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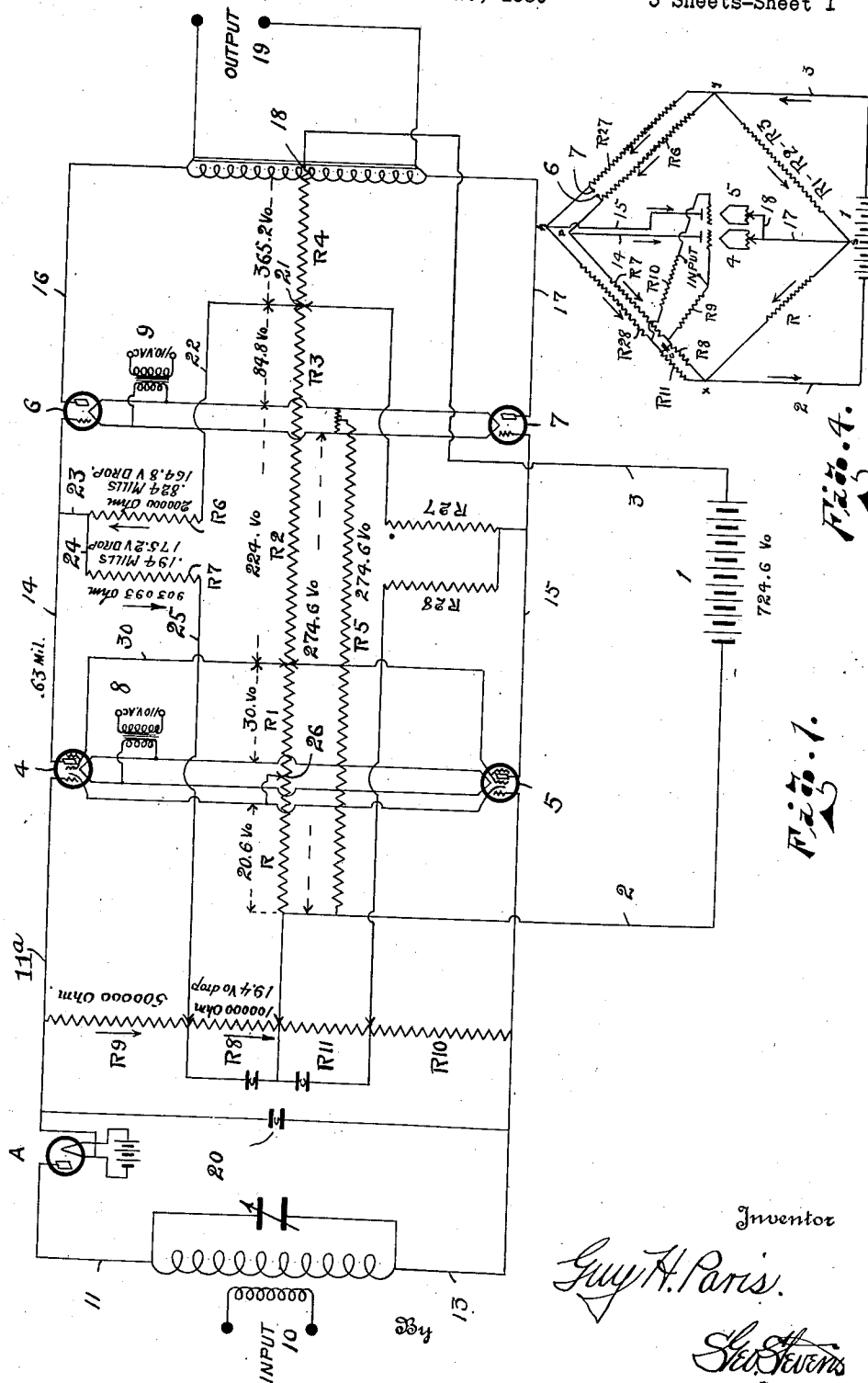
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2,065,610

