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C. S. ROOT

2,226,074

AMPLIFIER

Filed Aug. 5, 1938

Fig. 1.

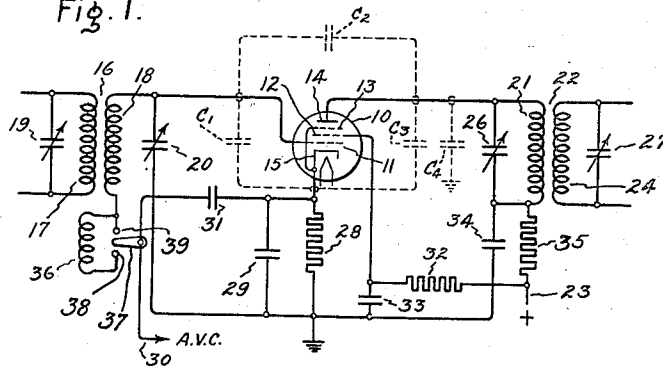


Fig. 3.

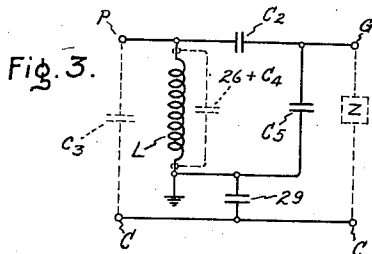


Fig. 4a.

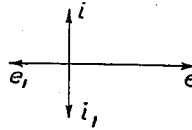


Fig. 4b

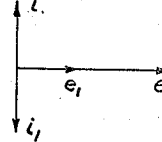


Fig. 2.

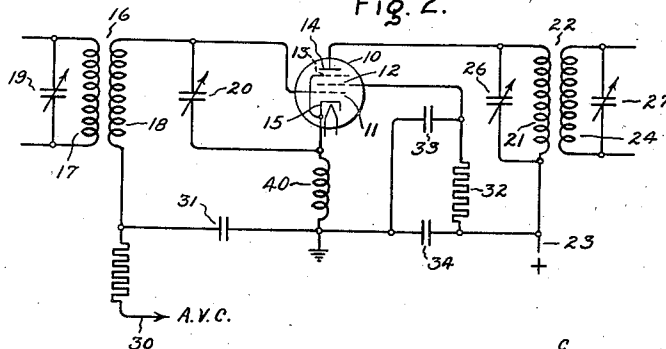


Fig. 5.

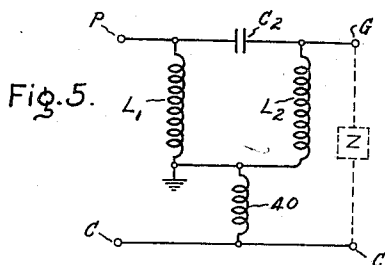
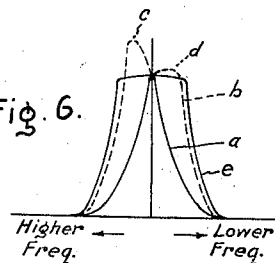


Fig. 6.



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UNITED STATES PATENT OFFICE

2,226,074

AMPLIFIER

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Application August 5, 1938, Serial No. 223,179

8 Claims. (Cl. 179—171)

My invention relates to amplifying systems and more particularly to amplifiers of high frequency potentials. In greater particularity, my invention relates to an improved and simplified arrangement for compensating, in an amplifier of this type, the effect of the retroactive currents which flow through the inherent anode-grid inter-electrode capacity of an electron discharge device employed in high frequency signal amplifiers.

One of the factors which limits the maximum amplification obtainable in a single stage of amplification is the regenerative action inherently present in the amplifier as a result of the inter-electrode capacity, particularly the anode-grid capacity, of an electron discharge device employed in the amplifier. This interelectrode capacity serves to couple the output circuit of the discharge device to the input circuit of the device and eventually leads to uncontrollable free oscillation of the amplifier stage when an attempt is made to realize greater amplification beyond a certain point. Where two or more stages of high frequency amplification are used, sufficient amplification can usually be realized without extending the amplification of any one stage into the regenerative region where a state of free oscillation is likely to occur. Where, however, it is possible to employ only a single stage of amplification, it has been common practice to allow a certain amount of regeneration to exist in order that the amplifier stage may produce a greater output since it has been found exceedingly difficult to reduce the regeneration sufficiently to avoid its undesirable effects without greatly reducing the amplification in so doing. The reduction of regeneration, where accomplished, has been effected in the past by the use of interstage coupling transformers having a lower voltage step-up ratio or having low impedance windings for the purpose of providing a poorer impedance matching of the transformer to the amplifier tube, or by biasing the tube to a point on its operating characteristic where the voltage amplification of the tube is greatly reduced. These methods of reducing the regeneration accomplish their desired end only by effecting such a large reduction in the voltage gain between the input and output circuits of the electron discharge device that the feed-back of energy through the electron discharge device of the amplifier stage becomes negligible. Such methods,

