Feb. 9, 1943. M. ARTZT 2,310,342

BALANCED DIRECT AND ALTERNATING CURRENT AMPLIFIERS

Filed Nov. 29, 1940 2 Sheets-Sheet 1

Fig. 1.

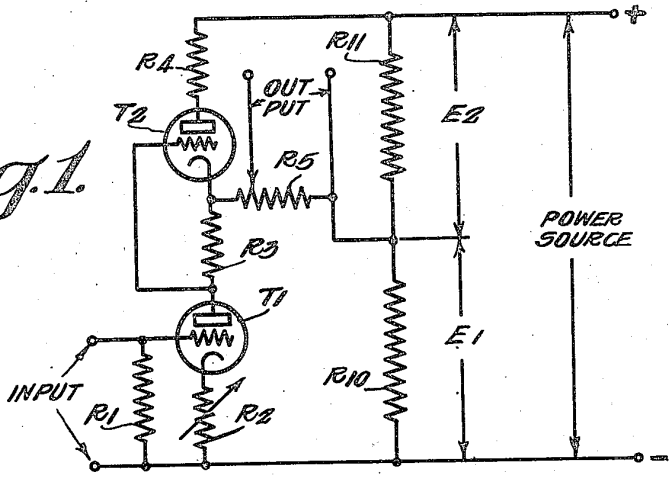

Fig. 2.

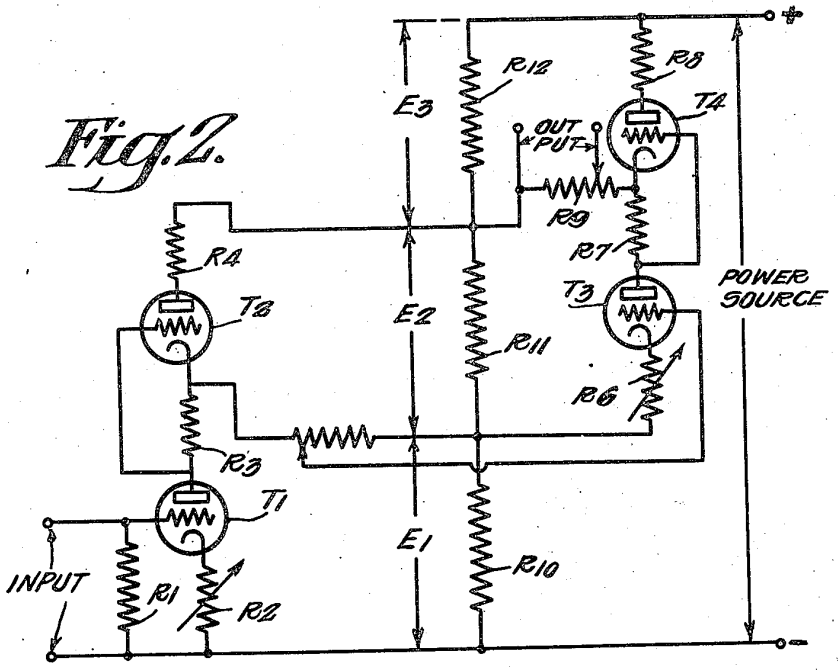

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Fig. 3.

