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2,248,793

METHOD OF REGULATING THE AMPLITUDE OF ELECTRIC WAVES

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2 Sheets-Sheet 1

Fig. 1.

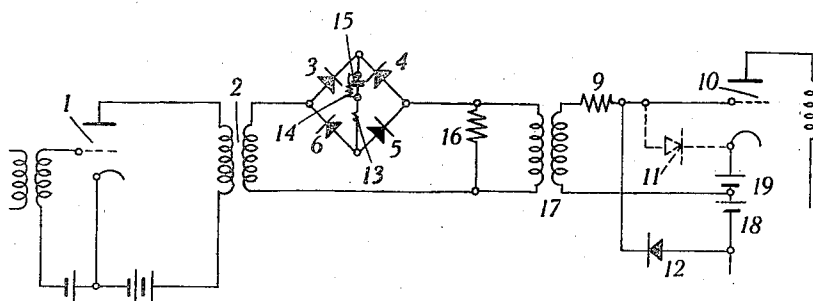
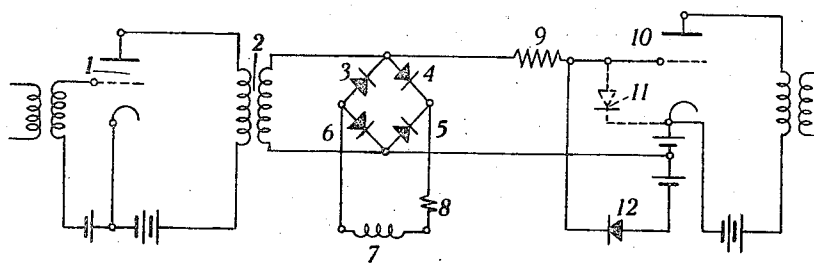


Fig. 2.



