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BALANCED MODULATOR

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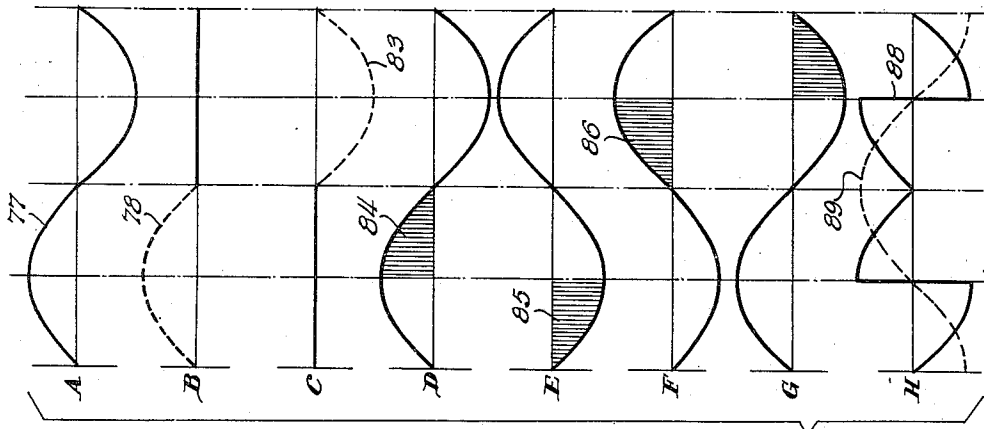
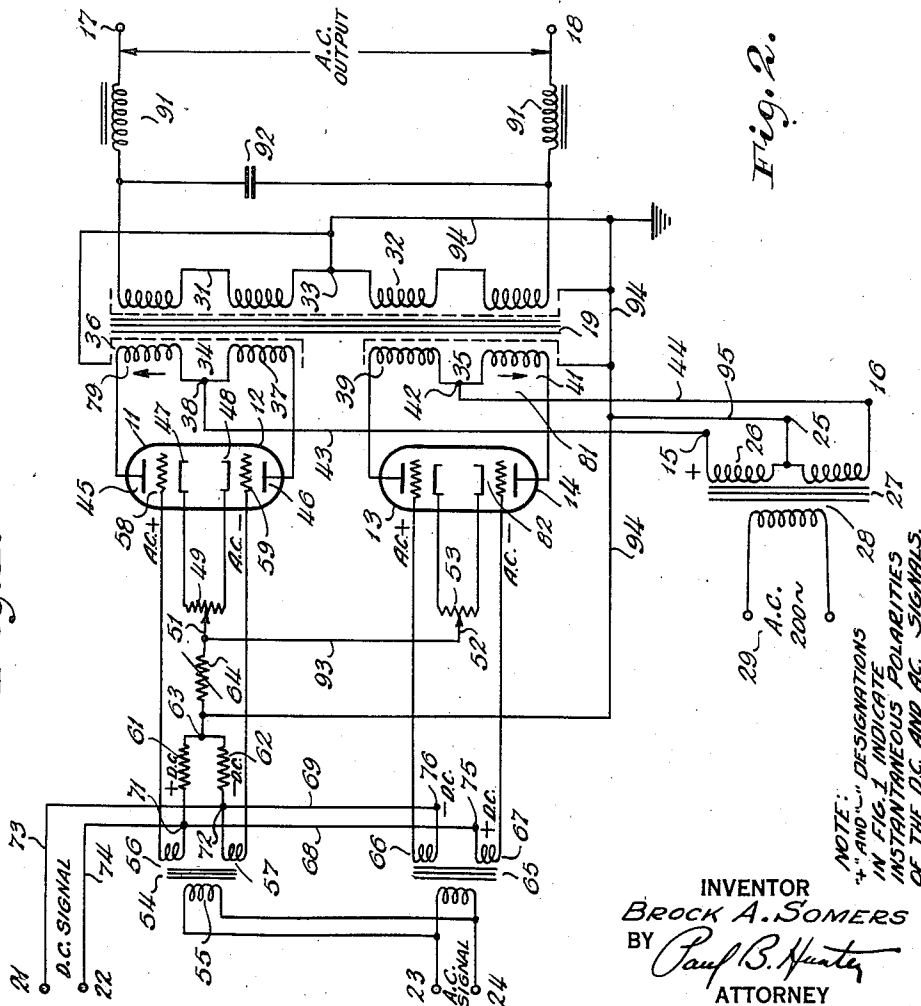


Fig. 2.

