June 7, 1955 F. G. LOGAN 2,710,313

ELECTROMAGNETIC AUDIO AMPLIFIERS

Filed Oct. 12, 1948 5 Sheets-Sheet 1

Fig. 1.

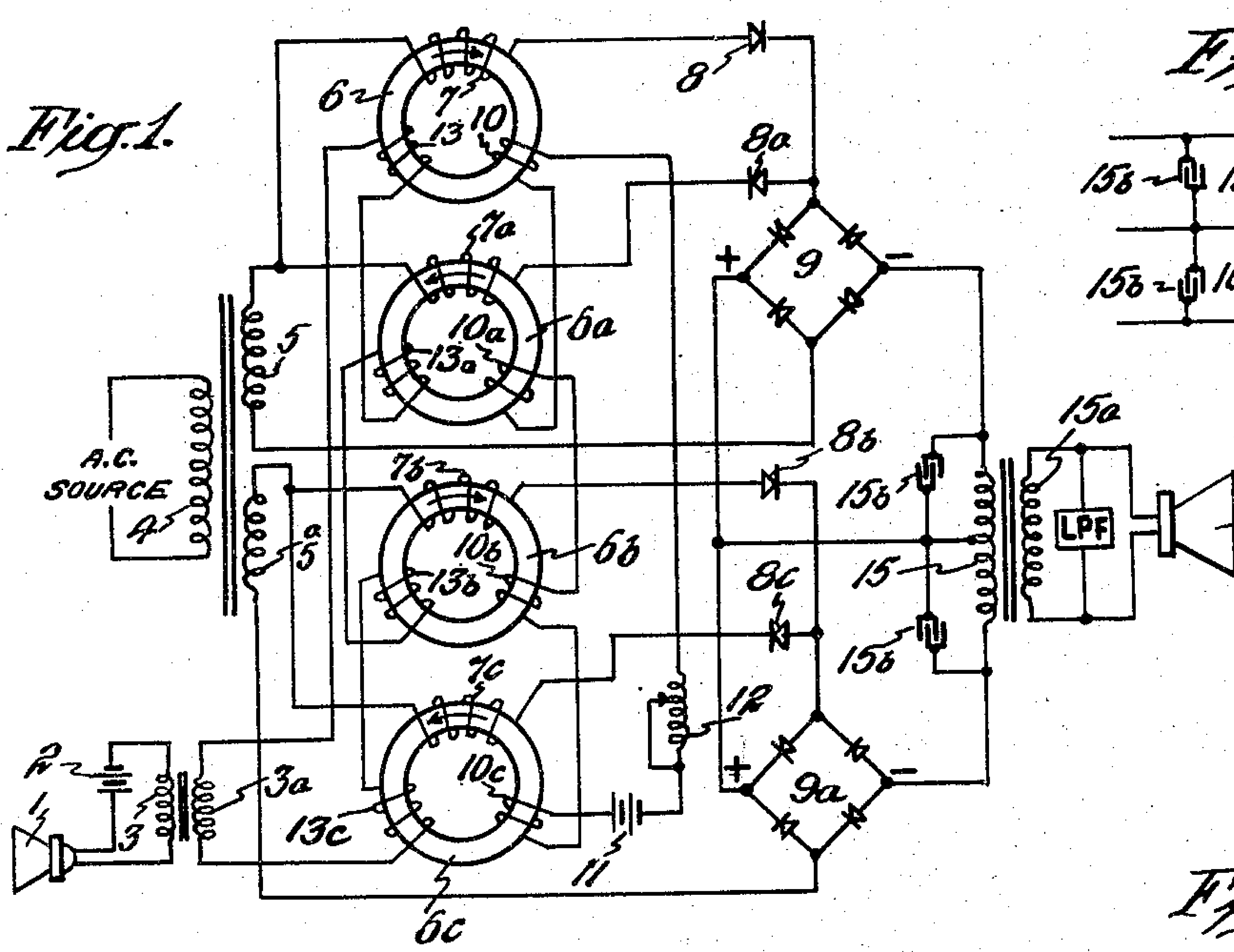


Fig. 1a.

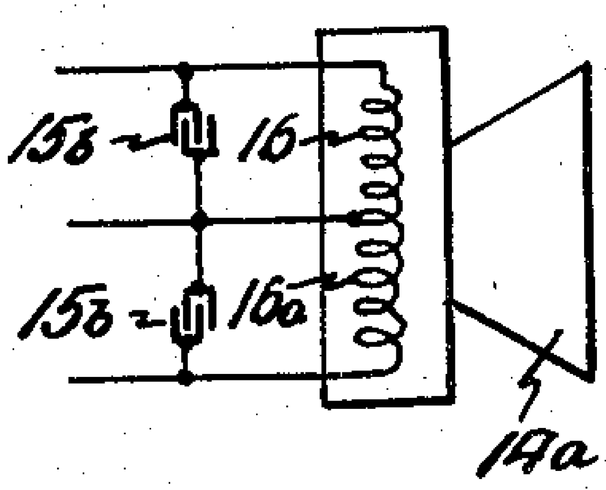


Fig. 1b.

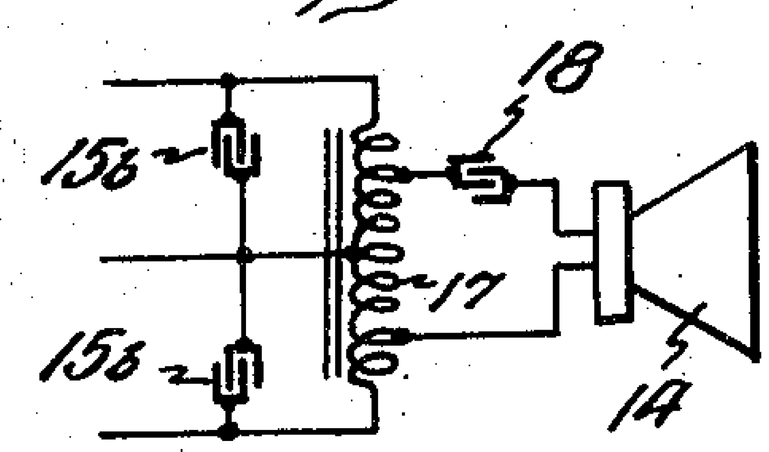
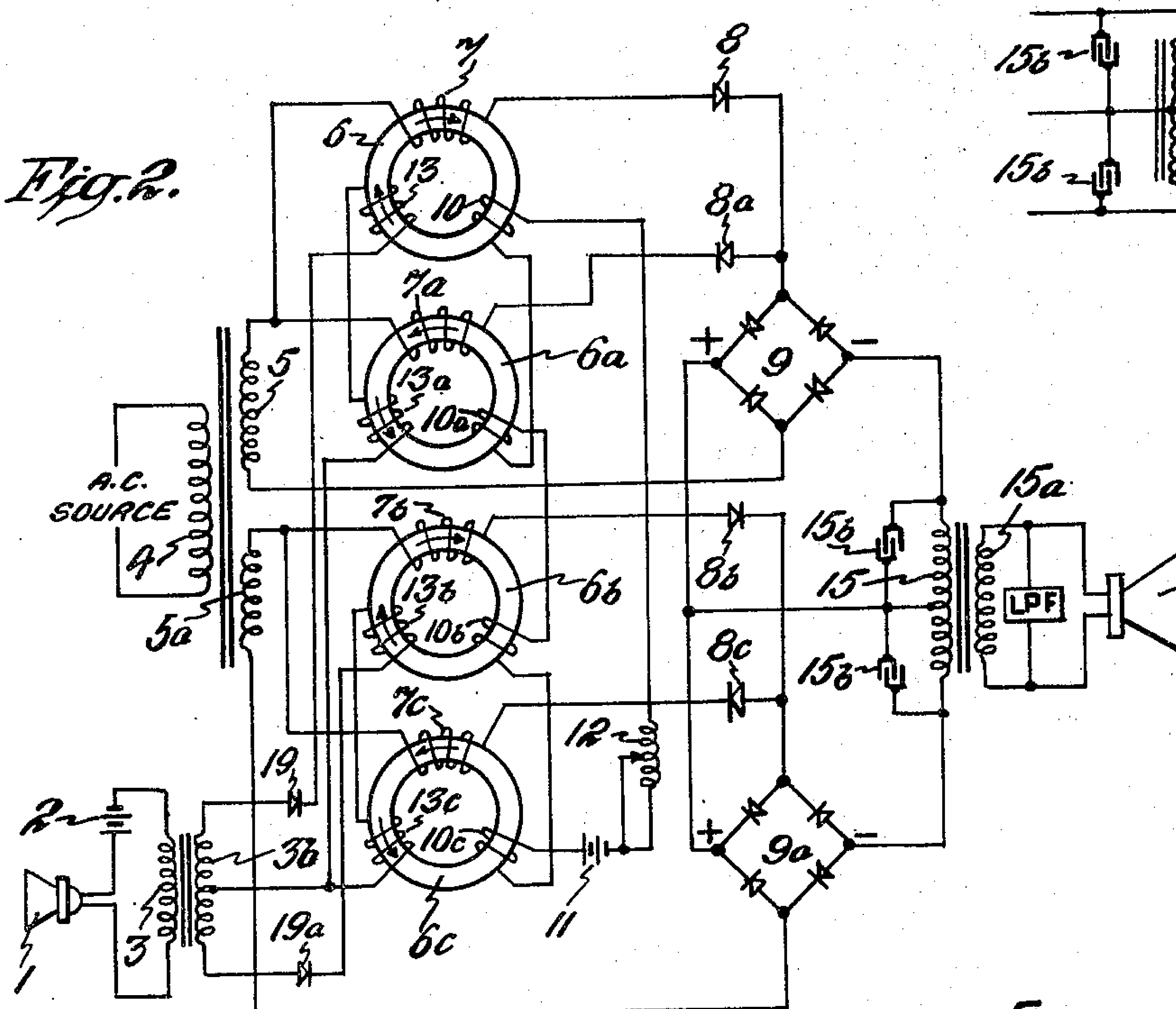


Fig. 2.



