Feb. 18, 1941. M. G. CLAY 2,231,863

BIRESONANT CIRCUIT

Filed Nov. 24, 1937 3 Sheets-Sheet 1

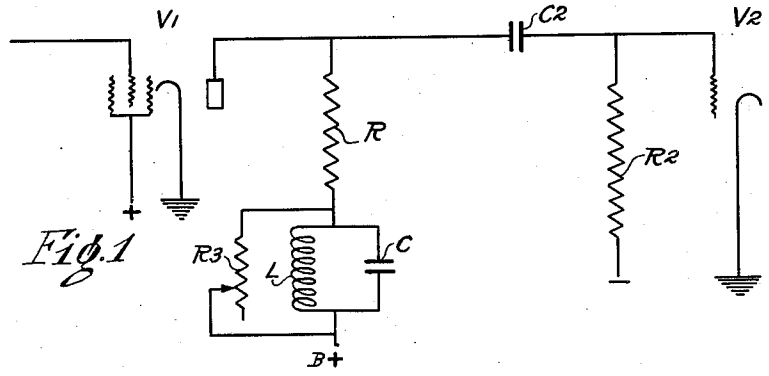


Fig. 1

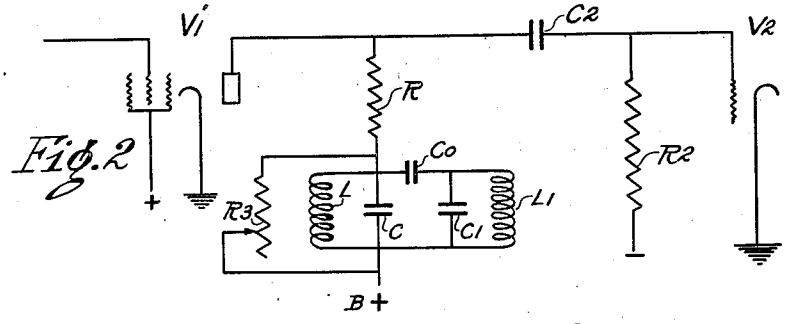


Fig. 2

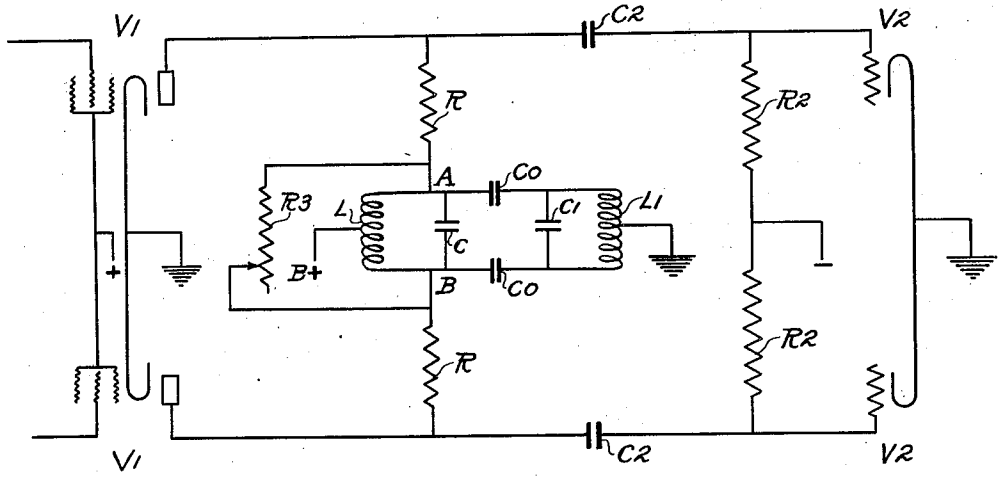


Fig. 3

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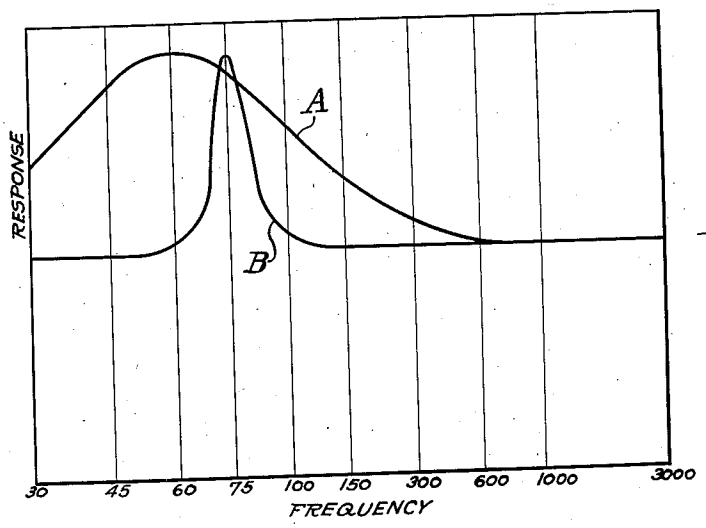


