Jan. 29, 1935. W. AULL, JR 1,989,394

VACUUM TUBE OUTPUT CIRCUIT

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Fig. 1.

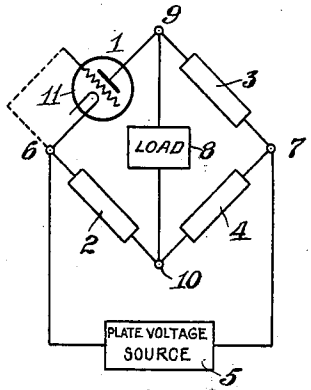


Fig. 2.

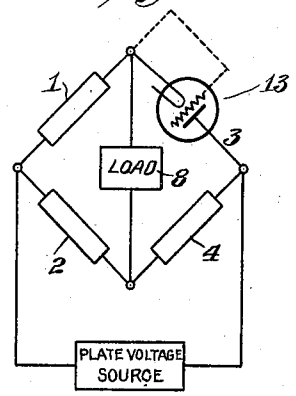


Fig. 3.

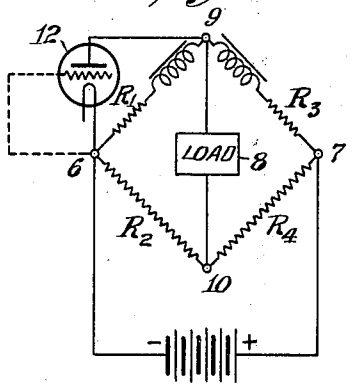


Fig. 4.

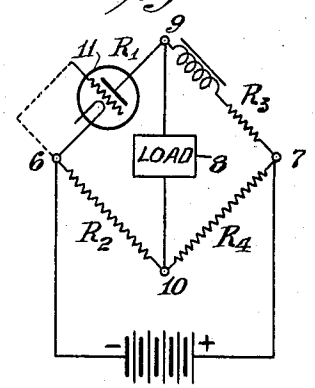


Fig. 5.

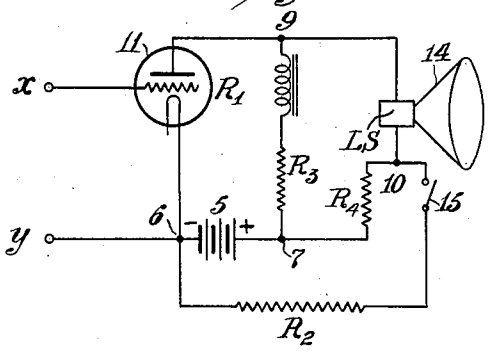
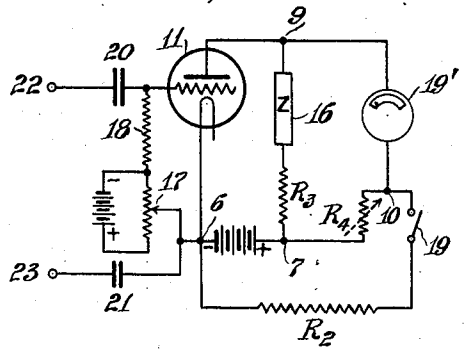


Fig. 6.



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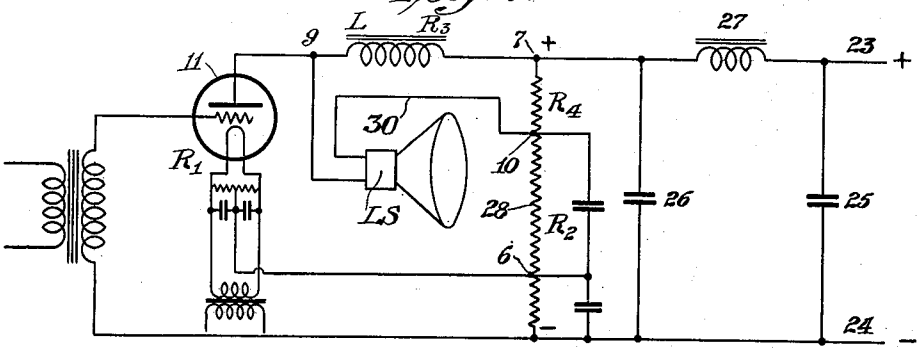
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Fig. 7.