Fig. 1.



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BALANCED MODULATOR

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14 Claims. (Cl. 179—171.5)

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My invention relates to current-controlling systems and concerns particularly balanced modulators.

It is an object of my invention to provide improved arrangements to control an alternating current in response to variations in magnitude and polarity or phase of either alternating or direct input signals.

A further object of my invention is to provide a balanced modulator for modulating an alternating current in response to variations in either an alternating-current or a direct-current signal.

Still another object of my invention is to provide a system for transferring alternating current in response to direct-current signals.

Still another object of my invention is to provide a system for supplying unidirectional current impulses to produce an alternating current output.

Other and further objects and advantages will become apparent as the description proceeds.

In accordance with my invention in its preferred form, I provide two pairs of current-controlling devices connected in push-pull with connections for supplying alternating current to one of said pairs of said current-controlling devices, connections for supplying alternating current reversed in polarity to the other of said pairs of current-controlling devices, and means for combining the outputs of said pairs of push-pull devices. For modulating the output in response to magnitude and variations in phase of an alternating-current signal, connections are provided for driving said pairs of current-controlling devices in substantially the same phase relationship in response to an alternating-current signal input. For modulating the output of said current-controlling devices in accordance with variations in magnitude and polarity of a direct-current signal input, connections are provided for supplying such direct-current signal input to one of said pairs of push-pull devices and for supplying the same direct-current input reversed in polarity to the other of said pairs of push-pull connected devices.

A better understanding of the invention will be afforded by the following detailed description considered in connection with the accompanying drawing, and those features of the invention which are believed to be novel and patentable will be pointed out in the claims appended thereto.

In the drawing,

Fig. 1 is a circuit diagram of one embodiment of my invention, and

Fig. 2 is a set of graphs explanatory of the

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principles of operation of the apparatus of Fig. 1.

In the form of my invention represented by way of illustration in Fig. 1, there are two pairs of current-controlling devices 11, 12 and 13, 14 connected in push-pull to power supply terminals 15 and 16 adapted to be connected to a source of alternating current. For combining the outputs of the pairs of current-controlling devices 11 to 14 and supplying the resultant output to a pair of output terminals 17 and 18, I provide an output transformer 19.

For modulating the output in accordance with a direct-current input signal, a pair of direct-current input terminals 21 and 22 are provided having suitable control connections to the current-controlling devices. Likewise, for modulating the output in accordance with an alternating-current input signal, a pair of alternating-current input terminals 23 and 24 is provided having suitable means for coupling them to the current-controlling devices.

Suitable means are provided for maintaining a terminal 25 at an intermediate potential between the supply terminals 15 and 16. For example, a resistor or an impedance 26 may be connected between the supply terminals 15 and 16 with a center tap connected to the intermediate-potential terminal 25. Particularly in cases where an elevated voltage is desirable for supplying the current-controlling devices 11 to 14 the potential-dividing impedance 26 may take the form of a secondary winding of a transformer 27 having a primary winding 28 connected to a suitable source of alternating current power 29 having any convenient voltage and being of a frequency adapted to the electrical parameters of the apparatus employed. For example, in the case of automatic follow-up systems, the source 29 may have a frequency of 200 cycles per second.

