Sept. 29, 1953 R. B. BUCHNER 2,654,029

ELECTRON TUBE CIRCUIT

Filed May 23, 1950 2 Sheets-Sheet 1

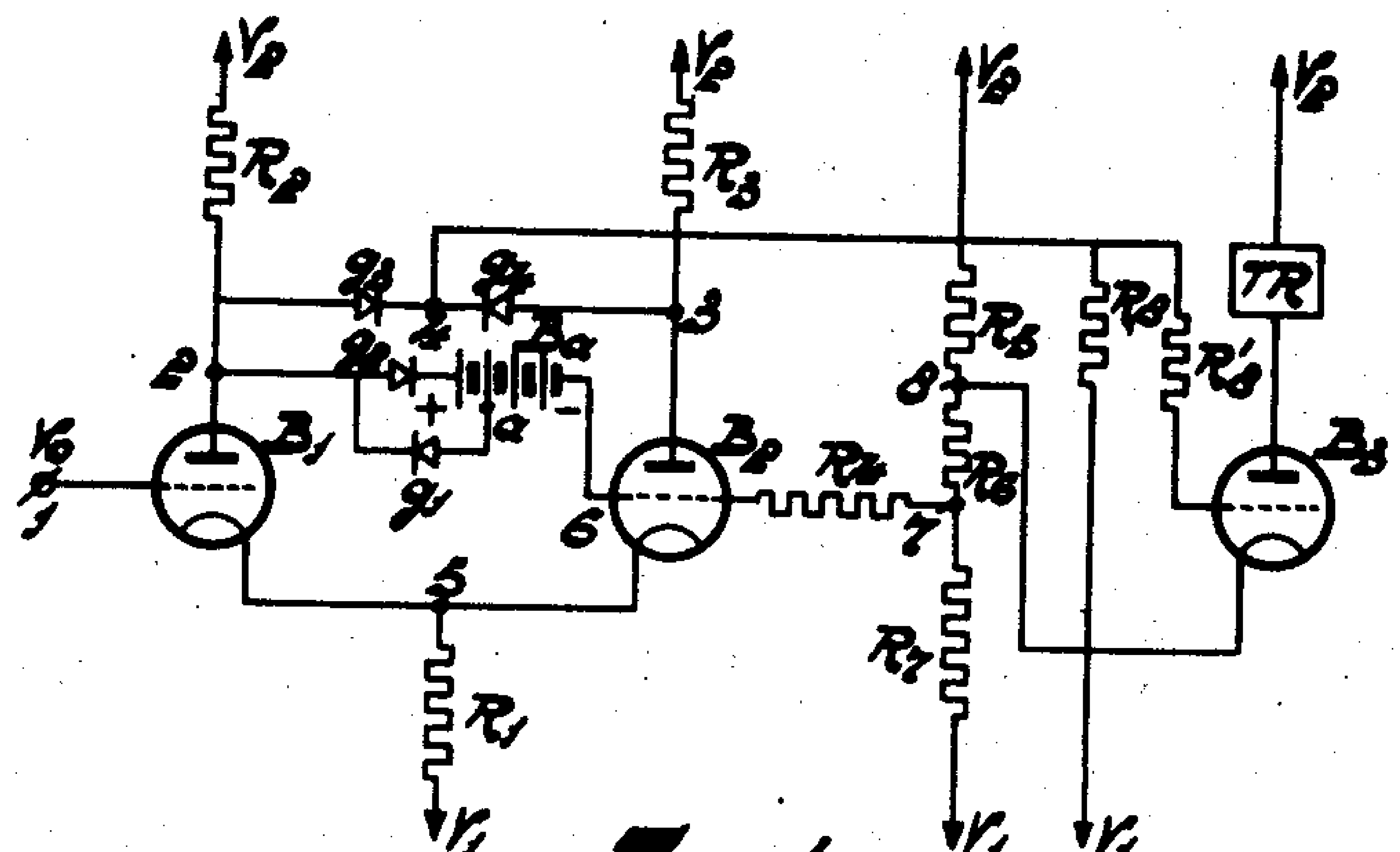

Fig. 1

