

April 10, 1945.

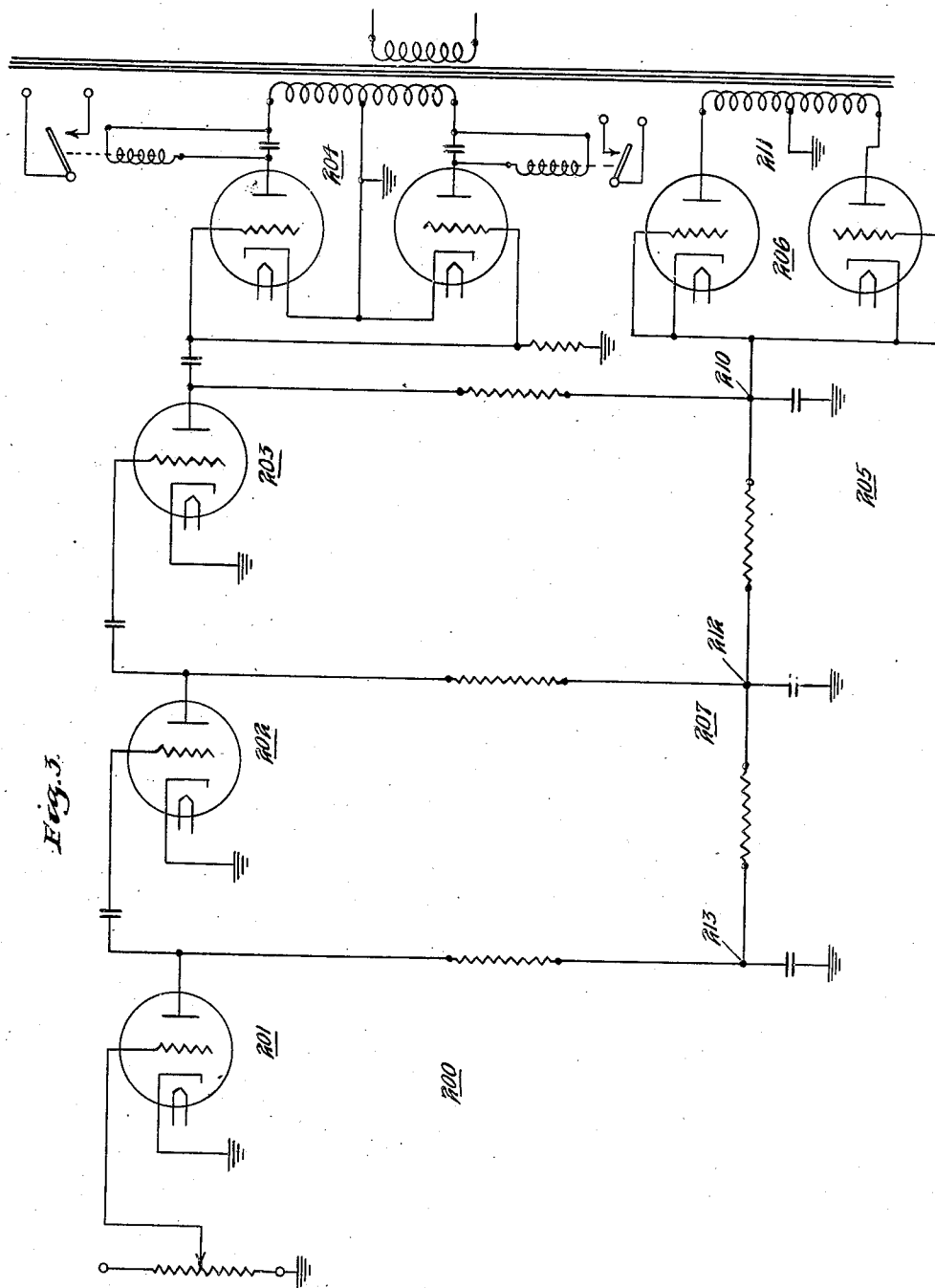
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2,373,241

AMPLIFIER CIRCUIT

Filed Nov. 18, 1942

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UNITED STATES PATENT OFFICE

2,373,241

AMPLIFIER CIRCUIT

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Application November 18, 1942, Serial No. 466,010

6 Claims. (Cl. 179-171)

The present invention relates to amplifier circuits, and particularly to circuit arrangements for preventing disturbances in amplifier circuits due to the use of a source of alternating electrical energy as a power supply.