AMPLIFIER

Filed Feb. 20, 1930

3 Sheets-Sheet 1



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3 Sheets-Sheet 2

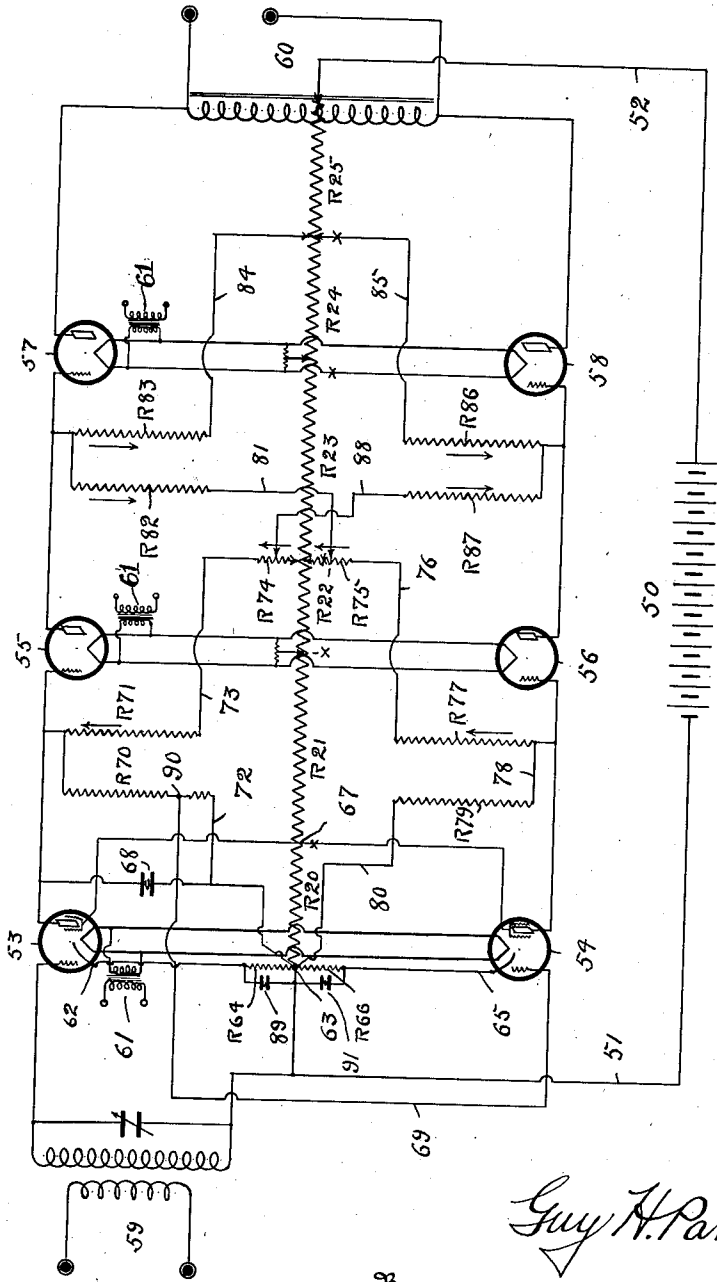


Fig. 2.

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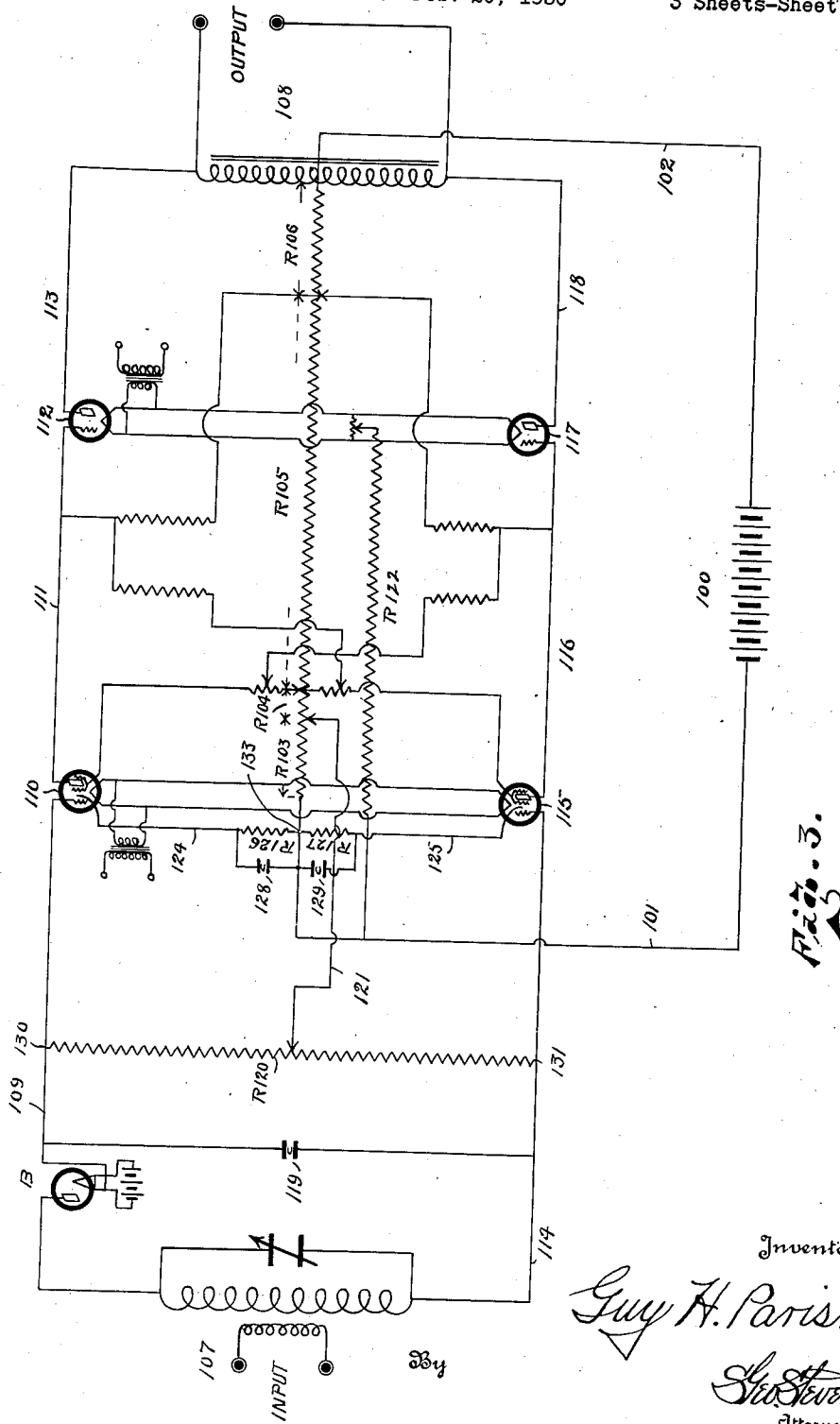
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AMPLIFIER

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3 Sheets-Sheet 3



UNITED STATES PATENT OFFICE

2,065,610

AMPLIFIER

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Application February 20, 1930, Serial No. 429,960

15 Claims. (Cl. 179—171)

This invention relates to circuits for radio receiving and thermionic amplifying apparatus.

