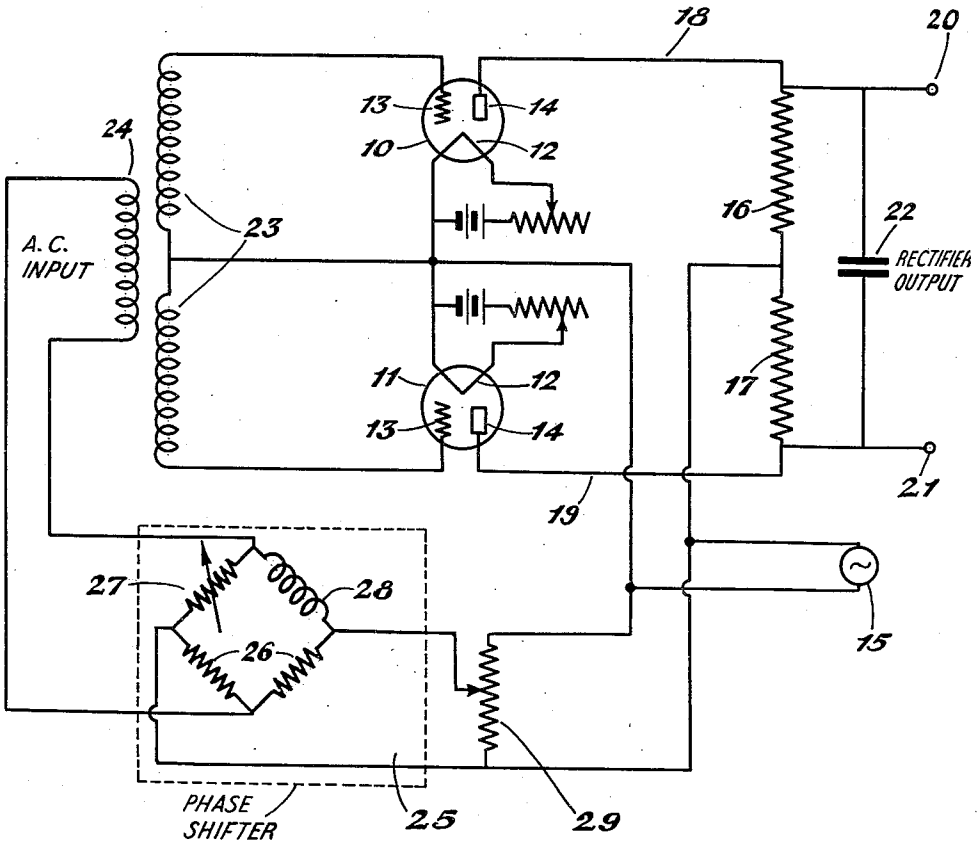
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RECTIFIER CIRCUIT

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RECTIFIER CIRCUIT

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My invention relates to rectifiers using electron discharge tubes and more particularly to means for controlling the magnitude and also, if desired, the polarity of the rectified output.

In the usual electron discharge tube rectifier the magnitude of the output is directly dependent on the alternating input voltage and the constants of the rectifier circuit. No convenient means has heretofore been available for controlling the magnitude of the output, and usually the polarity of the output voltage is fixed. In some cases it is desirable to control not only the magnitude but also the polarity of the rectified output over a wide range of frequencies.

An object of my invention is to provide a rectifier of the electron discharge tube type in which the output can be controlled either as to magnitude or as to both magnitude and polarity over a wide range of frequencies.

In a preferred embodiment of my invention the grids or control electrodes of a pair of electron discharge tubes are connected to an input circuit, the anodes to an output circuit, and an alternating voltage, preferably supplied from a common source, is applied to the grids thru the input circuit and to the anodes thru the output circuit, the polarity and magnitude of the rectified output voltage being controlled by varying the phase relationship of the alternating voltages applied to the grids and anodes; or, in the case where the electron discharge tubes are of the high vacuum type, the magnitude may also be controlled by the magnitude of the alternating voltage applied to the grids.

