Oct. 27, 1936. H. FRIEDRICH 2,058,972

GAIN CONTROL CIRCUITS

Filed May 14, 1934

Fig. 1

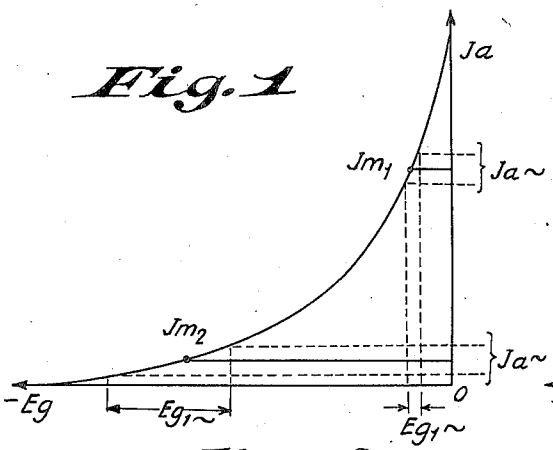


Fig. 3

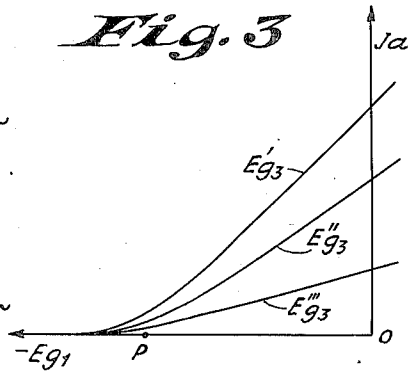


Fig. 2

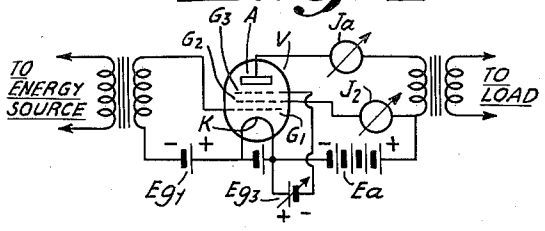


Fig. 6

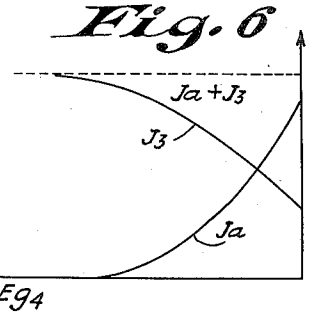


Fig. 4

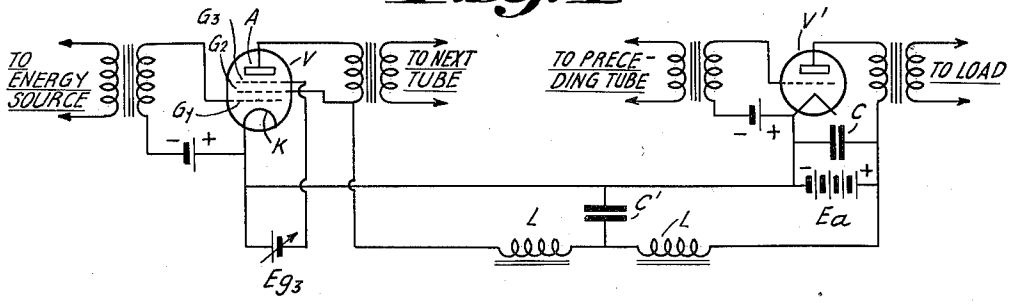
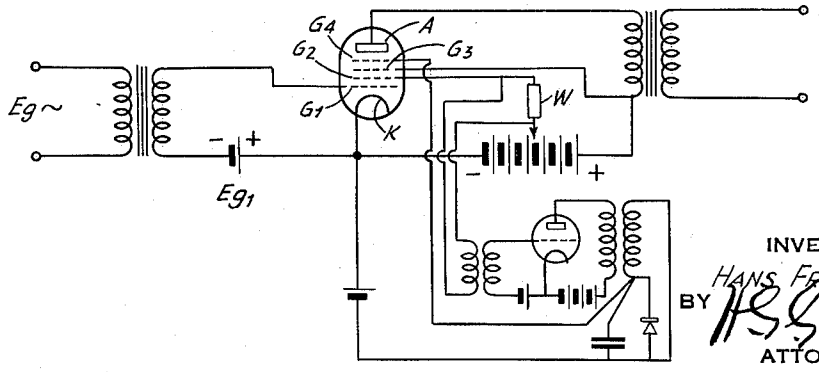


Fig. 5



INVENTOR
HANS FRIEDRICH
BY
ATTORNEY

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GAIN CONTROL CIRCUITS

Hans Friedrich, Berlin, Germany, assignor to Telefunken Gesellschaft für Drahtlose Telegraphie m. b. H., Berlin, Germany, a corporation of Germany

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In Germany May 2, 1933

6 Claims. (Cl. 250—20)

The present invention is concerned with a circuit scheme which is adapted to insure automatic gain or volume control, comprising the use of electron tubes furnished with five or more electrodes.

