Nov. 25, 1930. E. E. SPITZER 1,783,059

MEANS FOR RECTIFYING ALTERNATING CURRENT

Filed Oct. 12, 1928

Fig. 1.

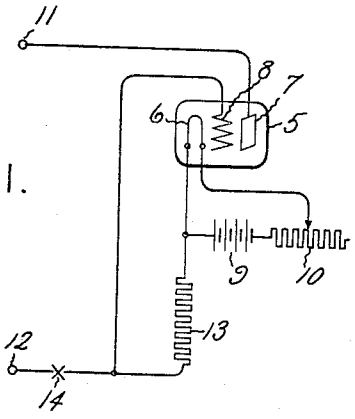


Fig. 2.

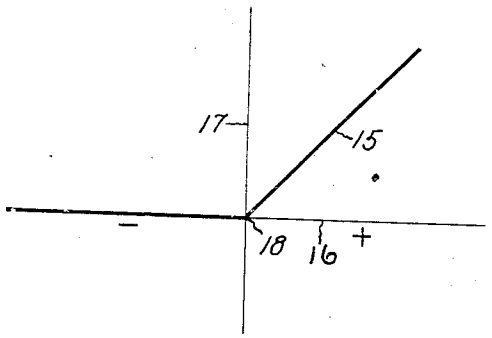
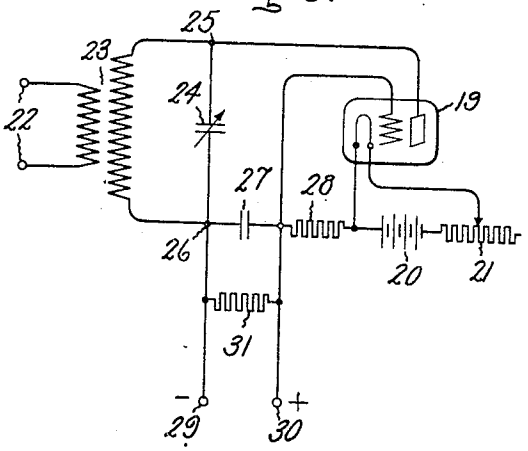


Fig. 3.



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Patented Nov. 25, 1930 1,783,059

UNITED STATES PATENT OFFICE

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MEANS FOR RECTIFYING ALTERNATING CURRENT

Application filed October 12, 1928. Serial No. 312,167.

The present invention relates to means for rectifying alternating current and has for its object to provide a rectifier having a rectilinear rectification characteristic. By a rectilinear rectification characteristic or linear rectification characteristic as it is more commonly termed and as hereinafter termed throughout the specification and claims, is meant that the rectified current from the rectifier is directly proportional to the voltage applied thereto, that is, the volt-ampere characteristic is linear. Stated in another way, a rectifier means having a linear rectification characteristic operates as a complete open circuit during one-half cycle and as a pure resistance during the remaining half cycle.

One advantage of such a characteristic is that modulated waves, such as broadcast signals for example, may be rectified without distortion, that is, all the signal components of the modulated wave may be reproduced thereby in their proper phase and amplitude relations. This makes it possible to completely eliminate the negative portion of any impressed alternating voltage wave without altering the shape of the positive portion.

Another object of the invention is to provide a rectifier means, the rectification characteristic of which is linear substantially up to the maximum safe working voltage of the device used therein to produce rectification.

A further object of the invention is to provide a rectifier means, the rectifying device of which may be a simple electric discharge device of the commercial three electrode vacuum-tube type.

My invention will however be better understood from the following description when considered in connection with the accompanying drawing, and its scope will be pointed out in the appended claims.

In the drawing, Fig. 1 is a circuit diagram of a linear rectifier means embodying the invention; Fig. 2 is a curve diagram illustrating the rectification characteristic of the means shown in Fig. 1; and Fig. 3 is a circuit diagram of a modification of the means and circuit of Fig. 1 for the detection or linear rectification of modulated waves.

