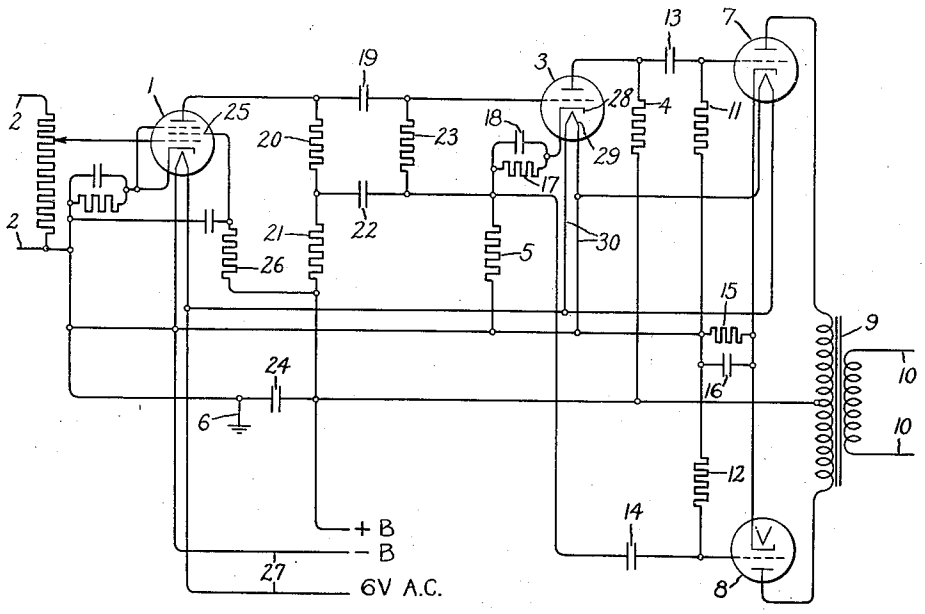
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AMPLIFIER

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AMPLIFIER

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My invention relates to amplifiers. It has for one of its objects to provide certain improvements in amplifiers employed between unbalanced and balanced circuits whereby the effects of degeneration and undesired noise due to energizing currents are reduced.

One common form of coupling between unbalanced and balanced circuits involves an amplifier in which the external anode cathode impedance is divided in two equal impedances by a ground connection. The balanced circuit is then connected between the anode and cathode and thus receives equal and opposite voltages with respect to ground on its two conductors. The unbalanced circuit is connected between grid and ground.

My invention has to do with such circuits and it has for one of its objects to reduce the degeneration produced by the impedance which is connected between the cathode and ground in such an amplifier.

A further object of my invention is to equalize the hum currents supplied to the balanced circuit by reason of the alternating cathode energizing currents of the amplifier so that such currents may be balanced out in that circuit.

The novel features which I believe to be characteristic of my invention are set forth with particularity in the appended claims. My invention, itself, however, both as to its organization and method of operation, together with further objects and advantages thereof, may best be understood by reference to the following description taken in connection with the accompanying drawing in which the single figure represents an embodiment of my invention.

Referring to the drawing I have shown therein an amplifier 1 connected to amplify signals received upon a circuit 2 and to supply such signals to the input circuit of an amplifier 3. The amplifier 3 is one having an output circuit comprising resistances 4 and 5 connected in series, the resistance 4 being connected between the anode and positive terminal of the anode energizing source indicated at +B and the resistance 5 being connected between the cathode and the negative terminal —B of this source, the two resistances being proportioned so that the voltages thereon are equal. This negative terminal —B is grounded as indicated at 6 whereby the anode and cathode of the device 3 operate with equal signal voltages thereon with respect to ground, these voltages being in opposite phase relation. Oscillations appearing on the resistance 4 are supplied to the input circuit of an amplifier 7 and oscillations appearing upon the resistance 5 are supplied to the input circuit of an amplifier 8, these amplifiers being connected in push-pull relation to supply their output currents through a transformer 9 to an output circuit 10.

Resistances 11 and 12 comprise the usual grid resistances for these amplifiers 7 and 8 and similarly condensers 13 and 14 comprise the usual coupling capacitors for these amplifiers whereby the grid of amplifier 7 is coupled to the anode of amplifier 3 and the grid of amplifier 8 is coupled to the cathode of amplifier 3.