A necessity for amplification control arises in connection with various kinds of work. Known from the prior art, for instance, is the control or regulation of the gain in receiver apparatus which are to produce a stable and constant acoustic volume in spite of variations in the input voltage. For other reasons regulation of the volume is required, e. g., in making disk records for phonographs, in the photographic recording of sound and in the modulation control of transmitters. The volume of sound of an orchestral program varies roughly inside the limits between 1 and 1000. In the recording of phonograph records there exists a lowermost acoustic volume limit or level which is imposed by the needle noise and below which one should not go. The uppermost limit is fixed by the inter-groove or track distance. However, in this manner it is possible only to arrive at an acoustic-volume ratio of about 1:50.

Hence, it is necessary to diminish the natural sound-volume ratio between the lowest and the loudest passages or notes (socalled volume-ratio) from 1:1000 to a value around 1:50. If the assumption be made that the median amplitude shall not be affected by the regulation or control action, it follows that subdued passages must be amplified more, comparatively speaking, than loud passages. The situation is similar, for instance, in the modulation of a broadcasting station; the percentage modulation in the case of low passages, with due regard for the interfering or side (background) noises in the receiver apparatus and atmospherics should not be too low, while, on the other hand, all chances of over-modulation should be carefully avoided on account of the distortions associated therewith.

Figures 1, 3, and 6 are curves illustrating the invention.

Figures 2, 4, and 5 are fragmentary circuit diagrams embodying the invention.

Regulation of the gain has heretofore been insured principally in amplifier stages containing exponential-type tubes especially suited for this purpose; in other words, tubes whose characteristic curve, as shown in Fig. 1, have an approximately negative-logarithmic form and which extends far into the negative grid biasing voltage region. Regulation is insured, as well known in the art, by reduction of the biasing voltage of the control grid. In this method, two disadvantages become evident. In the first place, there occurs a marked fluctuation of the means anode current Ja, as can be readily seen from Fig. 1. Jm_1 is the mean anode current, in the presence of low grid biasing voltages and high gain, while Jm_2 is a working point corresponding to a high grid biasing potential and small slope. In the second place, a relatively high regulating voltage is required in order to be able to cover the entire range of the slope.

Now, the purpose of the present invention is to obviate the said two drawbacks by the aid of a novel type of circuit arrangement for a tube containing five or more electrodes. Referring to Fig. 2, V represents an amplifier tube comprising a directly heated or an indirectly heated cathode K, an anode or plate A, a control grid G1, a screen grid G2, and an additional grid G3 (cathode or suppressor grid). Plotting the characteristic curve of such a tube in which the anode or plate current Ja is plotted against the grid voltage Eg_1, with the voltage Eg_3 being negative and constant for a given characteristic curve, there results a family of characteristics of different slopes or mutual conductances which intersect approximately at the point P of the abscissa axis, as shown in Fig. 3. The slope of the various characteristic curves is here a function of the voltage of the third grid. This indicates a chance of regulating the gain by variations of the voltage Eg_3 as a function of the amplitude of the input alternating voltage.

Inasmuch as the characteristics are essentially rectilinear over a major portion thereof, there results this advantage that, also for large amplitudes, non-distorted amplification is practicable, while in the case of the exponential curves shown in Fig. 1 this is feasible only to a substantially lower degree. It is also found that the regulating voltage which is required for gain control between definite limits, is considerably lower in the present novel mode of slope variation than in the case of exponential tubes (e. g., 5 volts compared with 30 v.).

In order to explain more clearly the effect of a change in the mean plate current as a result of gain control, reference is here made to Fig. 4, where V is the regulated amplifier tube, as explained in more detail by reference to Fig. 2, whereas V' is the end or power stage of the amplifier. For all of the tubes there is provided a joint anode source Ea. Although the resistance of this source of potential is comparatively low, and although it is further reducible by the parallel

connection of a blocking condenser C, there nevertheless happens a reaction upon the input stages by way of the voltage source, because of the size of the alternating voltage amplitudes arising in the end or power stage, unless special filter sections L and C′ are connected in the plate lead of the input stages. This filter chain has a time-constant or resonance frequency governed by its dimensions, and this is an impediment to a quick change in the mean plate current of the regulator stage V. By the adoption of a number of steps it has been ascertained that the transition from one extreme of the amplification or gain to the other must be accomplishable inside an extremely brief space of time, lest appreciable distortion become noticeable.

This drawback is obviated according to this invention by that the screen grid G2 is connected with the plate potential. The grid G3 insures a control action, without itself consuming any current, upon the distribution of the current emitted from the cathode between the screen grid G2 and the anode A. Hence, if for instance, the mean plate current is diminished as a result of an increase in the negative biasing voltage of the regulator grid G3 (curve Eg_3 in Fig. 3), then the screen grid current will grow a similar amount. Consequently, the aggregate current Ja+J2 (Fig. 2) derived from the plate-current source remains approximately constant, and the time-constant of the filter LC′ plays no part at all.