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ELECTROMAGNETIC AUDIO AMPLIFIERS

Filed Oct. 12, 1948 5 Sheets-Sheet 2

Fig. 3.

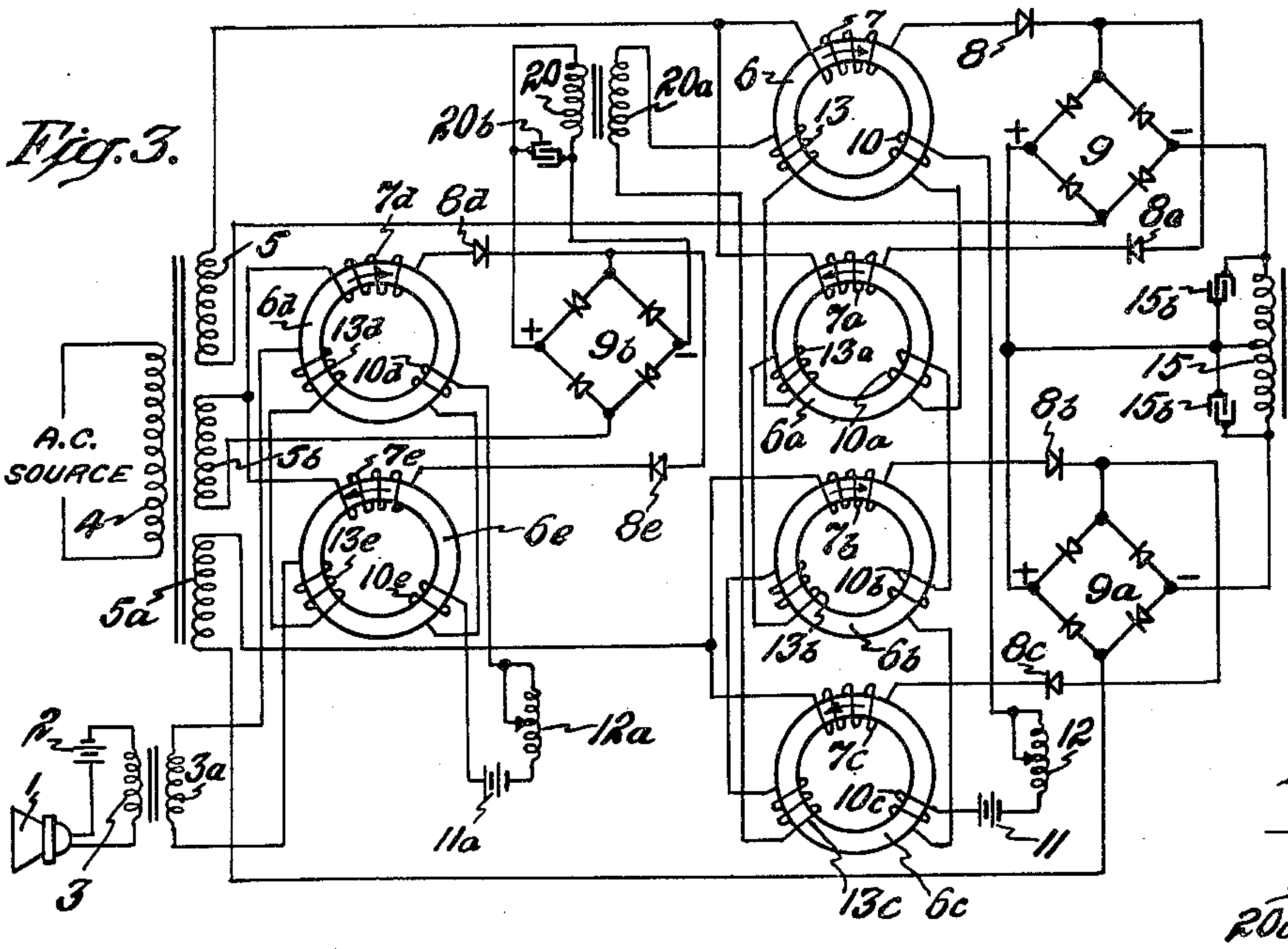


Fig. 3a.

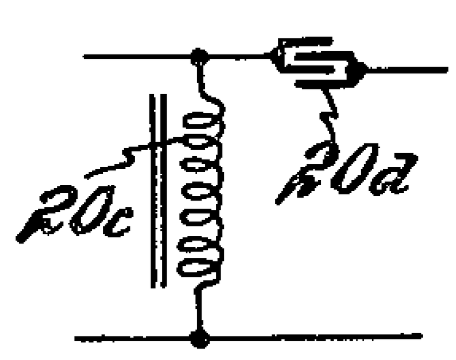
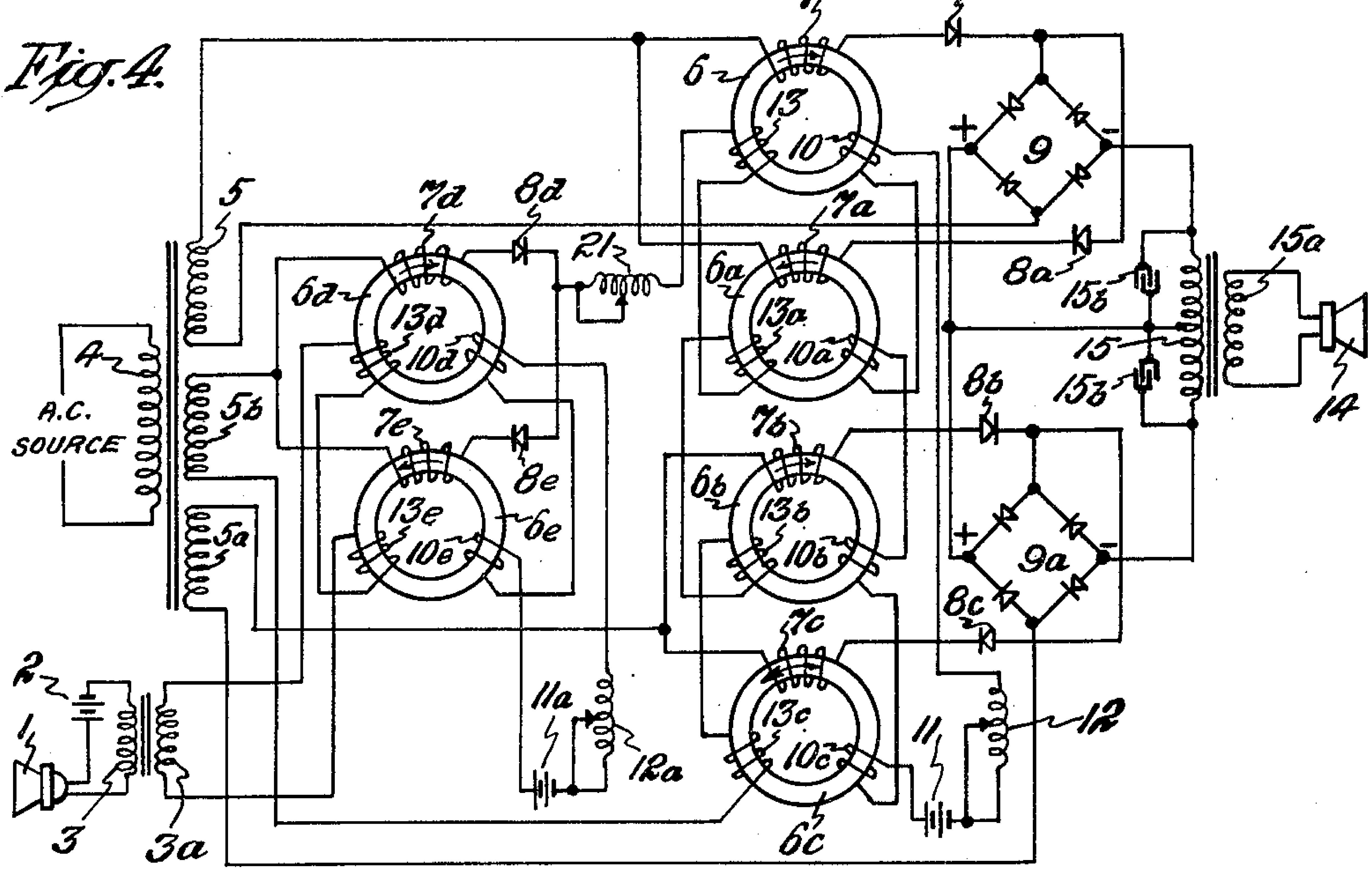


Fig. 4.



