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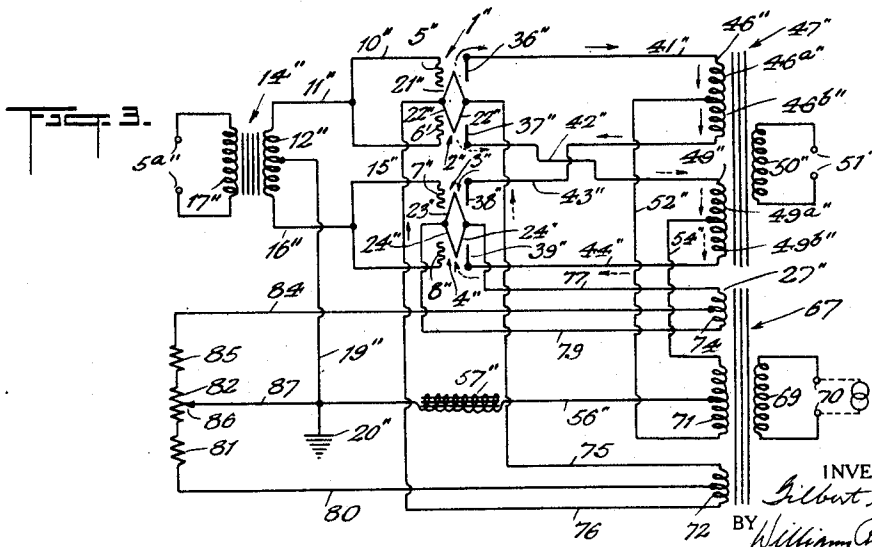
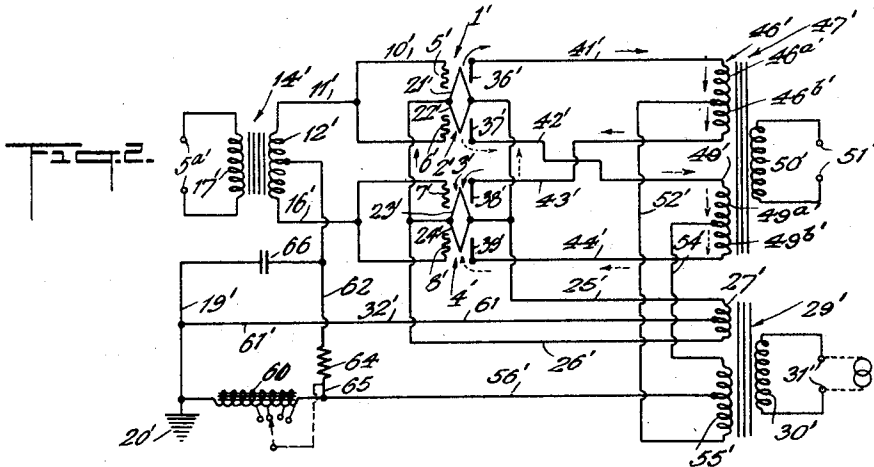
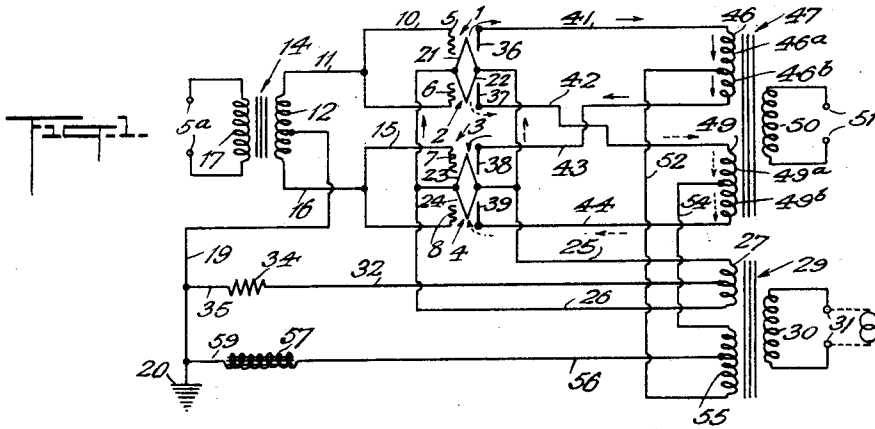
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1,909,153