The resistor 15 shunted by condenser 16 is the usual cathode bias resistance common to the grid and anode circuits of amplifiers 7 and 8 for producing bias upon the grids of these amplifiers. Also resistance 17, shunted by condenser 18, is connected in common with the grid and anode circuits of amplifier 3 for producing bias voltage upon the grid of this amplifier.

The grid of amplifier 3 is coupled to the anode of amplifier 1 by condenser 19, the anode of amplifier 1 being connected to the positive side of the plate energizing source +B through resistors 20 and 21, these resistors being separated by a connection through condenser 22 to the cathode terminal of resistance 5. The resistance 23 is also connected between the grid and the cathode terminal of resistance 5.

Condensers 19 and 22 have large capacity and very low impedance at the frequency of currents to be considered herein, namely, audio frequency currents which it is desired that the system shall amplify and also hum currents, which may be of sixty and one hundred and twenty cycles frequency, which it is desired to eliminate. Resistors 21 and 5 are thus effectively connected in parallel, the upper terminals of these resistors being connected together by condenser 22 and the lower terminals being connected together by condenser 24, which is of similar high capacity and low impedance. This latter condenser may be one of the usual plate smoothing or filter capacitors of the power supply system. Similarly resistances 20 and 23 are effectively connected in parallel for currents having the frequency herein to be considered.

In the operation of the system, currents which are to be amplified appear in the output circuit of amplifier 3 and electromotive force produced thereby on resistors 4 and 5 are supplied in opposite phase through condensers 13 and 14 to the grids of the two amplifiers 7 and 8.

In order to secure maximum amplification of the discharge device 3 it is desirable to reduce insofar as possible the effect of degeneration caused by resistance 5, that is, if the signal voltage on resistance 5 be impressed upon the grid of amplifier 3 in opposed phase to the voltage appearing there from amplifier 1, it tends to reduce the amplification of the amplifier by the extent of such opposition. It is for this reason that I employ the resistor 21 and the condenser 22 connected as shown. In this way the voltage which appears upon resistances 5 and 21, now

connected in parallel, can be supplied between the grid and cathode only through the internal impedance of discharge device 1. This internal impedance may be made very high by the choice of discharge device employed at 1 and by the proper selection of voltages applied thereto. For example, this discharge device may be one of the screen grid, or screen and suppressor grid, type and if desired the anode resistance may be materially increased by reducing the voltage supplied to the screen grid thereof to a suitably low value. This voltage, as shown in the drawing, is supplied to the screen grid 25 through resistance 26 from the positive voltage source +B.

It has been found that with the connections shown, by making the resistance of discharge device 1 high and the parallel resistance of resistors 20 and 23 as low as practicable, practically the full amplification of discharge device 3 may be taken advantage of, the effect of degeneration being reduced to a very low value.

This arrangement is also effective in reducing undesired, or hum currents produced by reason of the cathode energization of the amplifier 3. It will be observed that the amplifiers shown, as in common practice, are of the unipotential type energized with alternating current from a suitable cathode energizing circuit 27 which is commonly supplied with alternating voltage of about 6 volts. Leakage resistance commonly exists between heater and cathode in these tubes so that alternating, or hum current, passes through this leakage resistance from heater to cathode and thence to ground. The cathodes of discharge devices 1, 7 and 8 are grounded except for the impedance of their bias resistors, and thus hum voltage across this small impedance is low enough in value not to cause objectionable hum. The cathode of amplifier 3, however, is connected to ground through its bias resistor 17 and the resistor 5, which latter resistor, since it, in parallel with resistance 21, is the anode coupling impedance between device 3 and amplifier 8 is so proportioned with respect to resistance 21 that this coupling impedance is of value equal to that of resistance 4. The cathode of this device is thus effectively removed from ground by an impedance equal to the impedance between the anode and ground. A considerable leakage current of the hum frequency may flow between the cathode 28 of this discharge device and its heater 29 because of the leakage resistance therebetween. These currents in turn flow around the circuit comprising resistance 17, resistance 5, and the heating conductors 30, thereby setting up undesired hum voltages on resistance 5 which are amplified by amplifier 8. Unless an exactly equal voltage of like phase is produced on resistor 4 these currents are reproduced in the output circuit and cause objectionable hum.