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ELECTROMAGNETIC AUDIO AMPLIFIERS

Filed Oct. 12, 1948 5 Sheets-Sheet 3

Fig. 5.

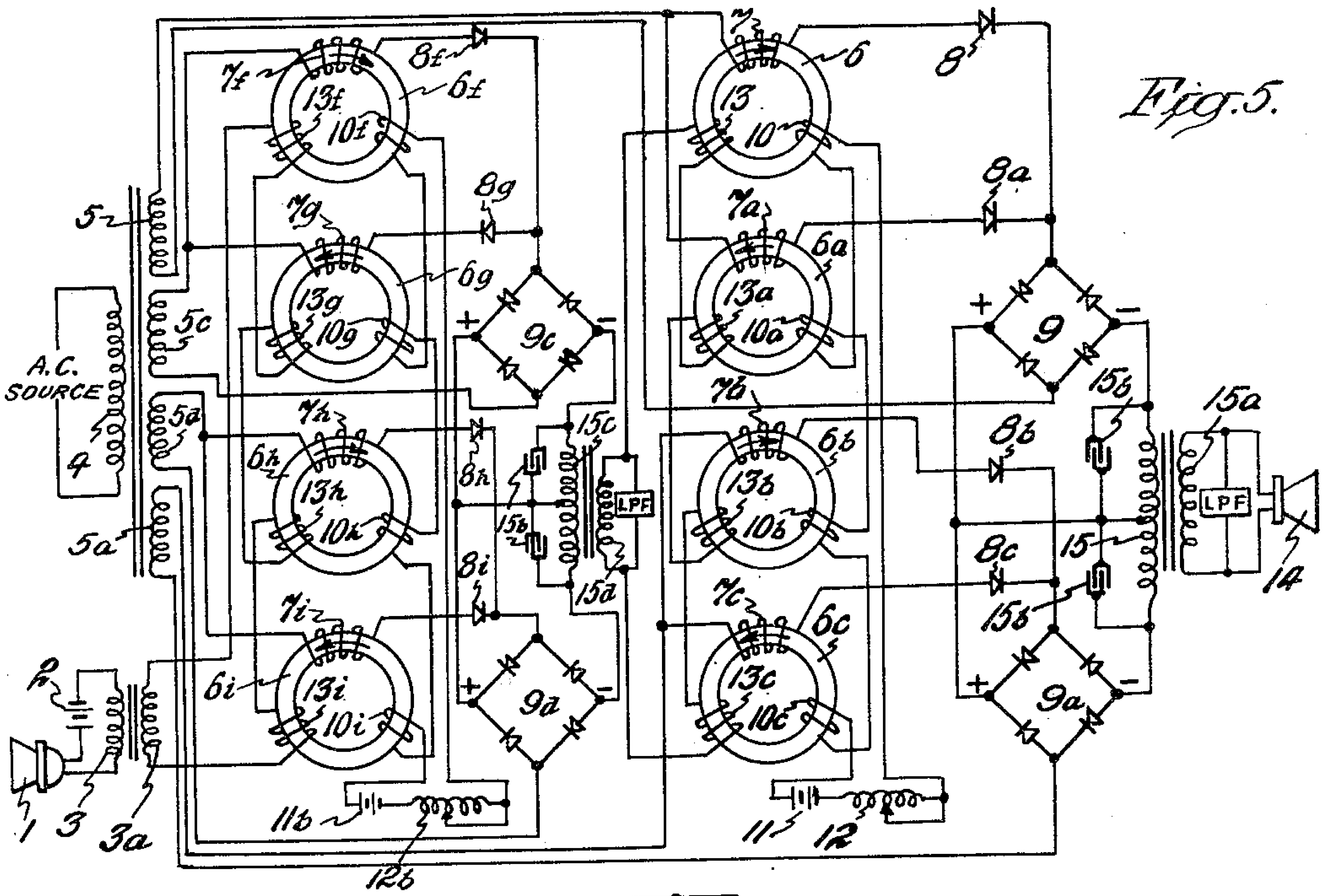
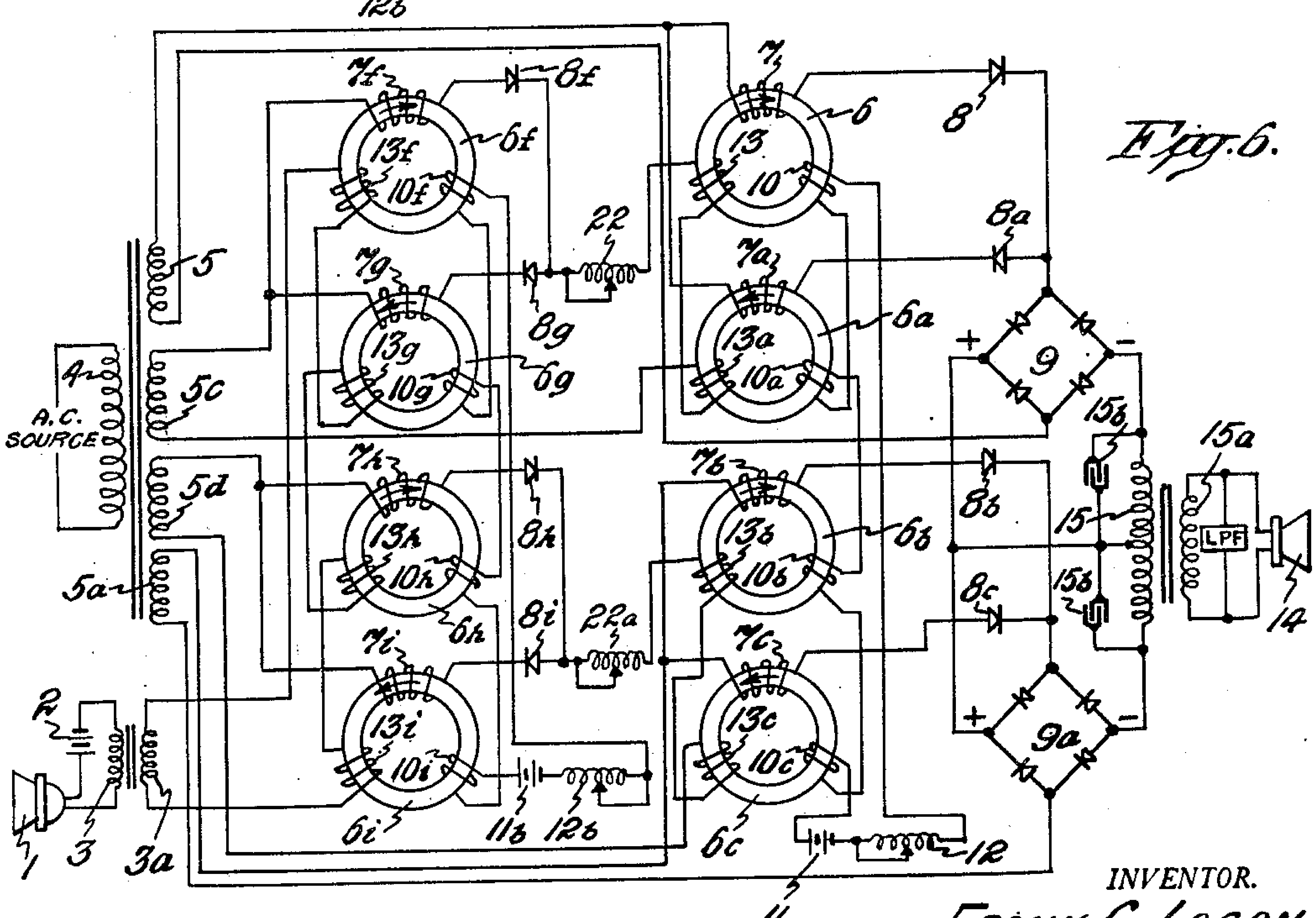


Fig. 6.



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June 7, 1955 F. G. LOGAN 2,710,313

ELECTROMAGNETIC AUDIO AMPLIFIERS

Filed Oct. 12, 1948 5 Sheets-Sheet 4

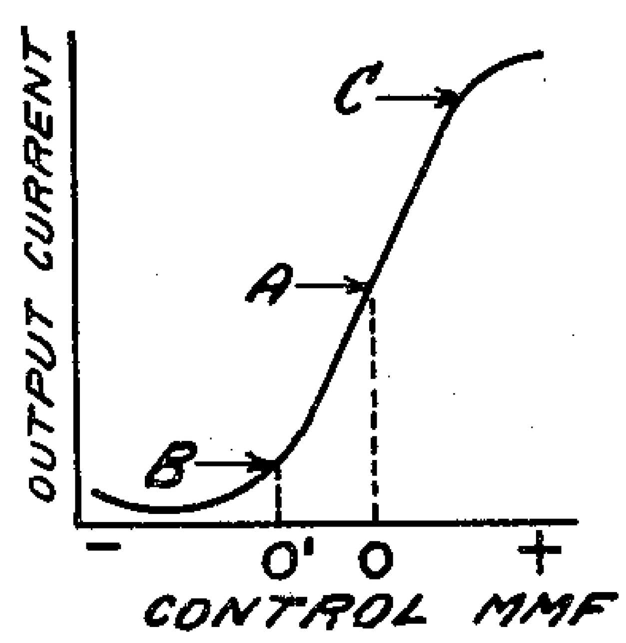

Fig. 7.