Fig. 4

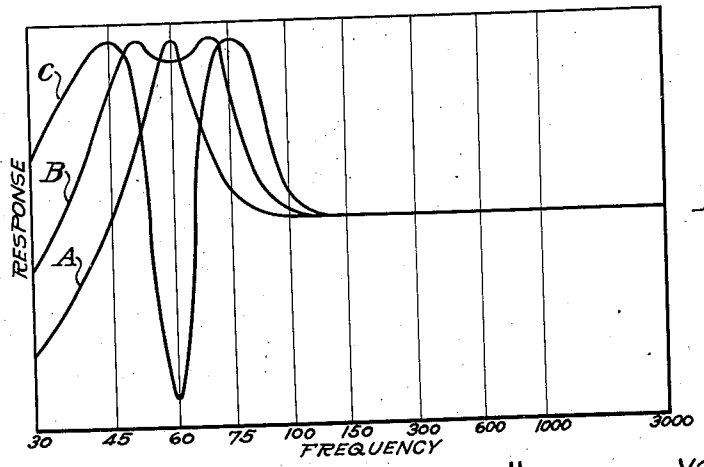


Fig. 5

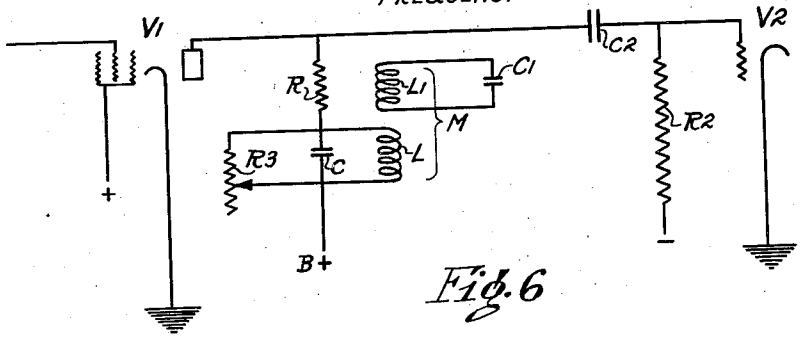


Fig. 6

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BIRESONANT CIRCUIT

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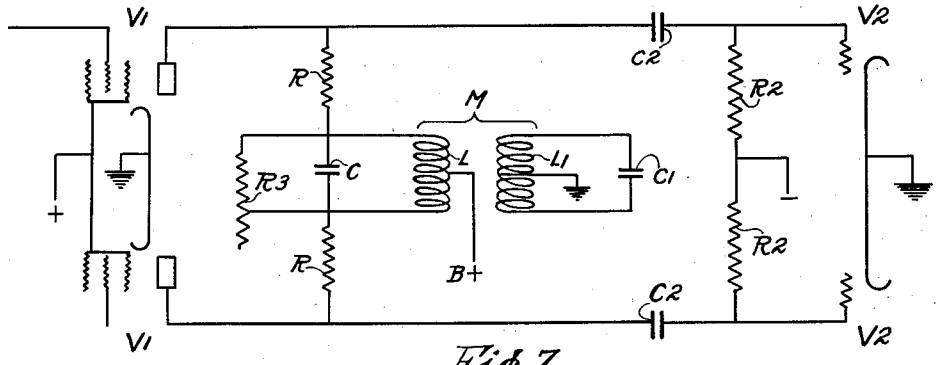