The current-controlling devices 11 to 14 may take the form of asymmetrical variable impedance units, having control elements for controlling their impedances, such as controlled rectifiers or the like. The current-controlling devices may take the form of vacuum tubes having anodes, cathodes, and control electrodes or grids so as to form triodes, as shown. It will be understood that my invention is not limited to use of triodes and does not exclude the use of multi-grid vacuum tubes such as tetrodes or pentodes. Since the connections of such additional grids are not involved in my invention, the additional grids and their connections are not shown to simplify the drawing, which will be described as if triodes were employed.

If desired, the current-controlling devices 11 and 12 may be combined to form a twin tube, and likewise, the current-controlling devices 13 and 14 may be combined to form a twin tube.

The transformer 19 comprises a secondary-winding circuit including two parts 31 and 32 connected in series to the output terminals 17 and 18. The transformer parts 31 and 32 have a junction terminal 33 which serves as a center tap for the transformer secondary winding. The transformer 19 comprises also two center-tapped primary windings 34 and 35, each of which may also be considered as two windings arranged and connected in series-opposition, considering the fact that all anode currents through devices 11 and 12 flow through windings 36 and 37 in the directions from the center tap 38. Thus, the winding 34 comprises winding elements 36 and 37 with a junction terminal or center tap 38 and the winding 35 comprises two winding elements 39 and 41 with a junction terminal or center tap 42. The center taps 38 and 42 are connected to the supply terminals 15 and 16, respectively, by means of conductors 43 and 44.

As will be explained more in detail hereinafter, unidirectional current impulses which flow through the windings 36 and 37 act in opposition with respect to the secondary winding circuit of the transformer 19, and likewise the unidirectional current impulses which flow through the windings 39 and 41 act in opposition with respect to the transformer secondary winding circuit. It will be observed also that the pair of windings 36, 37 is connected to the supply terminals 15 and 16 in opposite relation to the connection of the windings 39 and 41 to the supply terminals 15 and 16, so that when one pair of electronic current-controlling devices is supplied with positive anode potential, the other pair is supplied with negative potential, and hence is rendered inoperative throughout a half cycle of the voltage supplied through transformer 27.

The device 11 has an anode 45 connected to the free end of the transformer winding 36, and the device 12 has an anode 46 connected to the free end of the transformer winding 37. Furthermore, the devices 11 and 12 have cathodes 47 and 48 which may be connected together directly or through a resistor 49 having a balancing adjustable tap 51 which serves as a junction terminal for the current-controlling devices 11 and 12.

In a similar manner the current-controlling devices 13 and 14 are connected in a series opposition circuit with the transformer primary windings 35 and 36 and have a junction terminal 52 which may be in the form of a balance adjusting tap of a cathode connecting resistor 53.

For supplying an alternating-current input signal to the pair of current-controlling devices 11 and 12, a coupling transformer 54 is provided having a primary winding 55 connected across the alternating current signal terminals 23, 24 and having a secondary winding split into two parts 56 and 57. The parts 56 and 57 are connected in series with a junction effectively at the junction terminal 51 of the current-controlling devices 11 and 12 and have their free ends connected to the control electrodes or grids 58 and 59 of the current-controlling devices 11 and 12, respectively. The winding parts 56 and 57 are connected in series so that the control grids 58 and 59 are at opposite polarity with respect to the junction terminal 51, thus forming a push-pull grid excitation circuit.

In order to permit a unidirectional or gradually

varying signal also to be applied to the apparatus, in a manner which will be explained in greater detail hereinafter, a pair of resistors 61 and 62 is connected in series between the coupling transformer secondary windings 56 and 57. The resistors complete the series connection of these windings. The resistors 61 and 62 have a junction terminal 51 which may be connected to the junction terminal 51 of the current-controlling devices 11 and 12. If desired, a rheostat 64 may be interposed between the junction terminals 63 and 51, for providing adjustment of the characteristics of the apparatus by adjustment of bias and degeneration.