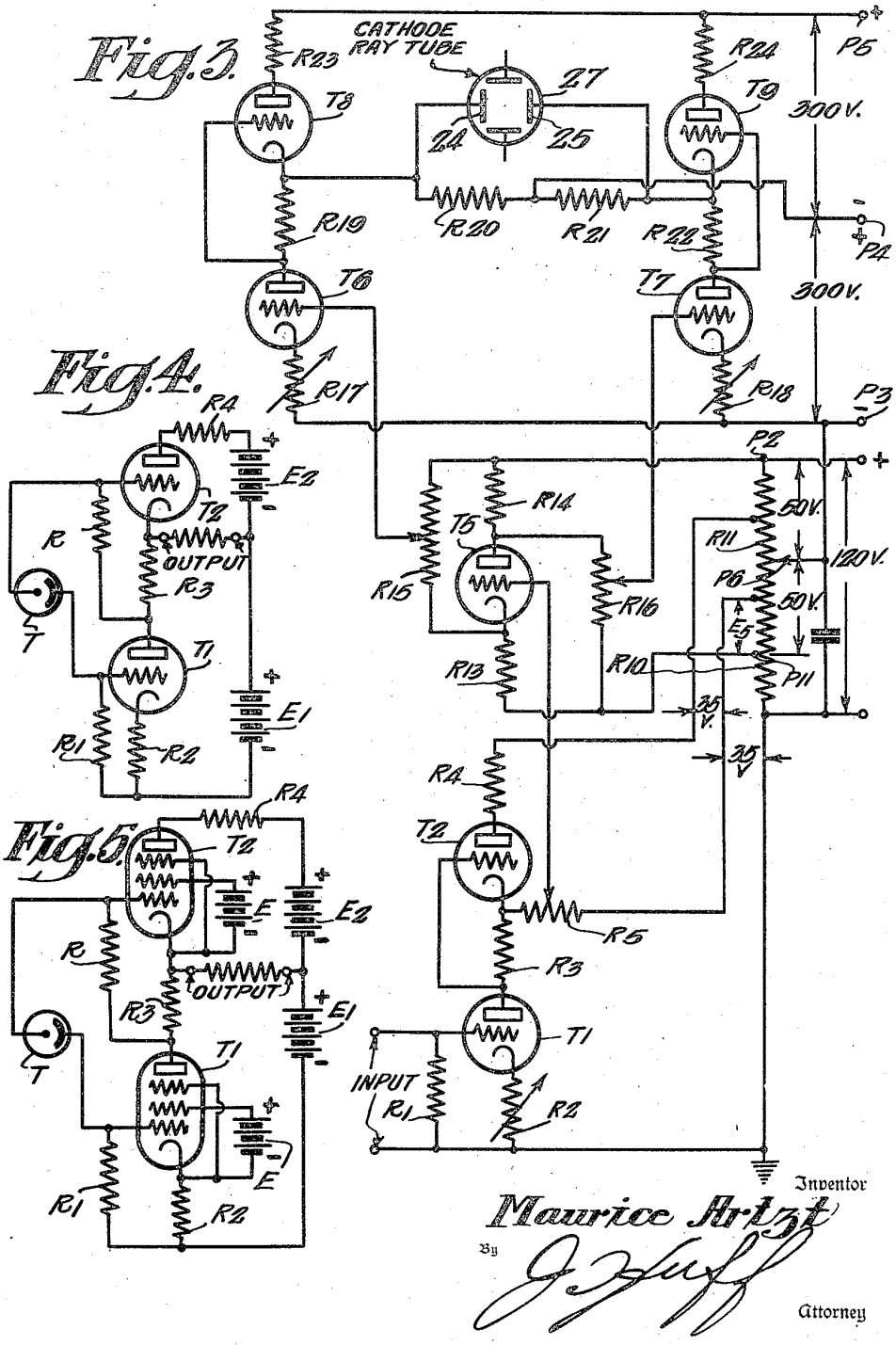

Fig. 4.

Fig. 5.

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BALANCED DIRECT AND ALTERNATING CURRENT AMPLIFIERS

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Application November 29, 1940, Serial No. 367,809

18 Claims. (Cl. 179—171)

This invention relates to direct and alternating current amplifiers and particularly to a balanced amplifier which is insensitive to variations in the power supply.

Direct current amplifiers are usually responsive to changes in the voltage of the power supply. These changes alter the gain of the amplifier and disturb its zero setting. In both A.-C. and D.-C. amplifiers, requiring a high degree of stability, it is customary to provide a regulated power supply. Such regulated power supplies are complicated, expensive and often fall short of the desired goal.

It is an object of this invention to provide a stabilized means for amplifying direct currents. Another object of the invention is to provide A.-C. and D.-C. amplifying means in which the gain is substantially independent of the voltage of the power source. An additional object is to provide stabilized D.-C. amplifying means in which the gain may be varied without disturbing the D.-C. zero setting. A further object is to provide current amplifying means which acts as its own regulator of its power source.

The invention will be described by referring to the accompanying drawings in which Figure 1 is a schematic circuit diagram of one embodiment of the invention; Figure 2 is a schematic circuit diagram of a two stage amplifier according to the invention; Figure 3 is a schematic circuit diagram of a balanced push pull amplifier embodying the invention; and Figures 4 and 5 are schematic diagrams of modifications in which photoelectric cells are connected to the amplifier inputs. In the several figures, similar reference characters are applied to similar elements.