Fig. 7

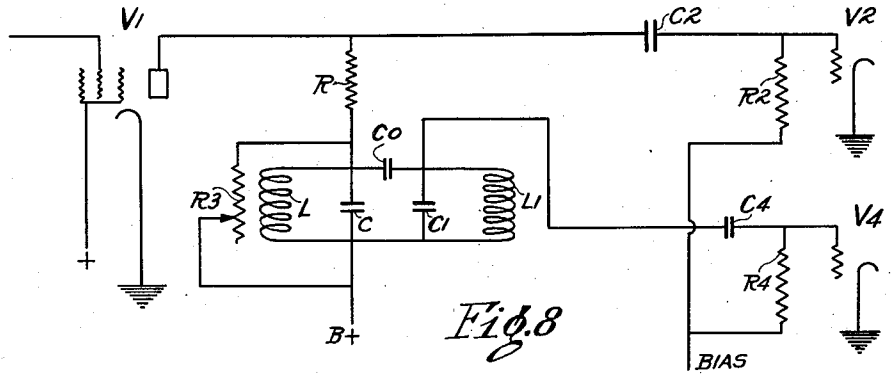


Fig. 8

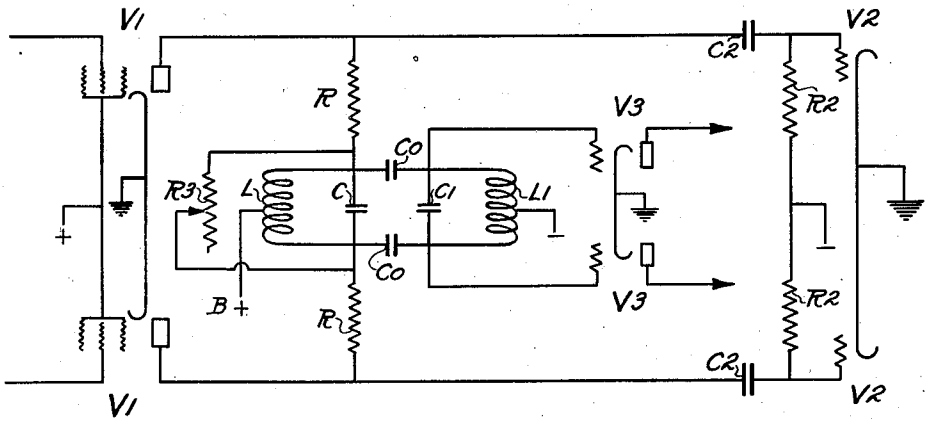


Fig. 9

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UNITED STATES PATENT OFFICE

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BIRESONANT CIRCUIT

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Application November 24, 1937, Serial No. 176,296

6 Claims. (Cl. 179—171)

My present invention relates to tuned alternating current coupling systems and more particularly to such systems which are capable of providing, in conjunction with electron discharge devices and suitable signal sources, response versus frequency characteristics in which the response over a considerable frequency range may be essentially constant while the response over a second considerable portion of the frequency range may be considerably augmented and may further be provided with a third frequency range, within the second, in which the input signals are considerably attenuated at some selected frequency.

Heretofore coupling circuits providing essentially constant response versus frequency characteristics over a considerable range of frequencies and a considerably augmented response over a second range of frequencies, have been available. However, practical experience has shown that these circuits of the prior art are, in many cases, inadequate to meet the exacting needs of the communication art. For example, it would be highly desirable, in the audio frequency amplifying system of a radio broadcast receiver, to considerably augment the reproduction of the lower audio frequencies corresponding to the bass notes in musical reproduction, without, at the same time, intensifying the lower voice frequencies which results in "boomy," unnatural reproduction of speech. However, systems of the prior art which augment a range of lower audio frequencies acceptably wide for musical reproduction intensify the lower voice frequencies excessively, while systems of the prior art which do not excessively intensify the lower voice frequencies fail to augment a sufficiently wide band of frequencies to include all of the important lower audio frequencies corresponding to the bass notes in musical reproduction.

Accordingly it may be stated that it is one of the principal objects of this invention to provide a configuration of circuit elements which, in conjunction with suitable electron discharge devices, or a suitable signal source, is capable of affording a response versus frequency characteristic which is essentially constant over a considerable range of frequencies and is considerably augmented over a second band of frequencies which is sufficiently wide to include all of the important lower audio frequencies corresponding to the bass notes in musical reproduction, but which does not appreciably intensify the lower voice frequencies.