The novel features which I believe to be characteristic of my invention are set forth with particularity in the appended claims, but the invention itself will best be understood by reference to the following description taken in connection with the accompanying drawing in which the figure in the drawing is a diagrammatic representation of a rectifier made in accordance with my invention.

The rectifier shown in the drawing has two electron discharge devices 10 and 11 which may be of either the high vacuum or gaseous discharge type, each having a thermionic cathode 12, control grid 13 and anode 14. Although shown as triodes any type of multi grid or screen grid tube could be used without changing the operating principles involved. The alternating voltage to be rectified is supplied from the source 15 having one terminal connected to the anodes of the tubes thru the two equal portions 16 and 17 of a load impedance shown by way of example as resistance which has its end terminals connected to the anodes 14 and its mid-point connected to the cathodes 12 of the tubes. The output circuit of the rectifier comprises a conductor 18 connected to the anode of tube 10 and a conductor 19 connected to the anode of tube 11. The two equal parts 16 and 17 of the impedance are connected in series across the rectifier output terminals 20 and 21 of the output circuit, the mid-point of the impedance being connected to one terminal of the alternating voltage source 15. A by pass condenser 22 may be connected across the output circuit in shunt with the impedance. The rectified output voltage is obtained between the terminals 20 and 21 of the rectifier output circuit.

To control the rectifier, an alternating voltage, preferably from the same source as that to be rectified is applied to the control grids thru an input transformer, the phase of the voltages applied to the grids being varied with respect to the voltages applied to the anodes to control the magnitude and polarity of the rectified output voltage. The phase shifting may be accomplished by means of any suitable phase shifting device connected preferably between the alternating voltage source and the input transformer.

The grids 13 are connected preferably to opposite ends of the secondary 23 of an input transformer, the mid-point of the secondary being electrically connected to the cathodes of the tubes either directly or thru the usual grid biasing battery (not shown). The primary 24 of the input transformer is connected thru a conventional phase shifting device 25, preferably comprising fixed resistors 26, a variable resistor 27 of high value and an inductance 28, connected in a bridge arrangement to the alternating voltage supply source 15.

Where it is desired to control only the magnitude of the voltage applied to the grids of the tubes a conventional type potentiometer 29, for example, can be connected between the source of alternating voltage and the phase shifting device 25 to control the magnitude of the voltage impressed on the primary of the input transformer. Within the usual operating range, the larger the voltage impressed on the grids the greater will be the current in the anode circuits of the tube and hence the greater the rectified output voltage. While the alternating current source is preferably shown as a common source for the input and output circuits, separate sources of alternating voltage could be used.

By controlling the phase relationship between

the alternating voltages applied to the grids and to the anodes of the tubes by means of the phase shifting device 25 which is capable of shifting the voltage applied to the primary 24 of the input transformer thru 180°, it is possible to reverse the polarity of the rectified output voltages at the output terminals of the rectifier. The degree of shift in phase between the alternating voltages applied to the grids and the alternating voltages applied to the anodes determines the magnitude of the rectified output voltage. The source of alternating voltage supply can be of any desired frequency.

More specifically, with the phase shifter adjusted to have all of resistance 27 in circuit the alternating voltage applied to the grid of the tube 10 will be in phase with the alternating voltage applied to the anode of the tube 10 while the voltage on the grid of tube 11 will be 180° out of phase with the voltage on the anode of tube 11 and a maximum rectified output voltage will be obtained, the terminal 20 connected to the anode of the tube 10 being negative.

If now the phase shifter is adjusted by reducing the resistance 27 to zero, the alternating voltage applied to the grid of tube 11 will be in phase with alternating voltage applied to the anode of tube 11, while the voltage applied to grid of tube 10 will be 180° out of phase with the voltage applied to the anode of tube 10. Under these conditions the maximum output voltage is again obtained but now has an opposite polarity. With the phase shifter adjusted so that the alternating voltages applied to the grids are 90° out of phase with the alternating voltage applied to the anodes there is no rectified output voltage.