It has been found, however, that with the system connected as shown, the parallel resistance of resistances 20 and 23 may be so proportioned relative to the internal anode impedance of discharge device 1 and the gain of amplifier 3 that a hum voltage is produced on resistance 4 which is equal to that produced on resistance 5, whereby equal hum voltages are supplied to the grids of amplifiers 7 and 8 in like phase, whereby these currents are effectively balanced out in the output transformer 9. To accomplish this result it is necessary that the hum voltage which initially appears upon resistance 5 shall be supplied between the grid and cathode of discharge device 3 to such an extent that after amplification by amplifier 3 it produces the same magnitude of voltage in the anode circuit of this amplifier. This latter voltage is divided equally between resistances 4 and 5 and since the portion which appears on resistance 5 opposes that initially produced there by the cathode leakage currents the remaining voltage equals that which appears on resistance 4. The remaining voltage on resistance 5 has the same phase as, and half the magnitude of, the initial voltage which appears there and is such that the anode and cathode of this device oscillate in like phase with respect to ground at the hum frequency.

Since the total output hum voltage of amplifier 3 must equal the initial hum voltage of resistance 5, the hum voltage supplied between cathode and grid of amplifier 3 must equal this initial hum voltage divided by the gain of amplifier 3. This grid to cathode voltage is derived from the half initial hum voltage existing across resistance 5. Thus the parallel resistance of resistors 20 and 23 must be so proportioned with respect to the internal impedance of discharge device 1 that, of the half initial hum voltage existing across resistor 5, a portion equal to the initial hum voltage divided by tube gain is supplied between grid and cathode of amplifier 3.

The resistance of resistors 20 and 23 must, therefore, be proportioned in accordance with the following relation:

$$\tfrac{1}{2}\text{ initial hum voltage}\times\frac{R_a}{R_a+R_p}=\frac{\text{initial hum voltage}}{g}$$

or

$$\frac{R_a}{R_a+R_p}=\frac{2}{g}$$

Where R_2 is the parallel resistance of resistors 20 and 23, R_p is the internal anode resistance of discharge device 1 and g is the amplification of amplifier 3. It has been found when so proportioned the hum voltages produced by leakage currents between the cathode and heater of discharge device 3 appear with equal intensity and like phase upon the grids of amplifiers 7 and 8 and thus are effectively neutralized or balanced out in the transformer 9. This latter condition requires that the resistance 20 and 23 be made as small as practicable and the internal resistance of amplifier 1 as large as practicable, these being the conditions necessary to the reduction of degeneration as previously explained. Thus both of the two results secured by my invention, namely the reduction of degeneration and the elimination of hum due to these leakage currents, are effectively secured.

While the values of the various resistances and capacitances involved may vary widely, one set of values which have been found satisfactory are as follows:

Resistance 20	ohms	180,000
Resistance 23	do	180,000
Resistance 21	do	47,000
Resistance 5	do	39,000
Resistance 4	do	22,000
Resistance 26	megohms	2.2
Condenser 19	microfarad	.05
Condenser 22	do	.1

The discharge device 1 was of 6B8G type and discharge device 3 was of the 6J5G type.

While I have shown but a single embodiment of my invention it will of course, be understood

that I do not wish to be limited thereto since different modifications both in the circuit arrangement and in the instrumentalities employed may be made, and I contemplate by the appended claims to cover any such modifications as fall within the true spirit and scope of my invention.

What I claim as new and desire to secure by Letters Patent of the United States is:

1. In combination, an electron discharge amplifier having a grid, an anode, and a cathode, a balanced output circuit connected between said anode and cathode, an unbalanced input circuit connected between said grid and the midpoint of said output circuit and a connection from said cathode to an intermediate point on said input circuit, the impedance of said input circuit between said grid and said intermediate point being proportioned to reduce degeneration due to voltage supplied from the cathode side of said output circuit to the grid through the impedance of the input circuit.

2. In combination, an electron discharge amplifier having a grid, an anode, and a cathode, a balanced output circuit connected between said anode and cathode, an unbalanced input circuit connected between said grid and the midpoint of said output circuit, and a connection from said cathode to an intermediate point on said input circuit, the impedance between said intermediate point and grid being proportioned relative to the impedance of said input circuit and the gain of said amplifier to minimize the voltage across said output circuit produced by undesired oscillation of said cathode with respect to said midpoint of said balanced output circuit.