Electronic amplifier circuits of conventional type use an electrical discharge device having an anode, a cathode and a control electrode, and a source of substantially unidirectional electrical energy for supplying power to the anode-cathode circuit of the device. Since sources of alternating electrical energy are frequently much more accessible and convenient than a source of unidirectional energy, it is customary to utilize an alternating source, and to provide a rectifier and filter circuit for obtaining unidirectional energy therefrom. Most rectifier circuits have a considerable alternating component in their output, and the filter circuit is utilized to remove this alternating component so that the amplifier may be supplied with purely unidirectional electrical energy. Absolutely perfect filter circuits are, however, unknown. Furthermore, the more perfect a filter circuit is, the more complicated and expensive it is likely to be.

It is therefore an object of the present invention to provide a circuit arrangement wherein a relatively simple filter circuit may be used between a rectifier and an amplifier circuit, and wherein improved means are provided to prevent the appearance of any substantial alternating component in the final stage of the amplifier.

Another object of the present invention is to provide a power supply circuit for a multiple stage amplifier, in which two stages of the amplifier are connected to electrically spaced points in the power supply circuit, and in which the attenuation of the alternating component in the power supply circuit between these two points are proportioned to the gain in the amplifier circuit. A still further object is to provide, in an amplifier and power supply circuit of the type described, means whereby the phase shift between the aforesaid two points in the filter circuit is supplementary to the phase shift occurring between the amplifier stages.

Other objects and advantages of my invention will become apparent from a consideration of the appended specification, claims and drawings, in which:

Figure 1 is an electrical wiring diagram of an amplifier and power supply circuit embodying the principles of my invention,

Figure 2 is a somewhat diagrammatical repre-

sentation of a control system wherein the amplifier circuit of Figure 1 may be used, and

Figure 3 is an electrical wiring diagram of a modified form of amplifier circuit embodying the principles of my invention.

Referring now to Figure 2, there is shown a system for controlling the movements of the rudder of an aircraft in accordance with the deflection of a directional gyroscope, diagrammatically indicated at 10, from a normal position. The gyroscope 10 is indicated as rotating a shaft 11 whenever the aircraft upon which the gyroscope is mounted changes its direction. Fixed on the shaft 11 is a slider 12, which cooperates with a slidewire resistance 13. The slider 12 and the resistance 13 together form a control potentiometer 14.

The resistance 13 is connected in an electrical network 15, of the Wheatstone bridge type. The network 15 also includes a slidewire resistance 16 with which is associated a slider 17. The resistance 16 and slider 17 together form a follow-up potentiometer 18. The network 15 is supplied with electrical energy from a transformer secondary winding 19, whose terminals 20 and 21 are connected through conductors 22 and 23, respectively, to the left and right terminals of resistances 13 and 16. The sliders 12 and 17 form the output terminals of the network 15. The slider 17 is fixed on a shaft 24 for rotation therewith. The shaft 24 also carries a pulley 25 and a gear 26. A cable 27 runs over the pulley 25. This cable 27 may be the conventional control cable used in aircraft for positioning the rudder.

The gear 26 engages a pair of gears 28 and 31, which are fixed on shafts 32 and 33, respectively. The shaft 32 is connectable through an electrically operable clutch device schematically indicated at 34 to a driving shaft 35. Similarly, the shaft 33 is connectable by an electrically operable clutch device 36 to a driving shaft 37. The shafts 35 and 37 carry gears 38 and 39, respectively, which mate with each other so that the shafts 35 and 37 rotate in opposite directions. The gear 38 engages a gear 41 which is driven by a continuously running motor 42.

The motor 42 may be supplied with electrical energy from any suitable source, as for example a battery 43. An energizing circuit for motor 42 may be traced from the upper terminal of battery 43 through conductors 44 and 45, motor 42, a conductor 46, ground connections 47 and 48, and a conductor 49 to the lower terminal of battery 43.

The battery 43 also supplies electrical energy

to a converter 51, which may be of any conventional type, and serves to supply alternating electrical energy to an amplifier 52, which is described in detail in Figure 1. The direct current input circuit for converter 51 may be traced from the upper terminal of battery 43 through conductors 44 and 53, converter 51, a conductor 54, ground connections 55 and 48, and conductor 49 to the lower terminal of battery 43. The converter 51 supplies alternating electrical energy through conductors 56 and 57 to power input terminals 58 and 59 of amplifier 52.