Another frequently encountered important respect in which systems of the prior art have been inadequate to meet the needs of the communication art in a simple practical manner is cited herewith: Due to the inevitable presence of a sometimes small, but more frequently considerable amount of low frequency voltage, corresponding mainly to the first or second harmonic of the alternating current power supply frequency introduced into the signal circuits of either the broadcasting stations or the receiver, or both, it would be highly desirable to avoid intensifying alternating voltages appearing at exactly these two frequencies without sacrificing an appreciable portion of the musical bass frequency range within which the first and second harmonics of the power supply frequencies generally appear.

Accordingly it may be stated that it is another principal object of this invention to provide, in conjunction with suitable electron discharge devices or a suitable signal source, a considerably augmented frequency response over the major portion of the frequency range corresponding to the important bass note frequencies of musical reproduction, and at the same time, considerable relative attenuation of the first and second harmonics of the power supply frequency.

It is a fact well known to those skilled in the art that it is possible to obtain a considerably improved ratio of inductive reactance to effective resistance in an "iron core" type inductor if the magnetizing flux, due to the direct current component in the anode circuit of the electron discharge device or devices to which it is connected, is either minimized or eliminated.

Hence, another important object of the present invention is to provide a coupling system in which the resultant magnetic flux, remaining in the iron cored inductors used in the system, due to the direct anode current component of the electron discharge devices associated with the inductors, may be substantially eliminated.

The novel features which I believe to be characteristic of my invention are set forth in particularity in the appended claims. The invention itself, however, both as to its organization and method of operation, will best be understood by reference to the following description taken in connection with the drawings, in which I have indicated diagrammatically several circuit organizations whereby my invention may be put into effect.

In the drawings—

Fig. 1 shows a conventional tuned coupling system of the prior art for the purpose of analyzing the present invention;

Fig. 2 shows a circuit embodying the present invention in one of its aspects;

Fig. 3 shows a circuit embodying the present invention in another of its aspects;

Fig. 4 is a graph indicating qualitatively the response versus frequency characteristics obtainable with the conventional tuned coupling system of the prior art, shown in Fig. 1, using circuit elements having two different qualities;

Fig. 5 is a graph indicating qualitatively some of the response versus frequency characteristics obtainable with circuits embodying the present invention;

Fig. 6 shows a modification of Fig. 2 for inductive instead of capacitive coupling;

Fig. 7 shows a modification of Fig. 3 wherein inductive instead of capacitive coupling is used:

Fig. 8 shows a circuit having provision for two channel operation representing another embodiment of the present invention;

Fig. 9 shows a modification of the circuit of Fig. 8 providing for complete balanced push-pull operation.

Referring now to the accompanying drawings, wherein similar circuit elements are denoted by corresponding reference numerals and letters, it is first pointed out that the general purpose of the circuit arrangements to be hereinafter disclosed is to make it possible, in an alternating current coupling system, to obtain:

First; a wide frequency transmission band of substantially constant attenuation, within which, or adjacent to which, is a second transmission band, of considerable width, having considerably less attenuation.

Second; a transmission frequency range, as described, having the additional characteristic that the changes in transmission level occur rapidly with small frequency changes at the transition points.

Third; an additional characteristic in which a narrow frequency band, within the less attenuated band, is subjected to considerable attenuation.

In order to clearly point out the features of the present invention which make it possible to attain these objects, there is shown, in Fig. 1, a conventional tuned coupling system of the prior art in which a tuned circuit, LC, shunted by variable resistor, R3, and connected in series with resistor R, constitute the anode load circuit of screened grid electron discharge device V1. An electron discharge device having a high effective internal anode resistance is to be preferred at V1 in order to bring out markedly the characteristics of the circuits to be disclosed as well as those of the circuit of the prior art shown in Fig. 1, since changes in impedance of the anode load circuit with changes of frequency are then accompanied by nearly proportional changes in the voltages appearing across the elements of the anode load circuit. Anode operating potential is supplied from the point marked B+, though L and R to the anode. Voltages applied to one or more of the grids of V1 produce corresponding changes in the anode current, flowing through the complex impedance of the anode load circuit.

A signal grid of electron discharge device V2 is coupled to the anode of V1 through a condenser, C2, for the purpose of isolating the anode potential from this circuit and for the purpose of passing alternating voltages appearing at the anode of V1 by virtue of the changing current in the anode load circuit. A resistor, R2, having a resistance value sufficiently high to avoid affecting the anode load circuit of V1 which it shunts, supplies constant operating potential to the signal grid of V2.