THERMIONIC AMPLIFIER

Filed July 27, 1931

2 Sheets-Sheet 1



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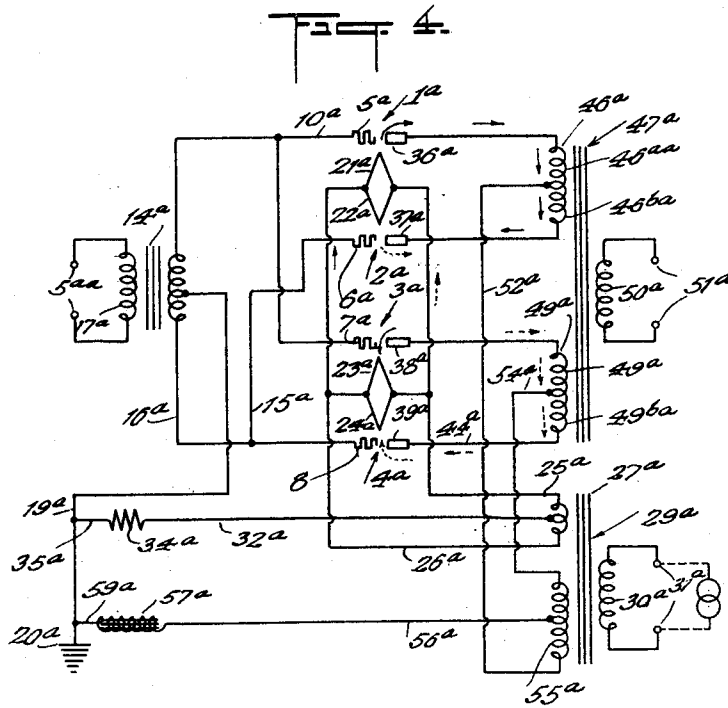
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1,909,153

THERMIONIC AMPLIFIER

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2 Sheets-Sheet 2



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THERMIONIC AMPLIFIER

Application filed July 27, 1931. Serial No. 553,305.

The present invention relates to an apparatus utilizing thermionic devices or vacuum tubes for amplifying feeble electric currents, electric waves, or signals.

5 An object of my invention is to provide a thermionic electric wave amplifier which is simple in construction and low in cost of manufacture, and which is very efficient in affording amplification of the signals without the introduction of noticeable distortion or other disturbances resulting from the action of the tubes per se in passing signals, or as a result of the action imparted to them by the character of the source of current supply.

10 Another object of my invention is to provide an apparatus of this character which may be operated from a local source of alternating current such as house lighting or public service circuit mains, without requiring the use of additional apparatus such as rectifying devices, and the like, which have been heretofore deemed necessary for maintaining steady potentials at the electrodes of the vacuum tubes.

15 A more specific object of the present invention is to provide a novel circuit arrangement for vacuum tubes, coupled into a common output, utilizing both the amplifying and rectifying properties of such tubes and possessing certain advantages all of which will be hereinafter described.

20 Other objects of the invention will become apparent from the following description taken in connection with the accompanying drawings in which Fig. 1 is a schematic illustration showing one embodiment of the present invention in a simplified form; Fig. 2 is an illustration showing a modified type of apparatus also embodying the invention; Fig. 3 is a similar illustration of a preferred commercial type of circuit; and Fig. 4 is a diagram showing another method of illustrating the general idea of connecting the tubes in pairs.