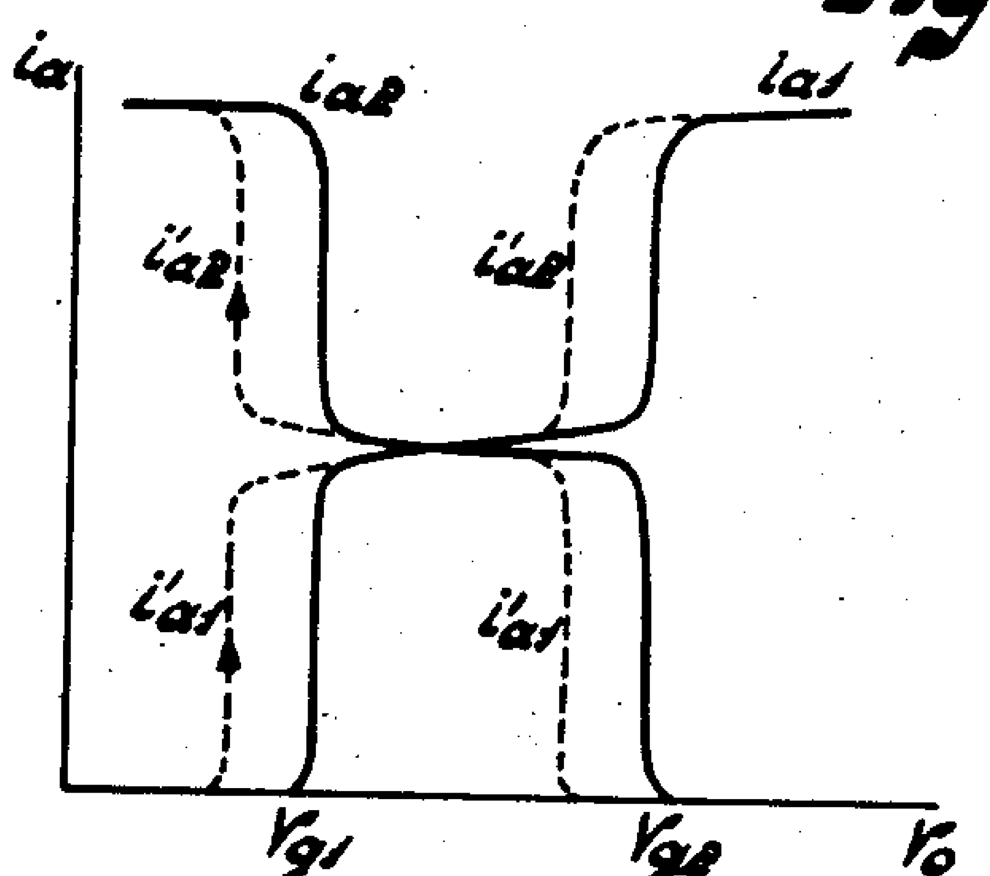

Fig. 2a

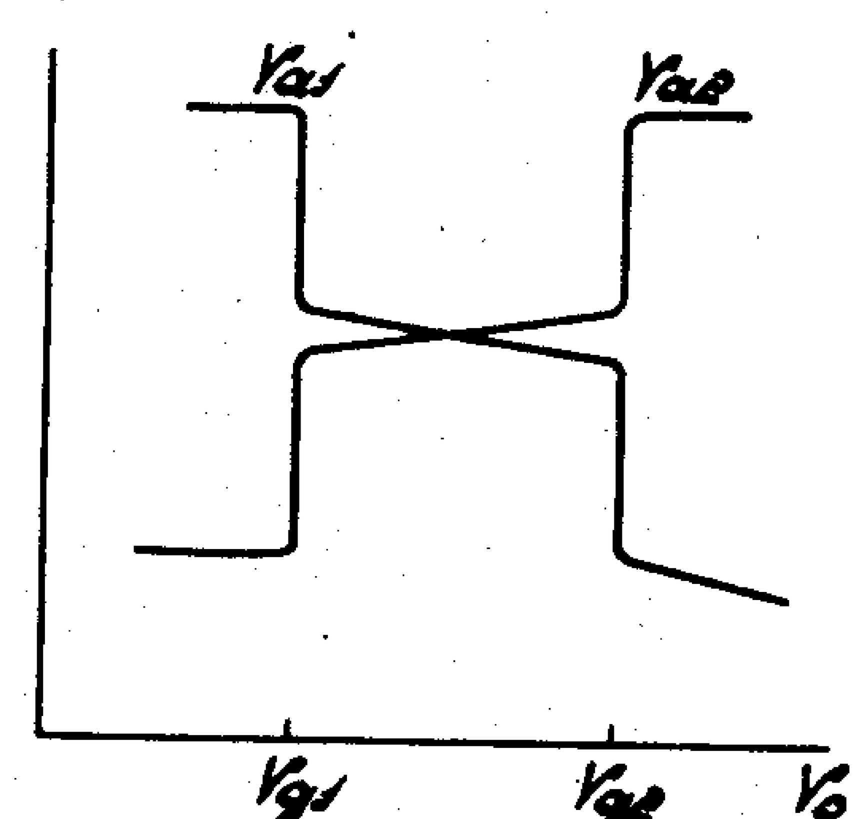

Fig. 2b

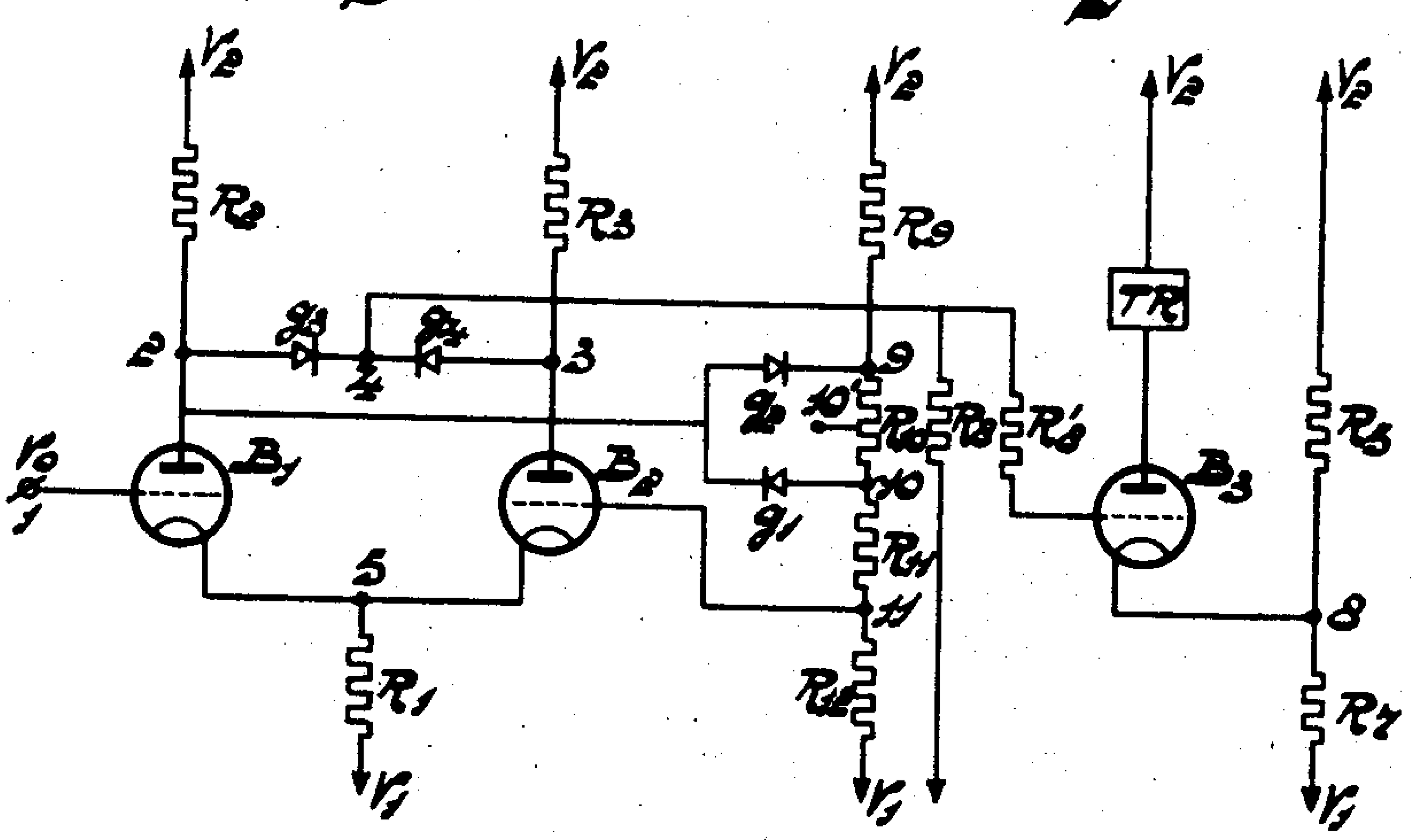

Fig. 3

INVENTOR.