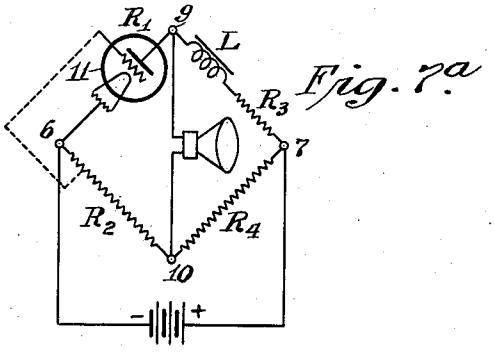
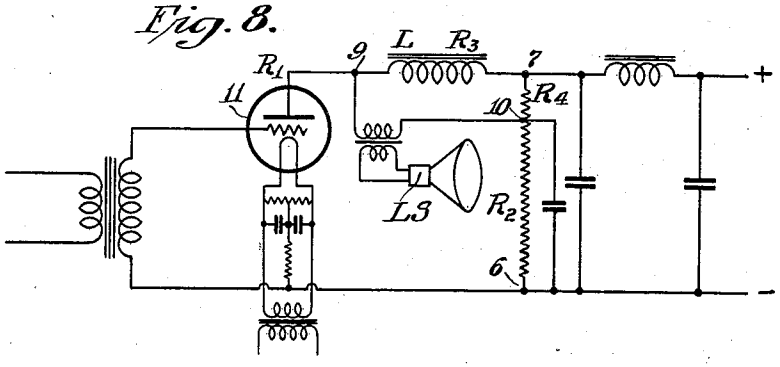


Fig. 7a

Fig. 8.



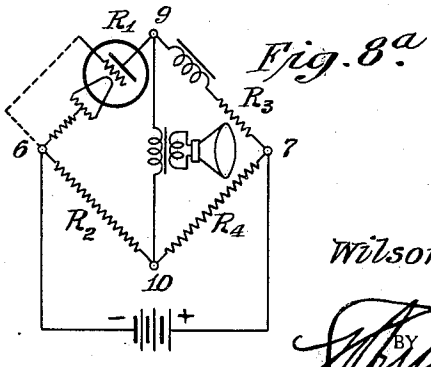


Fig. 8a

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Fig. 9.