however, result in a very inefficient arrangement and a considerable loss of amplification.

The detrimental effects of regeneration in an amplifier stage are at once evident when it is considered that the presence of regeneration causes first, a pronounced sharpening of the resonance curve of the amplifier, thereby to restrict the range of frequencies which may pass through the amplifier for a given selectivity; secondly, by greatly increasing the difficulty of alignment of intermediate frequency stages of amplification due to a certain amount of interaction between the several electron discharge devices with their interconnecting circuits, a condition which necessitates that all of the intermediate frequency transformer trimmer condensers must be carefully adjusted and readjusted before a final balance of the amplifier stage may be accomplished; and thirdly, by greatly increasing the difficulty of properly aligning an intermediate frequency amplifier for both narrow and broad frequency band-pass operation where the amplifier stage has its frequency response expanded as by any of the several types of expanding systems now in common use.

Furthermore, it is well-known that tuning of a receiver in which regeneration exists is always accompanied by a characteristic "swish" noise and a high level of "hiss" background when listening to weak signals. There is also great danger of uncontrollable free oscillation of the amplifier when the amplifier tube (or an associated component) happens to be at or near the maximum limit of the tolerance range of amplification that is necessary to allow the manufacture of radio tubes and components. Additional trouble occurs in large quantity production of radio receivers due to abnormal differences in gain and selectivity resulting from the large variations in regeneration caused by variations in manufactured parts, as mentioned above.

It is an object of my invention to provide an amplifier arrangement in which the regenerative action caused by the grid-anode interelectrode capacity of the amplifier electron discharge device is either partially or completely compensated as desired even though the effect of such capacity may be small, and therefore relatively difficult to exactly compensate, as where a screen grid type of electron discharge device is employed.

A further object of my invention is to neutralize

or compensate in a high frequency amplifier the regenerative effect of the grid-anode interelectrode capacity by an arrangement which maintains the cathode of the discharge device at a slight radio frequency potential above ground by action of the output circuit radio frequency currents thereby to provide a potential in the cathode circuit which may be returned to the input circuit as a degenerative potential.

Another object of my invention is to provide an intermediate frequency amplifier whose frequency band characteristic may be expanded over a wide range of expansion values without destroying the symmetry of the response curve of the amplifier about the intermediate frequency.

A further object of my invention is to provide an amplifier, particularly of the intermediate frequency type, having greatly improved selectivity and stability characteristics and one whose degree of amplification, or gain, is very materially increased over that obtainable by the prior art amplifier arrangements.

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 Fig. 1 illustrates an embodiment of my invention, Fig. 2 represents a modification thereof, and Figs. 3 to 6 inclusive are graphs and diagrams used in explanation of the operation of my invention.

Referring more particularly to Fig. 1 of the drawing, my invention is illustrated as embodied in an intermediate frequency stage of amplification which employs an electron discharge device 10 having electrodes including a control grid 11, a screen grid 12, a suppressor grid 13, an anode 14, and a cathode 15. Modulated intermediate frequency signal oscillations are supplied through an input transformer 16 to the grid 11 and the cathode 15 of the device 10. The primary winding 17 and secondary winding 18 of the input transformer 16 are respectively tuned to the frequency of the intermediate frequency oscillations by the small trimmer condensers 19, 20. The output circuit of the electron discharge device 10 is connected between the anode 14 and the cathode 15 and includes the primary winding 21 of an input intermediate frequency transformer 22 and a source of anode potential, not shown, whose positive terminal is connected to the conductor 23 and whose negative terminal is connected to ground. The intermediate frequency output transformer 22 has a secondary 24 connected to supply the amplified intermediate frequency oscillations to a utilization circuit, not shown, which may include further stages of amplification, a demodulating device, an amplifier of the modulation components of the intermediate frequency oscillation, and a translating device. The primary winding 21 and the secondary winding 24 of the output transformer 22 are tuned to the frequency of the intermediate frequency oscillations by the respective trimmer condensers 26, 27.