The principal object of the invention is to provide a method of connecting elements of thermionic vacuum tubes to different points or voltage levels along a resistor or battery to obtain the proper operating voltages, such that the grid of each tube is at the same electrical potential as the plate of the preceding tube, and at the same time the plate of each tube is at the proper operating potential with respect to its filament, and the grid of each tube is at the proper potential with respect to its filament, thus permitting the plate of one tube to be connected direct to the grid of the following tube by a wire. This eliminates the use of transformers or condensers customarily used as a coupling means between tubes; and also eliminates bucking voltages sometimes used in circuits where transformers or condensers are eliminated.

The invention particularly refers to a push pull amplifier, although the principle can be equally well applied to a single sided circuit with correspondingly equal advantages, and it is not intended to limit the invention to a push pull amplifier.

Another object of the invention is to provide a method of substantially blocking out or attenuating direct current voltage or slow voltage changes across the input of the amplifier, preventing these direct current voltages or slow voltage changes from progressing through the amplifier and being amplified through each succeeding stage, and at the same time permitting the comparatively fast varying signal voltages to progress through the amplifier and be amplified through each stage, thus providing a practical method whereby the detected signal can be applied direct to the input of an audio frequency amplifier eliminating the necessity of using condensers or transformers customarily used to prevent the direct current voltage component in the output of a detector or other input source from being impressed on the grids and progressing through the amplifier.

Another object of the invention is to permit a regenerative feed back to be applied in the amplifier without the necessity of using reactances to accomplish this purpose.

A construction in accordance with the principal object of the invention results in its being possible to eliminate all reactance coupling otherwise necessary, which forms another object of the invention.

With the foregoing and other equally impor-

tant objects and advantages in view, the invention resides in the certain new and useful combination, construction, and arrangement of parts and circuits as will be hereinafter more fully described, set forth in the appended claims, and illustrated in the accompanying drawings, wherein:

Figure 1 is a wiring diagram illustrating a two element rectifier coupled to a push pull circuit wherein the plate of one tube is connected by a wire to the grid of the succeeding tube:

Figure 2 is a diagrammatic illustration of a method of coupling, by means of a phase inverter tube, a grid bias detector to a push pull circuit wherein the plate of one tube is connected by a wire to the grid of the succeeding tube; also showing a method of obtaining regenerative feed back: both obtained without the use of the customary reactances:

Figure 3 shows diagrammatically a method of coupling a two element rectifier to a push pull circuit wherein the plate of one tube is connected by a wire to the grid of the succeeding tube, and showing a method of obtaining regenerative feed back to the screen grid of the four element tube.

Figure 4 is a diagrammatic representation of that portion of Figure 1 which acts to permit the rectified output of a two element detector to be applied direct to the push pull circuit by stabilizing the circuit against slow voltage changes.

The fundamental circuits illustrated in the several views are identical, but referring particularly to Figure 1, the voltage supply source is indicated at 1 and may be a battery or any suitable rectifier capable of supplying 724.6 volts which is the proper voltage for the circuits herein described. The voltage source 1 is connected by the wires 2 and 3 to the plate voltage supply resistor R, R1, R2, R3, and R4, across which any voltage may be obtained, up to an amount equal to the voltage of the supply source, and to the center tap of the output audio frequency choke coil 18.

Two screen grid 224 tubes 4 and 5 and two 250 tubes 6 and 7 are used in the circuit herein described, and the filaments of the tubes are heated by alternating current, the transformers being indicated at 8 and 9.

The signal voltage supply or input is indicated at 10, passing through the customary tuned inductive resistance, and being connected as by the wire 11 to the plate of the tube A, and from the cathode of the tube A to the grid of tube 4 by the wire 11a, and directly to the grid of the tube 5 by the wire 13. The plate of tube 4 is connected

directly by the wire 14 to the grid of tube 6, and likewise the plate of the tube 5 is directly connected by wire 15 to the grid of the tube 7; the plates of the tubes 6 and 7 being connected by wires 16 and 17 to the center tapped audio frequency choke coil 18, across which the output 19 is taken.

The resistor R5 is attached to the wire 2 at one end and at the opposite end to the filament of the 250 tubes 6 and 7. This resistor R5 is permanently adjusted to the proper value so that the plate current flowing in the 250 tubes will cause a drop of just 274.6 volts across R5, thus leaving 450 volts across the filament and plate of the 250 tubes, which is the proper plate voltage for same.

At 20 is illustrated a small condenser connected to the wires 11a and 13 for bypassing the high frequency carrier currents in the output of the rectifier A.

R8, R9, R10, and R11 represent a resistance between the wires 11a and 13 through which the rectified signal currents are forced to flow, thus building up a voltage across this resistance which will be applied to the grids of tubes 4 and 5.

The resistance R6 is connected by the wire 22 to the point 21 at the junction of resistors R3 and R4 of the plate voltage supply resistor, which point is 365.2 volts negative with respect to the positive side of the voltage supply, and connected by the wire 23 to the wire 14.

The resistance R7 is connected by the wire 24 to the wire 23, and by the wire 25 to the junction of the resistors R8 and R9.

The resistance R6 forms what is commonly known as the plate or output impedance of tube 4 and across which the signal voltage amplified by the tube 4 appears; this resistance R6 being common to both the plate circuit of tube 4 and grid circuit of tube 6. Resistance R7 represents a high resistance used in a novel manner and connected as previously described for the purpose of providing an additional path whereby both steady and varying currents in R6 can flow and across which progressively decreasing potentials may be had, finally decreasing to a level with or lower than the potential of the grid or other element if desired, in which case the currents can be caused to flow through a resistor common to the grid or other circuit before returning to the battery, or voltage source. By this means any desired action may be obtained for instance direct current voltages impressed on the grids may be canceled out, or a regenerative action may be obtained by utilizing such potentials to assist voltages impressed on the grids. These actions are hereinafter more fully explained.