The operation of this circuit, familiar to those skilled in the art, may be described as follows:

Alternating voltages, of various frequencies, applied to a signal grid of electron discharge device, V1, produce corresponding voltages at the anode, of said electron discharge device, which are nearly proportional to the total impedance of the anode load circuit at these frequencies. At all frequencies considerably removed from the resonant frequency of tuned circuit LC the voltages appearing at the anode of V1 are mainly due to the alternating voltage drop through anode resistor R, since the impedance of LC is small compared to R at these frequencies, so that under these conditions, the system has a constant response versus frequency characteristic. However at the resonant frequency of tuned circuit LC, the alternating voltage appearing at the anode of V1 is equal to the sum of the alternating voltage drops through both resistor R and the tuned impedance of LC. Thus a frequency versus response characteristic is afforded which is relatively constant over a wide range but which rises, over a narrow frequency range, depending on the characteristics of the tuned circuit and on its associated circuit elements.

However, practical experience with this circuit of the prior art has shown that a rise in response over a relatively wide frequency range has been obtainable only with a wide gradually sloping characteristic connecting the region of high level response with the region of lower level response, as indicated graphically by curve A, of Fig. 4. Conversely, a narrow, steeply sloping characteristic connecting the region of high level response has been obtainable only with a serious sacrifice in the range of frequencies over which the higher level response has been maintained, as indicated graphically by curve B, of Fig. 4. Furthermore, it has frequently been desirable to obtain a frequency versus response characteristic having high level response over a considerable frequency range with the additional feature of a narrow range of considerably lower level response within this high level response range for the purpose of attenuating certain unwanted signals appearing at this frequency. Obviously such a characteristic cannot be obtained with the circuit of Fig. 1.

Another disadvantage of this circuit of the prior art resides in the fact that practically all of the direct current supplied to the electron discharge device, for the operation of its anode, flows through the inductor L thus considerably impairing its efficiency when, as is generally the case, it is of the iron core type.

Still another disadvantage of this circuit of the prior art resides in the fact that when the high level response control R3 is adjusted to shunt the tuned circuit LC with a low resistance, most of the anode current flows through the contacts of this control, thus producing electrical impulses which are amplified and reproduced as objectionable noises from the loudspeaker.

Referring now to Fig. 2, which shows the circuit of Fig. 1 modified to embody several aspects of the present invention, it will be noted that three additional circuit elements have been connected in shunt with the tuned circuit LC, these additional circuit elements being an inductor L1 (having an inductance value equal in most cases to that of L), a capacitor C1 (having a capacitance equal in most cases to that of C), and a capacitor C0 (having a capacitance depending on the desired characteristics of the system).

Now, assuming that inductor L1 is identical in every respect to inductor L, and capacitor C1 is identical in every respect to capacitor C, several useful characteristics of response versus fre-

quency may be readily obtained by simply varying the capacitance of capacitor C0 between the limits of zero and some value high compared to that of capacitor C. When the capacitance of C0 is zero a response versus frequency characteristic is obtained which is constant over a wide frequency range but rises abruptly to a peak over a narrow frequency range as indicated in Fig. 5, curve A.

Increasing the capacity of C0 to a suitable value (to approximately half that of C in one practical case) gives the system a response versus frequency characteristic which is constant over a wide frequency range but which rises abruptly to a relatively wide, substantially flat-tapped peak over a part of the frequency range as indicated in Fig. 5, curve B. It will now be apparent that this embodiment of the present invention permits the use of inductors of high electrical efficiency in order to confine the high level response region to the desired frequency range without sacrificing the extent of the substantially maximum response portion of the characteristic.

Further increasing the capacity of C0 to a suitably high value (to approximately the value of C in one practical case) gives the system a response versus frequency characteristic which is constant over a wide frequency range but which rises abruptly to a generally high level of response over a second wide frequency range in the middle of which is a sharp drop in the response over a narrow range of frequencies, as indicated in Fig. 5, curve C. A characteristic of this kind has been found useful in minimizing hum caused by the use of alternating current power supplies in receivers and transmitters.