25 I have illustrated in Fig. 1 a simplified embodiment of my invention which comprises four thermionic devices which for the purpose of illustration are shown as three element vacuum tubes but may be any

conventional or commercial form of tube. The four tubes shown in the several figures are indicated by the numerals 1, 2, 3 and 4. These tubes are as nearly as practical identical to one another and, as will be understood, provide an amplification of an incoming signal delivered at the input terminals 5a and received either from a stage or stages of preamplification, or directly from a signal voltage source such as a pick up, demodulator, microphone transmitter, photo-electric cell or the like. The respective grids 5 and 6 of the tubes 1 and 2 are connected together by a conductor 10, which is joined to one end 11 of a secondary winding or input portion 12 of an input coupling means 14. The respective grids 7 and 8 of the tubes 3 and 4 are connected together by a conductor 15 to the other terminal 16 of said secondary winding 12. The input coupling may also comprise the primary winding 17. The secondary winding 12 has an intermediate or center tap which is preferably connected by a conductor 19 to the point of grid bias potential for the tubes and to an optional ground 20. While a transformer has been illustrated it will be understood that it is merely representative of a means for supplying signal voltage in phase opposition to the grids of the separate pairs of tubes.

25 The respective filaments 21, 22, 23 and 24 of the several tubes are shown in Fig. 1 as being connected in parallel and derive their excitation or heating current through conductors 25 and 26 from a secondary winding or current-supply portion 27 of a transformer or power-supply device 29, the primary winding 30 of which is connected to the terminals 31 of a source of alternating current. The mid-point of said secondary winding 27 is connected by a conductor 32 to a grid-bias resistance 34, and the latter is connected by a conductor 35 to conductor 19.

30 The respective plates 36 and 38 of the tubes 1 and 3 are connected by conductors 41 and 43 to the end terminals of an output circuit which may be a winding 46 of a transformer or output coupling means 47. Likewise the respective plates 37 and 39 of

the tubes 2 and 4 are connected by conductors 42 and 44 to the end terminals of a second output circuit which may be a separate winding 49 of the output transformer 47. In the embodiment of the invention shown, the output coupling means are provided with a single output portion 50 constituting a secondary winding of the transformer 47. The two primary windings are made identical and have intermediate connections or center taps which are connected by conductors 52 and 54 to the end terminals of another secondary winding or voltage-supply output portion 55 of the power-supply device 29. It will thus be seen that potentials derived from the alternating current source terminals 31 are therefore applied to the plates 36 and 38 through the intermediate terminal of the primary winding 46 and to the plates 37 and 39 through the intermediate terminal of the primary winding 49. The secondary winding 55 supplying the plate current for the several tubes is center-tapped, and the output or plate circuits of the tubes 1, 2, 3 and 4 are completed by connecting the mid-point or intermediate terminal of the secondary winding 55 through a conductor 56 to the conductor 19. In said conductor 56 I place an inductance or current-steadying means 57 which together with the grid-bias resistance 34 is common to all of said plate circuits. As will be understood and further explained hereinafter, the grid-bias voltage supplied to the grids of the tubes is substantially constant. The effect of the pulsating voltage supplied to the plates of the four tubes causes a fluctuating change in the impedance and space current of the individual tubes. Supply-voltage fluctuations at the plates 36 and 38 of the tubes 1 and 3 are at any instant equal and opposite in direction to the supply-voltage fluctuations at the plates 37 and 39 of the tubes 2 and 4. Thus the sum of the normal space currents in the case of tubes 1 and 2 is at any instant substantially constant, and the sum of the normal space currents in the case of tubes 3 and 4 is also at any instant substantially constant. It will also be seen that fluctuations in the individual normal space currents are not transmitted to the circuit of the output winding 50, i. e., in the case of tubes 1 and 3 the normal space currents in the portions 46a and 46b of the primary winding 46 are opposite and are therefore not transmitted, and in the case of tubes 2 and 4 the normal space currents in the portions 49a and 49b of the primary winding 49 are opposite and are therefore not transmitted. Since the sum of the normal space currents for each of the pairs of tubes (1 and 2) and (3 and 4) is substantially constant, the effective plate impedance of each of said pairs of tubes, the grids of each of which are connected in parallel, is

substantially constant, except as varied by the signal voltage impressed on said grids. Hence, each of said pairs of tubes function to properly transmit a signal therethrough without undue distortion.