ROBERT BERTOLD BUCHNER

BY Fred M Vogel

AGENT

Sept. 29, 1953 R. B. BUCHNER 2,654,029

ELECTRON TUBE CIRCUIT

Filed May 23, 1950 2 Sheets-Sheet 2

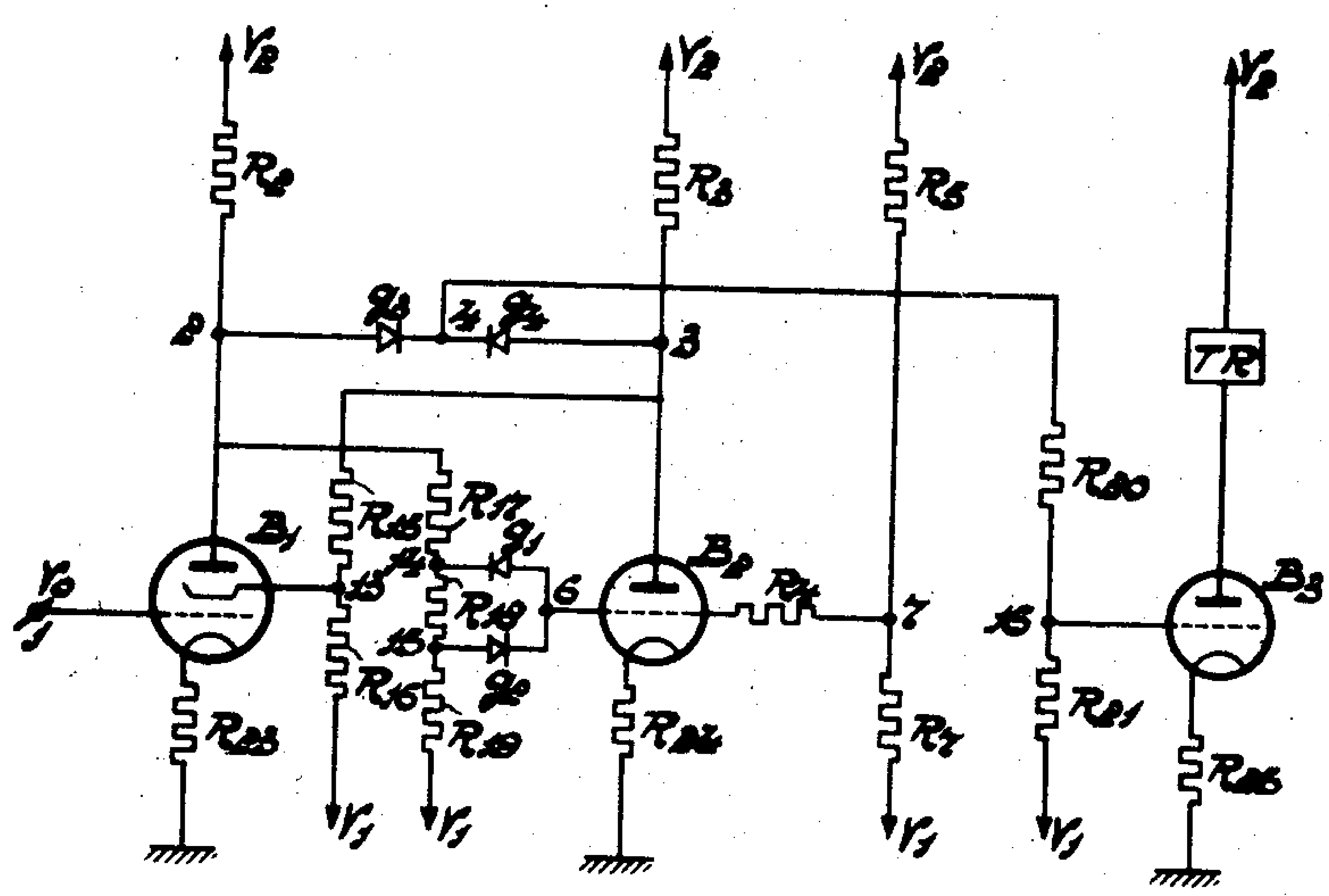

Fig. 4

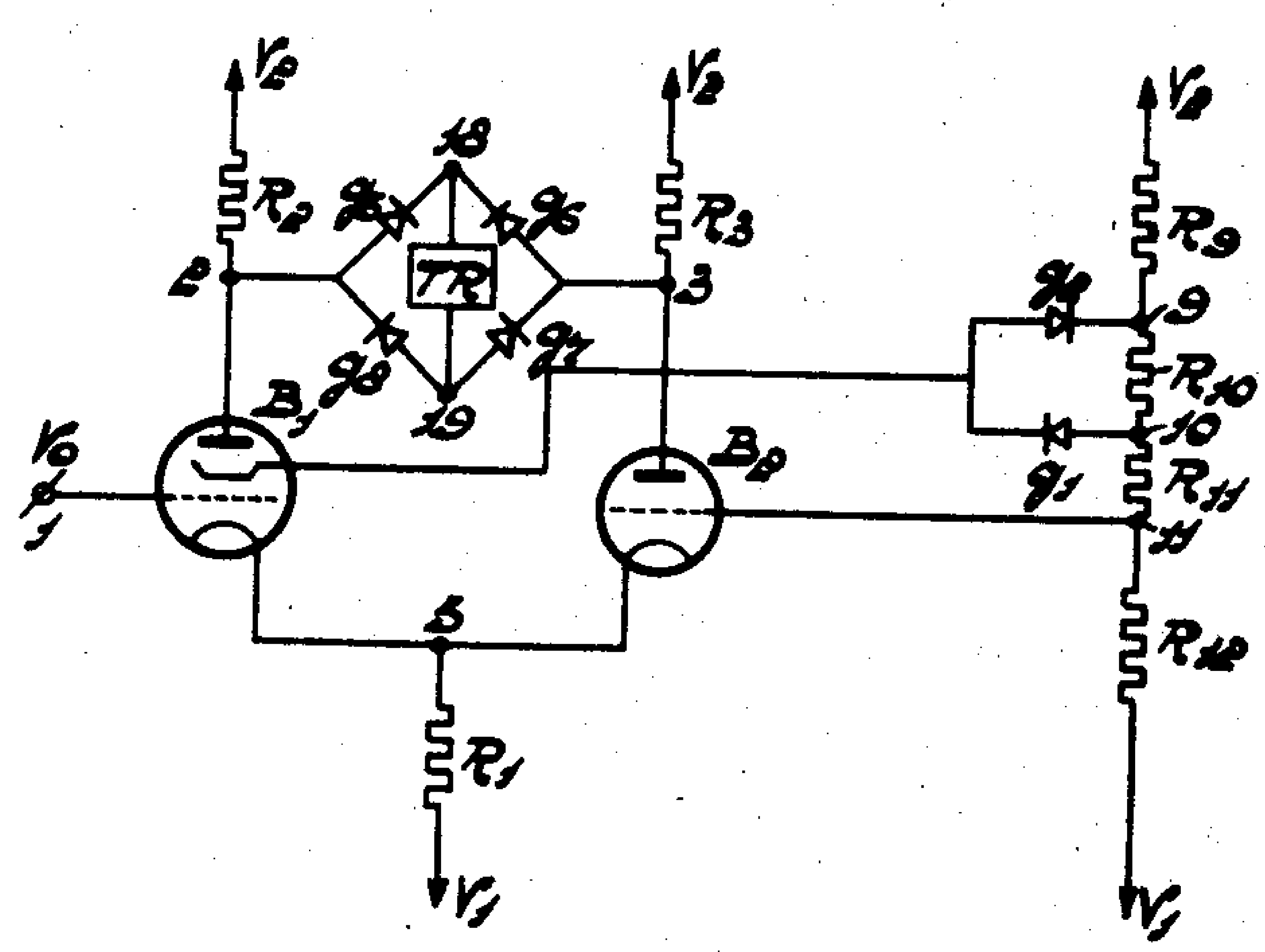

Fig. 5

INVENTOR.
ROBERT BERTOLD BUCHNER
BY [signature]
AGENT

Patented Sept. 29, 1953

2,654,029

UNITED STATES PATENT OFFICE

2,654,029

ELECTRON TUBE CIRCUIT

Robert Bertold Buchner, Hilversum, Netherlands, assignor to Hartford National Bank and Trust Company, Hartford, Conn., as trustee

Application May 23, 1950, Serial No. 163,615
In the Netherlands June 14, 1949

4 Claims. (Cl. 250—27)

1

This invention relates to electron-discharge tube circuit-arrangements.