The grid 11 of the device 10 has a normal operating bias provided by the potential drop appearing across the cathode biasing resistor 28, and parallel connected condenser 29, which results from the flow of anode current through this resistor. The control grid 11 may additionally

have impressed thereon an automatic volume control bias supplied from a demodulator device, not shown, which demodulates the output of the intermediate frequency stage of amplification and supplies a potential (whose magnitude varies with the average amplitude of the intermediate frequency oscillations) through the automatic volume control conductor 30 for the purpose of maintaining the output of the amplifier substantially constant notwithstanding that the input signal may vary over a wide range of signal strengths. The condenser 31 maintains the lower end of the transformer secondary winding 18 isolated from the cathode 15 for unidirectional potentials but maintains the lower end of this winding at cathode potential for potentials of intermediate frequency.

A positive potential is supplied to the screen grid 12 of the device 10 through a resistor 32 from the conductor 33. The condenser 33 maintains the screen grid 12 at ground potential for alternating currents of intermediate frequency.

The suppressor grid 13 is connected directly to the cathode 15 in a manner well-known in the art.

A tertiary winding 36 is provided in the input transformer 16 for purposes of varying the frequency band response of the amplifier. As shown, the winding 36 is arranged to overcouple the secondary circuit with the primary circuit of the transformer 16 when the switch 37 is manually moved to the lower switch contact 38. Overcoupling the windings in this manner provides a broad frequency band response with a resulting high fidelity operation of the amplifier, and minimizes distortion associated with the inaccuracies of present day mechanical tuning of the radio receiver input circuits. Movement of the switch 37 to the upper contact 39 removes the winding 36 from circuit and renders the amplifier tuned circuit highly selective. The introduction of the winding 36 into the tuned secondary circuit in this manner does not appreciably detune this circuit since the inductance of the winding 36 is relatively insignificant in comparison with a much larger inductance of the transformer secondary winding 18.

A condenser 34 maintains the lower end of the output transformer winding 21 at ground potential for alternating currents of intermediate frequency. A resistor 35 connects the lower end of the transformer winding 21 to the conductor 23 for unidirectional currents but effectively isolates this winding from the conductor 23 for currents of intermediate frequency.

The operation of this embodiment of my invention will now be explained by the aid of Figs. 3 and 4a of the drawing.

The several interelectrode capacities of the electron discharge device 10 are represented in Fig. 1 by the broken lines. The grid to cathode capacity is represented by the capacity C₁, the anode to grid capacity by the capacity C₂, and the anode to cathode capacity by the capacity C₃. The capacity to ground of the anode and associated wiring is represented by the capacity C₄.

If the capacity C₂ could be made zero, the output circuit of the discharge device 10 could be completely isolated from the input circuit of the device and the amplifier stage could be operated at its maximum possible amplification without experiencing the detrimental effects of regenerative feed-back. However much the capacity C₂ may be reduced by the use of the screen grid 12, there nevertheless exists a small capacity between the

anode and grid elements of the electron discharge devices customarily used at the present time. The regenerative feed-back of energy through the capacity C_2 , unless compensated by a corresponding degenerative feed-back of energy in the manner of my invention, not only prohibits the attainment of the maximum amplification which is otherwise possible in the modern amplifier arrangement, but additionally introduces into the operation of the amplifier the detrimental effects of regeneration considered heretofore.

The simplified impedance network shown in Fig. 3 represents, in a manner well-known in the art, the relation of associated impedances looking from the output circuit of the device 10 into the input circuit of this device. In this diagram, the terminal P represents the anode of the device 10, the terminal G represents the grid of the device, and the terminal C represents the cathode. The diagram has been simplified somewhat by omitting all values of resistance since the resistance present in any one branch of the circuit is relatively insignificant in comparison to the inductive and capacitive reactances at the intermediate frequency. Further simplification has been attained by lumping into the impedance Z, shown by broken lines in Fig. 3, certain elements having inductance or capacity which may be distributed or inherent, and which are present in the amplifier circuit but which are connected directly between the grid and the cathode and which, therefore, are not important in a consideration of the regenerative and degenerative currents that flow in the amplifier arrangement.