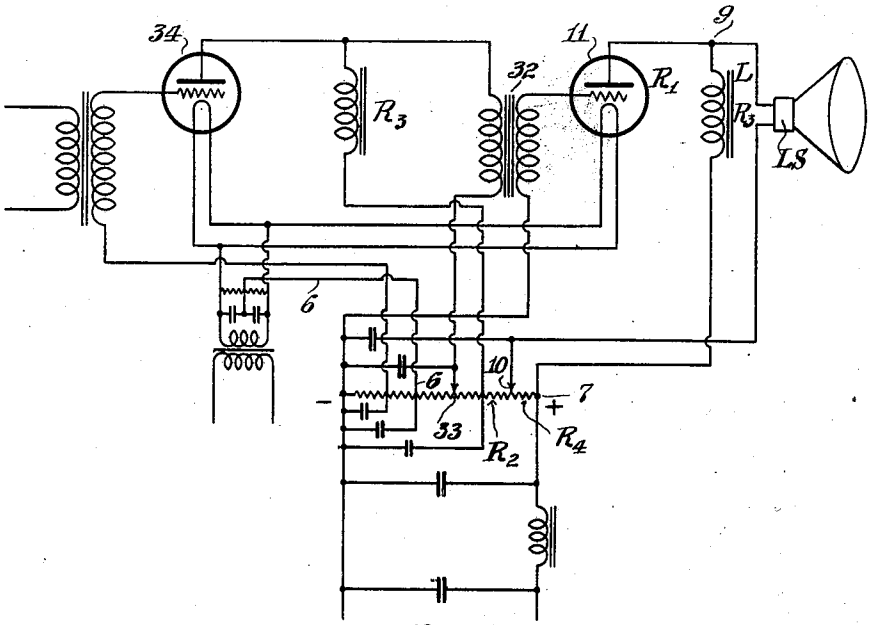
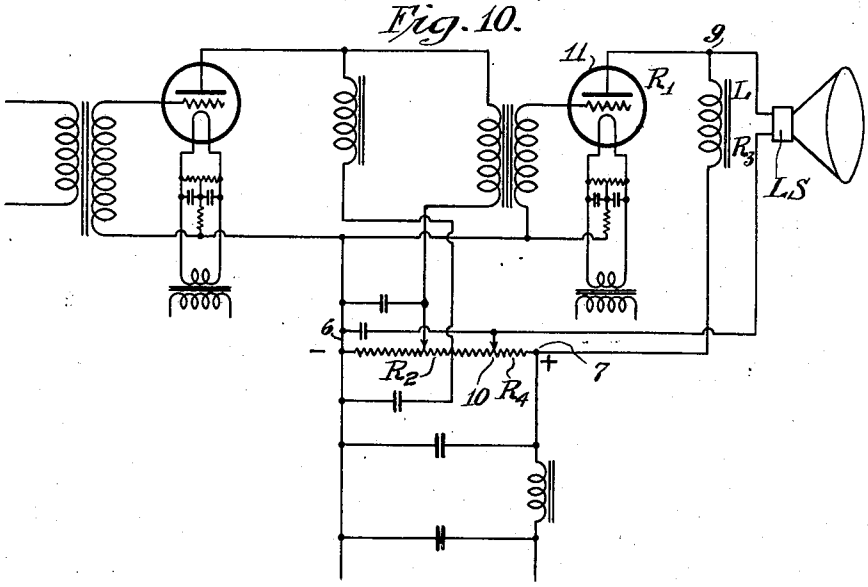


Fig. 10.



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Patented Jan. 29, 1935 1,989,394

UNITED STATES PATENT OFFICE

1,989,394

VACUUM TUBE OUTPUT CIRCUIT

Wilson Aull, Jr., Astoria, N. Y.

Application May 24, 1929, Serial No. 365,699

3 Claims. (Cl. 250—27)

This invention relates to vacuum tube output circuits and provides a method of and means for coupling an ordinary vacuum tube or power tube to an indicating device or coupling device.

One application of my invention is to provide a method of coupling the power tube in a radio receiver or power amplifier to the loud speaker, and at the same time eliminate the steady direct current from the loud speaker windings while maintaining a high quality of reproduction of musical sounds.

Another object is to eliminate the customary output transformer or output filter.

Another object is to reduce the manufacturing cost of high quality power operated reproducing apparatus such as power operated radio receivers.

Another object is to provide means for eliminating the steady direct current from sensitive indicating devices operated in plate circuits of vacuum tubes, such as vacuum tube voltmeters, relays, recorders, etc., while passing on minute signal operated direct current fluctuations designed to operate said indicating devices.

Another object is to provide an inexpensive method of coupling vacuum tubes in amplifiers.

Another object is to provide a method of eliminating the steady direct current from interstage coupling transformers or choke coils, thus reducing the likelihood of saturation and allowing the use of less iron in such devices, and cheapening the cost consistent with a given quality of output.

To accomplish these objects I separate the direct current source supplying plate voltage to a vacuum tube from the indicating device or coupling device operated by said vacuum tube and for this purpose the terminals of the indicating or other device are in effect connected to opposite pairs of bridge terminals and the power supply is connected between the intervening pairs of bridge terminals. The bridge network may consist of resistance elements, inductance elements, capacitive elements or combinations thereof.