The slider 12 is connected through a shielded conductor 61 to an input terminal 62 of amplifier 52. The slider 17, which serves as the other output terminal of network 15, is connected through a conductor 63 to ground at 64. The other input terminal 65 of amplifier 52 is grounded as at 66.

As explained in greater detail hereinafter in connection with the description of Figure 1, the amplifier 52 selectively controls the conductivity of the energizing circuits for the electrically operated clutches 34 and 36. The energizing circuit for clutch 34 may be traced from the upper terminal of battery 43 through a conductor 60, a terminal 67 of amplifier 52, an internal connection in amplifier 52, a terminal 68, a conductor 69, clutch 34, a conductor 70, ground connections 71 and 48, and conductor 49 to the lower terminal of battery 43. The energizing circuit for clutch 36 may be traced from the upper terminal of battery 43 through a conductor 73, a terminal 74 of amplifier 52, an internal connection in amplifier 52, a terminal 75, a conductor 76, clutch 36, a conductor 77, ground connections 78 and 48, and conductor 49 to the lower terminal of battery 43.

Suitable switch means may be provided for shutting down the entire system when not in use. Also, limit switch means may be provided for selectively preventing energization of one or the other of the clutches when the follow-up potentiometer, or the rudder, reaches the end of its range of travel. A suitable switching arrangement is shown, for example, in the co-pending application of Willis H. Gille, Serial No. 447,989, filed June 22, 1942.

Referring to Figure 1, there are shown the details of the amplifier circuit 52. This amplifier comprises a first preliminary voltage amplification stage 80, a second preliminary voltage amplification stage 81, and a final power amplification stage 82. The amplifier 52 also includes a power supply circuit, generally indicated at 83, which supplies power to the preliminary stages 80 and 81 and provides suitable biasing potentials for the second stage 81 and the final stage 82.

The first amplification stage 80 includes an electrical discharge device, shown as a triode 84, which may be, for example, one-half of a twin triode of the type known commercially as type 7F7. The triode 84 includes an anode 85, a control electrode 86, a cathode 87, and a heater filament 88.

A resistance 90 is connected across the input terminals 62 and 65 of amplifier 52, so that any signal potential occurring between these terminals causes a corresponding current flow through resistance 90. The resistance 90 is provided with an adjustable tap 91, which serves in a well known manner to control the gain of the amplifier 52.

The input circuit of amplifier stage 80 may be traced from control electrode 86 through a shielded conductor 92, tap 91, a portion of resist-

ance 90, terminal 65, and ground connections 86 and 93 to cathode 87. The output circuit of stage 80 may be traced from a conductor 94, which serves as the positive terminal of the output circuit power supply, through a load resistance 95, anode 85, and cathode 87 to ground at 93, the ground connection serving as the negative terminal of the output circuit power supply.

The second amplifier stage 81 includes a triode 96 having an anode 97, a control electrode 98, a cathode 99, and a heater filament 100. The triodes 84 and 96 may be, for example, the two halves of a single 7F7 twin triode. The input circuit of the stage 81 may be traced from the control electrode 98 through a resistance 101, a resistance 102, a resistance 103, and a condenser 104 in parallel therewith, and ground connections 108 and 109 to cathode 99. The output circuit of stage 81 may be traced from positive supply terminal 94 through a load resistance 111, anode 97, and cathode 99 to ground at 109.

A pair of resistances 112 and 113 are connected between positive power supply terminal 94 and ground at 114. The resistance 113 is provided with an adjustable tap 115, and the latter is connected through a resistance 116 to the lower terminal of resistance 102 in the input circuit of stage 81. This connection serves to provide a positive bias potential for this input circuit. An additional positive bias potential may be applied to this input circuit through a connection which may be traced from the lower terminal of resistance 102 in the input circuit through a conductor 117, either through conductor 118, contact 119, and switch arm 120 to a conductor 124, or through conductor 121, contact 122, and switch arm 123 to conductor 124, and thence through a variable resistance 125 and fixed resistance 126 to a terminal 180 in the power supply circuit 83. The terminal 180 is located at a point in the power supply circuit 83 which is positive with respect to ground. Variations in the potential of anode 85 caused by variations in the output current of the stage 80 are coupled to the input circuit of stage 81 through a blocking condenser 127 and a conductor 128.