Referring to Fig. 1, 5 is an electric discharge device having a cathode 6, an anode 7, and a control grid 8. This is the usual type of radio receiving tube and is preferably of the type having a relatively high emission, although it may be any suitable electric discharge device having the above elements and having an emission which does not limit its output, that is, it may be a device which operates below the emission saturation point. Stated in another way the electron emission saturation limit must be above the working range of the device, whereby its output will not be limited. The cathode in the present example is of the self-heated or hot filament type, heated from a suitable source of current such as a battery 9, with a variable resistor or rheostat 10 in circuit therewith as a means for controlling the voltage applied to the cathode.

The anode and cathode are connected with terminals 11 and 12 respectively for connection with an alternating current circuit such as a circuit carrying modulated waves, for example. Terminal 12 may be considered as the low potential terminal of the rectifier means and between it and the cathode is inserted a resistor 13, preferably of the non-inductive type, having a relatively high ohmic resistance, the value of which depends upon the type of rectifier device with which it is used as will be explained hereinafter. The control grid is connected with the same terminal as the cathode at the low potential end of the resistor whereby the resistor is connected between the grid and the cathode.

The above device and circuit arrangement operate as a linear rectifier for alternating current applied at terminals 11 and 12 as follows:—The device 5 functions as a rectifier and when the terminal 11 is negative with respect to terminal 12, no current can flow from the anode to the cathode because the anode is negative. When terminal 11 becomes positive, current flows from terminal 11 and the anode to the cathode and through resistor 13 to terminal 12, thus applying negative bias to the control grid. If the re-

sistance of resistor 13 were zero, the current flow would be proportional to the applied voltage at terminals 11 and 12 to the $\frac{3}{2}$ power which is a non-linear response. As soon as resistance is inserted at 13, the volt-ampere characteristic becomes more nearly linear. The higher the resistance of resistor 13 the more linear is the characteristic. At the same time however, the impedance of the rectifier means as a whole increases, as is evident, since the resistor is in the path of the rectified current. Thus in practice a balance must be found between the degree of linearity and the impedance of the rectifier means as a whole. For example, when using an ordinary radio receiving tube, known commercially as the radiotron UV–199, as the rectifier device 5, a suitable resistance value for resistor 13 has been found to be approximately 50,000 ohms.

It has also been found that the operating characteristic of the rectifier device for improved rectilinear response may be controlled to a certain extent by regulating the cathode voltage, in the present example, by adjusting rheostat 10 while the device is in operation. This does not vary the emission which is below its saturation limit, but slightly varies the bias effect since the filament is not at the same potential with respect to the grid throughout its length.

The rectified out-put from the device may be taken at any point in the circuit either external to terminals 11 and 12 or by breaking the circuit at a point 14 as indicated in the figure.

Referring now to Fig. 2, the operating characteristic of the above described rectifier means may be represented by a curve 15 plotted between impressed voltage on the high potential terminal 11 or anode 7 along abscissa 16 and rectified current along ordinate 17, negative voltages being plotted to the left of the origin 18 and positive values to the right thereof. From this curve it will be seen that the rectifier forms in effect an open circuit during the negative half cycle and as a pure resistance during the positive half cycle. It has been found that this characteristic continues up to substantially the maximum operating voltage permitted by the rectifier device. Thus by choosing the proper tube or rectifier device, voltages of any magnitude may be rectified without distortion.

This rectifier means is relatively simple since it permits the use of any electric discharge device having an anode, cathode and control grid and the desired safe working voltage range. The resistor element must be adapted to carry the rectified current and its resistance must be of such magnitude as to produce sufficient bias voltage to effect linear rectification to the degree required.