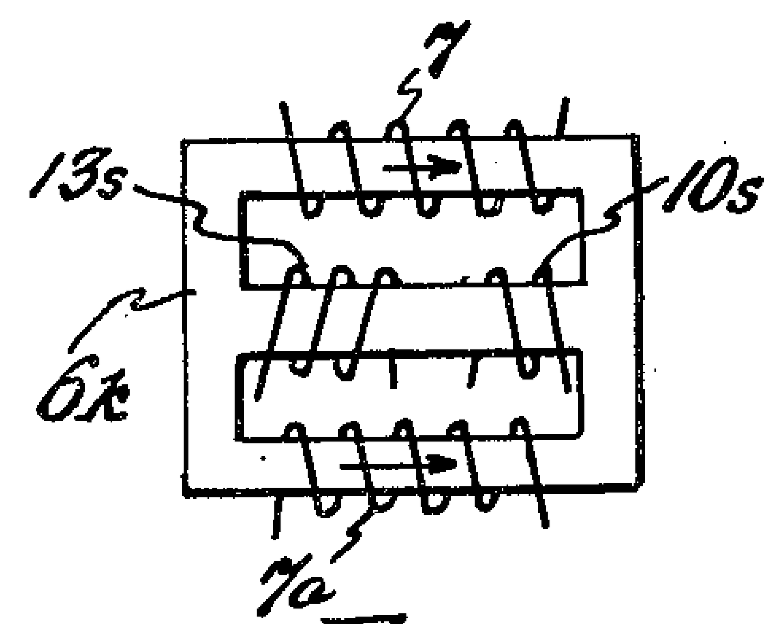

Fig. 8.

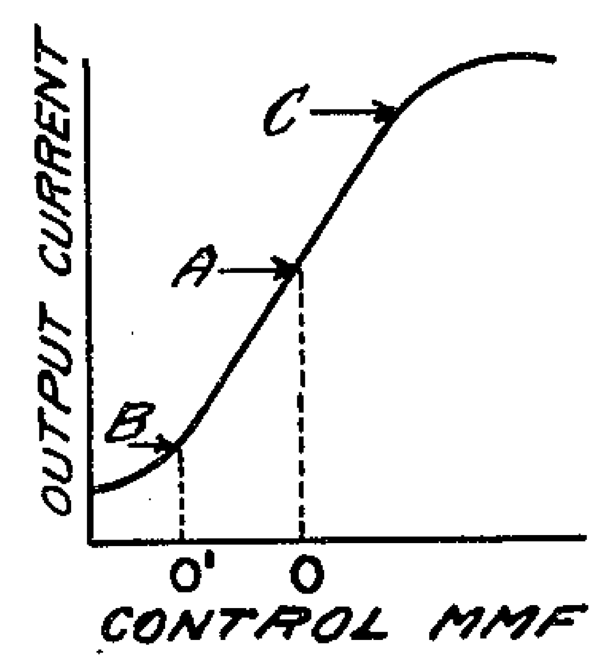

Fig. 9.

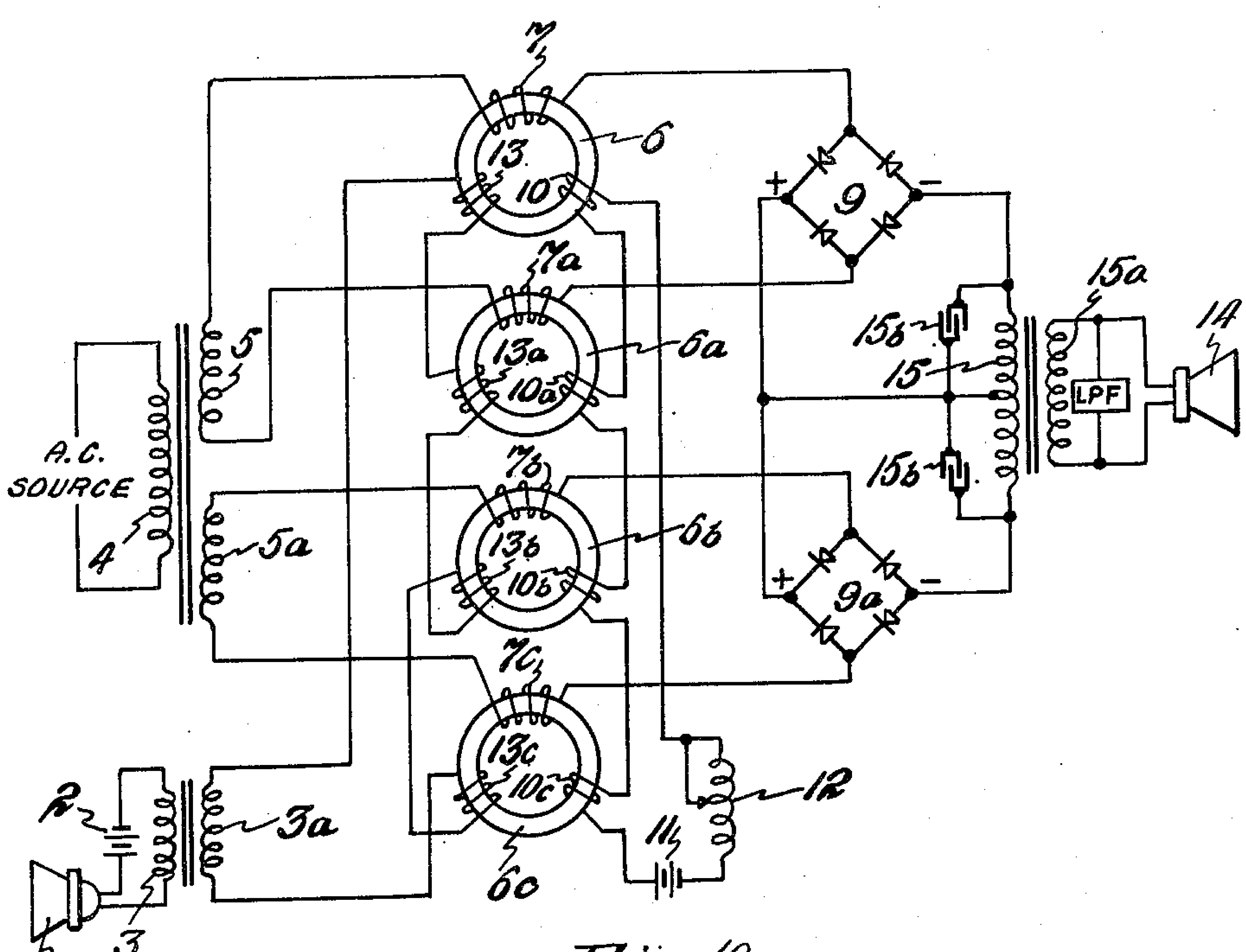

Fig. 10.

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June 7, 1955 F. G. LOGAN 2,710,313

ELECTROMAGNETIC AUDIO AMPLIFIERS

Filed Oct. 12, 1948 5 Sheets-Sheet 5

Fig. 11.

