April 30, 1935. T. A. SMITH 1,999,668

AUTOMATIC GAIN CONTROL

Filed Oct. 5, 1928

Fig. 1

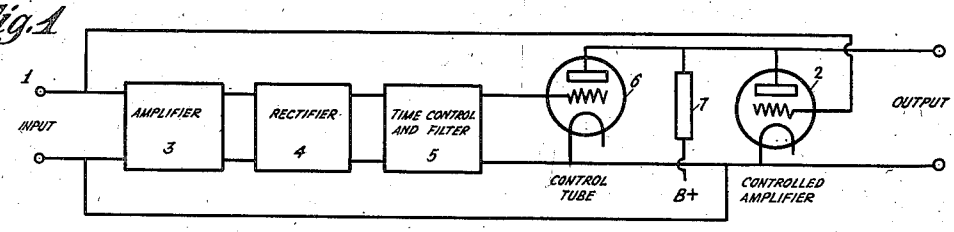


Fig. 2

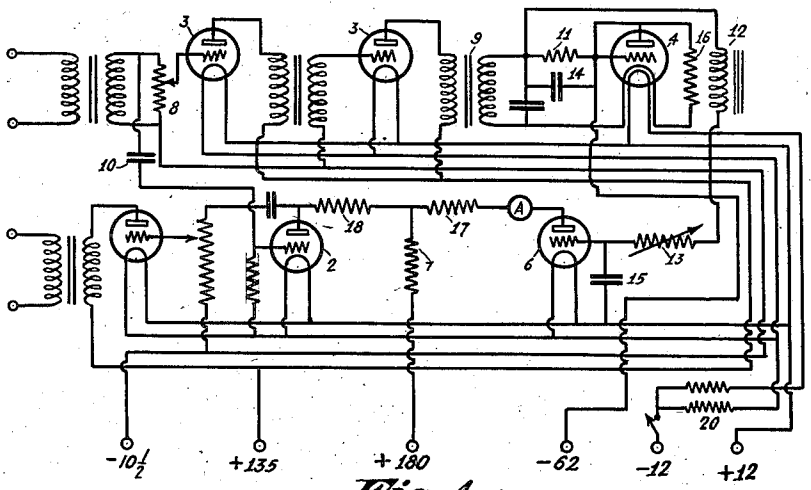


Fig. 3

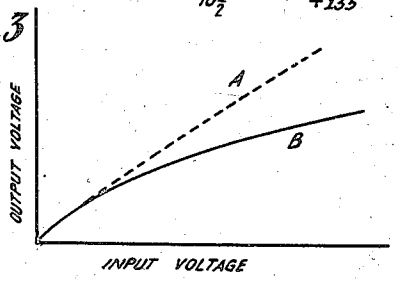


Fig. 4

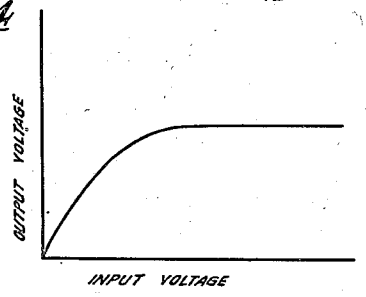
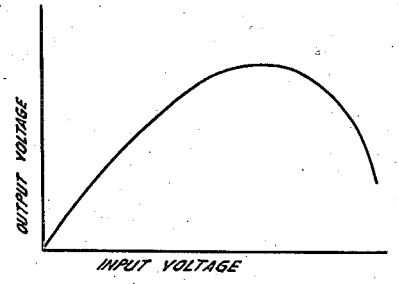


Fig. 5



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AUTOMATIC GAIN CONTROL

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29 Claims. (Cl. 179—171)

This invention relates to an automatic gain or amplification control and has as one of its objects the provision of an amplifier system whose output is made to vary by its input so that if desired, for a variable input a constant output may be had. That is, in this case, the output is made to vary inversely with the input. Briefly, the manner in which this object is attained is by varying the anode load of an amplifier tube by automatically adjusting the anode impedance of that amplifier tube in a predetermined manner by the uni-directional component of a rectified portion of the alternating input current which is to be amplified. The change in the anode load of the amplifier alters its amplification.

Another object of this invention is to vary in a predetermined manner the speed of control, or in other words the quickness with which the amplification of the amplifier is made to vary with the input. This is done by providing a filter arrangement comprising condensers and a variable resistance for controlling the speed at which the impedance of a control tube, shunting the anode impedance of the amplifier, varies.

