a common impedance element through which the plate-circuit of one tube and the grid circuit of another tube are energized and a high resistance element connected between the grid and cathode of said other tube.

6. In an electron tube system, the combination of a plurality of electron tubes direct coupled in cascade, the coupling element between two tubes comprising a plurality of energy transfer elements one of which has high impedance to high frequency currents and low impedance to low frequency currents and another of which has high but substantially like impedance for currents of both frequencies.

7. In an electron tube system, the combination of a plurality of electron tubes direct coupled in cascade, the coupling element between two tubes comprising a tunable circuit and a high impedance of substantially constant value to low frequency currents.

8. In an electron tube system, the combination of a plurality of electron tubes direct coupled in cascade, the coupling element between two tubes comprising a tunable circuit and a high impedance of substantially constant value to low frequency currents and means for shunting high frequency currents around said last mentioned impedance.

9. In an electron tube signal transfer system including a source of fluctuating unidirectional potential, means and connections for energizing tube electrodes of said system, and an electron discharge tube having the average potential difference between its cathode and control electrode differentially determined by two potential developing elements one of which is disposed for energization by discharge current of said same tube and the other of which is disposed for energization predominantly at least by discharge current of another tube of said system, the combination therewith of a condensive-resistive impedance having its resistive element arranged between said cathode and control electrode for lowering the potential of said control electrode under the influence of space charge current therethrough and having both its elements so arranged as to divert from said two potential developing means fluctuating components of said source.

10. In an electron tube signal transfer system including a source of fluctuating unidirectional potential, means and connections for energizing tube electrodes of said system, and a screen-grid electron discharge tube having the average potential difference between its cathode and control electrode differentially determined by two potential developing elements one of which is disposed for energization by discharge current of said same tube and the other of which is disposed for energization predominantly at least by discharge current of another tube of said system, the combination therewith of a resistive element in the screen-grid connection of said screen-grid tube, and a condenser disposed between said resistive element and a potential point in said two potential developing elements, whereby fluctuating components of said source are diverted from said screen grid and the potential of said screen grid is lowered under the influence of space current therethrough.

11. In an electric signal transfer system including two electron discharge tubes, a source of potential, and means for energizing tube electrodes of said system from said source, the combination of a potential developing means common to the cathode-anode and cathode-control electrode circuit of the one of said two tubes, and a connection between a point in said potential developing means and the control electrode of the other of said two tubes, whereby through said connection signal energy is transferred from said one tube to said other tube.

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