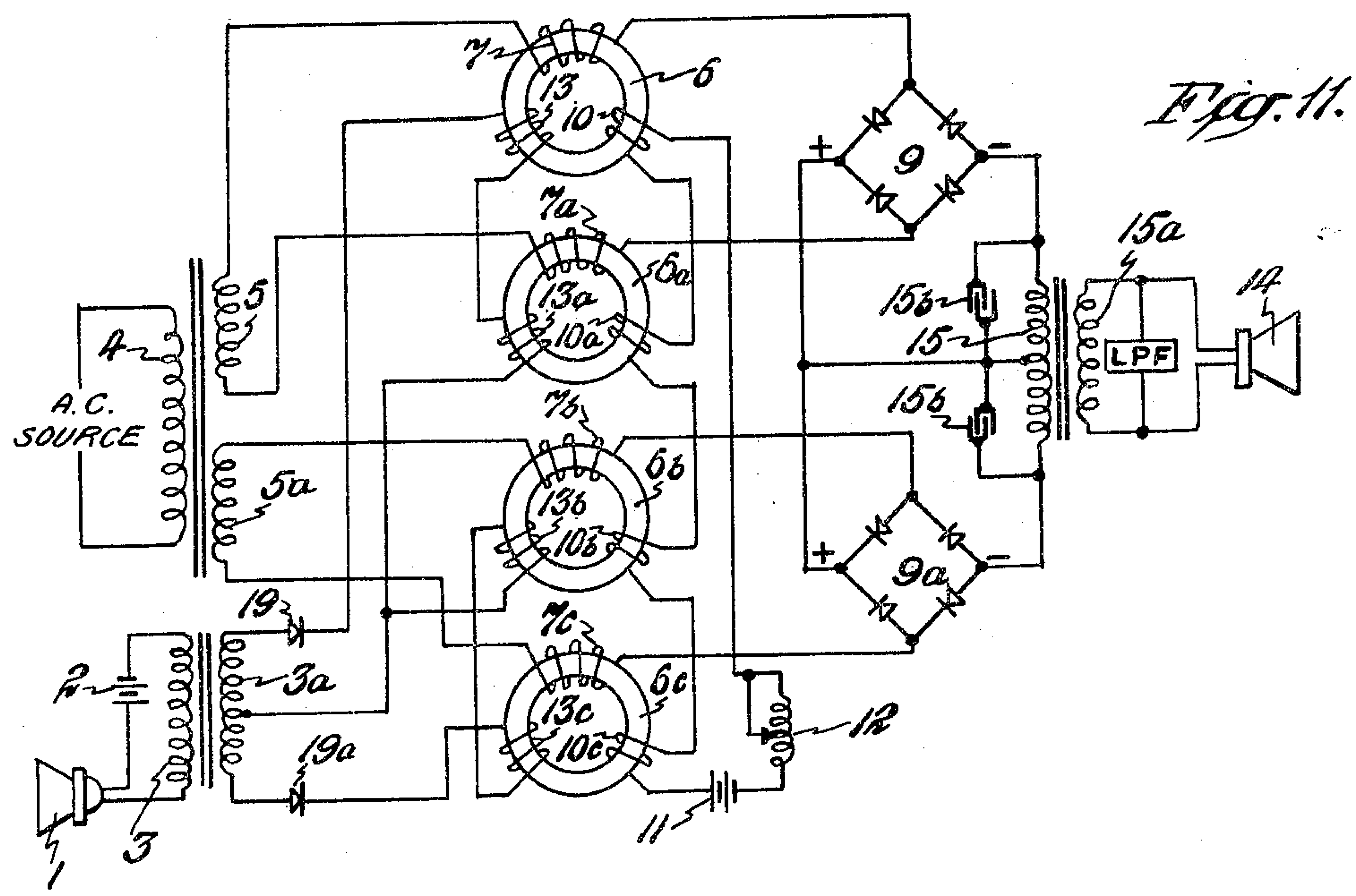
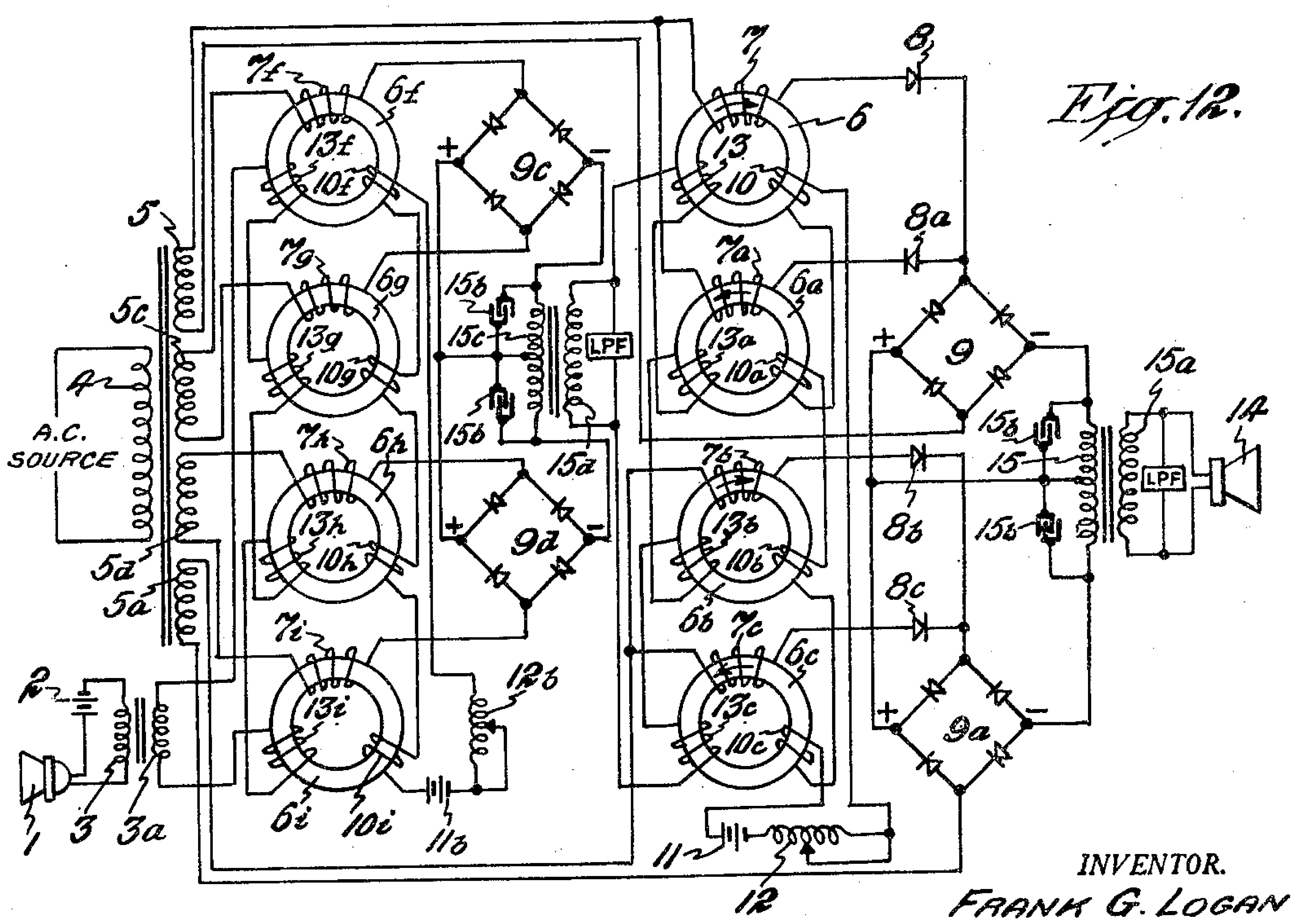


Fig. 12.



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United States Patent Office

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ELECTROMAGNETIC AUDIO AMPLIFIERS

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Application October 12, 1948, Serial No. 54,169

3 Claims. (Cl. 179—171)

This invention relates to electromagnetic audio amplifiers applicable to a wide variety of uses and to signal amplifiers and controls within the audio range. It particularly relates to what may be termed a push-pull type of control and to various relationships thereof and combinations therewith.

One object is to provide audio amplifiers which avoid the use of vacuum tubes with their likelihood of failure and their necessity of more or less frequent replacement. Another object is to produce audio amplifiers which will be dependable in long continued use and substantially free from deterioration and the necessity of replacement of parts. A further object is to produce apparatus of a simple character which may be readily manufactured and assembled. Another object is to produce apparatus adapted for low as well as high output units. Other objects, advantages and applications will be understood from the following description and accompanying drawings which illustrate preferred embodiments of the invention.

Fig. 1 is a diagram showing a single stage of amplification of the push-pull type; Figs. 1*a* and 1*b* show modified forms of couplings to the output circuit; Fig. 2 is a diagram of a single stage of this type with a modified form of controlling current; Fig. 3 is a diagram showing two stages of amplification wherein the first stage is of the single ended form and the second stage is of the push-pull type; Fig. 3*a* shows a modified form of coupling between the two stages; Fig. 4 is a diagram similar to Fig. 3 showing a different form of control applied to the second stage; Fig. 5 is a diagram showing two stages of amplification each of the push-pull type; Fig. 6 is similar to Fig. 5 except as to derivation of the control current applied to the second stage; Fig. 7 is an explanatory chart; Fig. 8 shows one form of combined core and windings, as distinguished from the use of separate or individual cores; Fig. 9 is another explanatory chart; Fig. 10 is a diagram showing one amplification stage of the push-pull type wherein non-self-saturating reactors are used; Fig. 11 is a diagram similar to Fig. 10 except as to the character of the control current; and Fig. 12 is a diagram showing two stages of amplification wherein the first stage utilizes non-self-saturating reactors and the second stage utilizes self-saturating reactors.

The accompanying disclosures are based upon the use of amplifying reactors which may be of the self-saturating type or of the non-self-saturating type. The signal or audio input to the amplifying apparatus has, of course, a variable frequency within the range that is capable of being heard; and in order to obtain amplified reproduction of fair quality the input power must have a frequency higher than that of the highest audio frequency or of the signal frequency that is to be amplified. In order to obtain good quality of reproduction the input power frequency should be several times that of the highest audio frequency which it is desired to be amplified. Where the input signal or audio input had a range of from 30 to 3,000 cycles per second, good results have been obtained by using a power input having a frequency of 10,800 cycles per second. Where the input signal or audio input had a range of from 30 to 10,000 cycles per second, good results have been obtained by using a power supply having a frequency of 30,000 cycles per second.