Referring to Fig. 1, a power source is connected to a pair of serially connected resistors R10, R11 having equal resistances. A cathode resistor R2, amplifier T1, anode resistors R3, R5 are serially connected across the lower of the pair of resistors R10. The input of the amplifier includes the resistor R1, which is connected between the lower end of the cathode resistor R2 and the grid. A second amplifier T2, having parameters similar to the first amplifier, is connected as follows: The anode is connected through an anode resistor R4 to the positive terminal of the resistor R11; the cathode is connected to the junction of the resistors R3 and R5; and the grid is connected to the anode of the first tube T1.

The operation is as follows: Whatever the voltage of the power source may be, it is divided equally across R10 and R11. Preferably the voltage of the power source is made to equal twice the rated voltage of either tube. If the resistors R2 and R3 are equal and of the value which permits normal anode current to flow for class A operation, it follows that the current through R2 will equal the current through R3 and will be of the proper value to bias amplifier T2 for correct class A operation. Furthermore, if the resistance of R4 is made equal to the resistance of R2+R3, the anode current through T2 will equal that of T1. Therefore, the voltage drop through T1+R2+R3 will equal the voltage E1 and the voltage drop through T2+R4 will equal the voltage E2. Since the currents through R5, in the absence of an input signal, are equal and opposite, there will be zero output voltage across R5. Furthermore, the output voltage across R5 will remain zero for all variations of the voltage of the power source.

If a signal of, say, one volt positive, is applied to the grid of T1, the anode current of T1 will increase, and this will increase the voltage drop in R2, R3 and R5. The current in R2 will be degenerative and the final change in bias across R2 may be one volt less a half volt or a half volt positive. A similar voltage change across R3 will be in the opposite direction and will decrease the current flowing through resistors R4 and R5. Since, in the presence of an input voltage, the anode current of T1 increases the voltage drop across R5 and the anode current of T2 decreases the voltage drop across R5, it follows that a negative output voltage will be developed across R5. If the input to T1 had been assumed negative, the anode current of T1 would have decreased and the anode current of T2 would have increased making the output voltage across R5 positive. By setting R2 to the value which makes the potential across R5 zero with no input signal, the system will be balanced, the output voltage will be affected only by the input signal, and the gain will be constant over wide variations of supply voltage. The gain may be varied by making resistor R5 a potentiometer.

The system may be extended to several stages by adding additional resistors across the power supply and by using the output of the first stage as the input of the second. The schematic circuit diagram of a two stage balanced amplifier is shown in Fig. 2. In this circuit the three bleeder resistors R10, R11 and R12 are all equal so that the voltages across them are equal. The first stage corresponds to the arrangement of Fig. 1. The second stage is similar to the first

stage but is connected across the second and third bleeder resistors R11, R12. The output potentiometer R5 of the first stage applies the input signal to the second stage. The output signals from the second stage are developed across the resistor R9 which may be a potentiometer.

The invention may be used as the deflecting amplifier of an oscillograph as shown in Fig. 3. The output from the first balanced amplifier stage T1, T2 appears across resistor R5. The output from R5 is applied to the phase inverting tube T5, which is connected as follows: The cathode is connected through a cathode resistor R13 to a point P11 intermediate the terminals of the bleeder resistor R10. The anode is connected through anode resistor R14 to a point P2 at higher positive potential than the positive terminal of bleeder resistor R11. One output potentiometer R15 is connected between the cathode and the positive point P2; the other output potentiometer R16 is connected between the anode and the point P1.

The output potentiometers R15 and R16 are connected respectively to the input amplifiers T6 and T7 of the pushpull stage. The cathodes of the amplifiers T6 and T7 are connected respectively through cathode resistors R17 and R18 to the negative terminal of a power source indicated by the reference characters P3, P4. The anodes of the amplifiers are connected through anode resistor R19, and output resistor R20 and anode resistor R22 and output resistor R21, respectively, to the positive terminal P4 of the power source P3, P4. The output resistors R20 and R21 are connected to the deflecting electrodes 24, 25 of a cathode ray tube 27.

The remaining amplifiers T8 and T9 of the pushpull stage are connected as follows: The inputs to amplifiers T8 and T9 are obtained from the anode resistors R19 and R22, respectively. The cathodes are connected, respectively, to the junction of R19 and R20, and to the junction of R21 and R22. The anodes of amplifiers T8 and T9 are connected through anode resistors R23 and R24 to the positive terminal P5 of a power source P4, P5 whose voltage equals P3, P4. The terminal P3 is connected to a slider P6 on the resistor R11 and through a capacitor C to ground.