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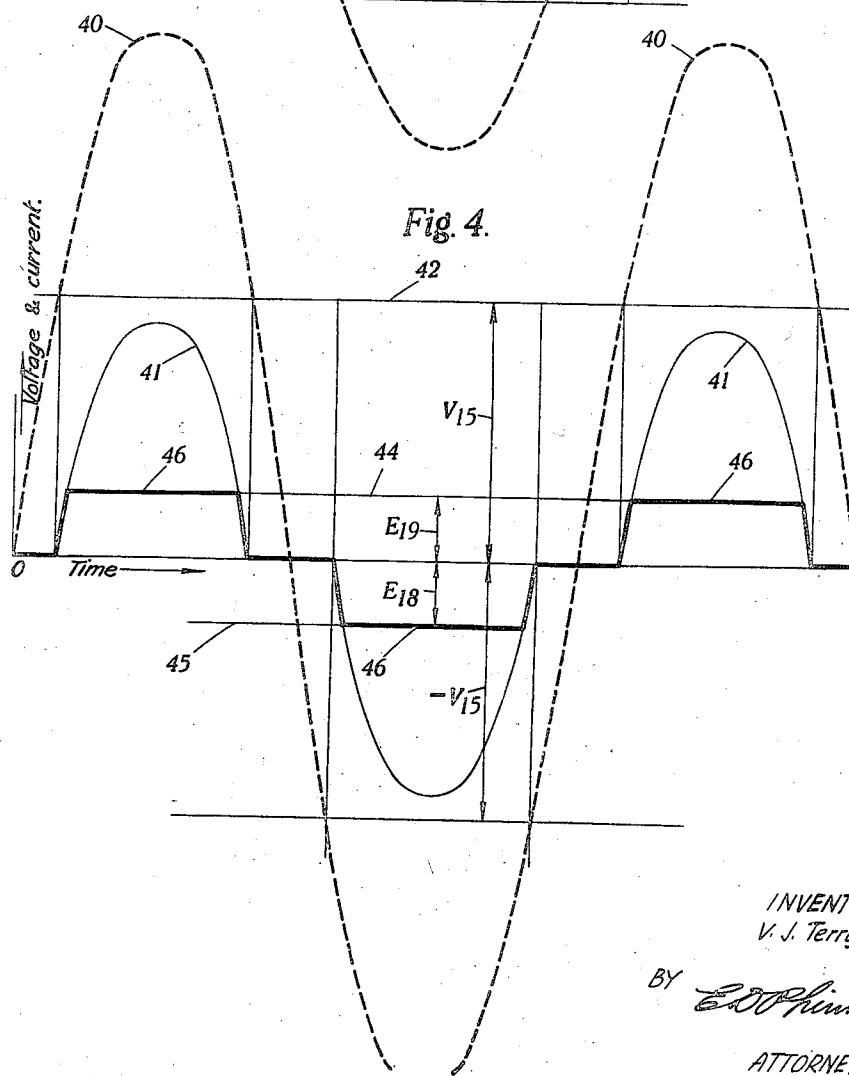
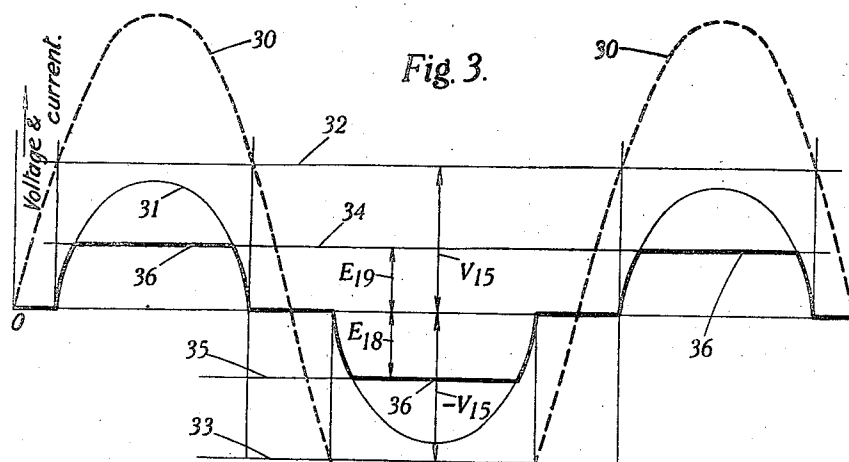
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METHOD OF REGULATING THE AMPLITUDE OF ELECTRIC WAVES

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2 Sheets-Sheet 2



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METHOD OF REGULATING THE AMPLITUDE
OF ELECTRIC WAVESVictor John Terry, London, England, assignor to
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New York, N. Y.Application May 11, 1939, Serial No. 273,092
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6 Claims. (Cl. 178—44)

This invention relates to the regulation of the amplitude of electric impulses, particularly waves.

In accordance with this invention a regulating device for electric impulses accepts only incoming impulses of an amplitude greater than a certain value, which value increases and decreases with increase and decrease in the rate at which energy is being received from incoming impulses, and cuts down these accepted impulses so that their amplitude shall not exceed a fixed maximum.

In accordance with a further feature of the invention a regulating device for electric impulses is characterized in that energy derived from a series of incoming impulses is stored in a storage means from which it is dissipated at a steady rate, and in that only incoming impulses of an amplitude above a value determined by the level of energy in the storage means are accepted, and are passed on with an amplitude limited to a certain maximum.

Thus a device in accordance with this invention is capable of distinguishing between slow and rapid variations in the strength of the incoming impulses, being substantially unaffected by the former for a considerable range of amplitude.

In accordance with yet a further feature of the invention, a regulating device for electric impulses capable of distinguishing between slow and rapid variations in the amplitudes of a series of incoming impulses, characterized in that when a series of incoming impulses consists in a sinusoidal wave-train, the resultant output wave-train contains substantially no even harmonic components and substantially no third harmonic component.