The final power amplification stage 82 includes a twin triode 130, which may be of the type commercially known as type 7N7. The twin triode 130 includes two separate triodes 131 and 132. The triode 131 includes an anode 133, a control electrode 134, a cathode 135, and a heater filament 136. The triode 132 includes an anode 137, a control electrode 138, a cathode 139, and a heater filament 140.

The power amplification stage 82 includes a common input circuit for both the triodes 131 and 132. This common input circuit may be traced from either control electrode 134 or control electrode 138 through a conductor 142, a conductor 143, a movable tap 144, a portion of a resistance 145, and ground connections 146 and 147 to cathodes 135 and 139. Variations in the potential of anode 97 caused by variations in the output current of the second amplifier stage 81 are transmitted to the common input circuit of the final stage 82 through a blocking condenser 148 and a conductor 149 to conductor 142 in the common input circuit. The resistance 145 is so connected in the power supply circuit 83 that the tap 144 is negative with respect to ground. The setting of tap 144 with respect to resistance 145 therefore determines a negative bias potential applied to the common input circuit of final

stage 82 and hence determines the normal current flow in the output circuits of that stage.

The output circuit of final stage 82 is divided into two branches, each of which includes the anode and cathode of one of the triodes 131 and 132. Both branches of the output circuit of stage 82 are supplied with alternating electrical energy from a secondary winding 151 of a transformer 152. The transformer 152 also includes a primary winding 153 and two additional secondary windings 154 and 155.

The upper branch of the output circuit of final stage 82 may be traced from the upper terminal of secondary winding 151 through a winding 156 of a relay 158 and a condenser 157 connected in parallel with winding 156, anode 133, cathode 135, and ground connections 147 and 108 to a center tap 160 on transformer secondary winding 151. The lower branch of the final stage output circuit may be traced from the lower terminal of secondary winding 151 through a winding 161 of a relay 162 and a condenser 163 in parallel with the winding 161, anode 137, cathode 139, and ground connections 147 and 108 to center tap 160 on winding 151.

The two branches of the output circuit of final stage 82 may be conductive on opposite half cycles of the alternating energy supplied by the winding 151, that is, the triode 131 may be conductive during the half cycle when the upper terminal of winding 151 is positive with respect to the center tap 160, while the triode 132 may be conductive during the half cycle when the lower terminal of secondary winding 151 is positive with respect to center tap 160. The secondary winding 154 of transformer 152 is connected through the terminals 20 and 21 to the network 15 (see Figure 2). Therefore, any signal which appears between the output terminals of the network 15 is of the same frequency as the energy supplied to the final output stage 82. In accordance with the well known characteristics of alternating current bridge circuits, it will be understood that the time phase of such a signal depends upon the direction of unbalance of the network 15. If the phase of the signal is such that the control electrodes 134 and 138 are positive when the upper terminal of secondary winding 151 is positive, the current flow through triode 131 is increased above the normal value determined by the setting of tap 144 on resistance 145, while if the phase of the signal is such that the control electrodes 134 and 138 are positive when the lower terminal of secondary winding 151 is positive then the current flow through the triode 132 is increased. Condensers 157 and 163 operate to maintain energization of the relay windings 156 and 161, respectively, over a period longer than the half cycles during which the triodes associated with the respective relays are conductive. During the half cycle when a particular triode is conductive, the output circuit current flows through the relay winding and also charges the condenser. During the half cycle when the triode is non-conductive, the condenser discharges through the relay winding, thereby maintaining the current flow.

Relay 158 includes, in addition to the winding 156, the switch arm 128 previously mentioned, and a switch arm 165 which cooperates with a stationary contact 166. Both the switch arms 128 and 165 are biased, by means not shown, to the circuit opening position and are moved to circuit closing position upon sufficient energization of relay winding 156.

The relay 162 similarly includes, in addition to winding 161 and the switch arm 123 previously mentioned, a switch arm 167 which cooperates with the stationary contact 168. Both switch arms 123 and 167 are biased to the circuit opening position and are moved to their circuit closing position upon sufficient energization of winding 161.