From the above description it becomes apparent that a signal proceeding through the input transformer 14 will produce equal and opposite potential changes in the grids 5 and 7 of the tubes 1 and 3 and hence equal and co-directional changes in the ampere turns of the two portions 46a and 46b of the primary winding 46 to which the respective plates of said tubes 1 and 3 are connected. Also, the signal will produce equal and opposite potential changes in the grids 6 and 8 of the tubes 2 and 4 and hence co-directional changes in the ampere-turns of the two portions 49a and 49b of the primary winding 49 to which said tubes 2 and 4 are connected. Thus the tubes (1 and 3) and (2 and 4) function simultaneously in a manner to assure balanced amplification. Two tubes, i. e. one tube of one pair (1 and 3) and one tube of the other pair (2 and 4), are always functioning, and at times, when the voltage in winding 55 is nodal, all the tubes are functioning. Stated otherwise, the tubes 1 and 3 may at a given instance be operating to transmit a signal and are assisted by the tubes 2 and 4. As tubes 2 and 4 take up the signal, tubes 1 and 3 gradually cease to function.

The novel circuit arrangement of the four tubes provides the effect of two amplifying stages of balanced amplification placed in parallel, the signal being repeated from both primary windings 46 and 49 into the secondary winding 50 and into the load (not shown) attached to the output terminals 51. The four tubes may each be operated at approximately full rated average plate current, allowing only for "form-factor" (the ratio of heating to average current) to obtain the same effective heating current as when similar tubes are operated in a conventional manner on steady supply-potentials. Thus, the power output of the four tubes so employed closely approximates the power output which would be available from four similar tubes employed in a balanced or symmetrical amplifier, sometimes referred to conventionally as a "push-pull" amplifier, having in each side two tubes connected in parallel.

In Fig. 1, the arrows shown in full lines indicate the path of the amplified output alternating signal current derived from tubes 1 and 3 at an instant when all of the tubes are operating. The arrows shown in dotted lines are an indication of the path at the same instant of the amplified output alternating signal current derived from tubes 2 and 4. These two output currents are additive in effect when passing through the

primary windings 46 and 49. Thus, the sum of the signal currents in the primaries 46 and 49 at any instant is the true amplified signal, which is transmitted to the output winding 50. Since each of the pairs of tubes (1 and 3) and (2 and 4) are arranged in a balanced or "push-pull" amplifying circuit, the resultant effect produced by the four tubes will be to smooth out any irregularities that may occur due either to the amplification of the signal in the tubes per se, or to the operation of said tubes by reason of the plate and filament current being derived from a source of alternating current. It is noted that these alternating output currents or their sum do not flow through that portion of the plate circuits common to all four tubes (including the inductance 57 and the grid-bias resistance 34), said common plate circuit portion being traversed normally only by such unbalanced, out of phase or distortion currents as may occur. This is a feature of balancing the amplification from a plurality of tubes which I am able to obtain and is an advantage in that the inductance 57 may be made high with no detrimental effects and because, by reason of the introduction of a high inductance, undesirable currents may be materially reduced. Said circuit portion common to all four plate circuits is also traversed by the normal space currents of the four tubes, and it is to be particularly noted that, since the sum of the normal space currents of tubes 1 and 3 and the sum of the normal space currents of tubes 2 and 4 are substantially constant at any instant, the sum of the normal space currents of all four tubes in said common plate circuit portion is at any instant substantially constant. Therefore, observing that the inductance 57 functions to prevent any tendency toward pulsation or fluctuations of current therethrough, the current in said common plate circuit portion which includes the grid-bias resistance 34 is maintained substantially steady and the grid-bias potential impressed on the grids of the four tubes, or the supply-potential applied thereto relatively to the potentials of the cathodes of the tubes, is maintained substantially constant.