In many cases, for example, in automatic telephone systems, echo-suppressor circuits, measuring circuits and control-circuits it is required to provide a device which permits the value of a direct voltage to be tested selectively to ascertain whether the tested voltage lies within or without a given voltage range, for example by the response of a relay when the voltage is between definite limiting values or non-response of the relay when the voltage exceeds the higher limiting value or is lower than the lower limiting value. It is desirable that the limiting values should be sharply defined, i. e. the output voltage or output current of the circuit should be subject to a considerable variation, if the test voltage, upon variation, passes a limit value, while furthermore the limit value should be constant if the voltage is varied either in an increasing or in a decreasing sense.

In the copending U. S. patent application, Serial No. 107,411, filed July 29, 1949, a circuit-arrangement is suggested for comparing two voltages, in which at two definite limiting values of the voltage difference a steep variation of the output-voltage or current is obtained by means of feedback. In the said circuit-arrangement, the voltages to be compared are supplied to control-grids of two discharge tubes, the common cathode circuit of which comprises a third tube. A control-electrode of a fourth tube is coupled, through a rectifier, to the anode circuits of the first two tubes, and the fourth tube is coupled to the third tube such that feed-back takes place. If the input voltage difference is lower than a definite threshold value, the rectifiers are cut off and the feed-back factor is zero. If the absolute value of the input voltage difference exceeds a threshold value, one of the rectifiers becomes conductive and the feed-back factor is approximately unity, so that a very small variation of one of the input voltages produces a considerable variation of the current passing through the fourth tube.

The object of the present invention is to provide a simple circuit-arrangement which comprises fewer tubes than the aforesaid arrangement. It utilizes a circuit-arrangement of a kind known per se, in which a control-voltage is supplied to a control-electrode of a first discharge tube, one output circuit of which is aperiodically coupled to a control-electrode of a second discharge tube, and one output circuit of the second tube is aperiodically coupled to an input circuit of the first tube in such manner as to obtain

2

positive feed-back. Such a circuit-arrangement is sometimes referred to as a "trigger circuit." A trigger circuit may, for example, be arranged in such manner that a control-electrode of each tube is coupled, through a battery or through a potentiometer circuit-arrangement, to a point of an output circuit, for example an anode circuit of a screen-grid circuit of the other tube. Use may also be made of a circuit, in which the cathode circuits of the tubes have a common resistance and only the control-electrode of the first tube is coupled to an output circuit of the other tube.

It is known to choose the elements of such a circuit such that the feed-back factor is substantially unity. However, these known circuits have only one limiting value.

According to the invention, a circuit-arrangement in which a control voltage is supplied to a control electrode of a first discharge tube of which an output circuit is coupled aperiodically to a control-electrode of a second discharge tube and an output circuit of the second tube is coupled aperiodically to an input circuit of the first discharge tube such that positive feed-back occurs, is characterized in that the coupling circuit between the output circuit of the first tube and the control-electrode of the second tube comprises a parallel-connection of two branches, each of which comprises a rectifier, the rectifiers being conductive in opposite senses and having different biassing voltages such that the first rectifier is conductive when the control-voltage exceeds a definite first limiting value and the second rectifier is conductive when the control-voltage is lower than a definite second limiting value which is lower than the first limiting value, the feed-back factor being substantially unity, if one of the rectifiers and the two tubes are conductive.

The feed-back factor is zero or at least very low when the two rectifiers are cut off, i. e. if the voltage to be tested has a value between the two limiting values.

In one embodiment of the circuit-arrangement, a potentiometer is connected between two points of constant potential and the series-connection of the two rectifiers is connected between two points of the said potentiometer, the junction point of the rectifiers being connected to a point of the output circuit of the first discharge tube and the control-electrode of the second tube being connected to a further point of the potentiometer.

In a further embodiment, a potentiometer, part of which is shunted by the series-connection of the rectifiers is connected between a point of the output circuit of the first discharge tube and a point of constant potential. The junction point of the rectifiers is connected to the control-electrode of the second tube, and the control-electrode is furthermore connected, through at least one resistance, to a point of constant potential.

The output voltage is preferably taken from a point coupled to a point of an output circuit of each of the tubes through a rectifier, the rectifiers being so arranged that said point invariably follows either the higher or the lower potential of the points of the output circuits of the tubes.

In order that the invention may be more clearly understood and readily carried into effect, it will now be described more fully with reference to the accompanying diagrammatic drawings, given by way of example, in which:

Figs. 1, 3, 4 and 5 each show an embodiment of the circuit-arrangement according to the invention, and

Figs. 2*a* and 2*b* are diagrams by means of which the operation of the circuit-arrangements will be explained.

In the circuit-arrangement shown in Fig. 1, a voltage V_0 to be tested is supplied by way of a terminal to the control-grid of a tube B_1. The cathode circuits of the tube B_1 and a tube B_2 comprises a common resistance R_1. The anodes of these tubes are fed through resistances R_2 and R_3, respectively, from a voltage source V_2.