Another object of this invention is to provide a method of, and means for, controlling the amplification of a vacuum tube amplifier which consists in rectifying a portion of the input energy and applying the direct current component of the rectified energy to the anode circuit of the tube to determine the static potential thereof whereby a predetermined ratio between the input energy applied to the amplifier and the output energy transmitted from the amplifier will be obtained, and further whereby the amplifier will be enabled to discriminate against input energies having amplitudes varying from predetermined value or values.

The internal impedance of the control tube shunts the plate load impedance of the controlled amplifier tube whereby, according to the bias placed on the grid or control electrode of the control tube, the effective anode load impedance of the said amplifier tube is adjusted by virtue of the variable internal impedance of the control tube. Consequently, the static anode potential, and the amplification of the amplifier varies, the speed of amplification variation corresponding to that of the variable potential applied to the control electrode of the control tube.

Still another object of this invention is to provide an automatic gain control, especially adapted for use with the audio frequency amplifier of a radio receiver, which will act without producing appreciable distortion and which will be useful as a fading compensator.

In the accompanying drawing:

Fig. 1 is a schematic diagram showing diagrammatically the essential elements of an automatic gain control built according to this invention;

Fig. 2 is a circuit diagram showing in greater detail the various elements of Fig. 1; and,

Figs. 3, 4 and 5 are curves illustrating the manner in which the apparatus shown in Figs. 1 and 2 may be made to operate.

Referring to Fig. 1 there is fed into the apparatus at point 1 a varying alternating input. A portion of this input is fed directly into the controlled amplifier 2. Another portion of the alternating input is fed into amplifier 3, which may, if desired, be omitted, and thence into rectifier 4. The uni-directional component of the rectified current is then fed into the filter and time control device 5 which controls the speed at which the bias on the control electrode of control tube 6 is varied by the changes in the uni-directional component of the rectified current. Control tube 6 has its anode to cathode current supplied through the anode impedance 7 which is also in the anode to cathode circuit of controlled amplifier tube 2. The output of amplifier 2 may be amplified and utilized as desired.

In operation the uni-directional component of the output of rectifier 4 controls the control electrode bias of tube 6. This in turn adjusts the internal impedance of tube 6 which is shunted across the anode impedance 7 of amplifier 2, thereby varying the anode load of tube 2 as well as its static potential and thereby controlling the amplification of the amplifier 2. The filter is used to prevent the application of an alternating current to the output circuit of amplifier 2. A combination of resistances and condensers, more fully disclosed in Fig. 2, is utilized to vary the speed at which the bias acting on the control electrode of tube 6 is varied.

Fig. 2 shows in greater detail the connections and apparatus utilized in the construction shown in Fig. 1. The amount of the input energy applied to amplifiers 3 is varied by means of a manually controlled resistance 8. The output of the amplifiers 3 is fed into rectifier 4 having a cathode of the heater type, by means of transformer 9. The control electrode and anode of the rectifier 4 are connected together forming a two element rectifier, used so as to produce a more nearly perfect rectilinear characteristic. The other portion of the input alternating energy is fed through condenser 10 to amplifier tube 2.

The time control and filter 5 shown diagrammatically in Fig. 1 comprises, in Fig. 2, resistance 11, choke coil 12, variable resistance 13 and condensers 14 and 15.

With a sufficiently large input the negative bias on the control electrode of control tube 6 is reduced so that controlling action results. That is, under those circumstances the internal impedance of tube 6 is reduced and, as its anode current passes through the anode impedance or resistance 7 of amplifier tube 2, a change occurs

in the effective value of the anode impedance or load of tube 2 which latter consists of the resistance 7 in parallel with the control tube 6. The latter effect lessens the amplifying effect of tube 2 on the input supplied to it through condenser 10.

The speed of control is varied by varying resistance 13. The reason why variation of resistance 13 will control the speed of operation of the apparatus may be explained as follows. When a high input which has been applied is suddenly removed, and assuming that the condensers 14 and 15 remain charged, the charge on condenser 14 can only leak through high resistance 11, as the impedance of the rectifier tube 4 is high. Condenser 15 can only leak through the series combination of variable resistance 13, choke 12, and resistance 11, since the internal impedance of the control tube is also high.

When the rectifier impedance is low, as for example when a large voltage is supplied by transformer 9 to rectifier 4, then the charge on condenser 14 can leak off across it. However, condenser 15 will still have to discharge through resistance 13 which may be varied to control its speed of discharge. Hence the speed at which the bias on the control electrode of tube 6 varies may be adjusted as desired by the manipulation of resistance 13.