The combination of plate current as indicated in Figure 1 flowing in the 224 tube 4 and the current through resistances R7 and R8 in series, flowing in R6, will cause a voltage drop across R6 of 164.8 volts. As the grids of the 250 tubes should be operated at 80 volts negative with respect to their filaments, it is necessary to connect the lower end of R6 by wire 22 to a point having a potential of 164.8 minus 80 volts, or 84.8 volts more positive than the potential level of the filaments of the 250 tubes.

If the cathode of the tube 4 is connected at the point indicated at 26 there will be an impressed plate voltage of 338.8 volts, and subtracting the drop across resistor R6, an effective voltage of 174 volts is impressed on the plate of the 224 tube, which is the amount indicated as proper by curve taken of the tube.

Thus the filament and plate returns of the various tubes used are connected to points along a voltage supply resistor, or battery if desired, at such points that the plate voltages are correct, and so that the grid end of plate resistor (R6 in this case) is negative with respect to the filament of the 250 tube by an amount that is proper for that tube or other proper values where other tubes are used.

The screen grid voltage is supplied by the wire 30 to the tube 4 by virtue of the drop across resistor R1.

Grid voltage to the tube 4 is applied as follows: A voltage of minus 20.6 volts is impressed between filament and grid of tube by the drop across R. This is too great a negative potential for this tube so the drop across resistor R8 due to currents which flow in resistors R6, R7, and R3 in series is used to oppose this excessive negative voltage. The drop across R8 is shown as fixed at 19.4 volts and the current flows in a direction such that this 19.4 volts opposes the 20.6 volts across R; both voltages being impressed between grid and filament of tube 4. Thus there is an effective negative voltage of 20.6 minus 19.4 or 1.2 volts applied to the grid of tube 4, which is proper.

The rectifier A is in series with the resistors R8, R9, R10, and R11, and also in series with the signal voltage supply, thus there will be a signal voltage in resistors R8, R9, R10, and R11, which is desired; however there will also be a direct current component across R8, R9, R10, and R11 which is not desired and which is balanced out in the following manner to prevent it from unbalancing the two sides of the amplifier.

Assume that a direct current flows through resistors R8, R9, R10, and R11 in such a direction as to cause the grid of the tube 4 to be 1 volt more positive. A plate current grid voltage curve taken of the tube 4 indicates an increase of .38 milli-ampere in plate current per grid volt applied under the conditions shown and described in Figure 1. Assuming this increase could occur in the above circuit, it would cause an additional drop across resistor R6 of 76 volts, therefore an equal decrease will be found across R7 and R8 in series. (Resistor R is also in series with R7 and R8 and the tubes 4 but the same condition is occurring on the opposite side of the push pull circuit but in an opposite direction and the two currents will cancel each other out through R, thus there will not be an effective drop across R due to these changes being described.) A decrease of 76 volts across R7 and R8 would cause a decrease of current in these resistors of .076 milli-ampere. This decrease in current in R8 would cause a decrease of 7.6 volts across R8 and as the drop across R8 is utilized to oppose the excessive negative potential being applied to grid of the tube 4, a 7.6 volt greater negative potential is impressed on the grid than was had before the 1 volt positive potential was impressed, thus a large decrease opposes a small increase, tending to balance the actual grid voltage at some small fraction of the 1 volt impressed. This fraction depends mainly on the relationship between the resistors R7 and R8 and the amplification constant of the tube, thus stabilizing the circuit in so far as impressed direct current voltages are concerned. A large condenser C is connected across R8 to prevent a changing signal current from building up a counter voltage across R8, permitting the signal voltage to be impressed on grids and progressing through the amplifier to the

output, but blocking any direct current changes from progressing through the amplifier.

Steady plate current varies a small amount in different tubes of the same kind and should another 224 tube be used which draws a slightly higher plate current the same effect occurs in that the drop across R6 will be greater and the drop across R7 and R8 less, causing a slightly more negative voltage to be applied to the grid, thus inherently tending to keep current in plate circuit constant.

As an example of the above action we can assume an increase of 1 volt across grid filament of the 224 tube and also assume an amplification of 90. This 1 volt across grid filament would be, if it were possible, amplified, so that an increase of 90 volts would appear across R6 and the same decrease across R7 and R8. It may be assumed for example that the resistance of R8 is $\frac{1}{10}$ of R7 plus R8, therefore $\frac{1}{10}$ of this 90 volts or 9 volts would appear across R8. If this 9 volts did appear across R8 the potential would not be the 1 volt positive but an 8 volt negative potential on the grid, and with an 8 volt negative potential on the grid the 90 volts increase across R6 which it was assumed above would be due to the original 1 volt positive potential impressed on the grid, could not be obtained.

To indicate about what the actual effective increase on the grid due to the 1 volt impressed would be, start with an increase of $\frac{1}{10}$ of a volt on the grid. $\frac{1}{10}$ of a volt if amplified 90 times would appear across resistor R6 and also across resistors R7 and R8 as 9 volts, and R8 being $\frac{1}{10}$ of R7 plus R8, we would find $\frac{1}{10}$ of the 9 volts, or .9 volt, across R8. Thus if 1 volt were impressed on the grid, it would require only $\frac{1}{10}$ of this volt to support .9 volt across R8 to cancel out the balance of the 1 volt impressed. Thus an impressed direct current voltage is reduced to $\frac{1}{10}$ of its original value due to the action through the circuit.

For convenience and simplicity the action through one side of the push pull amplifier is described, but it will be perfectly obvious that the same action would obtain on the opposite side under the same conditions, the same values and circuit constants prevailing on both sides of the amplifier.