The control-grid of tube B_2 is connected, through the series-combination of a rectifier g_2 and a battery B_a, to a point **2** of the anode circuit of tube B_1. A rectifier g_1 is connected between point **2** and a tapping on battery B_a. The control-grid of B_2 is furthermore connected through a resistance R_4 to a point **7** of a potentiometer $R_5R_6R_7$ connected between the voltage sources V_1 and V_2.

The control-grid of an auxiliary tube B_3 is coupled through a leakage resistance R^1_8 and rectifiers g_3 and g_4 to the anodes of tubes B_1 and B_2. Leakage resistances R^1_8 prevent the control-grid of tube B_3 from assuming a high positive potential relative to its cathode. The rectifiers are arranged such that the control-grid assumes the higher of the potentials of the point **2** and a point **3** of the anode circuit of tube B_2. Owing to the presence of the leakage resistance R_8 between point **4**, intermediate the rectifiers **93** and **94**, and the voltage source V_1, at least one of the rectifiers is conductive. The cathode of tube B_3 is connected to a point **8** of the potentiometer $R_5R_6R_7$. The resistances R_5, R_6 and R_7 are chosen such that the potentials of points **7** and **8** are only slightly affected by the emission-current of tube B_3. The anode circuit of B_3 includes the winding of a test relay TR.

This circuit-arrangement operates as follows. Tube B_1 is cut off if a comparatively low test voltage V_0 is supplied to its control-grid, the anode voltage at point **2** then being equal to V_2. The potential of point **7** is lower than the potential V_2 less the voltage of battery B_a. The rectifier g_2 is then conductive, so that the control-grid of tube B_2 has a comparatively high potential and tube B_2 is conductive. Consequently, the potential of the control-grid of tube B_3 has a comparatively high value, so that relay TR is energized.

If the potential of the control-grid of tube B_1 is caused to increase, tube B_1 becomes conductive at a definite limiting voltage V_{g1}, the voltage of point **2** drops and consequently also the potential of the control-grid of tube B_2 drops. Since the potential of the control-grid of tube B_2 varies in an absolute sense more than the potential of point **1**, the current flowing through tube B_2 decreases more than the current passing through tube B_1 increases, so that the voltage drop across the cathode resistance R_1 **decreases.**

The voltage across resistance R_1 is operative in the grid circuit of tube B_1 and in such sense that the variation of the control-grid potential of tube B_1 is supported, so that a feed-back effect is obtained. The variation of the anode currents of tubes B_1 and B_2 is shown in Figs. 2*a* by the curves ia_1 and ia_2 as functions of the input voltage V_0.

Fig. 2*b* shows the variation of the anode voltages V_{a1} and V_{a2} as functions of the input voltage V_0. By a suitable choice of the circuit elements, the feed-back factor is unity so that an extremely small variation of the input voltage V_0 at the threshold value V_{g1} produces a considerable variation of the current ia_1 passing through tube B_1.

The current passing through tube B_1 increases rapidly until the potential of point **2**, less the voltage of battery B_a, is equal to the potential of point **7**. Owing to the potential drop of point **4**, the tube B_3 is cut off and the relay TR is de-energized.

The process is completely reversible, if the feed-back factor is equal to or smaller than unity, i. e., in this case, each value of the voltage V_0 is associated with only one value of ia_1 or ia_2. However, if the feed-back factor exceeds unity, the currents vary with an increase of V_0 according to the full-line curve ia_1 and ia_2 and, with a decrease of V_0, according to the broken-line curve ia^1_1 and ia^1_2. In this event, consequently, the threshold value is not constant.

With a further increase of voltage V_0, rectifier g_2 is cut off. The control-grid of tube B_2 is no longer coupled to the anode of tube B_1 and assumes the constant potential of point 7. The current ia_1 subsequently increases comparatively slowly. Owing to the increase in voltage drop across resistance R_1, the effective voltage between the grid and the cathode of tube B_2, and consequently also the current ia_2 decreases. If the resistance R_1 has a high value, the slope of the variation of ia_1 as a function of V_0 is, in this interval, approximately equal to half the mutual conductance of each of the tubes B_1 and B_2.

As soon as voltage V_0 has increased to the value V_{g2}, at which the potential of point 2, less the voltage between the taping *a* and the negative terminal of the battery, is equal to the potential of point **7**, rectifier g_1 becomes conductive and the feed-back factor is again unity. With a very small increase of voltage V_0 the action is similar to that at the limiting value V_{g1} and the voltage at the control-grid of tube B_2 drops to such an extent that tube B_2 is cut off and the anode current of tube B_1 increases considerably.

The control-grid of tube B_3 follows the potential of point **3** and the potential increases very rapidly. Tube B_3 again becomes conductive and relay TR is energized. The current ia_1 increases very slowly, owing to the high resistance R_1 in the cathode circuit of tube B_1. The value of resistance R_1 is preferably high so that the control-grid of tube B_1 does not carry grid-current at the highest voltage V_0 to be tested and the input resistance of the circuit is substantially infinitely high.

The difference between the limiting values V_{g1} and V_{g2} i. e. the limit width of the arrangement may be varied by means of the tapping a of battery B_a.