It will be observed that I obtain a balanced amplification in an amplifier by utilizing the general scheme of connection of tubes 1, 2, 3 and 4. If the primary windings 46 and 49 be accurately center-tapped and the tubes on each of said primary windings be accurately matched, there is a complete cancellation of such portions of the normal space currents as would otherwise magnetize the core of the output transformer 47. This may be understood by observing that the same supply-voltage value is applied at any instant to the plates of the tubes 1 and 3 and that likewise the same

supply-voltage value is applied at any instant to the plates of tubes 2 and 4. Therefore, the normal space currents in the plate circuits of tubes 1 and 3 are at any instant equal and opposite in direction when flowing, respectively, through portions 46a and 46b of the primary winding 46, and their magnetizing effect on the core of the output transformer 47 is neutralized. Likewise, the normal space currents in the plate circuits of tubes 2 and 4 are at any instant equal and opposite in direction when flowing, respectively, through portions 49a and 49b of the primary winding 49, and their magnetizing effect on the core of the output transformer 47 is neutralized. For similar reasons, there is also a cancellation in the two portions 46a and 46b of the primary winding 46 and in the two portions 49a and 49b of the primary winding 49 of undesirable currents produced, for example, by hum pick-up resulting from the lighting of the filaments of the tubes from a source of alternating current or from pulsations in the grid bias potential.

By properly choosing the value of the grid-bias potential for the grids of the four tubes, which is accomplished by establishing the proper value of the biasing resistance 34, the best results in the amplification of the received signal is obtained. Since tubes 1 and 2 operate on one portion of the grid-voltage plate-current characteristic curve (common to all four tubes) on one side of the point on said curve determined by the grid-bias potential, while tubes 3 and 4 operate at the same instant on the other portion of that curve on the other side of said point, the apparatus, when employed as an amplifier, will by reason of said four tubes substantially eliminate the distortion arising through the action of the tubes and taking the form of even harmonics of the signal voltage. This form of distortion is inherent in the operation of vacuum tubes used singly.

The circuit arrangements illustrated in Figs. 2, 3 and 4 are modifications of the apparatus shown in Fig. 1, and many of their parts are similar or identical to parts of the apparatus which has been described. For the sake of brevity, the similar parts shown in these figures will be designated by corresponding numerals, primed in Fig. 2, double primed in Fig. 3, and provided with the suffix *a* in Fig. 4.

In the embodiment of the invention shown in Fig. 2, the resistance of the inductance common to the plate circuits of all four tubes is utilized to obtain the grid-bias potential to be applied to their respective grids. Thus an inductance 60 is connected at one end by the conductor 56' to the center-tap of the secondary winding 55' of the power supply transformer 29'. The center-tap of

the secondary winding 27', serving to supply current to the filaments of the tubes, is connected directly by a conductor 61 to the ground 20'. The center-tap of the secondary winding 12' of the input transformer 14' is connected by a conductor 62 to one end of a resistance 64, the other end of the latter being connected by a conductor 65 to the conductor 56'. A capacity 66 is connected at one end to the ground 20' and at the other end to the conductor 62. Owing to the inherent resistance of the inductance unit 60 there is a D. C. potential across this inductance, which potential, if the resistance is high enough, may be utilized for grid bias purposes. This voltage exists in addition to the high pulsating voltage across the inductance 60. The resistance 64 and the capacity 66 act as a resistance-capacity filter which reduces the effect of the high pulsating voltage across the inductance 60 before the grid-bias potential is applied to the grids. It is evident that the inductance 60 may be provided, as indicated by dotted lines, with various taps, so that the grid-bias voltage may be adjusted without altering the current steadying effect of the inductance.

The embodiment of the invention shown in Fig. 3 is particularly advantageous in that it permits adjustment of the grid-bias voltage in the two sides of the apparatus in which the two pairs of tubes are respectively connected. A power supply transformer 67 is provided with a primary winding 69 connected to the terminals 70 of a source of alternating current, and with a secondary winding or voltage-output portion, the end terminals of which are connected to the conductors 52'' and 54'' leading to the respective mid-points of the primary windings 46'' and 49'' and the intermediate terminal of which is connected to the conductor 56'' leading to the inductance 57''. The transformer 67 is also provided with two additional secondary windings or separate current-output portions 72 and 74. One winding 72 serves to supply current through the conductors 75 and 76 to the filaments 21'' and 22'' of the tubes 1'' and 2'', and the other winding 74 serves to supply current through the conductors 77 and 79 to the filaments 23'' and 24'' of the tubes 3'' and 4''. The mid-point of the winding 72 is connected by a conductor 80 to one end of a resistance 81 the other end of which is connected to one end of a voltage divider or "potentiometer" 82, and the mid-point of the winding 74 is connected by a conductor 84 to one end of a resistance 85 the other end of which is connected to the other end of the "potentiometer" 82. The intermediate or adjustable terminal 86 of the "potentiometer" 82 is in electrical connection through a conductor 87 with the grid return connec-