The action on opposite sides of the amplifier will however be 180 degrees out of phase which is desired and is well understood to be the case in a push pull circuit.

Referring now specifically to Figure 2, which represents a method of connecting a three element or grid bias detector to one side of my improved circuit and the use of a phase inverter tube for impressing the signal on the opposite side of the push pull circuit in such a manner that the currents in the two sides will be 180 degrees out of phase.

In this circuit 50 represents the voltage supply source, which, as in the modification disclosed in Figure 1, can be any suitable direct current source of high voltage. The voltage source is connected by the wires 51 and 52 to the plate voltage supply resistors R20, R21, R22, R23, R24, and R25, and by the wire 52 to the center tap of the output audio frequency choke coil.

53 represents a screen grid 224 tube operated as a detector; 54 represents a screen grid 224 tube operated as a phase inverter tube, while 55 and 56 represent 210 tubes, and 57 and 58 represent 250 tubes employed in the circuit. The input is indicated at 59 and the output at 60.

A novel feature of this circuit resides in the

installation of a screen grid tube 53 as a detector, the filament of which is directly coupled with the filament of the tube 54 and heated by the same transformer 61. The cathode 62 of tube 53 is connected to a point indicated at 63 along the main plate voltage supply resistor but through the resistor R64, while the cathode 65 of tube 54 is connected through the resistor R66 to the same point 63. The screen grid returns of these latter tubes are connected at 67 to the plate voltage supply resistor at the juncture of R20 and R21. A condenser 68 is connected between the plate and cathode of tube 53 for bypassing high frequency carrier currents in the output of the tube. The grid of tube 54 is connected by the wire 69 to the resistor R70 at a point 90, the object of which will be hereinafter described. The opposite end of resistor R70 is connected to the grid end of the resistor R71. The wire 72 connects the lower end of resistor R70 to the plate voltage supply at the point 63. The wire 73 is connected to the resistor R71 and to the resistor R74 which is also connected to the plate voltage resistor at the juncture of R22 and R23. At this same point the resistor R75 is connected, the opposite end of which is connected by the wire 76 to and through the resistor R77 and by the wire 78 to the resistor R79, the opposite end of which is connected by the wire 80 to the point 63. Resistor R75 is connected by the wire 81 to the resistor R82, the opposite end of which is connected to the grid end of resistor R83. The opposite end of R83 is connected by the wire 84 to the plate voltage supply at the juncture of R24 and R25. From said juncture the wire 85 leads to the resistor R86, the grid end of which is connected to resistor R87, and the opposite end of the latter is connected by the wire 88 to the resistor R74. As is obvious all tubes are directly connected in series as in Figure 1, the last ones 57 and 58 being connected in the usual manner to the output impedance, and the input is connected between the grid of tube 53 and point 63.

The grid bias of tube 53 is obtained by the voltage drop across resistor R64 due to the plate and screen grid currents in said tube which flow through R64 in a direction to hold the cathode of the tube positive, with respect to the grid, at the proper potential for good detection. The degree of steady plate current in said tube is dependent upon its grid bias, but since the grid bias is obtained from the flow of plate and screen grid currents in the tube through resistance R64, the resistance R64 becomes the controlling factor in determining the degree of steady plate current. Condensers 89 and 91 are used to bypass audio frequency currents around R64 and R66 to prevent signal voltages from being attenuated.

The grid of tube 54, as previously described, is connected to the resistor R70 at the point 90. The signal voltage across point 90 and point 63 will thus be impressed on grid of tube 54; point 90 being determined such that this voltage will be an amount which when amplified by tube 54 will appear across resistor R77 as an amount equal but opposite in phase to the voltage across R71. The potential of point 90 being thus determined it will be necessary to regulate the value of resistor R66 so that the voltage drop across R66 due to the plate and screen grid currents in tube 54 with no signal impressed will be 1.2 volts, (or an amount such that is proper for the grid of the tube operated as an amplifier) 75

greater than the drop between point 90 and point 63 when no signal is impressed, in which event the proper voltage will be applied to grid of tube 54.

5 There is also shown in this circuit a novel method of obtaining a regenerative feed back, this being obtained by causing the signal current in R82 to flow through part of resistor R75, and as these signal currents in resistor R82 are
10 in phase with signal currents in resistors R77 and R75, any voltage across R75 due to these feed back currents will be impressed between grid and filament of tube 56 in phase with voltage across R77, thus obtaining a regenerative
15 feed back from the plate circuit of tube 55 to the grid circuit of tube 56. The same action occurs by the regenerative feed back from the plate circuit of tube 56 to the grid circuit of tube 55 due to resistor R87 being connected to resistor
20 R74. The wires 81 and 88, if desired, could be reversed, connecting wire 81 to R74 and wire 88 to R75 and by placing large condensers across R74 and R75 a greater stability to slow voltage changes, identical with the stability obtained in
25 Figure 1, is obtained, due to the fact that the currents in R7 are caused to flow through R8. The effect in this case would be to tend to keep steady plate currents in tubes 55 and 56 constant, permitting values of R83 and R86 to be varied
30 somewhat to cause equal amplification of the two sides of the circuit without changing the bias on the tubes 57 and 58. This is desirable for a number of obvious and well known reasons.

The resistors R83, R86, R71 and R77 operate,
35 in all other respects, similar to the corresponding resistors in the modified circuit described in Figure 1.

The wire 80 could be connected to the cathode end of R64 instead of to the point 63, making
40 R64 a part of R79, the additional currents in R79 assisting the screen grid and plate currents of tube 53 to stabilize the circuit against slow voltage changes.