In the arrangement described, the relay TR is only energized, if voltage V_0 is lower than V_{g1} or exceeds V_{g2}, and the relay is not energized, if V_0 lies between the limiting values. The limiting values are very sharply defined. It is obvious that if the rectifiers g_3 and g_4 are connected in opposite senses and the leakage resistance R_8 is connected to voltage source V_2 instead of to voltage source V_1, point **4** will follow the lower of the potentials of points **2** and **3**. In this variant, the tube B_3 is conductive and relay TR energized only, if V_0 lies in the range between the limiting values V_{g1} and V_{g2}.

The use of the battery B_a as a coupling element involves various practical disadvantages. The battery has a fluctuating potential and every test circuit requires a separate battery. These disadvantages are avoided in the circuits shown in Figs. 3, 4 and 5.

The circuit shown in Fig. 3 resembles that of Fig. 1 and corresponding elements bear the same references. However, the manner in which the control-grid of tube B_2 is coupled to the anode circuit of tube B_1 is different.

The control-grid of tube B_2 is connected to a point **11** of a potentiometer R_9, R_{10}, R_{11}, R_{12} connected between voltage sources V_1 and V_2. The resistance R_{10} is shunted by the series-connection of rectifiers g_1 and g_2 and the anode of tube B_1 is connected to the junction point of the rectifiers.

Rectifier g_2 is conductive when tube B_1 is cut off, hence when voltage V_0 has a comparatively low value. Upon an increase of voltage V_0 to the alue V_{g1}, B_1 becomes conductive and the potential of the point **2** and a point **9** of the potentiometer drops, so that the potential of the control-grid of tube B_2 also decreases. The feed-back factor is now substantially unity and the anode current ia_1 varies extremely steeply as a function of voltage V_0, similarly as in the circuit shown in Fig. 1, until the potential of point **2** has decreased to such an extent that rectifier g_2 is cut off. Rectifiers g_1 and g_2 are thus both cut off and the control-grid of tube B_2 assumes a constant potential which is determined by the ratio in which potentiometer R_9, R_{10}, R_{11} and R_{12} is divided by the point **11**. The anode currents ia_1 and ia_2 then vary comparatively slowly. Upon an increase of voltage V_0 to the value V_{g2} the potential of point **2** has decreased to a value equal to the potential of point **10**, provided the rectifiers g_1 and g_2 are both cut off. Upon a further increase of voltage V_0, rectifier g_1 becomes conductive, due to which the potential of point **10** follows that of point **2**.

The feed-back factor is now again substantially unity. If rectifier g_1 is conductive, the feed-back factor is naturally not exactly equal to that when rectifier g_2 is conductive. If, however, the value of resistance R_{10} is low with respect to the sum of resistances R_{11}, R_{12} the difference is practically negligible.

In the device shown in Fig. 4, use is made of a trigger circuit in which the control-electrode of each of the tubes B_1 and B_2 are coupled to an output circuit of the other tube.

The screen-grid of tube B_1 is connected to a tapping **13** of a potentiometer $R_{15}R_{16}$ connected between the anode of tube B_1 and the voltage source V_1.

Between the anode of tube B_1 and the source V_1 is connected a potentiometer $R_{17}R_{18}R_{19}$, of which resistance R_{18} is shunted by the series-connection of rectifiers g_1 and g_2. The control-grid of tube B_2 is connected to the junction point **6** of these rectifiers and is furthermore connected through resistance R_4 to point **7** of the potentiometer R_6R_7 connected between the sources V_1 and V_2. The cathode leads of the tubes B_1 and B_2 comprise resistances R_{23} and R_{24}, respectively, which may sometimes be dispensed with. The anodes are fed through resistances R_2 and R_3, respectively. The test voltage V_0 is supplied to the control-grid of tube B_1. Similarly to the circuits shown in Figs. 1 and 3, the output voltage is taken from point **4** which is coupled, through rectifiers g_3 and g_4, to the anodes of tubes B_1 and B_2.

The control-grid of the auxiliary tube B_3, the anode circuit of which comprises the relay TR, is connected to point **16** of a potentiometer $R_{20}R_{21}$ connected between point **4** and source V_1.

The cathode lead of tube B_3 comprises a resistance R_{25}. At a comparatively high value of potential V_0, tube B_1 is cut off and points **2** and **4** have a potential substantially equal to source V_2. Tube B_3 is then conducting, relay TR is energized, and point **15** has a potential which exceeds the constant potential of point **7**.

In this case, the rectifier g_2 is conductive and the control-grid of tube B_2 has a potential at which the tube is conductive. The potential of the anode of tube B_3 and consequently of the screen-grid of tube B_1 is comparatively high and the rectifier g_4 is cut off. If the voltage V_0 is caused to increase, tube B_1 becomes conductive at a definite limiting voltage V_{g1}. Due to this, the potential of the control-grid of tube B_2 decreases, so that the potentials of the anode of tube B_2 and of the screen-grid of tube B_1 increase. The increase of the voltage V_0 is thus supported by the increase in screen-grid potential of tube B_1. The elements are such that the feed-back factor is practically unity, so that in the conductive state of the two tubes B_1 and B_2 and of the rectifier g_1 or g_2, a very small variation of voltage V_0 produces a great variation of the emission current of tube B_1.

Owing to the sharp drop of potential of point **2**, tube B_3 is cut off and relay TR is de-energized.