It is important to note that the trimmer condenser 26 in Fig. 1 has connected directly across its terminals two capacitive paths, one comprised by the capacity C_3 , the condenser 29, and the condenser 34 all in series, while the second path is comprised by the capacitor C_4 and the condenser 34 in series. The reactance of the condenser 34 in practice is so low in comparison to that of the other capacities that it may be neglected and is omitted from the diagram of Fig. 3. The capacitive reactance of the condenser 26 considered alone, is therefore larger than the terminal inductive reactance of the winding 21 when the primary circuit of the transformer 22, including capacities C_3 and 29, is tuned to resonance with the intermediate frequency oscillations. Since the terminal inductive reactance of the transformer winding 21 is smaller than the capacitive reactance connected in shunt thereto (comprised by the combined reactances of the condenser 26 and the capacity C_4), the net series reactance appearing between the anode 14 and ground (which, as more clearly shown in Fig. 3, constitutes one component of the impedance network connected between the anode and cathode) is predominantly inductive and the excess of the series inductive reactance over the series capacitive reactance from anode to ground is represented in the diagram of Fig. 3 by the inductance L.

It should further be noted that the trimmer condenser 20 in Fig. 1 is connected from the grid 11 to ground. The condenser 20 is represented in the diagram of Fig. 3 by the capacity C_5 . The capacity C_2 in the Fig. 3 diagram is the anode to grid capacity inherent in the device 10 and is represented by the corresponding legend C_2 in Fig. 1. The condenser 29 of Fig. 3 represents the corresponding condenser 29 of Fig. 1.

It will be evident from the diagram of Fig. 3 that whenever a radio frequency potential exists

between the terminals P and C, a current flows through the capacity C_2 and through the impedance Z to the cathode C. This current, in flowing through the impedance Z, produces a radio frequency potential on the grid G which gives rise to the regenerative action so detrimental to the operation of the amplifier stage. With my arrangement, the inductance L and the condenser 29 are connected in series as a voltage divider and phase inverter between the anode terminal P and the cathode terminal C and the voltage between the anode and cathode divides between the inductance L and the condenser 29 in magnitude and in phase according to their respective values of reactance. My amplifier arrangement supplies the voltage appearing across the condenser 29 through the capacity C_5 to the grid terminal G and through the impedance Z to the cathode terminal C. It will be shown hereinafter by reference to the vector diagram of Fig. 4a that the current supplied through the capacitor C_5 is a degenerative current which, at the intermediate frequency, is 180 degrees out of phase with the current which flows through the capacity C_2 . The effect of the regenerative current through the capacity C_2 in producing changes of the potential of the grid G is, therefore, neutralized or compensated since any potential drop produced across the impedance Z by this current is counteracted by a corresponding though opposite potential drop across the impedance Z caused by the neutralizing or compensating degenerative current through the capacity C_5 .

Referring now to the vector diagram Fig. 4a, the vector e represents the anode to cathode radio frequency potential. This potential produces a current through the capacity C_2 which may be represented by the vector i and which leads the potential e by substantially a 90 degree phase angle. The potential e likewise produces a potential drop across the series circuit comprised by the inductance L and the condenser 29 and, since the reactance of condenser 29 is smaller than the reactance of L and opposite in sign, the proportional part of the potential e which appears across the condenser 29 is represented by the vector e_1 displaced from the vector e by a 180 degree phase angle. The potential e_1 produces a current flow through the capacity C_5 which leads the potential e_1 by a phase angle of 90 degrees and which may be represented by the vector i_1 . In practice, the values of the capacity C_5 and of the condenser 29 are generally (though not necessarily, depending upon the desired degree of compensation) so chosen that the magnitude of the current i_1 is equal to the magnitude of the current i . Since the current i_1 is, as has been shown, 180 degrees out of phase with the current i , each of the currents i and i_1 when of equal magnitude completely neutralizes or compensates the effect of the other as each flows through the impedance Z connected between the grid and cathode of the amplifier.

It will be observed that the circuit conventionally represented in Fig. 3 (and as later to be explained, that represented in Fig. 5) comprise infinite attenuation networks having input terminals P and C connected respectively to the anode and cathode; and having output terminals G and C connected respectively to the grid and cathode, and having infinite attenuation between these input and output terminals at the frequency to be amplified.