When a strong signal is applied to the amplifiers 3, condensers 14 and 15 will become highly charged and because of the reduced control electrode or grid bias on tube 6, control tube 6 will have its impedance reduced. If this strong signal is suddenly cut off the impedance of rectifier 4 will increase rapidly. Condensers 14 and 15 will retain their charge until resistors 11 and 13 discharge them. As a result the control tube grid bias will remain momentarily reduced and the amplification of controlled tube 2 low. The placing of a resistance 16, of a higher order of magnitude than resistance 11, across the anode to cathode circuit of rectifier 4 decreases the time of discharge in this case, and makes the controlling action more uniform. Of course, the speed of action can still be manually controlled by adjusting resistance 13 which determines the discharge rate of condenser 15.

An ammeter A may be placed in the output circuit of tube 6 to indicate its operation. A resistance 17 may also be placed in the anode circuit of tube 6 which will prevent overcontrol when the control tube anode impedance becomes too low relative to anode impedance 7. Resistance 18 may be placed in the anode circuit of amplifier tube 2 for the purpose of preventing distortion which would otherwise occur when the control tube anode impedance becomes too low. It may also be found necessary to place a grounded shield about rectifier 4 in order to prevent distorted signals from getting into amplifier 2. The voltages indicated in Fig. 2 are those which have been found to be satisfactory in practice. Resistances 20 are used to obtain correct voltages for the tube filaments.

The ratio of the input voltage to output voltage of the device can be caused to vary as shown in Figs. 3, 4 and 5. Dotted curve A of Fig. 3 shows the ratio of output to input voltage when there is no control of the anode static potential acting on the amplifier tube 2. Curve B of Fig. 3 illustrates a condition of insufficient control. The curve shown in Fig. 5 shows a condition of overcontrol. The condition illustrated in Fig. 4 is the most useful one, and shows how the output voltage remains uniform over a wide range when the input varies widely. The characteristics of Figs. 3, 4 and 5 may be obtained by a suitable choice of values for elements 7, 17 and 18.

It is to be understood that while the invention is especially adapted for use with audio frequency currents it may, if desired, be utilized in a radio frequency amplifying system. Furthermore, it is to be understood that although one form of the invention has been disclosed various changes may be made, as will readily occur to one skilled in the art without departing from the spirit and breadth of the invention and accordingly it is to be understood that the invention is not to be limited by the illustrations and description thereof but is to be given such scope as indicated in the appended claims.

The invention having thus been described what is claimed is:—

1. In an amplifying system an electron discharge device comprising an anode, a cathode and a control electrode, means to apply energy variations to said device, means for rectifying a portion of an alternating current to be amplified by said device and means including a control tube to vary the effective anode load of said device according to the amplitude of the rectified current.

2. In an amplifying system, a vacuum tube amplifier, means to apply alternating current to the control electrode of said tube, means for producing a direct current whose value is determined by the amplitude of said alternating current and means including an electron discharge tube to apply said direct current to said vacuum tube to control the anode potential thereof.

3. In an amplifying system a vacuum tube amplifier, means to apply an alternating current to the input circuit of said amplifier, a rectifier, means to apply said alternating current to said rectifier, thereby producing a rectified direct current and means including an electron discharge path to control the static potential of the anode of said vacuum tube amplifier in accordance with the amplitude of the rectified direct current, said path being independent of said amplifier tube.

4. An alternating current amplifier comprising a vacuum tube having an anode, a cathode and a control electrode, an impedance in the anode circuit of said tube, another vacuum tube shunting said impedance, means for applying a portion of the alternating current to said first mentioned tube, means for rectifying another portion of said alternating current, and means for applying to the control electrode of the tube shunting said impedance, the direct current component of said rectified alternating current.

5. An audio frequency amplifier comprising a three electrode vacuum tube, a resistance in the output circuit of said tube, a control vacuum tube shunting said resistance, means for applying a portion of an alternating current to be amplified to the control electrode of said first mentioned vacuum tube, means for rectifying another portion of said alternating current and means for applying the uni-directional component of the rectified current to the control electrode of said control tube whereby the anode resistance of said first mentioned tube is varied in accordance with the strength of the rectified current.

6. In an amplifying system, an electron discharge device comprising an anode, a cathode and a control electrode, means to apply an alternating current to be amplified to said device, means for rectifying a portion of the alternating cur-

rent to be amplified by said device, means to vary the effective anode impedance of said device according to the amplitude of the rectified current, and means to control the speed at which said anode impedance is varied.