Figure 7 of the accompanying drawings is a chart showing the characteristics of a self-saturated reactor where the controlling magnetomotive force is plotted as the abscissas and the controlled output current is plotted as the ordinates. In the present invention the steep part of the curve or range from B to C is utilized and the nearer this approaches a straight line the better is the quality of reproduction.

When the controlling magnetomotive force is at 0 on the chart and the magnetization of the reactor is adjusted to yield a controlled output current having a value at or near the middle of the steep portion of the line, as at A, the controlling action may be indicated as Class A. In this case when the controlling magnetomotive force is in a positive direction, that is to the right of the zero in Fig. 7, the output of the controlled current will be increased from A toward C; and when the controlling magnetomotive force is negative, that is to the left of the zero, the controlled output current will be decreased from A towards B. In the present invention the controlling magnetomotive force is that due to the variable controlling current from the input signal or audio source; and the controlled output current is that due to the power output of higher frequency as modulated by the controlling magnetomotive force. When the controlling current and controlling magnetomotive force has a variable positive and negative direction, it is advantageous to operate the reactor on the basis of Class A. Referring to Fig. 7, it should be noted that the change in the output current from A to C and from A to B is very pronounced as compared with the required change in the controlling magnetomotive force for obtaining these limits. Also when the controlling magnetomotive force is increased in a negative direction beyond where the condition B is obtained, no appreciable change in output current is obtained and it only begins to rise slightly under a very considerable increased magnetomotive force in a negative or opposing direction.

Another mode of control differs from Class A and may be designated as Class B. Referring to Fig. 7, consider the control magnetomotive force to have a zero value indicated on the figure at 0′ and that the output current at such zero value is of an amount to have a value corresponding to the location B on the line. This is obtainable by adjustment of the magnetization of the reactor core to have such a value when the controlling magnetomotive force is zero as at 0′. Under such conditions any change in value of the controlling magnetomotive force in a positive direction gives a wide and very pronounced range of control from B to C on the line. In this case the controlling current for causing change of the controlling magnetomotive force is effective in responsive results only as regards variations in value thereof in one direction only. When the reactor is controlled in this manner by changes of value of the magnetomotive force in one direction only it is designated as Class B control. Obviously the most effective response is then obtained when the range of control is effectively utilized over the range from B to C.

Fig. 1 shows an embodiment operable as Class A of the push-pull type with one stage of amplification. Four separate reactors of the ring type are shown for simplicity, although they may be of any suitable form and the two upper reactors may be combined in one unit of suitable design and the two lower reactors may similarly be combined. The signal or audio source is indicated as a microphone 1 in circuit with a battery 2 supplying current to the primary 3 of a transformer. The power source of alternating current indicated as "A. C. source" has a frequency higher than that of the highest frequency of the signal source and preferably several times higher; and may be of any type for securing the desired frequency at approximately constant voltage. This source supplies current to a transformer having a primary winding 4 and two secondary windings 5 and 5*a* for securing an output of the desired constant voltage value.

The reactor cores 6, 6*a*, 6*b* and 6*c* are respectively provided with load current windings 7, 7*a*, 7*b* and 7*c*, the upper windings 7 and 7*a* being supplied with current from the secondary winding 5 and the lower windings 7*b* and 7*c* being supplied with current from the secondary winding 5*a*. The windings 7 and 7*a* are connected in parallel with each other from one terminal of the winding 5 and in series with the winding 7 is a half-wave valve 8; and in series with the winding 7*a* is a half-wave valve 8*a*. These valves are preferably of the dry plate type but may be tubes, crystals or of other forms. The output sides of the valves are connected together but the valves are connected in reversed relation with reference to each other with the result that the output therefrom is alternating. Thus the load windings 7 and 7*a* alternately carry intermittent direct pulsating currents. These windings supply current to a full wave rectifier 9 indicated as of the bridge-connected dry plate type, although other forms may be used. The return circuit from the rectifier is completed by a connection back to the secondary winding 5. The main windings 7*b* and 7*c* are similarly provided with half-wave electric valves 8*b* and 8*c*, the circuit therefrom passing through a full wave rectifier 9*a* indicated as of the bridge-connected dry plate type, from which its return circuit passes to the secondary winding 5*a*.

Each reactor is provided respectively with a biasing winding 10, 10*a*, 10*b* and 10*c* supplied with direct current from any suitable source indicated as a battery 11. The windings 10 to 10*c* are connected in series with each other and in series with an adjustable impedance device 12. For Class A operation assumed in Fig. 1, the current in the windings 10 to 10*c* is adjusted to have such relation to the current supplied by the load windings as to bring the magnetization of the cores to a region that will result in the output current of the load windings being at about the middle point of the steep portion of the output current curve when no current is supplied to the controlling windings later described. This condition corresponds to the point A of Fig. 7 with zero control magnetomotive force.

The control or controlling windings 13, 13*a*, 13*b*, and 13*c* are located respectively on the reactor cores and are connected in series with each other and supplied with current from the secondary winding 3*a* of the transformer having the primary winding 3. The current in the primary winding 3 is in one direction and varies in amplitude and in frequency of pulsations when subjected to signals or audio input to the microphone 1. The secondary winding 3*a* imparts current to the controlling windings 13 to 13*c* which is variable in amplitude and in frequency and also in positive and in negative directions as determined by the signal input. With reference to the two upper reactor cores, the controlling windings should be connected in such relation to their respective main power windings and to each other that when the magnetomotive forces of the main and controlling windings are in the same direction in one reactor core, the same condition should apply to the main and controlling windings on the other core under corresponding conditions. That is if a current which passes in the controlling circuit in one direction has its magnetomotive force in an aiding direction with the magnetomotive force of the main winding in one core, then the same direction of current in the controlling circuit should cause the magnetomotive force of the controlling winding to be in an aiding direction with the magnetomotive force of the main winding on the other core, as shown in Fig. 1. It follows that these controlling currents impose a variable controlling magnetomotive force on the reactors corresponding to the control magnetomotive force of Fig. 7. This variable controlling magnetomotive force affects the output current of the main windings and causes modulation of the output current from the load or main windings 7 and 7*a* so that the envelope of these currents is a function of the amplitude and wave form of the signal currents.

The foregoing likewise applies to the relationship of the control windings 13*b* and 13*c* to the windings 7*b* and

7*c*. However, these controlling windings 13*b* and 13*c* are connected in reversed relation respectively with reference to the windings 13 and 13*a*, as shown in Fig. 1, with the result that when the current in the controlling circuit is passing in a direction to cause the output from the main windings 7 and 7*a* to increase, the same direction of current will have the reverse effect on the output of the main windings 7*b* and 7*c* and reduce the output current therefrom. When the current passes in the controlling circuit in the opposite direction, the output from the windings 7*b* and 7*c* is increased and the output from the windings 7 and 7*a* is decreased. This accomplishes the push-pull control of the amplifying reactors.

The biasing windings 10 to 10*c* are subject to induced electromotive forces by reason of being directly coupled with the other windings on the reactor cores; and in order to reduce the current due to the ripple induced therein, the impedance device 12 in the circuit of the biasing windings should have high resistance or inductance values, or else the biasing windings themselves should have sufficiently high resistance to properly reduce the induced ripple currents. In some cases where the cores and value of the ampere turns of the main power windings 7 to 7*c* are properly proportioned to deliver a current output corresponding to the point A of Fig. 7 with zero control magnetomotive force, the biasing windings may be omitted.

The currents derived from the main windings 7 and 7*a* of the upper set of reactive means are demodulated by the rectifier 9 which delivers direct current from its output terminals as modulated by the audio signals; and similarly the output currents from the main windings 7*b* and 7*c* of the lower set of reactive means are demodulated by the rectifier 9*a* which delivers direct current from its output terminals as modulated by the audio signals. The amplified signal output currents of the rectifiers 9 and 9*a* are utilized to have a combined effect upon the controlled circuit in which may be connected any form of a transducer, such as the loud speaker 14. As shown in Fig. 1 two terminals of the rectifiers 9 and 9*a* which have the same polarity are connected respectively to the end terminals of a primary winding 15 of a transformer, secondary 15*a* of the transformer serving to supply current to the loud speaker. A mid-tap of the primary winding 15 is connected to the other two terminals of the rectifiers having the same polarity. By reason of this form of connection the current in one-half of the primary winding is always in the opposite direction to that in the other half. When no change in the value of the current supplied to the primary winding 15 occurs, as under the condition of no signal being imposed upon the amplifying apparatus, there is no electromotive force induced in the secondary winding 15*a* owing to the counter-acting effect of the current in the two halves of the primary winding 15. Now assume that an amplified signal wave has caused an increased current to be delivered from the rectifier 9 to its half of the primary winding 15 and a decreased current to be delivered from the rectifier 9*a* to its half of the primary winding 15. As a result of the push-pull effect on the two pairs or sets of reactors as already explained, the resultant increase of current in one-half of the winding 15 in one direction and the resultant decrease of current in the other half of the winding 15 in the opposite direction produces a cumulative effect upon the induced electromotive force in the secondary winding 15*a* with the result that the loud speaker or other transducer is pronouncedly affected by the current supplied thereto. Similarly, when the amplifying signal wave in the opposite direction results in a decrease in the output of the demodulating rectifiers 9 and 9*a*, the reverse effect takes place in the two halves of the primary winding 15 and an electromotive force in the opposite direction is induced in the secondary winding 15*a* and thereby correspondingly affects the loud speaker. Thus the variations in the frequency and form of the signal currents are greatly amplified in the corresponding variations imposed upon the loud speaker or other form of transducer.