In the foregoing circuit arrangement the grid return through R5 to the junction of the bleeder resistors R10, R11 is so set that with zero signal input, and therefore zero signal across R5, the input to the phase inverter T5 is biased to the center of its characteristic for class A operation. The sliders on the potentiometers R15 and R16 are adjusted so that the signal representing voltages are equally and oppositely applied to the pushpull stage. The slider P6 is adjusted so that in the absence of input signals the potentials applied to the grids of amplifiers T6 and T7 is zero and the outputs of the pushpull stages is zero.

The function of the inverter tube T5 may be considered that of a center tap across bleeder network between ground and P2, and therefore voltage changes between ground and P2 cause no drifts in its setting. The input stages are balanced against line voltage changes as previously described. The pushpull stages are likewise balanced. Therefore, the entire amplifying system is balanced and the amplifier is extremely stable. The actual voltages, by way of example, may be those shown in Fig. 3. In one such amplifier, voltage gains of 1000 were obtained. An input signal voltage of 0.05 volt D. C. swings R20 to −220 volts and R21 to +220 volts. Line voltage variations of 100 to 130 volts produced changes of less than 1 volt on the cathode ray deflecting electrodes.

Referring to Fig. 4, if the input to the balanced amplifier is a photoelectric cell T, the bias for the cell may be obtained from the lower voltage source E1. This is accomplished by inserting a resistor R between the grid of the second amplifier tube T2 and the anode of the first amplifier T1. The terminals of the photoelectric cell are connected respectively to the grids of the amplifiers T1, T2. The connection described not only provides the bias for the photoelectric cell but it also applies the output voltage from the cell to the inputs of both amplifiers. The gain of the device is four times that which would be obtained if the voltage were applied only to the input of the first amplifier.

In the several amplifier circuits, triode tubes have been shown. The invention is not limited to triodes; other types of tubes may be used. For example, the circuit lends itself to pentode operation, as illustrated in Fig. 5. The circuit is similar to that of Fig. 4. It differs therefrom in that additional batteries E are used to bias the screen grids of the amplifiers. Pentodes in this connection are especially advantageous because their output impedance which is very high may be matched by applying the output circuit to the input of an high impedance device such as a thermionic tube. Thus connected, not only is the amplifier balanced, but the high amplification of the pentodes may be obtained.

Thus the invention has been described as a self-stabilizing amplifier. The amplifier may be used to amplify direct or alternating currents. The gain of the amplifier is made independent of the power source by a novel balancing circuit. The balance also tends to buck out hum or like disturbances in the power source and thus permits a cheaper and more efficient rectifier and filter system than is ordinarily used as a power source for high fidelity amplifiers. The amplifier is especially useful with a cathode ray tube because the stabilizing connections eliminates deleterious variations of the trace.

I claim as my invention:

1. A balanced amplifier including an impedance means having end terminals and an intermediate terminal, a pair of electron discharge devices provided with cathode-anode circuits including three anode circuit resistors connected in series between said end terminals and the cathode of one device and the anode of the other device and between the remaining anode and cathode of said devices respectively, one of said discharge devices having its input circuit connected across the anode circuit resistor of the other device and its cathode connected through an output impedance to said intermediate terminal, and signal supply means connected to the input circuit of at least one of said devices.

2. A balanced amplifier including an impedance means having end terminals and an intermediate terminal, a circuit between said end terminals including the cathode-anode circuits of a pair of electron discharge devices, said circuit including a resistor between one of said end terminals and the anode of one of said devices and a resistor between the cathode of the other of said devices and the other of said end terminals and a third resistor between the remaining anode and cathode of said devices respec-

tively, one of said discharge devices having its input circuit connected across the anode circuit resistor of the other device and its cathode connected through an output impedance to said intermediate terminal, the second of said resistors forming a self-biasing means for the device to which it is connected, and signal input means connected to at least one of said devices.

3. A balanced amplifier including an impedance means having end terminals and an intermediate terminal, a circuit between said end terminals including the cathode-anode circuits of a pair of electron discharge devices, said circuit including a resistor between one of said end terminals and the anode of one of said devices and a resistor between the cathode of the other of said devices and the other of said end terminals and a third resistor between the remaining anode and cathode of said devices respectively, one of said discharge devices having its input circuit connected across the anode circuit resistor of the other device and its cathode connected through a load circuit to said intermediate terminal, the second of said resistors forming a self-biasing means for the device to which it is connected, and means for applying input signals to said other device.