Adjusting the phase shifter so that the voltage on the grid of the tube 10 shifts from in phase to 90° out of phase with voltage applied to its anode, the rectified output voltage will be decreased from a maximum to zero, the terminal 20 connected to the anode of the tube 10 being the positive terminal. If the phase difference is shifted from 90° to 180°, which in effect makes the voltage on the grid of tube 11 shift from 90° out of phase to in phase with the voltage on the anode of tube 11, the magnitude of the rectified output voltage can be varied from zero to maximum, the polarity in this case however being opposite to that when the voltage on the grid of the tube 10 was varied from 0° to 90° out of phase with the voltage on the anode of tube 10.

In addition to the polarity control of the rectified output, in the case in which substantially high vacuum electron discharge devices are used, the magnitude of the output may also be varied by varying the magnitude of the alternating grid voltages as described above. Thus the magnitude of the rectified output voltage is directly dependent upon the magnitude and the phase of the input voltage with respect to the voltage on the anodes and the polarity of the output voltage is dependent only upon the phase of the input voltage with respect to the voltage on the anodes.

While I do not wish to be restricted to any particular theory, it is believed that in a circuit arranged according to my invention the following action takes place:

The alternating voltages applied to the anodes 14 of the tubes 10 and 11 from the source 15 are in phase and of equal magnitude so long as each tube is passing no current or an equal current, since under these conditions the terminals 20 and 21 of the output circuit are at the same potential, there being no drop or an equal drop across each part 16 and 17 of the impedance, it being understood that the rectified current from each tube passes thru the part of the impedance connected to its anode, from the anode to its cathode. If, however, one of the tubes passes more rectified current than the other an unequal voltage drop will take place across the two parts of the impedance, and the terminals of the output circuit will then be at different potentials; this difference appearing as a rectified output voltage having a value equal to the difference between the voltage drops across the parts of the impedance. The condenser 22 will filter out any alternating voltages which may appear in the output. More specifically, if the current thru tube 10 is greater than the current thru tube 11 the drop across the part 16 will be greater than the drop across part 17 of the impedance, the difference appearing as a voltage across the output terminals 20 and 21 which has a polarity such that the terminal 20 connected to the anode of tube 10 is negative. Conversely, if the current thru the tube 11 is greater than that thru the tube 10 an output voltage will again appear across the terminals of the output circuit but in this case the terminal 21 connected to the anode of the tube 11 will have the negative sign.

If the alternating voltage applied to the grid of tube 10 is in phase with the anode voltage; i. e. the grid becomes increasingly positive as the anode becomes increasingly positive; then, because of the push-pull input connection, the voltage applied to the grid of tube 11 will be in opposite phase with its anode voltage. Tube 10 will then be more conducting than tube 11 during the part of the cycle in which the anodes are positive and a greater direct voltage will appear across impedance 16 than appears across 17 so that a unidirectional output voltage equal to their difference will appear across terminals 20 and 21. A reversal of phase of the grid voltages with respect to the anode voltages reverses the above conditions so that tube 11 is now more conducting than tube 10 and the unidirectional output is reversed in polarity. When the grid voltages are in quadrature (90° out of phase) with the anode voltages, the two tubes pass equal currents and the equal drops across parts 16 and 17 of the impedance result in no rectified output. For intermediate conditions the output has intermediate values. The amount by which one tube becomes more conducting than the other is also dependent on the magnitude of the alternating grid voltage applied so that the rectified output is also dependent on the magnitude of the input.

In order to control the magnitude of the rectified output voltage, the voltages on the grids of the tubes are shifted with respect to the voltages on the anodes so that the grid voltages and anode voltages are out of phase, the degree of shift between the two voltages determining the magnitude of the output voltage. While any method can be used for controlling the application of the voltage to the grids of the tubes I show a conventional phase shifting device for this purpose.