It should be understood that my broad invention contemplates the attainment of any one or more of the foregoing objects although I prefer to design and arrange the elements to accomplish all of them.

Referring to the drawings, Fig. 1 illustrates diagrammatically one arrangement by which an indicating device, operated by a vacuum tube is isolated from the local source of plate voltage.

Fig. 2 illustrates another form, in which the same object is accomplished, the vacuum tube being in another position.

Fig. 3 shows a modification of the type depicted in Fig. 1 and Fig. 4 shows still another practical form of Fig. 1.

Fig. 5 shows a practical form of the invention adapted to the output circuit of a modern radio receiver.

Fig. 6 illustrates the application of the invention to a circuit including a vacuum tube voltmeter.

Fig. 7 shows a practical application of the circuit to a modern power operated radio receiver or other reproducing equipment and 7*a* shows a corresponding bridge circuit.

Fig. 8 shows another practical circuit some details of which are different from Fig. 7, and Fig. 8*a* is the equivalent bridge circuit.

Figs. 9 and 10 are illustrations of the method for both an output circuit and a coupling circuit to a preceding vacuum tube in a cascade amplifier, both tubes receiving power from the same source.

In Fig. 1 I have shown an arrangement corresponding in some ways with what is commercially termed a Wheatstone bridge having the four bridge arms 1, 2, 3 and 4, each of which may include various elements and combinations of elements as will hereinafter be set forth. The source of plate voltage is indicated diagrammatically at 5 and its terminals connected at 6 and 7 between the arms 1 and 2 on one side and the arms 3 and 4, on the other side.

The indicating device or coupling device is shown diagrammatically at 8 with its terminals connected at the points 9 and 10 between the arms 1 and 3 on one side and 2 and 4 on the other side. In the form shown in Fig. 1 I have illustrated the vacuum tube 11 which may typify the plate circuit of one or more vacuum tubes. When the bridge arms 1, 2, 3 and 4 are so proportioned that the bridge is balanced for direct current, the bridge terminals 9 and 10 are isolated electrically from the bridge terminals 6 and 7. Consequently no direct current will flow through the indicating device assuming that the bridge was balanced for the steady state condition with normal filament voltage, plate voltage and grid biasing voltage on the vacuum tube.

When the signal or other source of voltage is applied to the grid of the vacuum tube, its plate circuit impedance is changed, the bridge unbalanced and a corresponding pulsation is applied to the indicating device. The constants of arms 2, 3 and 4 will depend largely upon the type of vacuum tube used and other design considerations which will be apparent to one skilled in the art. While I have shown a vacuum tube in bridge arm

1, it could be replaced of course by a transformer secondary, the primary of which is in the plate circuit of the corresponding vacuum tube.

In Fig. 3 I have shown an arrangement similar to that above described in which the arms 1, 2, 3 and 4 are now represented by resistances R1, R2, R3 and R4. In this case R1 and R3 each includes a choke coil which may provide all or part of the necessary resistance for the steady state bridge balance. Bridge arm R1 is part of the plate circuit of the vacuum tube 12 which may unbalance the bridge circuit in the same general manner as vacuum tube 11 in Fig. 1.

In the arrangement of Fig. 2 I have shown the vacuum tube 13 with its plate circuit connected in arm 3 of the bridge. It should be understood of course that the filament heating source may be provided in any suitable manner and that the grid circuit may be connected in any suitable manner.