tion of the several tubes. Thus the resistance 81 and that portion of the "potentiometer" 82 located between its lower end and the adjustable contact 86 constitute a grid-bias resistance which permits the proper grid bias potential to be applied to the grids of tubes 1'' and 2'', and the resistance 85 and that portion of the "potentiometer" 82 located between its upper end and the adjustable contact 86 constitutes a separate grid-bias potential to be applied to the grids of tubes 3'' and 4''. A variation of the adjustable contact 86 permits the grid-bias potential on the grids of the tubes of one of said pairs of tubes to be decreased while that on the grids of the tubes of the other of said pairs of tubes is increased. This adjustment provides a means for correcting for such differences as occur in the characteristics of commercially available vacuum tubes, which frequently vary as much as twenty per cent, and it has been found to be of particular value in the reduction of hum in the load attached to the output terminals 51'', such for instance as a loud-speaker.

In the description of the circuits of Figs. 1, 2 and 3 the arranging of the tubes in pairs has for convenience been explained by reference to the manner in which the plates and the two output circuits are connected. That is, one terminal of each of the output coils is connected to the plates of the first tube of each pair and the other terminals of said coils are attached to the plates of the other remaining tubes. This arrangement calls for a crossing of two of the plate conductors and the tubes will be paired in the order heretofore referred to. The same result will be accomplished by the arrangement depicted in Fig. 4 which shows two of the grid conductors 10a and 15a crossed. Hence, using the previous nomenclature and following the order of the tubes shown in the former figures (and reading from the top of Fig. 3 downwardly), the disposition of the tubes in pairs is (1 and 3) and (2 and 4) and, as previously described, the separate output circuits are each connected at one terminal to the anodes of one pair of tubes and at their other terminals to the anodes of the two remaining tubes. Therefore, whichever form of connection is utilized, it will be seen that, broadly stated, the pairing of the tubes, irrespective of their physical arrangement, is that in which the grids are connected to the same side of the input circuit, and that in both forms of illustration the signal voltage is supplied to the grids of the separate pairs of tubes in phase opposition.

The circuit arrangements which I have disclosed eliminate the need of separately rectifying the supply current for the tubes when such supply currents are obtained from an A. C. source, and I am also able to obvi-

ate the use of some of the filtering devices which have heretofore been considered essential for maintaining steady potentials at electrodes of thermionic devices.

5 The form of amplifier I have devised may be constructed in units, each embracing four tubes, and may be used separately, or as a final stage of power amplification, or as an intermediate stage in a radio receiving set,
10 or as a telephone repeater.

While I have illustrated the invention by using standard three element thermionic devices, it is to be understood that other forms of vacuum tubes may be employed possessing
15 a larger number of elements with appropriate circuit connections. The term three element thermionic device as employed herein is therefore not to be considered as a limitation, but as descriptive of any vacuum tube
20 structure embodying the necessary input and output electrodes and means for creating an electron stream, whether or not a plurality of one or more of such elements is included in the assembly of a single envelope or bulb.

25 I claim:

1. In an amplifier, the combination with two pairs of thermionic devices each comprising a cathode, a grid and an anode, and an input circuit connected to the grids of
30 each pair of tubes, of two output circuits each connected at one side to the anode of a tube of one pair and at its other side to the anode of a tube of the other pair, a heating circuit for the cathodes of all the tubes, return
35 conductors for the input circuit common to the two pairs of tubes and return conductors for the two output circuits, said conductors being arranged in electrical communication with each other and with the
40 filament heating circuit.