Examination of the circuit diagram of Fig. 2 reveals the fact that no direct current flows through inductor L1 thus avoiding the loss of efficiency due to the usual presense of magnetizing current in circuit elements of this kind. While direct current does flow through the windings of inductor L, the increased efficiency of L1 partially offsets this detriment.

Referring now to Fig. 3, which shows another practical embodiment of the present invention, it will be noted that the system of Fig. 2 has been arranged for push-pull operation with the addition of only one circuit element, C0, within the resonant configuration. The operation and advantages of this system, over the circuit of the prior art shown in Fig. 1, are similar to those described in connection with the circuit diagram of Fig. 2. However, assuming the circuit elements and the characteristics of the electron discharge devices V1 are reasonably well balanced, there is no appreciable constant difference of potential between points A and B, in Fig. 3, with the result that adjustment of the value of variable resistance R3 causes no sound from the loudspeaker. Also, in this case, both inductors are free from constant magnetizing flux, since with a properly center-tapped inductor the magneto motive force developed by the ampere turns between B+ and A is almost exactly offset by the opposite magneto motive force developed by the ampere turns between B+ and B.

In Fig. 6 is shown another practical embodiment of this invention which is similar to that shown in Fig. 2 except that magnetic instead of capacitive coupling is used between the two tuned circuits.

In this case signal voltages applied to the signal grid of V_1 cause corresponding changes in the anode circuit of V_1 producing alternating potentials across the complex anode load impedance R, and LC. However, if the generally similar tuned circuit L_1, C_1 is closely coupled magnetically to tuned circuit L, C, as indicated by the bracket M, representing the mutual induction, the phenomena of double resonance, known to those skilled in the art, appears across the terminals of either inductor. Thus the voltages appearing at the anode of V, being the vector sum of the alternating potentials appearing across R, and L, C, exhibit the composite characteristics of each element of the complex anode load impedance.

Fig. 7 indicates another embodiment of this invention which is similar to that shown in Fig. 3 except that magnetic instead of capacitive coupling is used between the two tuned circuits.

Fig. 7 is also similar in operation to Fig. 6 as described in the previous paragraph, except for the addition of several circuit elements provided for push-pull operation.

The circuit of Fig. 8 shows an important embodiment of the present invention wherein only alternating potentials to which the resonant circuits respond are applied to the signal grid of one electron discharge device while the vector sum of these same alternating potentials and those appearing across resistance R are applied to the signal grid of another electron discharge device, thus establishing two audio channels. By making the reactance of condenser C2 high, at low frequencies, compared to the resistance of R2 a considerable portion of the lower frequency signals may be eliminated from the audio channel of which electron discharge device V2 is an element. Note that the setting of the variable control resistor R3 determines the degree of augmentation of all alternating voltages, appearing within the frequency response range of the resonant circuits, in both amplifying channels.

In Fig. 9 is shown a circuit similar to that of Fig. 8 except that provision has been made for complete push-pull operation. This circuit embodies all the advantages described in connection with the circuits of Figs. 2, 3, and 8, with the additional advantages, familiar to those skilled in the art, of completely balanced push-pull operation.

While I have indicated and described several systems for carrying my invention into effect, it will be apparent to one skilled in the art that my invention is by no means limited to the particular organizations shown and described, but that many modifications may be made without departing from the scope of my invention, as set forth in the appended claims.

I claim:

1. An audio frequency amplifier stage of the type including a pair of electron discharge devices in which the anode of one electron discharge device is connected to the signal grid of another electron discharge device through a condenser passing only alternating current, an inductor and condenser connected in parallel, a resistor having one of its terminals connected to said anode and its second terminal connected to one terminal of said inductor and condenser, a source of positive voltage connected to the second terminal of said parallel connected inductor and condenser for supplying operating potential to said anode, a second parallel connected inductor and condenser and another condenser having one of its terminals connected to the junction of said resistor and said first parallel connected inductor and condenser and its other terminal connected to one

terminal of said second parallel connected inductor and condenser, and a conductive connection from the second terminal of said second parallel connected inductor and condenser to the junction of said source of positive voltage and the second terminal of the first mentioned parallel connected inductor and condenser.