Fig. 4 corresponds with the circuit of Fig. 1. It will be understood of course that the proper resistance relation for a steady state balance is:

$$\frac{R1}{R2}=\frac{R3}{R4}.$$

The circuit of Fig. 5 shows a practical application as applied to a receiving circuit including a loud speaker 14 which takes the place of the indicating device 8 being connected between the terminals 9 and 10. It will be seen that the plate circuit of the vacuum tube 11 constitutes the arm R1 of the bridge. R2 includes a switch 15. R3 represents one arm including a choke having the necessary direct current resistance. R4 includes the necessary resistance. Obviously Fig. 5 in some respects resembles the normal circuit for a loud speaker connected to a power tube except that I have added resistances R2 and R4 in proper proportions which combined with the resistance of the choke coil represented as R3 and the plate resistance of the tube R1 forms a balance so that the ordinary condenser usually connected with the loud speaker is unnecessary inasmuch as no current will flow through the loud speaker except when the bridge is unbalanced by a signal voltage applied to the grid of the tube 11.

By this arrangement the loud speaker condenser is done away with. This is of great advantage in high quality reproduction inasmuch as the condenser offers a high reactance to low frequencies as compared to the reactance it offers at high frequencies and consequently unless it is of a very large capacity, is a source of distortion. Unless of high grade the condenser is also a source of trouble inasmuch as it is subjected to high voltages and may break down completely.

Fig. 6 shows the principle of Fig. 4 as applied to a vacuum tube voltmeter in which the bridge arms R1, R2, R3 and R4 are shown in a manner similar to those of Fig. 5, resistance R3 being the direct current resistance of the choke coil or other impedance 16. Vacuum tube 11 may have its grid bias adjusted so that it functions as a plate rectifier. This adjustment may be made by potentiometer 17 by means of which an adjustable negative grid bias may be fed to the grid of tube 11 through grid leak 18. After this adjustment has been made the bridge arms should be adjusted for zero current on the indicating meter 19'. This adjustment may easily be effected by letting R4 be an adjustable resistance. The other bridge arms may be fixed in value. Switch 19 is merely diagrammatic—in practice it could be combined with the "A" battery switch. In general this vacuum tube voltmeter may be operated in a manner similar to that described in U. S. Patent 1,232,919 issued to R. A. Heising. In my arrangement, however, I have included condensers 20 and 21 to which input terminals 22 and 23 are connected.

Another simple method of operation consists in calibrating the indicating meter 19' in volts with a given vacuum tube after the bridge has been balanced, by means of the grid bias adjustment 17 or the equivalent. Thereafter before using the instrument it is only necessary to adjust the bridge until the meter reads zero on the calibrated scale.

Thus sources of voltage of any frequency may be measured even though the external circuit is not closed inasmuch as the input circuit of vacuum tube 11 is so arranged that the grid biasing is independent of the source of voltage being measured as long as this voltage is within the limits of the vacuum tube voltmeter.

This method for a vacuum tube voltmeter has some advantages over the usual method inasmuch as the device may be operated on a steeper portion of the grid-voltage plate-current characteristic, giving greater sensitivity and in addition, allows the use of sensitive direct current indicating instruments for measuring alternating currents of high frequencies.

In a similar manner, other sensitive direct current indicating instruments may be operated by alternating currents thus obtaining the sensitivity of direct current instruments on alternating currents. For instance, the microammeter 19 of Fig. 6 may be replaced by a direct current relay sensitive enough to give a positive indication when supplied with a very few micro-amperes of direct current. This would not be possible if the steady state direct current were not balanced out as the normal plate flow would not only operate but possibly burn out the winding. Obviously a filter or transformer would not suffice as alternating current only would be passed, which of course would not operate a direct current instrument. In short, this output circuit may be used in connection with a vacuum tube in any case where it is desired to utilize the weak pulsating direct current without the presence of the relatively great steady state direct current flowing in the plate circuit.