Assuming that the voltage on the grid of tube 10 is in phase with its anode voltage, the maximum rectified output voltage is obtained with the terminal 20 of the rectifier connected to the anode of tube 10 being positive. By adjusting the phase shifter to reduce the resistance 27 the alternating voltage on the grid of tube 10

can be shifted out of phase with the alternating voltage on the anode. This at the same time results in shifting of the alternating voltage applied to the grid of tube 11, which is 180° out of phase with the alternating voltage on the anode toward an in phase relationship with the voltage applied to the anode of tube 11. Thus during a portion of the time both the grid and the anode of tube 11 will have voltages applied to them so that there will be a rectified output current in the portion 17 of the impedance. However, since the current and hence the voltage drop in impedance 16 is greater than in impedance 17, the terminal 20 will be at a higher potential than the terminal 21, the result being a rectified output voltage which is still positive with respect to the side of the line connected to the anode of tube 10, but of less magnitude than when the voltage on the grid and anode of tube 10 were in phase. The by-passing condenser prevents any alternating voltages being transferred into the output circuit. By continuing to reduce the resistance 27, the time during which tube 11 is conducting and the magnitude of the rectified current thru the tube is increased while decreased with respect to tube 10 so that the magnitude of the rectified output voltage is reduced.

By continuing to adjust the phase shifting device a condition will be obtained where the voltage applied to the grids of both tubes is 90° out of phase with the voltages applied to the anodes. Under these conditions the same drop for the same space of time occurs across both parts of the impedance and the terminals of the rectifier output are then at the same potential so that there is no rectified output voltage across the rectifier output terminals. Further reduction of resistance 27 will cause the tube 11 to develop a greater drop across the part 17 of the impedance, than the tube 10 does across part 16 of the impedance, so that the rectified output voltage across the terminals of the output circuit reverses its polarity and starts to again increase. The phase shifter can thus be progressively varied until the voltage applied to the grids has been shifted thru 180°, whereupon the terminal 21 connected to the anode of tube 11 will be positive and a maximum output voltage will again be developed across the output terminals of the rectifier.

The arrangement as shown is essentially a half wave rectifier but by using two such arrangements, full wave rectification is possible.

It is apparent from the above description of applicant's invention that by using only one tube, for example tube 10 and only part 16 of the impedance and connecting the rectifier condenser 22 across this part of the impedance, so that an alternating voltage is applied to the anode of the tube thru the part 16 of the impedance and to the grid thru the input transformer with its secondary connected between the grid and the cathode of the tube, it would be possible by varying the phase relationship between the voltage applied to the anode and the voltage applied to the grid to vary the magnitude of the rectified output voltage at the rectifier output terminals connected to opposite ends of part 16 of the impedance altho under these conditions it would not be possible to change the polarity of the rectified output voltage.

It will thus be seen that I have provided a rectifier in which either the magnitude or both the magnitude and polarity can be controlled over a wide range of frequencies.

While I have indicated the preferred embodiment of my invention of which I am now aware and have also indicated only one specific application for which my invention may be employed, it will be apparent that my invention is by no means limited to the exact forms illustrated or the use indicated, but that many variations may be made in the particular structure used and the purpose for which it is employed without departing from the scope of my invention as set forth in the appended claims.

What I claim as new is,—

1. An alternating current rectifier including a pair of electron discharge devices each having a cathode, grid and anode, an input circuit connected between the grids and an output circuit connected between the anodes of said electron discharge devices, a resistance connected across the rectifier output circuit, an alternating voltage supply source connected between the cathodes of said electron discharge devices and a mid-point of the resistance, and connected to apply alternating voltages to said grids through the input circuit, and means associated with said alternating voltage supply source for controlling the voltage phase relationship of the alternating voltages applied to said anodes and to said grids to control the polarity and magnitude of the rectified voltage across the rectifier output.