4. A balanced amplifier including an impedance means having end and midpoint terminals, a pair of electron discharge devices each provided with a cathode and anode, resistance means connected in series between said end terminals and the cathode of one of said devices and the anode of the other of said devices and between the remaining cathode and anode, the device including a resistor from its cathode to said end resistor being self-biased by current through said cathode to said terminal resistor, the other of said devices having its input circuit connected to the anode circuit of the self-biased device and its cathode connected through an output impedance to said midpoint, the resistances of the self-bias resistor and the anode circuit resistor of the self-biased device equalling the resistance of the anode circuit resistor of the other device.

5. A balanced amplifier including an impedance means having end and midpoint terminals, a pair of electron discharge devices each provided with a cathode and an anode, three resistors connected respectively between the cathode of one of said devices and the anode of the other of said devices and the anode of the said one device and one of said end terminals and the cathode of the said other device and the other of said end terminals, the resistor between said cathode and end terminal forming a self-biasing means and at least in part signal input means, and the other of said devices having its input circuit connected to the anode circuit of the self-biased device and its cathode connected through an output impedance to said midpoint, the resistances of the self-bias resistor and the anode circuit resistor of the self-biased device equalling the resistance of the anode circuit resistor of the other device.

6. A balanced amplifier including a first amplifier, a second amplifier, a first resistor connected in common to the input and output of said first amplifier, a second resistor connected in common to the output of said first amplifier and the input of said second amplifier, an output load resistor common to the outputs of both of said amplifiers, a third resistor connected to the output of said second amplifier, a pair of terminals and a common terminal representing a power source having equal voltages between said common terminal and said pair of terminals, said common terminal being connected to said output load resistor, means connecting one of said pair of terminals to said third resistor to apply therethrough one of said voltages to said second amplifier, and means connecting the other of said pair of terminals to said first resistor to apply therethrough the other of said voltages to said first amplifier.

7. A balanced amplifier including a first amplifier, a second amplifier, a first resistor connected in common to the input and output of said first amplifier, a second resistor connected in common to the output of said first amplifier and the input of said second amplifier, an output load resistor common to the outputs of both of said amplifiers, a third resistor connected to the output of said second amplifier, a pair of terminals and a common terminal representing a power source having equal voltages between said common terminal and said pair of terminals, said common terminal being connected to said output load resistor, means connecting one of said pair of terminals to said third resistor to apply power to the amplifier connected thereto, means connecting the other of said pair of terminals to said first resistor to apply power to the amplifier connected thereto, and means for applying signals to the input of said first amplifier.

8. A balanced amplifier including a first amplifier, a second amplifier, a first resistor connected in common to the input and output of said first amplifier, a second resistor having a resistance equal to that of said first resistor connected in common to the output of said first amplifier and the input of said second amplifier, an output load resistor common to the outputs of both of said amplifiers, a third resistor connected to the output of said second amplifier, a pair of terminals and a common terminal representing a power source having equal voltages between said common terminal and said pair of terminals, said common terminal being connected to said output load resistor, means connecting one of said pair of terminals to said third resistor to apply power to the amplifier connected thereto, and means connecting the other of said pair of terminals to said first resistor to apply power to the amplifier connected thereto.

9. A balanced amplifier including a first amplifier, a second amplifier, a first resistor connected in common to the input and output of said first amplifier, a second resistor having a resistance equal to that of said first resistor connected in common to the output of said first amplifier and the input of said second amplifier, an output load resistor common to the outputs of both of said amplifiers, a third resistor, having a resistance equal to the sum of the resistances of said first and second resistors, connected to the output of said second amplifier, a pair of terminals and a common terminal representing a power source having equal voltages between said common terminal and said pair of terminals, said common terminal being connected to said output load resistor, means connecting one of said pair of terminals to said third resistor to apply power through said third resistor to said second amplifier, and means connecting the other of said pair of terminals to said first resistor to apply power through said first resistor to said first amplifier.

10. A balanced amplifier including a first amplifier, a second amplifier, a first resistor con-

nected in common to the input and output of said first amplifier, a second resistor connected in common to the output of said first amplifier and the input of said second amplifier, an output load resistor common to the outputs of both of said amplifiers, a third resistor, having a resistance equal to the sum of the resistances of said first and second resistors, connected to the output of said second amplifier, a pair of terminals and a common terminal representing a power source having equal voltages between said common terminal and said pair of terminals, said common terminal being connected to said output load resistor, means connecting one of said pair of terminals to said third resistor to apply power through said third resistor to said second amplifier, and means connecting the other of said pair of terminals to said first resistor to apply power through said first resistor to said first amplifier.