7. In an amplifying system, an electron discharge device comprising an anode, a cathode and a control electrode, means to apply an alternating current to be amplified to said device, means for rectifying a portion of an alternating current to be amplified by said device, means to vary the effective anode impedance of said device according to the amplitude of the rectified current, and means to control the speed at which said anode impedance is varied, said last mentioned means comprising a variable resistance.

8. An audio frequency amplifier comprising a three electrode vacuum tube, a resistance in the output circuit of said tube, a control vacuum tube shunting said resistance, means for applying a portion of an alternating current to be amplified to the control electrode of said first mentioned vacuum tube, means for rectifying another portion of said alternating current, means for applying the uni-directional component of the rectified current to the control electrode of said control tube whereby the anode resistance of said first mentioned tube is varied in accordance with the strength of the rectified current and means for controlling the speed at which said anode resistance varies.

9. An audio frequency amplifier comprising a three electrode vacuum tube, a resistance in the output circuit of said tube, a control vacuum tube shunting said resistance, means for applying a portion of an alternating current to be amplified to the control electrode of said first mentioned vacuum tube, means for rectifying another portion of said alternating current, means for applying the uni-directional component of the rectified current to the control electrode of said control tube whereby the anode resistance of said first mentioned tube is varied in accordance with the strength of the rectified current, and means for controlling the speed at which said anode resistance varies, said means comprising a variable resistance and a condenser.

10. The method of operating an electric circuit including an electron discharge device for amplifying an alternating current which consists in rectifying a portion of the alternating current to be amplified, applying the uni-directional current component of the rectified current to the anode circuit of the device to control the load thereof, and regulating the speed at which said load is controlled.

11. In an amplifying system, an electron discharge tube including a plurality of electrodes, means to apply alternating current to the control electrode of said tube, means for producing a direct current whose value is determined by the amplitude of said alternating current, means to apply said direct current to said tube to control the anode potential thereof, and means to control the rate at which said potential is varied.

12. A method of controlling the amplification of a vacuum tube amplifier which consists in rectifying a portion of the input energy, applying the direct current component of the rectified energy to the anode circuit of the tube to determine the static potential thereof, and controlling the rate at which the potential is developed.

13. The method of varying the amplification of an audio frequency vacuum tube amplifier which consists in producing current whose amplitude is proportional to the envelope of the alternating input energy applied to the tube, in adjusting the static anode potential in accordance with the amplitude of the current so produced, and controlling the rate at which the potential is adjusted.

14. The method of operating a translating circuit, including a multi-electrode vacuum tube, which consists in applying the input energy to the tube, rectifying a portion of the input energy before it is applied to the tube, controlling the static potential of the anode of the tube by means of the rectified energy so that the circuit will discriminate against input energies having amplitudes varying from a predetermined value, and regulating the rate of control of said potential.

15. An amplifier comprising a space discharge tube, a variable impedance path in shunt with the anode circuit of the tube, said path including an electron discharge device, a rectifier, a source of alternating current to be amplified connected to the inputs of said rectifier and tube, the output of said rectifier being connected to the input of said device.

16. An amplifier comprising a space discharge tube, a variable impedance path in shunt with the anode circuit of the tube, said path including an electron discharge device, a fixed impedance connected to the anodes of said tube and device, a rectifier, a source of alternating current to be amplified connected to the inputs of said rectifier and tube, the output of said rectifier being connected to the input of said device.

17. An amplifier comprising a space discharge tube, a variable impedance path in shunt with the anode circuit of the tube, said path including an electron discharge device, a resistor connected to the anode of said device, a rectifier, a source of alternating current to be amplified connected to the inputs of said rectifier and tube, the output of said rectifier being connected to the input of said device.

18. An amplifier comprising a space discharge tube, a variable impedance path in shunt with the anode circuit of the tube, said path including an electron discharge device, an impedance being disposed in the output of the device, a rectifier, a source of alternating current to be amplified connected to the inputs of said rectifier and tube, the output of said rectifier being connected to the input of said device.

19. In combination with an audio frequency amplifier circuit comprising an amplifier tube provided with an input and output circuit, and means for transmitting alternating current energy to be amplified from a source of such energy to the input of said tube, a device for controlling the gain of said amplifier tube including a rectifier tube having its input coupled to said source, a control tube having its input coupled to the rectifier output and its output in shunt with said amplifier tube output, and an impedance common to the anode circuits of said control and amplifier tubes.

20. In combination with an audio frequency amplifier circuit comprising an amplifier tube provided with an input and output circuit, and means for transmitting alternating current energy to be amplified from a source of such energy to the input of said tube, a device for controlling the gain of said amplifier tube including a rectifier tube having its input coupled to said source, a control tube having its input coupled

to the rectifier output and its output in shunt with said amplifier tube output, an impedance common to the anode circuits of said control and amplifier tubes and an amplifier connected between said source and said rectifier input.