2. An audio frequency amplifier stage of the type including a pair of electron discharge devices in which the anode of one electron discharge device is connected to the signal grid of another electron discharge device through a condenser passing only alternating current, a resistor having a resistance value high compared to the maximum total impedance of the load circuit of said anode over the operating frequency range of the circuit, said resistor having one of its terminals connected to said signal grid and its other terminal connected to a source of potential suitable for the operation of said grid, an inductor and condenser connected in parallel, a second resistor having one of its terminals connected to said anode and its second terminal connected to one terminal of said inductor and condenser, a source of positive voltage connected to the second terminal of said parallel connected inductor and condenser for supplying operating potential to said anode, a second parallel connected inductor and condenser and another condenser having one of its terminals connected to the junction of said resistor and said first parallel connected inductor and condenser and its other terminal connected to one terminal of said second parallel connected inductor and condenser, a conductive connection from the second terminal of said second parallel connected inductor and condenser to the junction of said source of positive voltage and the second terminal of the first mentioned parallel connected inductor and condenser, a variable resistance having a maximum value high compared to the maximum tuned impedance of said inductors and condensers, said variable resistance being connected in shunt with the first mentioned parallel connected inductor and condenser.

3. An audio frequency amplifier stage of the type including a pair of electron discharge devices in which the anode of one electron discharge device is connected to the signal grid of another electron discharge device through a condenser passing only alternating current, an inductor and condenser connected in parallel, a resistor having one of its terminals connected to said anode and its second terminal connected to one terminal of said inductor and condenser, a source of positive potential connected to the second terminal of said parallel connected inductor and condenser for supplying operating potential to said anode and a second parallel connected inductor and condenser having its inductance coupled to the inductance of the first mentioned inductor.

4. An alternating current amplifier of the type including an electron discharge device supplying alternating current signals to a complex coupling impedance in its anode circuit, said coupling impedance comprising an inductor and condenser connected in parallel, a resistor having one of its terminals connected to said anode and its other terminal connected to one terminal of said inductor and condenser, a source of positive operating potential for said anode connected to the other terminal of said parallel connected inductor and condenser, a second parallel connected inductor and condenser combination having one of its terminals connected to the junction of said source of positive operating potential and the low alternating potential terminal of the first mentioned parallel connected inductor and condenser, a third condenser connected between the high alternating potential points of both of said inductors, a variable resistor having a maximum resistance value high compared to the maximum impedance of the tuned circuits, said resistor being connected in shunt with the first mentioned inductor, a second electron discharge device and a resistor connecting its signal grid to a source of operating potential, the resistance value of said resistor being high compared to the maximum total load impedance appearing in said anode circuit, a condenser having a reactance value high at the resonant frequency of the tuned circuits compared to the resistance connected to said signal grid coupling said anode to said signal grid, a third electron discharge device and a resistor connecting its signal grid to a source of operating potential, the resistance value of said resistor being high compared to the maximum impedance of the tuned circuits, a condenser coupling the signal grid of said third electron discharge device to the high alternating potential terminal of the second mentioned inductor, said condenser having a reactance value low, at the resonant frequencies of the tuned circuits, compared to the resistance connected to said signal grid of said third electron discharge device.

5. In a circuit of the class described, an electron discharge device for amplifying a signal, means connected to the anode of said device to provide an anode load the impedance of which varies with frequency in a predetermined manner to afford voltages at said anode having predetermined frequency response characteristics including a biresonant circuit having two tuned circuits capacitively coupled to each other, resistance means conductively connecting one of said circuits to said anode, a second electron discharge device coupled to said anode (and being the input to an amplifier circuit) a high pass filter interposed between said second electron discharge device and said anode, a third electron discharge device being the input to a second amplifier capacitively coupled to the other of said tuned circuits of said bi-resonant circuit.

6. In a circuit of the class described, an electron discharge device for amplifying a signal, means connected to the anode of said device to provide an anode load, the impedance of which varies with frequency in a predetermined manner to afford voltages at said anode having predetermined frequency response characteristics, including a biresonant circuit having two tuned circuits capacitively coupled to each other, resistance means conductively connecting one of said circuits to said anode, a second electron discharge device coupled to said anode (and being the input to an amplifier circuit), a high pass filter interposed between said second electron discharge device and said anode, a third electron discharge device, being the input to a second amplifier, capacitively coupled to the other of said tuned circuits of said biresonant circuit, and variable resistance means connected to said anode through said first resistance and in parallel to said tuned circuit for controlling the resonant impedance of said biresonant circuit.

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