For impressing an alternating-current signal input on the control grids of the current-controlling devices 13 and 14, a second coupling transformer 65 is provided, and the transformer 65 is connected in a similar manner to the transformer 54 so that the control grids of the current-controlling devices 11 and 13 have the same polarity at any given instant, and likewise the control grids of the control devices 12 and 14 have the same polarity at a given instant, but have a polarity which is opposite to that of the control grids of the devices 11 and 13 at the same instant, all of these relations being expressed with respect to the alternating signal supplied between terminals 23 and 24. In the arrangement as shown, the coupling transformer 65 also has a secondary winding divided into two parts 66 and 67 with free terminals connected to control grids of the current-controlling devices 13 and 14 and with a series connection completed through the series resistors 61 and 62. As shown, the inner terminals of the transformer winding parts 66 and 67 are connected through conductors 68 and 69 to the inner terminals of the coupling transformer parts 56 and 57 and thus to the end terminals 71 and 72 of the series resistors 61 and 62.

For impressing a direct-current input signal on the current-controlling devices, connections 73 and 74 are made from the direct-current signal terminal 21 to the resistor terminal 72 and from the direct-current signal terminal 22 to the resistor terminal 71.

The terminals 21 and 22 are assumed to supply a signal which may be reversible in polarity but which is referred to as unidirectional in that it retains a given polarity for a period of time which is substantially greater than the time period of either the alternating current supplied to the alternating-current terminals 23, 24 or the alternating current supplied to the power supply terminals 15 and 16. Thus, the connections of terminals 21, 22 are such that the resistor terminal 71 corresponding to the control grids of devices 11 and 14 are positive when the resistor terminal 72 corresponding to the control grids of devices 12 and 13 are negative as a result of the energization of terminals 21, 22.

When the current supplied by the power supply terminals 15, 16 is to be controlled or modulated in accordance with variations in peak magnitude and phase relationship of an alternating current or voltage or other alternating current signal which has a frequency equaling the frequency of the source 29, which is of substantially the same order of magnitude or which is of a considerably higher order of magnitude, such an alternating-current signal input is applied to the terminals 23 and 24. On the other hand, when the alternating current supplied by the terminals 15, 16 is to be controlled or modulated in accordance with variations in mag-

nitude or polarity of a unidirectional voltage or other signal which remains unidirectional or which changes in polarity relatively infrequently with respect to the frequency of signals supplied to the terminals 23, 24 of the current supplied to the terminals 15 and 16, such a unidirectional or pulsating signal is supplied to the direct-current signal input terminals 21, 22. It is a characteristic of the apparatus shown in the drawing that it may be simultaneously modulated with direct-current and alternating-current input signals, and with appropriate magnitudes and polarities or phase relationships the direct-current and alternating-current input signals may be caused to counteract each other so as to result in zero output at the output terminals 17 and 18.

The manner in which modulation is obtained in response to a direct-current signal input may first be considered. If it be assumed that the polarity of the direct-current signal is as indicated in the drawing, the control grid 58 of the current-controlling device 11 will be positive with respect to the cathode 47, rendering the tube 11 conducting, and at the same time the control grid 59 of the current-controlling device 12 will be negative with respect to the cathode 48, rendering the device 12 non-conducting or at least causing it to have such a high impedance as to be relatively non-conducting. Assuming that the voltage at the power-supplying terminals 15 and 16 has a wave form represented by the curve 77 as shown in Fig. 2A, current will flow through the transformer primary winding 36 during the first half cycle of the wave 77, thus producing a half cycle of current having the wave form 78 as shown in Fig. 2B. No current will flow through the current-controlling device 12 if the potential of the control grid 59 is driven low enough to be beyond the cut-off potential of the tube 12. If the direct-current signal input is very weak, a small current may flow through the device 12, but in any event the current through the windings 36 and 37 which are in opposition will be unequal, and the net current will have the direction represented by the arrow 79.

During the first half cycle of the wave 77 thus considered, no current will flow through either of the current-controlling devices 13 and 14 because during this half cycle the junction terminal 42 is at negative potential.