21. In combination with an audio frequency amplifier circuit comprising an amplifier tube provided with an input and output circuit, and means for transmitting alternating current energy to be amplified from a source of such energy to the input of said tube, a device for controlling the gain of said amplifier tube including a rectifier tube having its input coupled to said source, a control tube having its input coupled to the rectifier output and its output in shunt with said amplifier tube output, an impedance common to the anode circuits of said control and amplifier tubes and a network for adjusting the speed of gain control connected between said rectifier output and said control tube input.

22. In combination with a source of alternating current energy to be amplified and an amplifier tube having its input connected to said source, a gain control circuit having its input coupled to said source and including a control tube connected to the amplifier tube in such a manner that the internal impedances of the tubes are in shunt, a common path, including a fixed impedance, for supplying a desired potential to the anodes of the control and amplifier tubes, and a rectifier connected between said source and said control tube input.

23. In combination, in an automatic gain control circuit for an amplifier, an amplifier tube having its input electrodes connected to a source of energy to be amplified, a gain control tube, a common path for connecting the anodes of said amplifier and control tubes to a source of positive potential, and means for impressing on the input of said control tube control energy derived from said source whereby the internal impedance of said control tube is adjusted to vary the anode circuit impedance of said amplifier in a predetermined manner with respect to variations of said source energy.

24. In combination with a source of alternating current energy to be amplified and an amplifier tube having its input connected to said source, a gain control circuit having its input coupled to said source and including a control tube connected to the amplifier tube in such a manner that the internal impedances of the tubes are in shunt, a common path, including a fixed impedance, for supplying a desired potential to the anodes of the control and amplifier tubes, and a rectifier connected between said source and said control tube input, and a visual current indicator in the anode circuit of said control tube.

25. In combination with an amplifier tube having an input circuit and an output circuit, means for impressing a signal modulated alternating current upon said input circuit, an automatic gain control arrangement for said amplifier comprising means for producing a direct current voltage whose value is dependent upon the amplitude of said alternating current, and means, including an electron discharge tube responsive to said voltage, for varying the anode potential of said amplifier tube.

26. In combination with an amplifier tube having an input circuit and an output circuit, means for impressing a signal modulated alternating current upon said input circuit, an automatic gain control arrangement for said amplifier comprising means for producing a direct current voltage whose value is dependent upon the amplitude of said alternating current, and means, including an electron discharge tube responsive to said voltage, for varying the anode potential of said amplifier tube in a direction to maintain the alternating current amplitude in said output circuit substantially constant regardless of amplitude variations in said input circuit.

27. In combination with a signal amplifier whose gain is to be automatically regulated, a path including a signal input circuit and resistor connected in series between the cathode and cold electrode of a diode, an electron discharge tube including a cathode, grid and cold output electrode, means for normally maintaining the grid of said tube negative with respect to its cathode, connections between said resistor and the grid and cathode of said tube, said tube grid being connected to a point on said resistor such that the negative direct current voltage of said grid with respect to said tube cathode decreases when the signal amplitude to the diode rectifier increases.

28. In combination with a signal amplifier whose gain is to be automatically regulated, a path including a signal input circuit and resistor connected in series between the cathode and cold electrode of a diode, an electron discharge tube including a cathode, grid and cold output electrode, means for normally maintaining the grid of said tube negative with respect to its cathode, connections between said resistor and the grid and cathode of said tube, direct current connections between the output electrode and cathode of said tube and the cathode and a cold electrode of said signal amplifier whereby variations in conductivity of said tube result in changes in the gain of said amplifier, said tube grid being connected to a point on said resistor such that the negative direct current voltage of said grid with respect to said tube cathode decreases when the signal amplitude to the diode rectifier increases.

29. In an alternating current transmission system, a controlled tube having at least a cathode and two cold electrodes, means for impressing alternating current energy on one of the cold electrodes, a rectifier tube including a cathode and at least one cold electrode, a path including an alternating current input circuit and a resistor in series connected between the cathode and cold electrode of said rectifier, a control tube including a cathode, grid and positive cold electrode, means for maintaining the grid of the control tube highly negative with respect to the cathode thereof with minimum alternating current input to said rectifier, a direct current connection between the control tube grid and a point on said resistor which becomes increasingly positive with respect to the control tube cathode as the alternating current input to the rectifier increases, and a direct current connection between the positive electrode of said control tube and one of the cold electrodes of said controlled tube.

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