The invention will be described with reference to two embodiments of the invention shown in the accompanying drawings in which:

Fig. 1 shows one embodiment of the invention in which two stages of an amplifier are connected in series with an amplitude regulator;

Fig. 2 shows a second embodiment of the invention in which the amplitude regulator is connected in shunt on the wires joining two stages of an amplifier;

Fig. 3 shows various curves relating to the operation of the embodiments of the invention shown in Figs. 1 and 2; whilst

Fig. 4 shows a similar set of curves for a much larger stimulus.

In both embodiments of the invention, the circuits are designed to eliminate slow variations from the amplitude of an electric wave; but to accentuate rapid variations so that the wave will be reduced to zero amplitude by a sudden fall in

strength of, say, half of the strength of the stimulus producing it.

In each embodiment the circuit is designed to respond more rapidly to increases in the strength of the stimulus than to corresponding decreases. The circuits are also designed so that with most increases in the value of the stimulus with which the circuit would have to deal the maximum amplitude of the wave is not even temporarily more than a third more than the steady value of the amplitude of the wave.

Such circuits have distinct advantages for use in receiving circuits designed for carrier telegraph and like systems in which the strength of signal may vary considerably and in which the intervals between consecutive signals may be obscured by echoes and interferences.

Referring now to Fig. 1, the wave to be regulated reaches the regulating means through an amplifying valve 1 and a transformer 2, the regulated output being applied to the control grid of a second amplifying valve 10. The rectifying property of the grid of this second valve also takes part in the regulating process and an imaginary rectifier 11, externally connected and shown dotted in the drawings, brings about a regulating effect which corresponds to that produced by the grid of the valve. In addition the grid of the valve is shunted by a rectifier 12, which is in parallel with the imaginary rectifier 11 but of opposite sense to it. Of course it may be advantageous to use an actual rectifier in the position 11, exactly like that employed in position 12; for then the variation of backward current through 12 (which normally takes place when there is little or no signal input) is balanced by a similar leakage through rectifier 11 and no change takes place in the grid voltage applied to valve 10.

The regulating process is accomplished in two stages, which will be fully explained by reference to the description of the curves shown in Fig. 3.

Four rectifying elements 3, 4, 5 and 6 joined in well known bridge formation, with a direct current load of resistances 13 and 14, and a condenser 15 bring about the first stage of regulation. These elements are so proportioned in relation to the anode impedance of the valve 1, the ratio of the transformer 2, and the value of a resistance 16, that the current flowing through the input terminals of the rectifier bridge is suppressed, during a predetermined portion of every cycle of input wave, by a potential developed across condenser 15.

The input terminals of the rectifier bridge are

connected in series with a resistance 16 which is shunted by the primary winding of a transformer 17. The resistance 9 in series with the secondary load of this transformer has a high value, so that the voltage across both primary and secondary of the transformer is approximately proportional to the current flowing through the input terminals of the bridge.

For small amplitudes the voltage applied to the grid of valve 10 is also proportional to the current through the rectifier bridge, because although resistance 9 is high the resistances of the rectifiers 11 and 12 which shunt the grid are also very high, by reason of the potentials applied to them by grid batteries 18 and 19. However, as soon as the secondary voltage of the transformer 17 exceeds the E. M. F. of battery 19 in a positive sense, current readily flows through rectifier 11 preventing any appreciable further rise in the potential of the grid, and similarly the voltage which can be applied to the grid of 10 in a negative sense is limited by rectifier 12 and battery 18.

The operation is illustrated in Figs. 3 and 4. Referring to Fig. 3, curve 30 represents the stimulus producing the regulated wave, that is, it represents the effective E. M. F. in the plate circuit of valve 1, corrected for the ratio of transformer 2. Line 32 represents the potential to which condenser 15 is charged by the rectified current when the stimulus has been constant long enough for a steady state to be reached. It is assumed that the capacity of condenser 15 is so large that no appreciable variation in potential takes place during a single cycle. Curve 31 represents the current flowing through the input terminals of the rectifier bridge.