In some cases, depending upon the characteristics of the loud speaker, an adjustable capacitor **15b** may be connected in shunt across each half of the primary winding **15** for by-passing therefrom or filtering out, the main portion of the pulsations due to the high frequency carrier wave. Also it is desirable in some cases to connect a low pass filter LPF across the output circuit from the secondary winding **15a** to reduce the passage of currents to the loud speaker which would have no controlling influence thereon.

The coupling between the transducer and the output circuits of the amplifier may be modified from that shown in Fig. 1. For example, Fig. 1*a* indicates a loud speaker **14a** having built-in controlling windings for directly affecting the loud speaker output. These windings **16** and **16a** are connected in series with each other with their outside terminals connected respectively to the terminals of the same polarity of the demodulators **9** and **9a** and a mid-connection connected directly to the other pair of terminals of the demodulators. Fig. 1*b* shows another form of coupling wherein an auto-transformer **17** has the terminals of its winding connected respectively to terminals having the same polarity of the rectifiers **9** and **9a** and a mid-tap connected to the other terminals having the same polarity. The circuit to the loud speaker **14** is shown connected to equally distant taps from the mid-connection of the winding **17** through a capacitor **18**. The capacitor **18** in the circuit to the loud speaker serves to block the passage of direct current from the loud speaker and permits only the varying currents to pass to the loud speaker due to changes in values of the electromotive force imposed upon the terminals of the loud speaker circuit. The modifications shown in Figs. 1*a* and 1*b* may be applied also to the other figures of the drawings.

Fig. 1, as already stated, shows for simplicity separate reactor cores and Fig. 8 shows an illustrative example of one form of a reactor core combining two separate cores with their windings. The core **6k** shown is of the three-legged type. The load windings **7** and **7a** for example, are on the outside legs of the core and their magnetomotive forces are in the same direction in the outside legs, indicated by the arrows as from left to right, and have a common direction in the middle leg. The controlling windings **13** and **13a** of Fig. 1 are combined in a single winding **13s** on the middle leg of the core in Fig. 8; and the biasing windings **10** and **10a** of Fig. 1 are combined in a single winding **10s** on the middle leg of the core in Fig. 8. The mode of operation when using a reactor of the form of Fig. 8 is similar in a general way to that described with reference to Fig. 1. It will be understood that in the other figures of the drawings showing single forms of reactors they may be combined as shown in Fig. 8 or otherwise modified.

Fig. 2 is similar to Fig. 1 except the operation of the amplifying reactors is under Class B as distinguished from Class A of Fig. 1. In Fig. 2 the secondary winding **3b** of the transformer deriving current from the signal source is tapped at its mid-point and the lines from its outside terminals pass through one-way electric valves **19** and **19a**. Current from the valve **19** passes through the controlling windings **13** and **13a** of the upper pair of reactors and returns to the mid-tap connection. Current from the valve **19a** passes to the controlling windings **13b** and **13c** of the lower pair of reactors and returns to the mid-tap connection. In view of the currents in the control windings being uni-directional, the reactor control is preferably Class B, and the controlling windings are connected to cause their magnetomotive forces to be additive to those of the main windings, as shown in Fig. 2. Also the current in the biasing windings **10** to **10c** is preferably adjusted to bring the output current of the load windings **7** to **7c** at the region B of Fig. 7 when no audio signals are imposed on the amplifying reactors. This gives a wide range of control from B to C of Fig. 7 with a corresponding increase in the amplification. The controlling influence exerted on the lower pair of reactors is, as shown by the connections of the control windings, in the same direction as that imposed upon the upper pair of reactors. It follows that when the signal current effect imposed on the secondary winding **3b** is in one direction, the upper pair of reactors may function over the range from B to C in Fig. 7, while in the lower pair of reactors the control current is at a minimum or zero value. When the signal current effect imposed on the winding **3b** is in the opposite direction, the lower pair of reactors function over a range from B to C of Fig. 7, while the control current in the upper pair of reactors is at a minimum or zero value. In this case the control windings of the lower pair of reactors are connected to have the same relationship to their main windings as regards direction of current, as the control windings of the upper pair of reactors have to their main windings. In other respects, the operation of Fig. 2 is similar to that of Fig. 1, the current imposed on the halves of the primary winding **15** controlling the output circuit being in opposite directions toward its mid-tap.

Fig. 3 shows two stages of amplification wherein the first stage is a single ended core set and the second stage is of the push-pull type having two core sets. An additional secondary winding **5b** is shown in Fig. 3 supplying current to the main windings **7d** and **7e** on a pair of cores **6d** and **6e**. The currents from these windings pass through reversed connected half-wave valves **8d** and **8e** to a bridge-connected full wave rectifier **9b** from which a return connection is made to the secondary winding **5b**. The control windings **13d** and **13e** are applied to these reactor cores and supply a variable current in positive and negative directions derived from the secondary winding **3a** which is related to the signal source. The biasing windings **10d** and **10e** are likewise applied to the reactor cores and supplied with current from a direct current source **11a** through an impedance device **12a**. The demodulated amplified signal current is supplied to the primary winding **20** of a transformer having a secondary winding **20a** which in turn supplies the control windings **13** to **13c** of the two pairs of amplifying reactors similar to those disclosed in Fig. 1. The output from these reactors is supplied to the demodulating rectifiers **9** and **9a** and to the loud speaker in the same manner as described with reference to Fig. 1. An adjustable capacitor **20b** is preferably connected across the primary winding **20** for by-passing therefrom the main portion of the pulsations due to the high frequency carrier wave. The first single ended stage of amplification is preferably operated Class A and the second stage is likewise preferably operated Class A.

Instead of the transformer **20**, **20a** and capacitor **20b** for the coupling between the two stages, a modified form is shown in Fig. 3*a* wherein a choke **20c** may be connected across the output of the rectifier **9b** and a capacitor **20d** connected in series in the circuit of the control windings **13** to **13c**. The choke serves to by-pass a major portion of unmodulated direct current whereas the capacitor serves to transmit the amplified signal currents to the control windings of the second stage.

Fig. 4 is similar to Fig. 3 except the alternating current output from the first stage is applied in proper phase relationship directly to the control windings of the second stage through an impedance device **21** inserted in the circuit of the control windings of the second stage. This results in the control windings **13** to **13c** of the second stage being subjected to modulated currents with amplified audio current influences. The first stage should preferably be operated Class A and likewise the second stage should be operated Class A. In place of the impedance device **21**, a coupling transformer could be used.

Fig. 5 shows two stages of amplification wherein each of the stages is of the push-pull type. The second stage is similar to that shown in Fig. 1 and is designated by corresponding reference characters. The first stage shows an upper pair of reactor cores **6f** and **6g** having main windings **7f** and **7g** supplied from a secondary winding **5c** and delivering current through the reversely connected electric valves or half-wave rectifiers **8f** and **8g** to a bridge-connected full wave rectifier **9c** from which the current returns to the secondary **5c**. The lower pair of reactor cores **6h** and **6i** are provided with main windings **7h** and **7i** supplied with current from the secondary winding **5d** and deliver current through the reversely connected electric valves **8h** and **8i** to the bridge-connected full wave rectifier **9d** from which the current returns to the secondary winding **5d**. The control windings **13f** to **13i** are respectively mounted on the cores **6f** to **6i** and supplied with current derived from the signal source. The biasing windings **10f** to **10e** are likewise applied to the cores and supplied with current from a direct current source **11b** through an impedance device **12b**. The output of the demodulating rectifiers **9c** and **9d** is supplied to a primary winding **15c** of a transformer, the connections thereto being the same as described with reference to Fig. 1. Its secondary winding **15d** supplies current to the control windings **13** to **13c** of the second stage. The capacitors **15b** and low pass filter LPF of each stage serve the same purpose as described with reference to Fig. 1. Thus an amplified signal impulse is derived from the first stage of amplification and the secondary winding **15d** delivers the amplified signal current to the control windings **13** to **13c** of the second stage of amplification which in turn further amplifies the signal impulses. The loud speaker **14**, or other transducer, thus is subjected to a greatly amplified series of impulses as result of this further amplification. In view of the fact that the controlling current impulses impressed on both stages of amplification is in both positive and negative directions, both stages would preferably be operated as Class A.

Fig. 6 is similar to Fig. 5 except instead of demodulating the signal impulses delivered from the first stage of amplification, the output from the two pairs of reactors of the first stage is delivered respectively to impedance devices **22** and **22a** and then in proper phase relation to the control windings **13** and **13a** and to the control windings **13b** and **13c** of the two pairs of reactors of the second stage. The two stages of Fig. 6 would preferably be operated as Class A. In place of the impedance devices **22** and **22a**, coupling transformers could be used.