11. A balanced amplifier including a first amplifier, a second amplifier, a first resistor connected in common to the input and output of said first amplifier, a second resistor having a resistance equal to that of said first resistor connected in common to the output of said first amplifier and the input of said second amplifier, an output load resistor common to the outputs of both of said amplifiers, a third resistor, having a resistance equal to the sum of the resistances of said first and second resistors, connected to the output of said second amplifier, a pair of terminals and a common terminal representing a power source having equal voltages between said common terminal and said pair of terminals, said common terminal being connected to said output load resistor, means connecting one of said pair of terminals to said third resistor to apply power therethrough to said second amplifier, means connecting the other of said pair of terminals to said first resistor to apply power therethrough to said first amplifier, and means for applying signals to the input of said first amplifier.

12. A balanced amplifier including a pair of terminals representing a power source subject to potential variations, means for dividing equally the potential across said terminals, a pair of amplifiers having input and output terminals, the output terminals of the first of said pair of amplifiers including a first resistor common to the input and the output of said first amplifier and a second resistor common to the output circuit of said first amplifier and the input circuit of the second of said pair of amplifiers, a third resistor connected to the cathode of said second amplifier and to a potential point midway between the terminals of said source and forming the output of said balanced amplifier, and a fourth resistor included between the output terminal of said second amplifier and one of said pair of terminals for applying power through said fourth resistor to said second amplifier, the other of said pair of terminals being connected to said first resistor for applying power through said first resistor to said first amplifier.

13. A balanced amplifier including a first amplifier, a second amplifier, a first resistor connected in common to the input and output of said first amplifier, a second resistor connected in common to the output of said first amplifier and the input of said second amplifier, a third resistor connected to the output terminal of said second amplifier, an output load resistor common to the outputs of said first and second amplifiers, a pair of terminals and a common terminal representing a power source having equal voltages between said common terminal and said pair of terminals, said common terminal being connected to said output load resistor, means connecting one of said pair of terminals to said third resistor, means connecting the other of said pair of terminals to said first resistor, a photoelectric cell, and means for connecting said cell to the inputs of said first and second amplifiers.

14. A balanced amplifier including a first amplifier, a second amplifier, a first resistor connected in common to the input and output of said first amplifier, a second resistor connected in common to the output of said first amplifier and the input of said second amplifier, a third resistor connected to the output terminal of said second amplifier, an output load resistor common to the outputs of said first and second amplifiers, a pair of terminals and a common terminal representing a power source having equal voltages between said common terminal and said pair of terminals, said common terminal being connected to said output load resistor, means connecting one of said pair of terminals to said third resistor, means connecting the other of said pair of terminals to said first resistor, a pair of resistors connected respectively to the inputs of said amplifiers, and means for applying currents to be amplified to said pair of resistors.

15. A device of the character of claim 6 in which said amplifiers are pentode tubes and a pair of biasing batteries for biasing the screen grid electrodes of said pentodes.

16. A device of the character of claim 6 in which said amplifiers are pentode tubes and including terminals connected effectively to the screen grids and cathodes of said amplifiers for applying biasing voltages from sources independent of said power source.

17. A pair of amplifiers of the character of claim 6 in which a single power source supplies power to both of said amplifiers and in which means are provided for applying input voltages in pushpull and in which means are provided for deriving output currents in pushpull.

18. A push-pull balanced amplifier including a first amplifier, a second amplifier, a first resistor connected in common to the input and output of said first amplifier, a second resistor common to the output of said first amplifier and the input of said second amplifier, a third amplifier, a fourth amplifier, a third resistor connected in common to the input and output of said third amplifier, a fourth resistor common to the output of said third amplifier and the input of said fourth amplifier, a pair of terminals and a common terminal representing a power source having equal voltages between said common terminal and said pair of terminals, means including resistors for connecting one of said pair of terminals and said common terminal respectively to the output terminals of said second and fourth amplifiers for applying power through said resistors to said second and fourth amplifiers, means for connecting the other of said pair of terminals to said first and third resistors for applying power through said resistors to said first and third amplifiers, means for applying input voltages in push-pull to said first and third amplifiers, and means for deriving output currents in push-pull from said second and fourth amplifiers.

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