2. In an amplifier, the combination with four thermionic vacuum tubes arranged in pairs and each comprising a grid, a filament and a plate anode, and an input circuit connected at its opposite terminals to the two
45 grids of each pair of tubes, of two output circuits, one terminal of each being connected to the anode of one tube of each pair and connected at its other terminal to the
50 anode of a tube of the other pair, a circuit for supplying current for heating the filaments of all the tubes, electrical connections from said heating circuit to the input circuit and to the output circuits, and means for
55 supplying a source of potential to said anode circuits.

3. In an amplifier, the combination with two pairs of thermionic vacuum tubes each comprising a filament, a grid and a plate,
60 and an input circuit arranged to feed the signal waves in phase opposition to each pair of tubes, of two output circuits each comprising two terminals, one of each of which is connected to a plate of one of the
65 pairs of tubes, each of the other terminals

being connected to the plate of the remaining tube of the other pair, a source of alternating current including a transformer arranged to supply current to heat the filaments of the several tubes and potential for
70 the plate circuits.

4. In an amplifier, the combination with two pairs of thermionic vacuum tubes each comprising a filament, a grid and a plate, and an input circuit arranged to feed the
75 signal waves in phase opposition to each pair of tubes, of two output circuits each comprising two terminals, one of each of which is connected to a plate of one of the pairs of tubes, each of the other terminals
80 being connected to the plate of the remaining tube of the other pair, a source of alternating current including a transformer arranged to supply current to heat the filaments of the several tubes and potential for
85 the plate circuits, circuit connections from the filaments to the input circuit, and circuit connections from the filaments to the output circuits including current steadying impedance means and grid bias resistance
90 means.

5. In an amplifier, the combination with an input circuit, two output circuits, and two pairs of thermionic vacuum tubes each comprising a grid, a filament and a plate,
95 the two grids of each pair of tubes being connected to the opposite terminals of the input circuit, the two plates of one of said pair of tubes being connected to a terminal of each output circuit and the two remaining
100 plates being connected respectively to the remaining terminal of each output circuit, of a circuit connection between the midpoint of the input and the midpoints of each of said outputs including an impedance, a
105 circuit for heating the filaments of the several tubes, a connection between said last mentioned circuit and said input including a resistance, and a source of plate potential for the several tubes.
110

6. A signal transmitting apparatus, comprising two pairs of three element thermionic vacuum tubes, means for impressing
115 signal potential changes in the grids of one of said pairs and for simultaneously impressing opposite signal potential changes in the grids of the other of said pairs of tubes, an output circuit connected to the plates of the first tubes of each pair of tubes, another output circuit connected to the
120 plates of the remaining tubes, and a source of current supplying plate current potential and cathode heating current for all of said tubes.

7. In a signal transmitting apparatus, two
125 pairs of thermionic vacuum tubes, means for impressing signal potential changes in the grids of one of said pairs of tubes and for simultaneously impressing opposite signal potential changes in the grids of the other
130

tubes, an output circuit connected to the plates of the first tubes of each pair of tubes, another output circuit connected to the plates of the remaining tubes, a source of alternating current, a transformer therefor, connections from the latter supplying plate current potential and cathode heating current for all of said tubes, connections for completing the plate circuits of all of said tubes, and a current steadying means located in said plate circuit connections.

8. In a signal transmitting apparatus, two pairs of three element thermionic vacuum tubes, means for impressing signal potential changes in the grids of the tubes of one of said pairs and for simultaneously impressing opposite signal potential changes in the grids of the tubes of the other pair, an output circuit connected to the plates of the first tubes of each pair of tubes, another output circuit connected to the plates of the remaining tubes, center taps on said output circuits, and a source of alternating current, a transformer therefor, connections from the latter to said center taps for supplying plate current potential to said tubes, and means for heating the cathodes of the tubes.

9. In a signal transmitting apparatus, two pairs of three element thermionic vacuum tubes, means for impressing signal potential changes in the grids of the tubes of one of said pairs and for simultaneously impressing opposite signal potential changes in the grids of the tubes of the other pair, an output circuit connected to the plates of the first tubes of each pair of tubes, another output circuit connected to the plates of the remaining tubes, center taps on said output circuits, a source of alternating current, a transformer therefor having two secondary windings, connections from one of said windings to the aforementioned center taps for supplying plate current potential to the several tubes, connections from the other secondary winding supplying heating current for the cathodes of said tubes, leads from intermediate points of the two secondary windings to the grid circuits, and a resistance and an inductance included in said leads.