During the next half cycle, the polarities at the terminals 15 and 16 having reversed, no current can flow through the windings 36 and 37 and through the current-controlling devices 11 and 12. However, a current which may be a net current will flow through the transformer primary winding 41 in a direction represented by the arrow 81 because the control grid 82 of the current-controlling device 14 is at positive potential. Thus, a half cycle of current having the wave form 83, as shown in Fig. 2C, flows through the transformer winding 41. The inductive effects on the secondary windings 31, 32 of the output transformer 19 are the same as if the half cycles of wave forms 78 and 83 had flowed in opposite directions through the same primary winding, and accordingly an alternating voltage appears at the output terminals 17 and 18. Such an alternating output voltage has a magnitude dependent upon the magnitude of the direct-current input signal. Its phase would be reversed 180° if the polarity of the input signal were reversed because in that case the half cycles of current would flow through the windings 37 and

39 instead of through the windings 36 and 41. As previously indicated, the winding 37 is so connected in relation to the supply terminals 15 and 16 as to act in opposition to the winding 36, and likewise the winding 41 acts in opposition to the winding 39 with respect to the supply terminals 15 and 16.

If an alternating-current signal is supplied to the terminals 23, 24 which has the same frequency as the source 29 and is in phase therewith, the control electrodes of the current-controlling devices 11 and 13 will become positive simultaneously. However, as in the previous case, only the winding 36 will carry current during the first or positive half cycle of the supply wave 77 so as to produce an output half cycle 78. Similarly, during the next half cycle of the supply wave 77 the controlling electrodes of the current-controlling devices 12 and 14 will become positive simultaneously, but current will flow only through the winding 41 producing a negative half cycle 83 in the output circuit. If the phase of the input alternating-current signal is reversed 180°, the phase of the voltage at the output terminals 17 and 18 will also change 180°.

Likewise, if the frequency of the alternating-current signal at the terminals 23 and 24 is high compared to the frequency of the source 29, a voltage of the same frequency as the alternating-current signal input will appear at the output terminals 17 and 18. No doubling of such frequency will take place because the opposite half cycles of the supply current are passed through different transformer windings and are controlled by different pairs of current-controlling devices.

In the event of a phase displacement of an alternating-current input signal having the same frequency as the power supply source 29, or a higher frequency, corresponding phase displacement of the voltage at the output terminals 17 and 18 will take place. For example, in the case of equal frequencies, assume that the alternating-current input signal at the terminals 23, 24 lags 90° behind the voltage at the supply terminals 15 and 16. Under these circumstances the tube 11 will conduct current only during the latter half of the first half cycle of the wave 77. This is illustrated by the shaded portion 84 of the curve in Fig. 2D. The tube 12 will conduct current during the first part of the first half cycle, and this current will be of opposite polarity with respect to the output terminals 17 and 18, as represented by the shaded portion 85 of the curve in Fig. 2E. In a similar manner the tube 13 will conduct current during the third quarter cycle as represented by the shaded portion 86 of the curve in Fig. 2F, and the tube 14 will conduct negative current during the fourth quarter cycle represented by the shaded portion 87 of the curve in Fig. 2G.

If the currents shown in the shaded portions 84 to 87 are combined, it will be observed that theoretically an output having the irregular wave form shown by the heavy line curve 88 in Fig. 2H would result. However, owing to the inherent smoothing action of the leakage reactance of the output transformer 19, there would be a tendency for such a curve to be simulated to the sine form shown by the dotted lines 89. It will be observed that the curves 88 and 89 lag the supply voltage 77, of Fig. 2A, 90°. If desired, choke coils 91 may be connected in series with the output terminals 17 and 18, and a smoothing condenser 92 may also be connected between the terminals in order to improve the wave form

of the output in the event of phase displacement between the alternating-current signal at the terminals 23, 24 and the current supply at the terminals 15 and 16.