It will be seen that no current except a small leakage, can pass until the E. M. F. of curve 30 exceeds the potential of line 32, but when it does so a current will flow. This will be limited by the resistance of the rectifiers 3, 4, 5 and 6, resistance 13 and the impedance of resistance 16 and transformer 17 connected in parallel. Provided the capacity of the condenser 15 is large resistance 14 has no effect on the current flowing except in so far as it determines the potential 32.

The impedance of transformer 17 and its connected load 9 being high, curve 31 also represents on a different scale, the secondary potential applied to the valve 10 through resistance 9 and in consequence of the rectifiers 11 and 12, the potential applied to the grid of valve 10, is limited to the form shown in curve 36, where E_{18} and E_{19} are the voltages of batteries 18 and 19.

Fig. 4, which is drawn to the same scale as Fig. 3, represents a similar set of curves for a much larger stimulus. In Fig. 4, curve 40 represents the E. M. F. (corresponding to curve 30 in Fig. 3) and, the line 42 the new value of the potential V_{15} to which condenser 15 is charged.

The ratio of V_{15} to the maximum value of the stimulus is determined chiefly by the relative proportions of the anode impedance of valve 1 (corrected for the ratio of transformer 2), the resistances of rectifiers 3, 4, 5 and 6 and resistances 13, 14 and 16. It is therefore the same in both figures. For this reason, current flows for the same proportion of a cycle in both figures and although the current represented by curve 41 is larger than that shown by curve 31, the maximum values of the potential 46 applied to the grid of valve 10 is almost unchanged, because they are determined almost entirely by E_{18} and E_{19} .

There is however, a slight difference between

curve 46 and curve 36, because although each exists for the same proportion of a cycle, curve 46 rises more rapidly to its maximum value and the average length of the current impulses is slightly greater. For very large values of the stimulus, the curve 46 assumes a rectangular wave shape, and the current impulses have a fixed length determined by the intersection of the curves 40 and 42.

If $E_{18}=E_{19}$, the regulated wave form (36 or 46) contains no even harmonics when the stimulus is sinusoidal, and further, if V_{15} is made equal to one half the maximum value of this stimulus, the duration of each positive and negative current impulse is one third of a cycle, so that for large values of the stimulus giving a rectangular current impulse, the regulated wave form is free from the third harmonic also.

Theoretically, the fifth and higher harmonics are present, the former with an amplitude of one fifth that of the fundamental, but in practice the wave being somewhat rounded diminishes this ratio and weakens the higher harmonics with the result that the regulated wave in spite of its appearance is fairly free from distortion components.

It is obvious that if the amplitude of the stimulus falls suddenly to less than the potential V_{15} , the regulated wave is suppressed entirely, thus fulfilling one of the conditions which the circuit was required to meet, and also the rate at which condenser 15 is charged on the application of a suitable stimulus can be made more rapid than its discharge on the cessation of the stimulus, because the time constant for charging is the product of multiplying capacity 15 by the effective value of resistance 14 in parallel with a series combination of the resistances 13, 16, and the anode impedance of valve 1 (corrected for the ratio of transformer 2), with an allowance for the series parallel resistances of the rectifiers, while the time constant for discharge is the product of capacity 15 and resistance 14 alone.

The circuit of Fig. 2 differs from that of Fig. 1 chiefly in that the voltage applied to the grid of valve 10 and resistance 9 is that produced across the input terminals of the rectifier bridge (instead of being proportional to the current through it) and the resistances 13 and 14 and condenser 15 are replaced by resistance 8 and inductance 7.

With the circuit according to Fig. 2 there is (when the steady state has been reached) a direct current through the inductance which is so large that no appreciable variation takes place during a single cycle of the applied stimulus.

Under these circumstances a forward current continues to flow through all the rectifiers 3, 4, 5 and 6 during those periods of the cycle when the stimulus is small. The resistance of the rectifier being small, the voltage produced by the alternating current flowing in the secondary of transformer 2 is very small.