The power supply circuit 83 is energized from secondary winding 155 of transformer 152. The power supply circuit 83 includes a twin diode 170 which may, for example, be of the type commercially known as type 7Y7. The twin diode 170, which serves in the power supply circuit 83 as a full wave rectifier, includes a first diode 171 having an anode 172, a cathode 173, and a heater filament 174. The second diode is generally indicated at 175 and includes an anode 176, a cathode 177, and a heater filament 178. On the half cycles when the upper terminal of secondary winding 155 is positive, current flows therefrom through anode 172 and cathode 173 of diode 171 to terminal 180. On the half cycles when the lower terminal of secondary winding 155 is positive, current flows therefrom through anode 176 and cathode 177 of diode 175 to terminal 180. The current supply to the output circuit of stages 80 and 81 passes from the terminal 180 through a filter network 190 comprising a choke coil 181 and condensers 182 and 183 connected between opposite terminals of the choke coil 181 and ground. After passing through the filter network, the current flows along conductor 184 to conductor 94 which serves as the positive power supply terminal for the output circuits of stages 80 and 81. The various ground connections serve as the negative power supply terminals of these output circuits. The current supplied by the rectifier 170 flows through the various amplifier output circuits and ground connections to ground connection 146, and thence through resistance 145 and conductors 185 and 186 to a center tap 187 on transformer secondary winding 155. It should be noted that the direction of current flow through resistance 145 is such as to make its left terminal positive with respect to its right terminal, as indicated by the legend in the drawings.

A filter condenser 188 is connected between terminal 180 and center tap 186.

In order to aid those skilled in the art in constructing an amplifier in accordance with my invention, the following table is appended, giving values of the various resistances and condensers used in one embodiment of my invention:

Reference character	Quantity
90.....	10,000 ohms.
95.....	$\frac{1}{2}$ megohm.
101.....	$\frac{1}{2}$ megohm.
102.....	$\frac{1}{2}$ megohm.
103.....	0.1 megohm.
104.....	.05 microfarad.
111.....	$\frac{1}{2}$ megohm.
112.....	$\frac{1}{2}$ megohm.
113.....	1 megohm.
116.....	$\frac{1}{2}$ megohm.
125.....	$\frac{1}{2}$ megohm.
126.....	.1 megohm.
127.....	.05 microfarad.
143.....	$\frac{1}{2}$ megohm.
145.....	.05 megohm.
148.....	.05 microfarad.
157.....	1 microfarad.
163.....	1 microfarad.
181.....	4,000 ohms D. C. resistance, 30 henries inductance.
182.....	$\frac{1}{2}$ microfarad.
183.....	.05 microfarad.
188.....	.05 microfarad.

The heater filaments 88, 100, 136, 140, 174, and 178 may be connected to any suitable source of electrical energy (not shown).

Operation

The operation of the amplifier circuit 52 and of the system shown in Figure 2 are described in detail in the copending application of Willis H. Gille, Albert F. Upton, and William J. Field, Serial No. 466,088, filed on even date herewith. It is believed sufficient for the purposes of the present application to state that the amplifier 52 operates to cause intermittent energization of one of the relays 158 and 162 when the signal impressed upon its input terminals 62 and 65 is small in value. When the signal increases in magnitude, the particular relay selected is continuously energized. As previously mentioned, the relays are selectively energized in accordance with the phase of the alternating signal potential impressed between the input terminals 62 and 65.

In each of the amplifier stages 80 and 81, there is a gain in the strength of the signal, which gain may be definitely determined, either from theoretical considerations or by direct measurement. Since the filter circuit 190 is very simple in construction, and therefore imperfect as a filter, an alternating component passes through the conductors 184 and 94 to the output circuits of the stages 80 and 81. The alternating component so impressed on stage 80 is amplified in stage 81 and transmitted through blocking condenser 148 to the input circuit of final stage 82. The alternating component so impressed on stage 81, although not amplified, is likewise transmitted through blocking condenser 148 to the input circuit of final stage 82. Due to the phase shift between stages 80 and 81, these two alternating components add vectorially, and not algebraically, but it is believed to be clear that the total alternating component passed through blocking condenser 148 is considerably larger, due to the amplification of one of its components, than the alternating component existing between terminal 191 of filter 190 and ground.