Although separate currents supply sources of opposite polarity or separate windings of the transformer 27 may be utilized for energizing the pairs of current-controlling devices 11, 12 and 13, 14, one may reduce the number of connections required by merely using a supply source 15, 16 having a center tap terminal 25. In this case the junction terminal 51 of the current-controlling devices 11 and 12 is connected to the junction terminal 52 of the current-controlling devices 13 and 14 by a suitable means such as a conductor 93. These junction terminals may also be connected to the center tap 33 of the secondary winding of the output transformer 19 and the center tap 25 of the current supply transformer 27. If the bias adjusting rheostat 64 is used, however, I prefer to connect the junction terminal 63 of the resistors 61 and 62 through a conductor 94 to a center tap 33 and through a conductor 95 to the center tap 25. The conductor 94 may also be grounded if desired.

As many changes could be made in the above construction and many apparently widely different embodiments of this invention could be made without departing from the scope thereof, it is intended that all matter contained in the above description or shown in the accompanying drawings shall be interpreted as illustrative and not in a limiting sense.

What is claimed is:

1. A balanced modulator for modulating an alternating current in accordance with variations in either an alternating quantity or a unidirectional quantity, said modulator comprising in combination two pairs of asymmetric current-controlling devices, each having an anode, a cathode and a control element, direct-current signal input terminals, alternating-current signal input terminals, output terminals, power supply terminals, a pair of resistors connected in series to said direct-current signal input terminals and having a junction terminal, connections between said junction terminal and the cathodes of said current-controlling devices, connections from one of said direct-current signal input terminals to one control element of each pair of current-controlling devices, connections from the other of said direct-current input terminals to the remaining control element of each pair of current-controlling devices, means for coupling said alternating-current signal input terminals to the control elements of one of said pairs of current-controlling devices, means for coupling said alternating-current signal input terminals to the control elements of the other of said pairs of current-controlling devices, the connections from said direct-current signal input terminals to the control elements of one pair of current-controlling devices being reversed, an output transformer having a center tap secondary winding and two pairs of primary windings, each pair of primary windings being connected in series aiding to one of said pairs of current-controlling devices, the latter being in series opposition, each of said pairs of transformer primary windings having a junction terminal, said junction terminals being connected to said supply terminals, said supply terminals having a point of intermediate polarity connected to the junction terminal of said pair of resistors and the center tap of said output transformer secondary winding.

2. A balanced modulator for modulating an alternating current in accordance with variations in either an alternating quantity or a unidirectional quantity, said modulator comprising in combination two pairs of asymmetric current-controlling devices, each having a control element, a pair of power supply terminals, an output transformer having a secondary winding with a center tap and having two primary windings with center tap connections to said supply terminals, means connecting one of said pairs of current-controlling devices in series opposition to one of said primary windings, means connecting the other of said pairs of current-controlling devices in series opposition to the other of said primary windings, a pair of direct-current signal input terminals, a pair of resistors connected in series to said terminals, and having a junction terminal connected to the junction terminals of said pairs of current-controlling devices, connections from said direct-current signal input terminals to the control elements of one of said pairs of current-controlling devices, reversed connections from said direct-current signal input terminals to the control elements of the other pairs of current-controlling devices, a pair of alternating-current signal input terminals, means for coupling said terminals to the control elements of one of said pairs of current-controlling devices, and means for coupling said alternating-current signal input terminals with polarity reversed to the control elements of the other of said pairs of current controlling devices, and connections joining the center tap of said output transformer secondary winding, the junction terminal of said pair of resistors and a point at intermediate polarity of said supply terminals.

3. A balanced modulator for modulating an alternating current in accordance with variations in magnitude and polarity of a direct-current input signal, said modulator comprising, in combination, two pairs of asymmetric current-controlling devices, each having a control element, a pair of power supply terminals, an output transformer having a secondary winding with a center tap and having two primary windings with center tap connections to said supply terminals, means connecting one of said pairs of current-controlling devices in series opposition to one of said primary windings, means connecting the other of said pairs of current-controlling devices in series opposition to the other of said primary windings, a pair of direct-current signal input terminals, a pair of resistors connected in series to said terminals, and having a junction terminal connected to the junction terminals of said current-controlling devices, connections from said direct-current signal input terminals to the control elements of one of said pairs of current-controlling devices, reversed connections to said direct-current signal input terminals to the control elements of the other of said pairs of current-controlling devices, a terminal for supplying a potential intermediate between the potentials of said supply terminals, and connections joining the center tap of said output transformer secondary windings, the junction terminals of said pair of resistors and said intermediate polarity terminal.