A rectifier of this type is particularly adapted for the rectification of modulated waves and in Fig. 3 to which attention is now directed a detector circuit for this purpose is shown. This comprises substantially the same circuit arrangement as Fig. 1 having a three-element rectifier tube 19 provided with a suitable cathode heating and voltage control means 20 and 21 respectively. Modulated wave signal energy is supplied to the anode and cathode from input terminals 22 through a radio frequency transformer 23 the secondary of which is tuned by a variable capacity 24 providing a circuit responsive to such waves. The anode is connected directly with the high potential end or terminal 25 of this tuned circuit, while the cathode is connected with the low potential terminal 26 of this circuit through a by-pass condenser 27 and bias resistor 28, the latter being connected between the grid and the cathode, with the grid connected to the low potential end of the grid bias resistor.

This device operates to rectify the alternating current or modulated wave supplied to it through the tuned circuit in the same manner as the rectifier means described in connection with Fig. 1. In this case the rectified output is taken from the low potential terminal 26 and the cathode through resistor 28 to direct current output terminals 29 and 30, the former being the negative terminal and the latter the positive terminal as indicated in the drawing.

In the present example a load resistor 31 is connected across the direct current output circuit to provide a conductive connection between the output terminals, in case such connection is not present in the apparatus to be supplied by terminals 29 and 30. However, 31 is not essential to the operation of the device itself.

The by-pass condenser 27 provides a path for the radio frequency component of the modulated wave, but operates as a blocking condenser for the direct current component which flows to the load through terminals 29 and 30. The direct current out-put may however, be taken from the circuit at any other suitable point, although it is preferably taken from the low potential side thereof, as shown, and of course must be taken at some point between the tuned input circuit, represented in the present example by the secondary of the transformer 23 and the tuning capacity therefor 24, and the rectifier anode or grid connection. As previously indicated, this arrangement rectifies or detects modulated waves without distortion and produces all the signal components thereof in their proper phase and amplitude relations.

What I claim as new and desire to secure by Letters Patent of the United States, is:

1. A linear rectifier means for alternating current comprising an electric discharge device having an electron emission limit

above its working range and provided with a cathode, an anode and a control grid, a resistor connecting said grid and the cathode, the resistance value of said resistor being such that the volt-ampere rectifier characteristic of said device is rendered substantially rectilinear, and alternating current supply terminals connected with the anode and the control grid.

2. A linear rectifier for alternating current comprising an electric discharge device having an electron emission limit above its working range and a cathode, an anode and a control grid, a resistor connecting the grid and the cathode, the resistance value of said resistor being such that said device operates alternately as an open circuit and as substantially a pure resistance when alternating current is applied between said grid and anode, circuit means for applying an alternating voltage between said grid and anode, and circuit means connected between the anode and the grid for receiving rectified alternating current through said device.

3. The combination with a circuit responsive to modulated waves and having a high potential terminal and a low potential terminal, of an electric discharge device having an anode connected with said high potential terminal and a control grid and a cathode, a resistor connecting said control grid and cathode, and out-put terminals connected with the low potential terminal of said circuit and with said cathode through said resistor, the resistance value of said resistor being in the order of several thousand ohms whereby said device operates to deliver to said terminals a rectified current directly proportional to the voltage amplitude of said modulated waves.

4. The combination with a circuit responsive to modulated waves and having a high potential terminal and a low potential terminal, of an electric discharge device having an anode connected with said high potential terminal and a control grid and a cathode, a resistor connecting said control grid and cathode, and means interposed between the low potential terminal of said circuit and said control grid and cathode for receiving rectified current from said circuit through said device and resistor, the resistance value of said resistor being of the order of several thousand ohms whereby said rectified current is directly proportional to the amplitude of the modulated waves.

5. In an alternating current circuit, a rectifier means including an electric discharge device having an anode, a cathode and a control grid, said circuit being connected with said device for conveying current from the anode to the cathode, a resistor connected with the cathode in series with said circuit, said grid being directly connected with said resistor to receive a bias voltage therefrom and said resistor having a relatively high resistance such that said device is caused to operate with substantially a rectilinear volt-ampere rectifying characteristic and said cathode being arranged to operate within a range below its electron emission saturation limit.

In witness whereof, I have hereunto set my hand this 11th day of October, 1928.

EDWIN E. SPITZER.