The following values of the several circuit elements employed in my amplifier may be considered as representative of an embodiment which I have found to operate in a satisfactory manner

in an intermediate frequency stage of amplification:

Type of discharge device-----	6K7
Inductance of input transformer windings:	
Primary (17)-----millihenries	0.7
Secondary (18)-----do-----	1.5
Inductance of output transformer windings:	
Primary (21)-----do-----	1.5
Secondary (24)-----do-----	0.7
Maximum value of condensers 20 and 26-----m. m. f.--	80
Condenser 31-----m. f.--	.05
Condenser 34-----do-----	.05
Condenser 29-----do-----	.05
Resistor 35-----ohms--	1000
Resistor 23-----do-----	330
Anode potential-----volts--	250
Screen grid potential-----do-----	100

A modification of my invention is illustrated in Fig. 2 wherein elements corresponding to like elements of Fig. 1 are designated by like reference characters. This embodiment is similar to that of Fig. 1 except that the impedance in the cathode circuit of Fig. 1, shown as a capacitive reactance 29, is replaced in this embodiment by an inductive reactance 40. The use of an inductive reactance in the cathode circuit necessitates certain changes in the manner of connecting the input circuit to the cathode 15 of the discharge device 10 if the proper phase relationship between the regenerative and degenerative currents is to be maintained. In this embodiment, the trimmer condenser 20 is connected directly between the control grid 11 and the cathode 15 while the trimmer condenser 26 is connected as in Fig. 1 between the anode 14 and the lower end of the transformer primary winding 21. The lower end of the input transformer secondary winding 18 is now connected through the condenser 31 to the lower end of the cathode inductance 40. The lower end of the output transformer primary winding 21 is connected as in Fig. 1 through the condenser 34 to the lower end of the cathode inductance 40. The normal operating bias for the control grid 11 in this modification is supplied through the automatic volume control conductor 30 in addition to the automatic volume control potential.

The equivalent impedance network, or infinite attenuation network, for this modification of my invention is shown in Fig. 5. Here again, the effective series reactance from anode to ground of the condenser 26 and the inductance 21 is inductive and is shown by the reference character L_1 in Fig. 5. The inductance 18 in Fig. 2 is represented in Fig. 5 by the inductance L_2 . The capacitive reactance of the condenser 31 in practice is so low in comparison to that of the other capacities that it may be neglected and is omitted from the diagram of Fig. 5. The inductance 40 of Fig. 5 corresponds to the inductance 40 of Fig. 2. The capacity C_2 corresponds to the anode-grid capacity, not specifically designated in Fig. 2, of the electron discharge device used in the Fig. 2 arrangement. It will, of course, be understood that the capacities other than C_2 shown by broken lines in Fig. 1 are inherently present in the arrangement of Fig. 2 but have been omitted from the diagrams of Figs. 2 and 5 for purposes of simplicity.

This embodiment operates in a manner similar to that of the Fig. 1 arrangement, the radio frequency potential between the anode and cathode producing a regenerative current which flows

through the capacity C_2 and through the grid to cathode impedance Z , while at the same time producing a voltage drop across the series connected inductances L_1 and 40. The potential drop appearing across the inductance 40 is supplied through the inductance L_2 to the grid electrode to produce a degenerative current having a phase 180 degrees different from that of the current flowing through the capacity C_2 thereby effectively to neutralize or compensate by its degenerative action the effect of the regenerative current through the capacity C_2 on the circuit elements connected between the terminals G and C of Fig. 5, represented by the lumped impedance Z .

The phase relationship of the regenerative and degenerative currents flowing in this embodiment of my invention are illustrated vectorially in Fig. 4b. As before, the anode to cathode potential is represented by the vector e . This potential produces a current i which flows through the capacitor C_2 and through the impedance Z of Fig. 5. The current i leads the potential e by a phase angle of substantially 90 degrees. The potential e likewise produces a potential drop across the inductance 40 which may be represented by the vector e_1 and which is smaller than but in phase with the potential e . The potential e_1 produces a current i_1 through the inductance L_2 , this current lagging the voltage e_1 by a phase angle of 90 degrees. The value of the inductance 40 and that of the inductance L_2 is generally (though not necessarily as where under or over compensation is desired) chosen such that the magnitude of the current i_1 is equal to that of the current i and, the two currents being 180 degrees out of phase with each other, their effect in producing potential changes on the grid G (by potential drops which these currents produce across the impedance Z) is thereby neutralized or compensated.