Upon a further extremely small increase of V_0, the voltage at point **15** drops below the potential of point **7** and the rectifier g_2 becomes conductive. In the next following voltage range of voltage V_0, the control-grid of tube B_2 assumes the constant value of point **7**. Consequently, the current flowing through the tube B_2 remains constant, as does the screen-grid potential of tube B_1.

The emission-current of tube B_1 slowly increases with an increase of voltage V_0, the slope being primarily determined by resistance R_{23} in the cathode lead. If voltage V_0 has increased to the value V_{g1}, the potential of point **14** has dropped to the voltage of point **7** and rectifier g_1 becomes conductive.

Upon a further increase of voltage V_0, the potential of point **6** drops below the potential of point **7**, so that the screen-grid potential of tube B_1 increases. The feed-back factor is now again unity and the anode voltage of tube B_2 increases steeply with an increase of voltage V_0, so that, since rectifier g_4 is now conductive and rectifier g_3 is cut off, tube B_3 becomes conductive and relay TR is energized.

Consequently, relay TR only becomes de-energized if the test voltage V_0 has a value between the limiting values V_{g1} and V_{g2}. The voltage range may be varied by varying the resistance

R_{18}. It is desirable that the value of this resistance should be low with respect to that of resistance R_{19}, in order to ensure that the feed-back factor has the same value, i. e. unity at the limiting values V_{g1} and V_{g2}.

The circuit may be varied in several ways. Thus, for instance, the method of coupling the control-grid of tube B_2 and the output circuit of tube B_1, as shown in Fig. 4, may also be used for the trigger circuit shown in Fig. 3, in which, consequently, the coupling between the output current of tube B_2 and the input control-circuit of tube B_1 is established by the common resistance R_1 in the cathode leads. Conversely, the method of coupling the control-grid of tube B_2 and the anode circuit of tube B_1 shown in Fig. 3 may be used for the trigger circuit shown in Fig. 4.

The output voltage of point **4** need not be used to control a relay, but may alternatively be supplied to a suitable indicator, for example a Braun tube. Furthermore, a test relay may be connected between output circuits of tubes B_1 and B_2, and the auxiliary tube B_3 omitted. Such a circuit is shown in Fig. 5, in which the trigger circuit corresponds to that shown in Fig. 3.

However, instead of the anode, the screen-grid of tube B_1 is connected to the common point of rectifiers g_1 and g_2. A rectifying bridge built up of four rectifiers g_5, g_6, g_7 and g_8 is connected between points **2** and **3**. The output diagonal of this bridge comprises the test relay TR between points **18** and **19**. This circuit operates similarly to that shown in Fig. 3.

At a low potential V_0, the tube B_1 is cut off, tube B_2 is conductive and relay TR is energized. If voltage V_0 increases and exceeds the limiting value V_{g1}, tube B_1 becomes conductive and the current through tube B_2 decreases. In the voltage range between the values V_{g1} and V_{g2}, the anode currents of tubes B_1 and B_2 differ comparatively slightly, so that relay TR is de-energized. If the voltage V_0 increases and exceeds the value V_{g2}, the tube B_2 is cut off and relay TR is energized.

Similarly to the circuits shown in Figs. 1, 3 and 4, the process is reversible if the feed-back factor is equal to or smaller than unity.

The rectifier-bridge g_5 to g_8 serves to prevent magnetic reversal of the relay TR and the relay TR from becoming temporarily de-energized if, in testing different voltages, voltages lying on different sides of the threshold range are successively supplied to the input terminal **1**.

It will be obvious that the circuits described can be used not only for testing voltages but also with advantage for other purposes, for example, for deriving pulses with constant amplitudes from an alternating voltage.

What I claim is:

1. A circuit-arrangement in which a control-voltage is supplied to a control-electrode of a first discharge tube having an output circuit coupled aperiodically to a control-electrode of a second discharge tube an output circuit of the second tube being coupled aperiodically to an input circuit of the first tube such that positive feed-back occurs, the coupling circuit between the output circuit of the first tube and the control-electrode of the second tube comprising a parallel-combination of two branches, each of which comprises a rectifier, the rectifiers being conductive in opposite senses and having different biassing voltages such that the first rectifier is conductive when the control-voltage exceeds a definite first limiting value and the second rectifier is conductive when the control-voltage is lower than a definite second limiting value lower than the first limiting value, the feed-back factor being substantially unity if one of the rectifiers and both tubes are conductive.

2. A circuit-arrangement as claimed in claim 1, characterized in that a voltage divider is connected between a point of the output circuit of the first discharge tube and a point of constant potential, part of which voltage divider is shunted by the series connection of two rectifiers, and the junction point of the rectifiers is connected to the control-electrode of the second tube, this control-electrode furthermore being connected, through at least one resistance, to a point of constant potential.

3. A circuit-arrangement, as set forth in claim 1, wherein said parallel combination of two branches comprises a voltage divider connected between two points of potential, the rectifier of one branch being connected between a first tap on said divider and the output circuit of said first tube, the rectifier of the other branch being connected in opposing polarity relative to the first rectifier between a second tap on said divider and the output circuit of said first tube, the control electrode of said second tube being connected to a third tap on said divider.

4. A circuit-arrangement, as set forth in claim 1, further including a pair of rectifying elements connected in series opposition between a point in the output circuit of the first tube and a corresponding point in the output circuit of the second tube, and means connected to the junction of said elements to derive a control voltage therefrom.

ROBERT BERTOLD BUCHNER.

No references cited.