Reference is now particularly made to the
45 showing in Figure 3 of the drawings, wherein the basic circuit employed is identical to that described and illustrated in Figures 1 and 2, and comprises a battery or other source of supply 100 connected by the wires 101 and 102 to the main
50 voltage supply resistor R103, R104, R105, and R106, and center tap of output audio frequency choke coil. The input is indicated at 107 and the output at 108, being in all respects identical to that shown in Figure 1. B represents a two element
55 rectifier used for the same purpose as that shown at A in Figure 1. A wire 109 connects the rectifier B to the grid of tube 110, the plate of which is connected by wire 111 to the grid of tube 112, and the plate of the latter is connected by
60 wire 113 to one side of the output impedance. The wire 114 connects the other side of the input tuned transformer to the grid of tube 115, the plate of which is connected by the wire 116 to the grid of tube 117, and the plate of the latter
65 is connected by wire 118 to the opposite side of the output impedance. A condenser 119 as commonly used for bypassing the high frequency component of the rectified current is connected to the wires 109 and 114. The resistor R120 is also connected across the wires 109 and 114 through which
70 the audio frequency component of the rectified current will flow for the purpose of building up a signal voltage to be impressed upon the grids of tubes 110 and 115. At the center of resistor
75 R120 is connected the wire 121 which is adjust-

ably connected to the main voltage supply resistor at the juncture of R103 and R104, this being for the purpose of adjusting the grids of tubes 110 and 115 at the proper negative voltage with respect to the cathodes of said tubes. A resistor
5 R122 is connected to the wire 101 and to the filament of tubes 112 and 117. The value of this resistor is adjusted so that the plate current flowing therethrough will cause a voltage drop, which drop, subtracted from the total supply voltage,
10 will leave the proper voltage applied to the plates of tubes 112 and 117. The cathodes 124 and 125 are connected together through the resistors R126 and R127 and to the wire 101 at point 133, and the large condensers 128 and 129 are placed across
15 R126 and R127. The action of the combination of these resistors and condensers is to provide a grid bias to tubes 110 and 115 and at the same time to permit the detected signal to be applied directly to the grids of tubes 110 and 115. These
20 two actions are accomplished as follows:

The steady plate and grid currents flowing in tubes 110 and 115 causes voltage drops across R126 and R127 respectively, this drop depending on the value of resistors R126 and R127 and the
25 value of the current. The value of the current when no signal is impressed will be a constant depending on circuit adjustments, the value of R126 and R127 being adjusted at approximately 20,000 ohms for reasons hereinafter explained.

The value of the plate and screen grid currents in each tube 110 and 115 with one practical circuit adjustment would be approximately .65 milliampere. This current flowing through the 20,000
30 ohms resistor R126 or R127 would cause a voltage drop of 13 volts across R126 and also across R127. This would hold the cathodes of tubes 110 and 115 at 13 volts positive with respect to grids of same tubes, whereas there should be approximately 1.2 volts potential difference between cathodes and grids. Wire 121 completing the circuit
40 between the cathodes and grids of tubes 110 and 115 is returned to a point at the juncture of R103 and R104, which point should be 11.8 volts more positive than the point 133, this adjustment leaving 13 minus 11.8 or 1.2 volts negative bias on
45 grids of tubes 110 and 115. As long as no voltage is impressed across points 130 and 131 and other conditions remain constant these grid voltage adjustments will remain the same.

Should a steady voltage be applied across points 130 and 131 such that point 130 for example is some amount positive with respect to point 131, there would be an increase in current in tube 110 and a decrease in current in tube 115. This
50 voltage across points 130 and 131 will be divided equally between the grid and cathode of tube 110 and the grid and cathode of tube 115.

The increase in current in tube 110 will cause an increase in voltage to appear across R126 and
55 the decrease in current in tube 115 will cause a decrease in voltage to appear across R127.

This increase in voltage across R126 will be impressed between cathode and grid of tube 110 and will add to the original negative 1.2 volts impressed and the decrease in voltage across R127 will be impressed across the cathode and grid of tube 115 and will subtract from the original 1.22 volts, and it is found that the voltage
60 impressed across points 130 and 131 will be opposed by the voltage difference across R126 and R127 due to this impressed voltage.

This voltage built up across R126 and R127 will be larger, the larger the values of R126 and R127, therefore values of R126 and R127 should be
75

chosen for maximum practical results in the stabilization of the circuit against direct current voltage changes across resistor R120, the value of 20,000 ohms, previously assigned, being about proper for this particular tube.

As was more fully described in the remarks applicable to Figure 1, this blocking out or attenuating of direct current voltage changes will permit the detected signal currents to be applied directly to the grids of tubes 110 and 115 without the customary use of reactances to prevent improper voltages being applied to the grids; this being the object in view in this case and forms one of the novel features of the invention. The condensers 128 and 129 prevent the signal currents from building up a voltage across R126 and R127 and thereby blocking out the signal voltage change in the manner that the direct current and slow voltage changes do.

There is also shown in Figure 3 a regenerative feed back as applied to the screen grids of tubes 110 and 115, the action of which is identical to that described in Figure 2 as applied to the control grid of tubes 55 and 56. This regeneration could be applied to an auxiliary control grid if such tubes were available, and the operation of the circuit otherwise would be identical to that illustrated and described in the other two views.

In the drawings and description, particular types of tubes have been referred to and certain adjustments which are to be made to permit these tubes to function properly. It is not my object to limit the application of the principle of the circuit to these particular tubes, nor to the particular adjustments necessary for operation of these tubes. These tubes were specified merely to disclose a clear description of the principal features of the circuit, and any other suitable tubes can be used when proper adjustment of circuit constants are made which are suitable to the type of tube used.