The embodiment of Fig. 2 is especially suitable in those amplifier arrangements where the normal operating bias of the control grid 11 is supplied through the automatic volume control conductor 30, an arrangement which dispenses with the cathode biasing resistor 23 and parallel connected condenser 29 of the Fig. 1 circuit arrangement.

With circuit elements having substantially the same value as those set forth in the table above with regard to the Fig. 1 arrangement, the inductance 40 of the Fig. 2 modification may be constituted by an inductance formed of a conductor of No. 18 wire of approximately 14 inch length.

The magnitude of the degenerative action of the Fig. 2 circuit arrangement may, when desired, be greatly increased by connecting the lower terminal of the condenser 26 directly to the upper end of the inductance 40 rather than to the lower end of the output transformer winding 21, the other circuit connections remaining the same.

It will now be evident that I have accomplished by my invention the very complete and effective control of the magnitude of the regenerative action experienced in the prior art amplifier arrangements. The advantages which follow from the use of my invention are manifold. Fig. 6 is a graph illustrating, in a manner well-known in the art, the frequency response of an intermediate frequency stage of amplification. The curve a represents the frequency response of a highly selective amplifier which, being selective, may completely fail to pass the higher audio frequencies. It has

become customary to provide in high fidelity radio receivers or in mechanically tuned receivers some form of frequency response expanding arrangement whereby the frequency response of the amplifier may be expanded in a manner to allow the passage of the higher audio frequencies to obtain high fidelity reproduction of the modulated intermediate frequency oscillation whenever receiving conditions render the use of a highly selective arrangement unnecessary. These receivers are aligned in the narrow band-pass position to have the highly selective frequency response represented by the curve *a*. When, however, the frequency response is expanded in these receivers, the prior art amplifier arrangements no longer have a symmetrical response curve about the intermediate frequency (represented by the vertical line of Fig. 6) but have, by virtue of the regenerative action present in the prior art amplifiers, a distorted response curve with abnormal double hump which may be represented by the broken line *b* of Fig. 6. The peak at *C* is higher than at *d* because the grid to anode capacity (*C*₂ in Fig. 1) produces greater regenerative feed-back at higher frequencies. This causes considerable distortion of the audio frequencies, thereby to produce a highly undesirable condition of operation. In addition, the user is more apt to tune the receiver to the peak *c* than to the intermediate frequency, causing further distortion. My invention, by eliminating the effect of the regenerative action, not only renders the response curve of the amplifier symmetrical about the intermediate frequency throughout a large range of values of frequency expansion, but also flattens off the top of the response curve by reducing any double hump which would otherwise be present (according to the well-known tendency of degeneration to flatten off a frequency response characteristic of an amplifier), giving a frequency response curve as shown by the full line *e* in Fig. 6.

The neutralization of the regenerative currents in the amplifier allows the realization of the highest possible amplification or gain for each stage of amplification since the amplifier no longer has a tendency to break into free oscillation. The gain or amplification obtainable in an amplifier arrangement embodying my invention is limited only by the design of the amplifier input and output transformers and by the maximum amplification obtainable with the particular electron discharge device used.

My invention has the further advantage that the degenerative voltage not only originates in but is utilized in each individual amplifier stage and, therefore, the degenerative circuit does not include interstage coupling transformers whose value of magnetic coupling may be changed by expansion of the frequency band response. The neutralization of the regeneration effected within a single stage has an important advantage in that it is unnecessary to consider and to cope with phase shifts between the regenerative and degenerative currents where the degenerative voltage originates in an amplifier stage following or preceding the neutralized amplifier stage. A phase shift of this nature may perhaps be corrected for a given frequency band response of the amplifier at a given amplifier output, but the correction is improper for other values of frequency band response or for higher or lower amplification since changes in either the frequency response or the amplification results in corresponding changes in the phase and magnitude between regenerative and degenerative currents. For high fidelity reproduction, this requires that the intermediate frequency stages of

amplification in the prior art arrangements be realigned for each and every value of frequency response expansion. The operating conditions of an amplifier embodying my invention do not affect the symmetry of the frequency band response about the intermediate frequency since the frequency response is unaffected throughout a large range of values of frequency expansion and is independent of the power output of the amplifier.