Fig. 7 shows the general arrangement of Fig. 5 applied to a modern power operated amplifier system in which the source of plate voltage which may be from direct current lighting mains or a rectifier system fed by alternating current lighting mains is applied to points 23 and 24 which are the input terminals of a filter comprising filter condensers 25 and 26 and choke coil 27. The customary voltage divider 28 is furnished as shown to which may be connected the customary voltage taps for feeding the amplifier plates and grid biases. In the normal system choke coil, R3 would be connected as shown, and the loud speaker in series with the customary blocking condenser connected. However, I have done away with the blocking condenser by connecting the loud speaker terminal which would ordinarily go to the filament circuit to point 10 on the voltage divider, thus forming the bridge circuit, the arms R1, R2, R3 and R4 of which I have indicated on the diagram. In actual operation, if a milliammeter be inserted in wire 30 and point 10 be progressively moved from near point 7, taking care not to burn out the loud speaker winding, a large current would be shown on the milliammeter, this

current will gradually decrease until point 10 is reached when no current will be indicated. If the wire be progressively moved further the current in the milliammeter will reverse in direction. Thus, by my invention, the usual condenser, a source of distortion and trouble, is done away with entirely and at no additional practical cost, in most cases, in fact, at a saving in cost.

In practice, of course, the usual impedance adjusting transformer may be connected to the loud speaker as shown in one of the diagrams. Fig. 7*a* shows the corresponding bridge circuit utilized in Fig. 7 together with the usual method of obtaining grid bias for the output tube 11.

Fig. 8 shows another loud speaker arrangement by which the steady direct current is eliminated from the loud speaker or transformer windings but another method of grid biasing is used. This also is a common method of obtaining the grid voltage, the corresponding grid circuit for which is shown in Fig. 8*a*.

My system is of advantage even when the loud speaker is connected through a transformer inasmuch as much less material is used in the transformer when the heavy direct current is balanced out inasmuch as the core cannot become saturated, which allows the use of a smaller core thus giving great saving in iron, copper and weight.

Fig. 9 includes the output circuit of Fig. 7 in which the direct current is balanced out of the loud speaker and shows in addition the direct current also balanced out of coupling transformer 32 by adjusting connection 33 on voltage divider 28. Thus the same voltage divider functions as arms R2 and R4 in two different bridge circuits. The corresponding bridge circuit together with the method of biasing the grid for the output of tube 11 as well as tube 34 is indicated in Fig. 7*a*.

In Fig. 10 I have indicated another circuit in which the output circuits of two vacuum tubes included in a cascade amplifier are treated by my method. Likewise any number of stages of amplification could be similarly treated.

Fig. 10 differs from Fig. 9 particularly in the method of biasing the grids of the two vacuum tubes and the corresponding bridge circuit is similar to that shown in Fig. 8*a*.

It will be understood that the general circuit arrangements may be varied within wide limits and that I have shown certain more or less well known circuits as typical examples.

I claim:

1. In the output circuit of a vacuum tube, four impedances at least one of which has a high inductive reactance to resistance ratio connected in series with the two outer ends joined together forming a closed bridge network, said bridge inductive reactance having a vacuum tube filament connected to it, the other end of said reactance being connected to the plate of said vacuum tube, a source of plate supply connected between the bridge junction to which the filament is attached and the bridge junction farthest removed electrically, a load device connected between the bridge junction to which the vacuum tube plate is attached and the fourth bridge junction, and means for so proportioning the bridge impedance arms that under normal conditions, substantially no direct current potential exists at the load terminals unless a change occurs in the grid circuit of the vacuum tube, and means for adjusting the biasing voltage of the grid of said tube.

2. In a vacuum tube output circuit, a bridge having arms comprising two resistance elements, the anode circuit of a vacuum tube and a choke of substantial alternating current impedance and of known resistance, a source of plate voltage supply connected at opposite junctions of the bridge and a load connected between intervening elements of said bridge so that substantially no direct current flows therethrough when said vacuum tube has zero input.

3. In a vacuum tube output circuit, a bridge having arms comprising two resistance elements, the anode circuit of a vacuum tube and a choke of known resistance, a source of plate voltage supply connected at opposite junctions of the bridge and a load connected between intervening elements, one arm of said bridge including the plate circuit of a vacuum tube and said bridge being so balanced that said load has substantially no direct current flowing therethrough until the input circuit of said vacuum tube is excited said choke having a substantial alternating current impedance.

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