4. A balanced modulator comprising two pairs of current-controlling devices, each pair connected in push-pull, connections for supplying alternating current from a source to be modulated to one of said pairs of current-controlling devices, connections for supplying from said source alternating current reversed in polarity to the other

of said pairs of current-controlling devices, means for combining the outputs of said push-pull devices, connections for supplying a first control signal to said first pair of devices for differentially varying the conductivity of the devices of said first pair and also supplying said first control signal to said second pair of devices for differentially varying the conductivity of the respective devices of said second pair in the same sense as the devices of the first pair, and connections for supplying a further control signal to said first pair of devices for differentially varying the conductivity of the devices of said first pair and also supplying said further signal to said second pair of devices for differentially varying the conductivity of the respective devices of said second pair in the opposite sense to the devices of the first pair.

5. A balanced modulator for modulating an alternating current in accordance with variation in input signals, said modulator comprising in combination, an output transformer having a secondary winding and two pairs of oppositely connected primary windings, output terminals connected to said secondary winding, first, second, third and fourth asymmetrical current controlling devices, each having a control element, the first and second current controlling devices being connected in series opposition to the first pair of primary windings and the third and fourth current controlling devices being connected in series opposition to the second pair of current controlling devices, means for applying unidirectional signal voltage to the control elements of the first and second current controlling devices, means for applying such signal voltage with reverse polarity to the control elements of the third and fourth current controlling devices, means for additively applying an alternating signal in the circuit of the control elements of the first and second current controlling devices, and means for subtractively applying such alternating signal in the circuit of the control elements of the third and fourth current controlling devices.

6. A balanced modulator for modulating alternating current in accordance with variations in input signal, said modulator comprising in combination, an output transformer having a secondary winding and two pairs of oppositely connected primary windings, first, second, third and fourth asymmetrical current controlling devices, each having a control element, means connecting the first pair of primary windings to the first and second current controlling devices, means connecting the second pair of primary windings to the third and fourth current controlling devices, resistance means having first and second end terminals connected respectively to the control elements of the first and second current controlling devices and to the control elements of the fourth and third current controlling devices, a transformer having an input winding carrying an alternating signal and having first, second, third and fourth output windings, the first and second output windings being connected in series with said resistance means to the control elements of the first and second current controlling device, and the third and fourth output windings being connected in series with said resistance means to the control elements of the third and fourth current controlling devices.

7. A signal responsive circuit comprising, in combination, first, second, third and fourth asymmetrical current controlling devices, each

having a control element, means for supplying current thereto, an output circuit to which the first and second current controlling devices are connected in opposition and to which the third and fourth current controlling devices are connected in opposition, means for varying the potentials of the control elements of the first and second current controlling devices in one direction and varying the control elements of the third and fourth current controlling devices in the opposite direction in response to a unidirectional signal, and means for varying the potentials of the control elements of the first and third current controlling devices in the same phase relation and varying the potentials of the second and fourth current controlling devices in phase relation opposite the variation of the first and third control elements in response to an alternating signal.

8. A balanced modulator comprising in combination, first, second, third and fourth asymmetrical current controlling devices, each having a control element, means for supplying the first and fourth devices and for supplying the second and third devices in opposition thereto from a first source, means for energizing the control elements of the first and second devices from a second source in opposition to the control elements of the third and fourth devices and means for exciting the control elements of the first and third devices from a third source in opposition to the control elements of the second and fourth devices, said third source being alternating in nature.

9. A balanced modulator comprising in combination, first, second, third and fourth asymmetrical current controlling devices, each having a control element, input connections for first, second and third sources, means for supplying the first and fourth devices in opposition to the second and third devices from the first source connections, means for energizing the control elements of the first and second devices in opposition to the control elements of the third and fourth devices through the second source connections, and means for energizing the control elements of the first and third devices in opposition to the control elements of the second and fourth devices through the third source connections.