My amplifier arrangement has another important advantage. In the design of the prior art high gain single stage amplifiers which, at best, include as much regeneration due to grid to anode inter-electrode capacity as can safely be tolerated, it becomes necessary to resort to great expense and trouble in reducing all other stray or circuit regeneration to an absolute minimum, often at a sacrifice of flexibility of receiver layout and even of receiver performance. With my invention, such elaborate precautions are no longer necessary since slight amounts of stray regeneration can be tolerated, and my invention may be utilized to compensate both the additional regeneration and that introduced by the grid to plate capacity. This, of course, requires the furnishing of degenerative currents in excess of those which would normally be required.

Previous neutralizing circuits have involved the added cost and complexity of an additional neutralizing winding or critically positioned tap on the transformer and a small, critical neutralizing capacitor whose leads were at a high radio frequency potential above ground and therefore inherently non-stable. By contrast, my invention does not require any additional components over and above those required for prior art amplifiers but uses the stable, low-potential cathode circuit components already present.

It is sometimes advantageous to furnish regeneration to the input circuit of an amplifier rather than degeneration. Thus in a tunable radio frequency amplifier which has greater gain at the high frequency end of its tuning band by virtue of regeneration, I have found that my invention has the advantage that it is possible to bring up the gain over the low frequency end of the band by using a capacitive reactance in the cathode to ground circuit as in Fig. 1, but with the current produced by the potential drop across this reactance and supplied to the grid electrode reversed 180 degrees in phase. This is accomplished by interchanging in Fig. 1 the connections of the right-hand terminal of the condenser *31* and the lower terminal of the condenser *20* to the terminals of the condenser *29* in the manner of the Fig. 2 arrangement. Likewise, the Fig. 2 circuit arrangement may be made regenerative by a similar interchange of the connections of the condensers *20* and *31* to the inductance *40* to provide a connection of these elements similar to that of the Fig. 1 arrangement. Inductance and capacity may be used in series in the cathode to ground lead, rather than using purely capacitive reactance as in Fig. 1 or purely inductive reactance as in Fig. 2, for the purpose of providing degeneration at one end of the amplifier tuning band and regeneration at the other end.

My invention when used in the intermediate frequency stages of amplification of a radio receiver may provide slightly more degeneration than necessary to exactly neutralize the regeneration present in the amplifier stage. This effects a flattening off of the peak of the amplifier frequency response curve shown in Fig. 6 without affecting to any appreciable extent the slope of

the sides of the curve. The amplifier is thus enabled to pass higher audio frequencies while dispensing with the requirement that the input circuits of the receiver be critically tuned to the signal frequency, an operating condition which is especially advantageous when the input circuits are mechanically tuned.

While I have illustrated particular embodiments of my invention, it will of course be understood that I do not wish to be limited thereto since many modifications may be made both in the circuit arrangement and in the circuit elements employed and I, therefore, 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 amplifier, having a cathode connected to ground through a reactance, a grid and an anode, an inductive reactance connected between said anode and ground, and a tuned input circuit comprising an inductive circuit element and a capacitive circuit element, one of said elements being connected between said grid and cathode and the other between said grid and ground, whereby said first reactance is included in said tuned circuit, and the voltage thereon produced by current in said anode is impressed on said grid with respect to said cathode through one of said circuit elements, said first reactance and said one circuit element being so chosen that said voltage is impressed on said grid in opposed phase relation to the voltage impressed on the grid through the interelectrode capacity between said grid and anode.

2. In combination, an amplifier, having a cathode, a grid, and an anode, an inductive utilization device and a reactance connected in series between said anode and cathode, a tuned input circuit having an inductive element and a capacitive element, one of said elements being connected between said grid and cathode, and the other between said grid and the point between said utilization device and said first reactance, said first reactance being between said cathode and said point, whereby the voltage on said first reactance with respect to said cathode is supplied through one of said elements to said grid, said utilization device, said reactance, said one element and the interelectrode capacity between said anode and grid being proportioned to act as an infinite attenuation network excluding from said grid and cathode voltage variations produced by voltage variations between said anode and cathode.