The input circuit of final stage 82 is connected to tap 144, which is associated with the power supply circuit 83 at a point where the alternating component of current flowing in the power supply circuit is much greater than the alternating component existing at terminal 191. It may be noted that a portion of the total alternating component in the output of rectifier 170 is by-passed from the filter 190 and from the resistance 145 by the condenser 188. Furthermore, the condensers 182 and 183 by-pass conditional fractions of the alternating component in the rectifier output, which additional fractions therefore do not pass through the output circuits of stages 80 and 81. These additional components do however pass through ground connection 146 and resistance 145 to the center tap 187 of transformer winding 155, and are therefore impressed through tap 144 to the common input circuit of the final stage 82.

I have found, that by properly proportioning the attenuation of the alternating component in the filter network 190 to the gain in the amplifier stage 81, the magnitude of the alternating component impressed on the common input circuit of final stage 82 through tap 144 may be made equal in magnitude to the total alternating component impressed on the common input circuit of the final stage through blocking con-

denser 148. Furthermore, by properly choosing the elements in the filter circuit 190 so as to make the phase shift of the alternating component between terminal 180 and ground supplementary to the resultant phase shift which takes place in the amplifier stages 80 and 81, it is possible to have the two alternating components which reach the input circuit of the final stage substantially opposite in phase. If these two alternating components are made equal in magnitude and opposite in phase, they cancel each other out and have no effect on the final stage output circuit.

While it is entirely possible to develop a theoretical analysis of the relationship between the amplifier gain and the loss in the filter circuit, and a similar relationship between the phase shifts in the amplifier and filter circuit, I have found it more convenient from a practical standpoint to determine the various values of circuit elements to be employed in any given case by empirical methods. The values given in the table previously set forth show values of the various circuit elements which have operated satisfactorily in one embodiment of my invention.

Figure 3

In Figure 3, is shown a somewhat different amplifier circuit embodying my invention. This amplifier circuit, generally indicated at 200, includes three preliminary voltage amplification stages 201, 202, and 203 and a final power amplification stage 204. The amplifier 200 also includes a power supply circuit 205 including a full wave rectifier 206 and a filter circuit 207.

In the amplifier 200 the final stage 204 is not supplied with a biasing potential, or in fact with any potential from the power supply circuit 205. It is therefore necessary, in applying my invention to this circuit, to proportion the alternating component applied from the rectifier 206 to the last preliminary stage 203 in such a manner that it is equal in magnitude and opposite in phase to the alternating components reaching the output circuit of stage 203 through the previous stages 201 and 202.

The rectifier 206 has a positive terminal 210 and a negative terminal 211. The filter circuit 207 is divided into two sections, one between rectifier output terminal 210 and a terminal 212, and the other section between terminals 212 and 213. The attenuation of the alternating component and the phase shift in the filter section between terminals 212 and 213 should be proportioned to the gain and phase shift in the amplifier circuit 202, in order to reduce as much as possible the resultant alternating component transmitted to the final stage 203. The alternating component attenuation and phase shift in the section of the filter circuit between terminals 210 and 212 may then be proportioned so that the alternating component supplied directly to the output circuit of stage 203 is of the proper magnitude and phase to cancel out the alternating component transmitted to stage 203 from the previous stages.

While I have shown and described certain preferred embodiments of my invention, other modifications thereof will occur to those skilled in the art, and I therefore wish my invention to be limited only by the appended claims.

I claim as my invention:

1. An amplifier circuit, comprising in combination, a plurality of cascaded amplifier stages, each stage having an input circuit and an output circuit, first power supply means for supplying an

alternating voltage to the output circuit of said final stage, second power supply means for supplying a unidirectional voltage to the remaining output circuits, said second power supply means including a source of alternating electrical energy, rectifier means having an appreciable alternating component in its output potential, and a filter network, connections between said remaining output circuits and a first point in said filter network electrically remote from said rectifier means, and a connection between the input circuit of said final stage and a second point in said filter network electrically closer to said rectifier means than said first point, said filter network including impedance means connecting said two points, said impedance means having a characteristic such that the alternating component of potential introduced into said final stage through said last-mentioned connection is substantially equal in magnitude and opposite in phase to the vector sum of the alternating components transmitted to said final stage through said amplifier stages.