Neither is it my object to limit the circuit to the amplification of the output of a grid bias and two element detectors, nor to the amplification of any certain frequency band. Any suitable signal source can be used and with proper adjustments any direct current voltages or varying voltages of any frequency can be supplied to the input and amplified through the circuit, the output of which can be used for any purpose to which it is applicable, neither is it my object to limit the application of the principle to push pull circuits.

Furthermore it is not the intention to limit the use of resistances as loads on the tubes, as it is clear that inductive reactances could be used in the plate circuits and a transformer could be used for inputting to the circuit in which case it would be less desirable to stabilize the circuit against slow voltage changes as the inductive reactances would not amplify slow changes.

Referring now particularly to Figure 4 which is a diagrammatic representation of that portion of Figure 1 which acts to permit the rectified output of a two element detector to be applied direct to the push pull circuit by stabilizing the circuit against slow voltage changes. The same reference characters are used in Figure 4 to identify corresponding parts as used in Figure 1.

The battery is represented at 1, and represents that portion of the battery in Figure 1 that would equal the drops between the negative side thereof to the junction of R3 and R4,

and is connected by wire 2 to point X of the network and by wire 3 to point Y of the network. Resistors R1, R2, and R3, are joined in series, and connected between points Y and point S of the network. Resistor R is connected between points S and point X of the network. Resistor R6 is connected between points Y and P of the network, and resistors R7 and R8 are connected in series between the points P and X, while resistor R27 is connected between points H and Y of the network. Resistors R28 and R11 are connected in series between points H and X, and R10 is connected at the juncture of R28 and R11 and the opposite end to the grid of tube 5. Resistor R9 is connected to the juncture of R7 and R8 and the opposite end to grid of tube 4. Point P of network is connected by wire 14 to the plate of tube 4, and point H is connected to plate of tube 5 by wire 15. The filament of tube 4 is connected to point S by wire 17, and the filament of tube 5 is connected by wire 18 to wire 17. Screen grids are omitted to simplify the drawings. The output is numbered 6 and 7 to indicate that output terminal 6 would connect the grid of tube 6 and output terminal 7 would connect to grid of tube 7. Arrows indicate the direction of the currents when no signal is impressed across the input.

As indicated in Figure 4 the fundamental stabilizing circuit forms an unbalanced double bridge, two of the arms of the bridge being common to both bridges.

The first bridge consists of arm R and arm R1, R2, and R3, which form one branch of the first bridge, the second branch consisting of arm R6 and arm R7 and R8 in series. Second bridge consists of the arm R and arm R1, R2 and R3, which form one branch of the second bridge, the second branch consisting of arm R27 and arm R28 and R11 in series.

Large condensers C, shown in Figure 1 as connected across R8 and across R11, are here replaced by a large condenser connected between the junction of R11 and R28 and the junction of R7 and R8.

Grid bias for tube 4 is obtained by the difference in voltage drop across R and the voltage drop across R8 and the grid bias of tube 5 is obtained by the difference in voltage drop across R and the voltage drop across R11. Signal voltage is built up by currents in R9 and R10 in the same manner as was fully explained in the description of Figure 1.

Figure 4 is presented to more clearly illustrate, diagrammatically, the action of the combination, and as the characteristics of bridges are well understood, it will be clear that if R6 and R27 are equal and R7 and R28 are equal, and that R8 and R11 are equal and the current in tubes 4 and 5 the same, then there will be no voltage difference found between terminals 6 and 7. With the values of resistors as given in Figure 1 both bridges are in an unbalanced condition and both bridges are equally unbalanced.

If a steady voltage is applied across the input such that the grid of tube 4 is positive with respect to the grid of the tube 5, then current in the tube 4 would tend to increase and current in the tube 5 would tend to decrease if there were no counter action to prevent this.

As the tube 4 is in series with R6 and the tube 5 is in series with R27, a greater voltage drop would appear across R6 and a lesser drop across R27, causing a difference in potential across terminals 6 and 7. R7 and R8 are in series

with R6 and the battery, and a smaller drop would be measured across R7 and R8 due to the larger drop across R6.

R28 and R11 are in series with R27 and the battery, and a larger drop would be measured across R28 and R11 due to the smaller drop across R27.

The point of junction between R7 and R8 would be at a lower potential and the point of junction between R11 and R28 would be at a higher potential than was the case before the voltage was applied across the input, thus the action of the bridge is to build up a difference in potential across the junction of R8 and R7 and the junction of R11 and R28 which will oppose any difference of potential applied across the input; however this will be the action only for comparatively slow rates of change in potential differences applied to the input terminals. Where comparatively fast varying differences in potentials are applied across the input terminals the condenser C will not permit a change in potential between the junction of R7 and R8 and the junction of R11 and R28 and the fast varying potentials will therefore cause a difference in unbalance between the two bridges and an amplified duplicate of the changes across the input will be found across the output terminals 6 and 7.

Thus a portion of the arm consisting of R7 and R8 and the arm consisting of R28 and R11 become the controlling factors governing the amount of current that can be passed by the tubes 4 and 5, tending to keep the currents constant when a slow varying difference in potential is applied to the input terminals, but permitting the currents to vary in step with any fast varying potential differences applied to the input terminals.

Should a small change in values of R6 or R27, or small changes in tube currents occur, the same action would obtain tending to hold the currents through tubes constant.

R and R8 and R11 are adjusted so that the grid bias with no signal impressed across input is proper for the type of tubes used.

R28, if desired, could be connected to R8 and R7 connected to R11 and condenser C eliminated and thus obtain a regenerative action rather than a degenerative action, at all frequencies, or if desired condenser C could be retained, in which case the regenerative action would obtain for slow varying potentials only.