3. In combination, an electron discharge amplifier having an anode, a cathode, and a grid, an input device connected between said grid and cathode to supply thereto potentials to be amplified, a utilization device connected between said anode and cathode to utilize the amplified potentials, a reactance common to both of said connections, one terminal of said reactance being connected to said cathode, the capacity between said grid and anode, said input device, said utilization device and said reactance being proportioned to act as a network having its input connected to said anode and cathode, and its output connected between said grid and cathode, an having infinite attenuation between said input and output terminals at the frequency to be amplified.

4. In combination, an electron discharge device having an anode, a cathode, and a grid, a circuit between said anode and cathode including a utilization device having inductive reactance and a capacitance in series, an input circuit to

impress electromotive force to be amplified upon said discharge device, said input circuit including a capacitance connected between said grid and a point between said utilization device and capacitance, and an inductance connected between said grid and cathode, whereby the potential on said point with respect to said cathode is opposite in phase to the potential produced on said grid with respect to said cathode by reason of capacity between said grid and anode, and said potential on said point is supplied to said grid through said second capacitance, said first capacitance being proportioned to produce neutralization of the two voltages supplied to the grid with respect to the cathode, one from said first capacitance and the other through the capacity between the grid and cathode.

5. In combination, an electron discharge device having an anode, a cathode, and a grid, a circuit between said anode and cathode including a utilization device having inductive reactance and a second inductance in series, a tuned input circuit to impress electromotive force to be amplified upon said discharge device, said input circuit including a capacitance connected between said grid and cathode and an inductance connected between said grid and a point between said utilization device and first inductance, whereby the potential with respect to said cathode supplied to said point through said utilization device is in the same phase as the potential supplied to said grid with respect to said cathode through the interelectrode capacity between said grid and anode and produces a current through the inductance of said tuned circuit and said grid and cathode opposite in phase to the current through said interelectrode capacity and grid and cathode, said first inductance being so proportioned that said two currents neutralize.

6. In combination, an amplifier, having a cathode, an anode, and a grid, a tuned input circuit connected between said grid and cathode and a tuned output circuit connected between said anode and cathode, each circuit including an inductance and a condenser, an inductance common to both of said circuits, said last inductance having one terminal connected to one side of each of said condensers and to said cathode and its other terminal connected to one side of each of said inductances, said common inductance being proportioned to produce a current between said grid and cathode equal and opposite to the current between the grid and cathode due to interelectrode capacity between said grid and anode.

7. In combination, an electron discharge device having an anode, a cathode and a grid, a circuit between said anode and cathode including a utilization device having inductive reactance and a capacitance in series, a tuned input circuit to impress electromotive force to be amplified upon said discharge device, said input circuit including a second capacitance connected between said grid and a point between said utilization device and said first capacitance, and an inductance connected between said grid and cathode, whereby said first capacitance is included in said input circuit and a potential is developed on said point with respect to said cathode from flow of anode current therein, said capacitances being proportioned to impress said potential on said grid in a degenerative sense with respect to the potential impressed on said grid through interelectrode capacity between said grid and said anode.

8. In combination, an electron discharge device having an anode, a cathode and a grid, a circuit

between said anode and cathode including a utilization device having inductive reactance and a second inductance in series, a tuned input circuit to impress electromotive force to be amplified on
5 said discharge device, said input circuit including a capacitance connected between said grid and cathode and a third inductance connected between said grid and a point between said utilization device and second inductance, whereby
10 said second inductance is included in said input circuit and a potential is developed on said point with respect to said cathode from flow of anode current therein, said second and third inductances being proportioned to impress said potential on said grid in a degenerative
5 sense with respect to the potential impressed on said grid through the interelectrode capacity between said grid and said anode.

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CERTIFICATE OF CORRECTION.

Patent No. 2,226,074.

December 24, 1940.

CHARLES S. ROOT.

It is hereby certified that error appears in the printed specification of the above numbered patent requiring correction as follows: Page 2, first column, line 53, for the word "input" read --output--; page 3, first column, line 31, for "betwen" read --between--; page 6, first column, line 68, claim 3, for "an" before "having" read --and--; and that the said Letters Patent should be read with this correction therein that the same may conform to the record of the case in the Patent Office.

Signed and sealed this 11th day of February, A. D. 1941.

(Seal)

Henry Van Arsdale,
Acting Commissioner of Patents.