2. An amplifier circuit, comprising in combination, a plurality of cascaded amplifier stages, each stage having an input circuit and an output circuit, first power supply means for supplying an alternating voltage to the output circuit of said final stage, second power supply means for supplying a unidirectional voltage to the remaining output circuits, said second power supply means including a source of alternating electrical energy, rectifier means having an appreciable alternating component in its output potential, and a filter network, connections between said remaining output circuits and a first point in said filter network electrically remote from said rectifier means, and a connection between the input circuit of said final stage and a second point in said filter network electrically closer to said rectifier means than said first point, said filter network including first impedance means connecting said two points, and second impedance means connecting said second point and said rectifier means, said first and second impedance means having characteristics so related that the alternating component of potential introduced into said final stage through said last mentioned connection is substantially equal in magnitude and opposite in phase to the vector sum of the alternating components transmitted to said final stage through said amplifier stages.

3. An amplifier circuit, comprising in combination, a plurality of cascaded amplifier stages, each stage having an input circuit and an output circuit, first power supply means for supplying an alternating voltage to the output circuit of said final stage, second power supply means for supplying a unidirectional voltage to the remaining output circuits, said second power supply means including a source of alternating electrical energy, rectifier means having an appreciable alternating component in its output potential, and a filter network, connections between all but the last in the cascade of said remaining output circuits and a first point in said filter network electrically remote from said rectifier means, and a connection between said last output circuit and a second point in said filter network electrically closer to said rectifier means than said first point, said filter network including impedance means connecting said two points, said impedance means having a characteristic such that the alternating component of potential introduced into said last output circuit

through said last mentioned connection is substantially equal in magnitude and opposite in phase to the vector sum of the alternating components transmitted to said last output circuit through the earlier amplifier stages.

4. An amplifier circuit, comprising, in combination, a plurality of amplifier stages, each having an input and output circuit, means coupling said stages so as to invert the phase of signal potentials transmitted therebetween, power supply means for said stages including a source of alternating electrical energy, rectifier means connected to said source, a filter network, said filter network comprising a condenser and a first substantially non-capacitive impedance connected in series with said rectifier and said power source, a second condenser and a second substantially non-capacitive impedance connected in parallel with said first condenser but not with said first impedance, means for applying a portion of the voltage across said second condenser to the input circuit of one of said stages, the output circuit of said one stage being connected to the input circuit of said final stage, and means for applying a portion of the voltage across said first named impedance to the input circuit of said final stage, the values of said condensers and impedances being so chosen that the ripple introduced directly into the input circuit of said final stage from said source of power is cancelled out by the ripple introduced by said source of power into said input circuit from said one stage.

5. An amplifier circuit, comprising, in combination, a plurality of amplifier stages, each having an input and output circuit, means coupling said stages so as to invert the phase of signal potentials transmitted therebetween, power supply means for said stages including a source of alternating electrical energy, rectifier means connected to said source, a filter network, said filter network comprising a condenser and a first substantially non-capacitive impedance connected in series with said rectifier and said power source, a second condenser and a second substantially non-capacitive impedance connected in parallel with said first condenser but not with said first impedance, means for applying a portion of the voltage across said second condenser to the output circuit of a first of said stages and hence to the input circuit of a second of said stages, the output circuit of said second stage being connected to the input circuit of a final stage, and means for applying a portion of the voltage across said first named impedance to the input circuit of said final stage, the values of said condensers and impedances being so chosen that the ripple introduced directly into the input circuit of said final stage from said source of power is cancelled out by the ripple introduced by said source of power into said input circuit from the first and second stages.

6. An amplifier circuit, comprising, in combination, a plurality of amplifier stages, each having an input and output circuit, means coupling said stages so as to invert the phase of signal potentials transmitted therebetween, power supply means for said stages including a source of alternating electrical energy, means for applying an alternating voltage from said source to the output circuit of the final one of said stages, rectifier means connected to said source, a filter network, said filter network comprising a condenser and a first substantially non-capacitive impedance connected in series with said recti-

fier and said power source and a second condenser and a second substantially non-capacitive impedance connected in parallel with said first condenser but not with said first impedance, means for applying a portion of the voltage across said second condenser to the output circuits of a first and a second of said stages, the output circuit of said second stage being connected to the input circuit of said final stage, and means for applying a portion of the voltage

across said first named impedance to the input circuit of said final stage, the values of said condensers and impedances being so chosen that the ripple introduced into the input circuit of said final stage from said source of power is cancelled out by the ripple introduced by said source of power into said input circuit from the first and second stages.

WILLIAM J. FIELD.