Having thus described my invention, what I claim and desire to secure by Letters Patent, is:

1. In a direct coupled radio receiving circuit, comprising resistance in the plate circuits, a two element rectifier, a resistance in series with the rectifier, and means for bypassing a portion of said latter resistance for cancelling out the direct current component in the rectified current.

2. An amplifier for radio receiving circuits including vacuum tubes directly connected in series, the output circuit of one tube being connected to the input circuit of the succeeding tube, and a plate voltage supply and a plurality of resistors connected to the common plate and grid connections providing a plurality of separate paths for the signal and other currents in the output of said tubes and across which plate potentials progressively decrease, a portion of a separate path being common to a preceding input circuit.

3. In combination with a radio receiving circuit, of an audio amplifier including a plurality

of vacuum tubes directly coupled, the output circuit of one tube being connected to the input circuit of the succeeding tube, and a plurality of resistors having common connections to said connected input and output circuits, at least one of said resistances being connected to bridge a portion of the input circuit of said first tube for the purpose of providing audio feed back.

4. In combination with a radio receiver circuit, an audio amplifier including a plurality of vacuum tubes arranged in a series of push-pull stages, the output circuit of each tube in one stage being directly connected to the input circuit of a corresponding tube in a succeeding stage, and resistance coupling means for providing regenerative feed back between the stages.

5. The combination with a receiving circuit of an amplifier therefor characterized by having the output of one tube directly connected to the input of the following tube, a plurality of resistors forming a portion of a bridge circuit, each resistor having one end connected in common with each other and to the common plate and grid circuit, one of said resistors having its other end connected to a source of high potential in said circuit, and another of said resistors having its other end connected to the bridge circuit of a preceding tube.

6. In a radio receiving circuit in combination, an amplifier including a plurality of vacuum tubes connected in cascade, the plate of one tube being directly connected to the grid of the succeeding tube, said connection having connected thereto the common ends of a plurality of resistances, one of said resistances having its other end connected to the input of a preceding stage, and another of said resistances having its other end connected to a source of plate supply.

7. The combination with a receiving circuit, of an amplifier including a plurality of vacuum tubes directly coupled, the plate of one tube being directly connected to a grid of the succeeding tube, and a plurality of resistors one end of each being connected in common with said plate and said grid, one of said resistors having its other end connected to a control grid of a preceding tube for the purpose of providing feed back.

8. A radio receiving circuit including a plurality of tubes arranged in a series of push-pull stages, interstage conductors each directly connecting the output of a tube in one stage to the input of a corresponding tube in the succeeding stage, and a plurality of groups of resistors each having one end connected in common with one of said conductors, one resistor in each group having its other end connected to a control grid of a tube of the opposite phase.

9. In a radio receiving circuit, a source of audio frequency current, an amplifier including a vacuum tube, and non-reactive connections between said source and said tube, a resistance in series with said source, a capacitor by-passing a portion of said resistance, a plurality of parallel resistors connected in common to the plate circuit of said tube, and means for providing direct current feed back to said source via one of said parallel resistors.

10. In a radio receiving circuit for radio signals, an amplifier including thermionic tubes in push-pull stages connected in series, one side of a push-pull stage being energized by an audio frequency current source and the other side of said stage being energized by a tube arranged as a phase inverter, and a plurality of parallel resistors one of which comprises the grid impedance for the tube energized by the source, a portion of the signal

voltage across another of said resistors being applied to a control grid of the inverter.

11. A radio amplifier including a plurality of tubes arranged in a series of push-pull stages, the outputs of the tubes in one stage being directly connected to the inputs of corresponding tubes in the succeeding stage, and a plurality of resistors coupling said tubes and some of which provide regenerative feedback between the stages.

12. In a radio amplifying circuit, a rectifier, an amplifier including a vacuum tube, non-reactive connections between said rectifier and said tube, a resistance in series with said rectifier, a capacitor by-passing at least a portion of said resistance, a plurality of parallel resistors connected in common to the plate circuit of said tube, and means for providing direct current feedback to said rectifier circuit via one of said parallel resistors.

13. In a direct coupled amplifier system, a plurality of resistors interconnected to form a bridge circuit, a thermionic tube having its plate connected to one corner of said bridge circuit, its cathode connected to an opposite corner of said bridge circuit, and its grid connected to one arm of said bridge circuit and adapted to control currents in said bridge circuit by means of the amplifying effect of said tube.

14. In a direct coupled amplifying system, a plurality of resistors interconnected to form an unbalanced bridge circuit, a thermionic tube having its plate connected to one corner of said bridge

circuit and having its cathode connected to an opposite corner of said bridge circuit, and a grid of said tube connected to one arm of said bridge circuit and adapted to control to prevent any further unbalancing of direct current in said bridge circuit, by means of the amplifying effect of the tube.

15. In a direct coupled amplifying system, a stage comprised of a pair of thermionic tubes connected in phase opposition to each other, a plurality of resistors having one end thereof connected in common to each other and connected to the plate of one of said tubes, a second plurality of resistors each having one end thereof connected in common to each other and connected to the plate of the other of said tubes, the other end of one resistor in each of said pluralities being connected to a source of plate potential, means connecting the other end of another resistor in each of the said pluralities to a source of potential less in value than that of said first source, means for impressing a modulated frequency on the grid of said first tube, and means for impressing a voltage from the output of said first tube upon the grid of said second tube, said last means being connected to a point, on one of said resistors associated with the plate of said first tube, at which the intensity of said last voltage when amplified by said second tube is substantially equal to the plate voltage of said first tube.

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