10. A signal responsive circuit comprising in combination, first, second, third and fourth asymmetrical current controlling devices, each having a control element, first, second and third input connections, means for supplying first and fourth devices in opposition to the second and third devices from the first input connections, means for unidirectionally energizing the control elements of the first and second devices in opposition to the control elements of the third and fourth devices through the second input connections, and means for exciting the first and third control elements in opposition to the second and fourth control elements with an alternating quantity through the third input connections.

11. Modulating apparatus comprising: transformer means having an output winding and first, second, third and fourth input windings; first, second, third and fourth non-linear current-conducting elements respectively connected to said input windings and determining directions of maximum current conduction there-through, said first and third windings and respective non-linear elements being connected for aiding each other and opposing said second and

fourth windings and respective non-linear elements in inducing current in said output winding; means for applying alternating voltage to all said input windings and non-linear elements, said voltage-applying means being so connected as to polarize said first and second non-linear elements for maximum conductivity alternately with said third and fourth non-linear elements; and means applying a further voltage to said non-linear elements for varying the current conduction through said first and fourth non-linear elements relative to the current conduction through said second and third non-linear elements.

12. Modulating apparatus as defined in claim 11, wherein each of said non-linear current-conducting elements comprises an electron discharge device having a cathode, an anode and a control electrode, and said means applying a further voltage to said non-linear elements comprises means for applying voltage to said control electrodes relative to the respective cathodes.

13. Modulating apparatus comprising: transformer means having an output winding and first, second, third and fourth non-linear current conducting elements respectively connected to said input windings and determining directions of maximum current conduction therethrough, said first and third windings and non-linear elements being connected for aiding each other and for opposing said second and fourth windings in inducing current in said output winding; first means for applying alternating voltage to all said input windings and non-linear elements, said first voltage-applying means being so connected as to polarize said first and second non-linear elements for maximum conductivity alternately with said third and fourth non-linear elements; second means for applying alternating voltage to all said non-linear elements, said second voltage-applying means being so connected as to polarize said first and third non-linear elements for maximum conductivity alternately with said second and fourth elements; and means for applying a third voltage to said non-linear elements for varying the conductivity of said first and fourth non-linear elements relative to said second and third elements.

14. A balanced modulator for receiving power from an alternating current source and delivering an output alternating current of the frequency of said source and of amplitude and phase relative to said source dependent upon an alternating signal or a unidirectional signal or both, said modulator comprising in combination, output transformer means having a secondary winding circuit and first and second primary windings connected in series-opposition and third and fourth primary windings connected in series-opposition, means for alternately passing unidirectional current impulses from said source through said first and fourth windings in opposite directions relative to said secondary winding circuit in response to a unidirectional input signal of a first polarity and for alternately passing unidirectional current impulses from said source through said second and third windings in opposite directions relative to said secondary winding circuit in response to a unidirectional input signal of the opposite polarity, said means for alternately passing unidirectional current impulses being arranged for alternately passing unidirectional current impulses through said first and fourth windings in response to an alternating input signal of frequency substantially equal to the frequency of said source and of a first phase relation thereto, and for alternately passing unidirectional impulses through said second and third windings in response to an alternating input signal of the opposite phase.

BROCK A. SOMERS.

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The following references are of record in the file of this patent:

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Certificate of Correction

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BROCK A. SOMERS

It is hereby certified that errors appear in the printed specification of the above numbered patent requiring correction as follows: Column 3, line 12, for the reference numeral "33" read *35*; column 7, line 5, for "currents" read *current*; column 8, line 60, for "levices" read *devices*; and that the said Letters Patent should be read with these corrections therein that the same may conform to the record of the case in the Patent Office.

Signed and sealed this 23rd day of November, A. D. 1948.

[SEAL]

THOMAS F. MURPHY,
Assistant Commissioner of Patents.