2. An alternating current rectifier including a pair of electron discharge devices each having a cathode, grid and anode, an input circuit including an input transformer having a primary and a secondary, the grids of said electron discharge device being connected to opposite ends of the secondary of said transformer, an output circuit having rectifier output terminals connected to opposite sides of said output circuit, a resistance connected across said output circuit, the anodes of said electron discharge device being connected to opposite ends of said resistance, an alternating voltage supply source connected between the cathodes of said electron discharge device and the mid-point of the resistance for applying an alternating voltage to said anodes, the primary of the input transformer being connected to the alternating voltage supply source for applying an alternating voltage to said grids, and a phase shifting device connected in circuit with said alternating voltage supply source for varying the phase relationship between the voltages applied to the grids of said tubes and to the anodes of said tubes to control the polarity and magnitude of rectified voltage at the rectifier output terminals.

3. An alternating current rectifier including two electron discharge devices each having an electron emitting cathode, a control grid and an anode, an input circuit including an input transformer having a primary and a secondary, the opposite terminals of said secondary being connected to the grids of said electron discharge devices and the mid-point of said secondary connected to the cathodes of said electron discharge devices, an output circuit with its opposite terminals connected to the anodes of said electron discharge devices, a resistance and a filter condenser connected across the output circuit, a source of alternating voltage connected between the cathodes of said electron discharge devices and the mid-point of said resistance and to the primary of said input transformer, and a phase shifting device connected in circuit with said

source of alternating voltage and with the primary of said input transformer for varying at will the phase relation of the alternating voltages applied to said anodes from said source of voltage and to said grids through said input transformer for controlling the polarity and magnitude of the rectified voltage at the terminals of said output circuit.

4. An alternating current rectifier including a pair of electron discharge devices each having a cathode, a control grid and an anode; an input circuit, the grid of each electron discharge device being connected to the opposite side of said input circuit; an output circuit for said rectifier, the anode of each electron discharge device being connected to an opposite side of the output circuit; means connected to the output circuit and the cathodes of said electron discharge devices for applying an alternating voltage to said anodes; means for applying an alternating voltage through said input circuit to said grids and means associated with the input circuit for controlling the alternating voltages applied to said grids to control the rectified voltage in the rectifier output circuit.

5. In combination, two grid control rectifiers, each including a grid, anode and a cathode, a push-pull input circuit connected to the grids of said rectifiers, each anode of said rectifiers being connected through a separate resistor to a source of alternating voltage, means to couple said input circuit to said source, and means for adjusting the phase relation of the voltage impressed on said input circuit with respect to the phase of the impressed anode voltage, and a load circuit connected across said resistors.

6. An alternating current rectifier including a pair of electron discharge devices each having a control electrode, an anode and a cathode, an input circuit connected between the control electrodes and an output circuit connected between the anodes of said electron discharge devices, a resistance connected across said output circuit, means for applying an alternating voltage in phase to said anodes through the resistance, means for applying an alternating voltage to said control electrodes through said input circuit, and means for varying the alternating voltage applied to the input circuit to control the rectified voltage across the output.

7. An alternating current rectifier including a pair of electron discharge devices each having a cathode, a control grid and an anode, an input circuit, the grid of each electron discharge device being connected to an opposite side of said input circuit, an output circuit for said rectifier connected between the anodes of the electron discharge device, each anode being individually connected through a separate resistance to one side of an alternating voltage supply source, said source being connected on its other side to the cathodes of said electron discharge devices, the input circuit being coupled to said source for applying alternating voltages to said grids, and means associated with the alternating voltage supply source for controlling the phase relationship of the alternating voltages applied to said grids and to said anodes to control the polarity and magnitude of the rectified voltage in the rectifier output circuit.

8. In combination, two grid control rectifiers each including a grid, an anode and a cathode, a push-pull input circuit connected to the grids of said rectifiers, the anodes of said rectifiers being connected together through a resistance, a source of alternating voltage connected between an intermediate point on said resistance and said cathodes, means to couple said input circuit to said source with means for adjusting the phase relationship of the voltage impressed on said input circuit with respect to the phase of the impressed anode voltage, and an output circuit to be energized by said resistance coupled to said resistance.

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