When, however, the current in the secondary of the transformer rises sufficiently to be equal to that flowing through the inductance 7, two of the rectifiers cease to conduct and any further rise in amplitudes of the stimulus appears as a voltage developed across the input terminals of the bridge, because no immediate increase of current through 7 is possible. The voltage applied by this circuit to resistance 9 and the grid of valve 10 is therefore of the same form as applied by circuit of Fig. 1, and the operations can likewise be illustrated by reference to Figs. 3 and 4.

When Figs. 3 and 4 are thus used, curves 30

and 40 again represent alternating E. M. F. in the anode circuit of valve 1, but to another scale they also represent the current which would be obtained by short circuiting the secondary to transformer 2. To the same scale lines 32 and 42 represents the steady state value of current through the inductance 7.

Curves 36 and 46 represent the voltage developed across the A. C. terminals of the rectifier bridge when the short circuit current (30 and 40) exceeds the steady state current (32 and 42). Curves 36 and 46 show the voltage which is applied to the grid of valve 10 after being limited by resistance 9, in combination with rectifiers 11 and 12.

In order that the voltage during that portion of each cycle in which the short circuit current (30 or 40) exceeds the current in the inductance should be zero, the forward resistances of the rectifiers 3, 4, 5 and 6 must be zero but in practice a sufficient approximation to this condition is possible to make the circuit function properly.

It is also true that to obtain complete suppression of the output from the circuit of Fig. 1, during periods when the stimulus is small, it is necessary that the backward resistance of the rectifiers should be infinite, but again a sufficient approximation to this ideal is possible in practice.

Although the operation of the circuits has been described with reference to a sinusoidal stimulus, its advantages are to a large extent retained when a complex input of two or more frequencies is employed, and it is found in practice, that the circuits described provide a given degree of amplitude regulation with less intermodulation between the frequencies in the complex wave than is possible with other circuits possessing similar amplitude regulation characteristics.

Consideration of the two circuits described shows that they consist of a rectifying arrangement, a condenser or inductance to store the rectified energy, a leakage path for the stored energy, a transmission path whose efficiency is dependent on the amplitude of the applied stimulus in relation to the energy stored, and in the final stage a limiting action.

What is claimed is:

1. A regulating device for electric impulses characterised by means for deriving energy from a series of incoming impulses, a storage means for storing said derived energy and dissipating it at

a steady rate, means for accepting only incoming impulses of an amplitude above a value determined by the level of energy in the storage means, and amplitude limiting means for passing on said accepted impulses with an amplitude limited to a certain maximum.

2. A device according to claim 1, characterised in that said storage device and said accepting means are so regulated that when a series of selected impulses consists in a sinusoidal wave-train, the resultant output wave-train contains substantially no even harmonic components and substantially no third harmonic component.

3. A regulating device for electric impulses capable of distinguishing between slow and rapid variations in the amplitudes of a series of incoming alternating impulses, comprising thermionic valve apparatus, bias control means responsive to said variations for maintaining said apparatus biased to a point substantially one-half the peak value of said incoming impulses, to avoid production of harmonics, for selecting said signal impulses according to amplitude variations, amplitude limiting means for said selected impulses for limiting the amplitude of both positive and negative peaks of said alternating impulses, and means for biasing said amplitude limiting means substantially identically for said positive and negative peaks to avoid the production of even order harmonics.

4. A device according to claim 3, said bias control means comprising a rectifier bridge with its input terminals in series with one of the impulse-transmission lines and its output terminals connected by a leaky condenser.

5. A device according to claim 3, said bias control means comprising a rectifier bridge with its input terminals shunting the impulse-transmission lines and its output terminals connected by an inductance.

6. A device according to claim 3, further comprising impulse-transmission lines carrying impulses after their selection according to amplitude, said amplitude limiting means comprising two rectifiers in parallel but of opposite sense connected in shunt to said line, the rectifiers allowing passage of a current only in response to an applied electromotive force in excess of a predetermined value.

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