The operation and effect of the regulating stage before described is still further improvable by the use of a six-electrode tube (hexode) being used in a circuit scheme as shown in Fig. 5. In addition to the cathode K and the anode A, this tube contains further four grid-type electrodes. G1 designates again the control grid upon which is impressed the input voltage Eg to be amplified. The grids G2 and G3 both act as screen grids, whereas the grid G4 is employed to act as a regulator electrode in a way previously described. Upon the second screen-grid G3 is again impressed the plate direct voltage, whereas the first screen grid G2 is advantageously connected with a lower positive voltage. Owing to the fact that ahead of the grid G3 there is mounted a further screen grid, a still better stabilization of the aggregate current which is taken from the plate-potential source is secured.

This is illustrated by Fig. 6 where the current J3 of the second screen grid G3 and the plate current Ja is plotted in dependence upon the regulator voltage Eg_4. There is moreover a chance to insert in the circuit of the first screen grid G2 a useful resistance W which may be rendered serviceable for various purposes. For instance, at this particular place a supervising (monitor) telephone may be inserted, or else the resistance W may serve for the connection of a branch amplifier which serves either for controlling or supervising purposes, or which may be used in combination with a rectifier for furnishing the regulator voltage Eg_3. It goes without saying that the circuit scheme here disclosed may analogously be applied to push-pull stages whereby non-linear distortions are avoidable.

While I have indicated and described several arrangements for carrying my invention into effect, it will be apparent to one skilled in the art that my invention is by no means limited to the particular constructions shown and described, but that many modifications may be made without departing from the scope of my invention as set forth in the appended claims.

What is claimed is:

1. In combination, a source of electric waves, a wave transmission tube provided with a cathode, anode and at least three grids interposed between them, said source being connected to said cathode and one of the grids, means for maintaining said one grid at substantially constant negative direct current potential, a source of direct current voltage, means for connecting the said anode and a second one of the grids to a common positive voltage point on said second source, means for varying the potential of the third of the grids with a direct current voltage in response to changes in amplitude of said waves, said third grid being disposed adjacent the said anode, and said second grid being disposed between the first and third grids whereby variation of said third grid potential has substantially no effect on the total current flowing to said plate and second grid from said direct current source.

2. In combination, a source of electric waves, a wave transmission tube provided with a cathode, anode and at least three grids interposed between them, said source being connected to said cathode and one of the grids, a source of direct current voltage, means for connecting the said anode and a second one of the grids to a common positive voltage point on said second source, means for varying the potential of the third of the grids with a direct current voltage in response to changes in amplitude of said waves, said third grid being disposed adjacent the said anode, and said second grid being disposed between the first and third grids, and an auxiliary electrode disposed between the first and second grids, the electrode being maintained at a positive voltage which is lower than that of the said anode.

3. In combination, a source of electric waves, a wave transmission tube provided with a cathode, anode and at least three grids interposed between them, said source being connected to said cathode and one of the grids, a source of direct current voltage, means for connecting the said anode and a second one of the grids to a common positive voltage point on said direct current source, means for varying the potential of the third of the grids with a direct current voltage in response to changes in amplitude of said waves, said third grid being disposed adjacent the said anode, and said second grid being disposed between the first and third grids, said varying means comprising an auxiliary electrode disposed adjacent the said first grid, and a wave rectifier circuit operatively associated with said auxiliary electrode and said third grid.

4. In an electric wave amplifying system of the type including a source of waves and a tube provided with a cathode, an anode and four successive grids disposed between the anode and cathode, means for maintaining the anode and two of the grids at positive potentials, said source being connected between the cathode and a third grid, and a wave rectifier circuit having its input coupled to one of said positive grids to derive wave energy therefrom for rectification, and means for connecting the fourth grid to a direct current voltage point in the rectifier circuit whose potential magnitude is a function of the wave amplitude.

5. In a system as defined in claim 4, the fourth grid being disposed adjacent the anode and between the latter and one of the positive grids.

6. In combination in an audio frequency amplifier, a source of waves to be amplified, a wave amplifier tube provided with a cathode, an anode,

and at least three control electrodes interposed between them, said wave source being connected to the cathode and one of the control electrodes, a source of direct current voltage, means for connecting the said anode and a second one of said control electrodes to a common positive potential point on said second source whereby they are maintained at the same positive direct current voltage with respect to the cathode, said one control electrode being disposed between the cathode and said second control electrode, the third control electrode being disposed between the second control electrode and said anode, means, responsive to variations in amplitude of waves from said source, for varying the direct current potential of said third control electrode over a range of potentials which are negative with respect to said cathode, and means for maintaining said first control electrode at a substantially constant negative direct current potential with respect to the cathode.

HANS FRIEDRICH.