In the foregoing disclosures the reactors have been of the self-saturating type but amplifiers with reactors which are not self-saturating may be used. Fig. 9 is a chart showing the general relationship between the output current from the main or load windings of the latter type of reactor as the magnetomotive force of the controlling winding or windings is increased from zero to a value that results in maximum output. The figure shows the steep portion of the curve from B to C. When this form of reactor is operated Class A, the biasing of the core is made such that with zero control magnetomotive force corresponding to location A on the curve, the output current of the power winding will have a value corresponding to location A; and when operated Class B the biasing is made such that with zero control magnetomotive force corresponding to location B, the output of the power winding will have a value corresponding to location B on the curve. In the following disclosures using non-self-saturating reactors separate cores are shown for simplicity but it will be understood they may be combined, one form of which is indicated in Fig. 8. When such a combined type of reactor is used as non-self-saturating, the load windings are connected to cause their magnetomotive forces to act cumulatively with each other in the outside legs of the core, as distinguished from the direction of the arrows indicated on the outside legs in Fig. 8.

Referring to Fig. 10, the parts are similar to Fig. 1 except that the load windings **7** to **7c** have no one-way valves in series therewith. Thus in Fig. 10 the load windings are subjected to alternating current as distinguished from intermittent direct currents. In Fig. 10 the modulated alternating currents of the load windings are delivered to the demodulating rectifiers **9** and **9a** respectively which in turn apply the amplified signal currents to the loud speaker or other transducer through the transformer connections already described with reference to Fig. 1. In Fig. 10 the input to the controlling windings **13** to **13c** from the signal source is variable not only in amplitude and frequency, but also in direction. Thus the reactors of Fig. 10 should be operated Class A; and in order to avoid objectionable distortion, the controlling magnetomotive forces should not exceed in opposite directions the limits of the locations B and C on the chart of Fig. 9. In this case the connections of the control windings **13** to **13c** are made such that when the derived signal current passes in one direction, and the magnetomotive forces of the control windings **13** and **13a** are additive to the magnetomotive forces of the biasing windings **10** and **10a**, the magnetomotive forces of the control windings **13b** and **13c** should then be in opposition to the magnetomotive forces of the biasing windings **10b** and **10c**, as shown in Fig. 10. When the derived signal current to the control windings passes in the opposite direction, the reverse action takes place. This results in the condition that when the amplified signal current is increased in one-half of the transformer primary winding **15**, it is simultaneously decreased in the other half giving the amplified push-pull effect.

Fig. 11 is similar to Fig. 2 except that the one-way valves are omitted from the circuits of the load windings **7** to **7c**. As distinguished from Fig. 10, the control windings of the non-self-saturating reactors are subjected to currents in one direction only owing to the valves **19** and **19a** being inserted in the circuits of the control windings. When signal impulse currents pass to the control windings **13** and **13a** of the upper pair of reactors, the control windings **13b** and **13c** of the lower pair of reactors are inactive; and when the latter control windings are active the control windings of the upper pair of reactors are inactive. This disclosure would preferably be operated as Class B and the current in the biasing windings **10** to **10c** is adjusted to cause the output current of the main windings to correspond to the location B when the control windings **13** to **13c** have zero control magnetomotive force. The control windings of each pair of reactors are so connected with reference to the main windings to cause the output current from the main windings of each pair to have a value within the range from B to C of Fig. 9 when the control magnetomotive force is increased from zero value.

Fig. 12 is similar to Fig. 5 except in Fig. 12 the reactors of the first stage are non-self-saturating as described with reference to Fig. 10, whereas in the second stage of amplification the reactors are shown as of the self-saturating type. In this case both stages would be operated as Class A.

The biasing windings on the reactor cores are indicated in the various embodiments as being supplied by direct current from any suitable available source. Generally these windings would be connected in the circuit to oppose the magnetomotive force of the main windings for securing the biasing for operation as Class A or Class B and in some cases these windings may be connected to create a magnetomotive force in the opposite direction, thus acting with that of the main windings for obtaining the desired results. In some cases these windings may be omitted when the magnetomotive forces of the main load windings are adjusted to create the condition for Class A or Class B operation as desired in the particular instance.

In general as to all of these disclosures the best results are obtained by the use of material in the reactor cores which has the highest constant permeability up to the saturation point, unity permeability beyond saturation, the smallest area of the hysteresis loop and the lowest eddy current losses.

As regards the source of the power supply and the obtaining of the desired frequency of this source, it will be understood that any of the available types may be used such as rotating machines of high frequency, oscillatory tubes and other forms.

In the foregoing disclosures the input audio signal to the controlling winding or windings of the initial stage of amplification has been indicated as derived from a carbon microphone. However, the signal source may be of any character and may be variously coupled to the circuit of the controlling winding or windings. Also the signal input may be derived from other types of microphones, phonograph pick-ups, radio receiver detector outputs and so forth.

In some cases instead of using a pair of individual reactor cores as shown herein, or a combined core as shown in Fig. 8, only one core with a power winding, a controlling winding and a biasing winding thereon may be used with some provision such as a low pass filter in the circuit of the controlling winding for avoiding induced electromotive forces in the controlling winding.

It will be understood that this invention may be modified in various ways as to the form of the reactors, the coupling to the signal source, the character of the signal source, the coupling to the loud speaker or output circuit, the number of amplifying stages and the character of the stages and the coupling between amplifying stages. Also various forms of filters may be used and connected in a manner to improve the quality and volume of the amplified output. Also the invention may be utilized in various applications for amplification of signals or controls within the audio range without departing from the scope thereof.

I claim:

1. A magnetic amplifier for amplifying audio signals from a signal source, said amplifier comprising an input circuit for receiving an alternating current having a frequency higher than the highest audio frequency to be amplified, two pairs of branches connected to be energized from said input circuit, each branch having a one-way valve and saturable reactor means including a main winding and control winding means for receiving audio signals from said signal source to modulate the currents of the main winding, each branch having a series circuit including the main winding and the one-way valve of the branch, said series circuits of each pair of branches being connected in parallel and one end of each pair of branches being connected to said input circuit, each pair of branches having connected to its other end an output circuit with a return path of said input circuit and the valves in each pair of branches being oppositely poled to deliver alternating current to each of said output circuits, said control winding means being related to said main windings to have reversed effects on the respective pairs of branches, a demodulator in each of said output circuits for demodulating the alternating currents in said output circuits, and an audio output transformer having input winding means with symmetrical halves, one of said halves being connected to receive the output of one of said demodulators, the other of said halves being connected to receive the output of the other demodulator, said halves being related to provide a cumulative audio frequency effect in response to simultaneously rising output currents of one demodulator and falling output currents of the other demodulator.

2. A magnetic amplifier for amplifying audio signals from an audio frequency signal source, said amplifier comprising an input circuit receiving an alternating current having a frequency higher than the highest audio frequency to be amplified, two pairs of branches connected to be energized from said input circuit, each branch including a

one-way valve and saturable reactor means having a main winding and a control winding, each branch having a series circuit including the main winding and the one-way valve of the branch, said series circuits of each pair of branches being connected in parallel and one end of each pair of branches being connected to said input circuit, each pair of branches having connected to its other end an output circuit with a return path to said input circuit and the valves in each pair of branches being oppositely poled to deliver alternating current to each of said output circuits, said control windings being interconnected to receive audio signals from the signal source for modulating the currents in the main windings, said control windings being related to said main windings to have reversed effects on the respective pairs of branches, a pair of full-wave bridge rectifiers, one in each of said output circuits for demodulating the alternating currents in said output circuits, and an audio output circuit for converting audio frequency currents into sound waves of the same frequency as said audio frequency signals, said audio ouput circuit having an input winding with opposite end terminals and an intermediate terminal, one of said end terminals being connected to an output terminal of one polarity of one of said rectifiers, the other of said end terminals being connected to the output terminal of said one polarity of the other rectifier, said intermediate terminal being connected to the output terminals of the other polarity of both rectifiers.

3. A magnetic amplifier for amplifying audio signals from a signal source, said amplifier comprising an input circuit for receiving an alternating current having a frequency higher than the highest audio frequency to be amplified, two pairs of branches connected to be energized from said input circuit, each branch including a one-way valve and saturable reactor means having a main winding and control winding means, each branch having a series circuit including the main winding and the one-way valve of the branch, said series circuits of each pair of branches being connected in parallel and one end of each pair of branches being connected to said input circuit, each pair of branches having connected to its other end an output circuit with a return path to said input circuit and the valves in each pair of branches being oppositely poled to deliver alternating current to each of said output circuits, said control winding means being interconnected to receive audio signals from the signal source for modulating the currents of the main windings, said control winding means being related to said main windings to have reversed effects on the respective pairs of reactor branches, a pair of full-wave bridge rectifiers, one in each of said output circuits for demodulating the alternating currents in said output circuits, and an audio output section for converting audio currents into audible reproductions of said audio signals, said section comprising electromagnetic winding means with symmetrical halves, one of said halves being connected to receive the output of one of said rectifiers, the other of said halves being connected to receive the output of the other of said rectifiers, said halves being related to provide a cumulative audio effect in response to simultaneously rising output currents of one rectifier and falling output currents of the other rectifier.

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