3. In combination, an electron discharge amplifier having an anode, a cathode, and a grid, an unbalanced input circuit, a balanced output circuit, said cathode being connected to one side of said input circuit and to the midpoint of said output circuit through an impedance, the opposite sides of said output circuit being connected respectively to said cathode and anode, and the opposite side of said input circuit being connected to said grid, an impedance connected across said input circuit having an intermediate point connected to said cathode, the impedance of said input circuit being sufficiently high and the impedance between said intermediate point and grid sufficiently low to minimize the reduction in gain of said amplifier caused by degeneration due to said first mentioned impedance.

4. In combination, an electron discharge amplifier having an anode, a cathode and a grid, an unbalanced input circuit, a balanced output circuit, said cathode being connected to one side of said input circuit and to the mid-point of said output circuit through an impedance, the opposite sides of said output circuit being connected respectively to said cathode and anode, and the opposite side of said input circuit being connected to said grid, energizing means for said cathode effective to produce undesired hum voltage across said impedance, an impedance connected across said input circuit having an intermediate point connected to said cathode, the impedance between said intermediate point and grid being of such value that the voltage produced between said cathode and said grid equals the intensity of said undesired hum voltage divided by the gain of the amplifier.

5. In combination, an electron discharge amplifier having an anode, a grid, a unipotential cathode and a heater for said cathode, said anode and cathode being connected to ground through equal impedances, an input circuit connected between said grid and ground, a source of alternating heating current connected to said heater, said heater and cathode being so arranged that voltage is produced between said cathode and ground due to leakage current from said heater, and means to produce voltage on said anode with respect to ground due to said leakage current equal to the effective voltage between said cathode and ground.

6. In combination, an electron discharge amplifier having an anode, a grid, a unipotential cathode, and a heater for said cathode, said anode and cathode being connected to ground through equal impedances, an input circuit connected between said grid and ground, a source of alternating heating current connected to said heater, said heater and cathode being so arranged that voltage is produced between said cathode and ground due to leakage current from said heater, and means to supply a sufficient portion of said voltage to said grid to produce on said anode with respect to ground a voltage equal to the effective voltage on said cathode with respect to ground caused by said leakage current.

7. In combination, an electron discharge device having an impedance connected between its anode and cathode, an electron discharge amplifier having a grid connected to said anode, a cathode connected to an intermediate point on said impedance and through a second impedance to said first mentioned cathode, and an anode connected to said first mentioned cathode through a third impedance equal to the impedance between said cathodes, whereby voltage produced on said first impedance is amplified by said amplifier and supplied equally to said second and third impedances, and whereby a portion of the voltage of said second impedance is supplied between said grid and cathode through said first mentioned discharge device to produce degeneration, and means to increase the impedance of said first mentioned discharge device to minimize said degeneration.

8. In combination, an electron discharge device having an impedance connected between its anode and cathode, an electron discharge amplifier having a grid connected to said anode, a cathode connected to an intermediate point on said impedance, and through a second impedance to said first mentioned cathode, and an anode connected to said first mentioned cathode through a third impedance equal to the impedance between said cathodes, whereby voltage produced on said first impedance is amplified by said amplifier and supplied equally to said second and third impedances, and whereby a portion of the voltage on said second impedance is supplied between said grid and cathode through said first mentioned discharge device, alternating current heating means for said cathode of said amplifier operating to produce hum currents in said second impedance, the proportions of said first impedance on opposite sides of said intermediate point and the impedance of said first mentioned discharge device being chosen substantially to equalize the hum voltages on said second and third impedances.

9. In combination, an amplifier having an anode, a cathode and a grid, said anode and cathode being connected to ground through equal

impedances, an input circuit connected between said grid and ground, an impedance connected across said input circuit having an intermediate point connected to said cathode, a source of alternating energizing current for said cathode operating to produce hum currents across said impedance between said cathode and ground, and means to minimize degeneration in said amplifier produced by said last mentioned impedance and simultaneously to equalize voltages produced across said equal impedances due to said energizing currents.

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