10. In a signal transmitting apparatus, two pairs of three element thermionic vacuum tubes, means for impressing signal potential changes in the grids of the tubes of one of said pairs and for simultaneously impressing opposite signal potential changes in the grids of the other of said pairs, an output circuit winding provided with an intermediate tap and having its end terminals connected to the plates of the first tubes of each pair of tubes, a second similar output circuit having its end terminals connected to the plates of the remaining tubes, a fluctuating source of current supply feeding plate current potential to the intermediate

taps of said two output circuits, connections from said current supply to the filaments of said tubes, and a current steadying means in said connections.

11. In a signal transmitting apparatus, two pairs of three element thermionic vacuum tubes, means for impressing signal potential changes in the grids of the tubes of one of said pairs and for simultaneously impressing opposite signal potential changes in the grids of the other of said pairs, an output circuit winding provided with an intermediate tap and having its end terminals connected to the plates of the first tubes of each pair of tubes, a second similar output circuit having its end terminals connected to the plates of the remaining tubes, a fluctuating source of current supply feeding heating current to the cathodes of the tubes and plate current potential to the intermediate taps of said output circuits, and connections from said current supply to the grid circuits of said tubes comprising an adjustable grid bias resistance.

12. In a signal transmitting apparatus, two pairs of three element thermionic vacuum tubes, means for impressing signal potential changes in the grids of the tubes of one of said pairs and for simultaneously impressing opposite signal potential changes in the grids of the other of said pairs, an output circuit winding provided with an intermediate tap and having its end terminals connected to the plates of the first tubes of each pair of tubes, a second similar output circuit having its end terminals connected to the plates of the remaining tubes, a fluctuating source of current supply feeding plate current potential to the intermediate taps of said two output circuits, said source of supply comprising two windings the terminals of which are connected to the cathodes of said pairs of tubes respectively, connections from intermediate points on said windings to the grids of all the tubes, and an adjustable grid bias means in said connections.

13. A thermionic amplifier and full wave rectifier comprising an input transformer comprising a secondary winding having an intermediate tap, two pairs of three element thermionic vacuum tubes, the grids of each of said pairs being connected to the end terminals of said secondary, an output transformer comprising two primary windings, one of which has its terminals respectively connected to the plate of one tube of one pair and to the plate of one tube of the other pair and the other of which has its terminals connected respectively to the plates of the remaining tubes, a source of alternating current supply, a power transformer therefor having two secondary windings, connections from one of said windings to intermediate points on the output primary

windings for supplying plate current potential to the tubes, connections from the other secondary winding to the filaments, leads from the two secondaries of the power transformer to the intermediate tap of the input secondary winding, a grid bias resistance in one of said leads, and a current steadying impedance in the other of said leads.

14. A thermionic amplifier and full wave rectifier comprising two pairs of three element thermionic vacuum tubes, means for supplying signal voltage in phase opposition to the grids of each of said pairs, an output transformer comprising two primary windings, one of which has its terminals respectively connected to the plate of one tube of one pair and to the plate of one tube of the other pair and the other of which has its terminals connected respectively to the plates of the remaining tubes, a source of alternating current supply, a power transformer therefor having three secondary windings each provided with an intermediate tap, connections from one of said windings to the intermediate tap points on the two output primary windings for supplying plate current potential to the tubes, separate connections from each of the other two windings to the cathodes of the respective pairs of tubes for supplying heating current to said cathodes, conductors joining the intermediate taps of the two heating current secondaries to the signal supply means, grid biasing resistors in said conductors, and a circuit connection from the intermediate tap of the plate current potential secondary to a common point of said signal supply means, said circuit connection being also joined to the aforementioned conductors at a point between said resistors.

In testimony whereof, I have signed this specification.

GILBERT SMILEY.