

Oct. 20, 1936.

K. STEIMEL ET AL

2,057,857

VARIABLE GAIN AMPLIFIER ARRANGEMENT

Filed Dec. 13, 1933

2 Sheets-Sheet 1

Fig. 1a

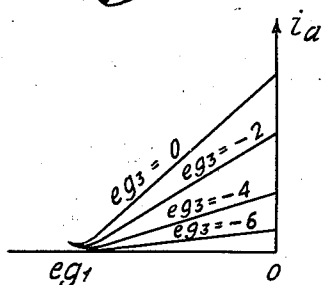


Fig. 1

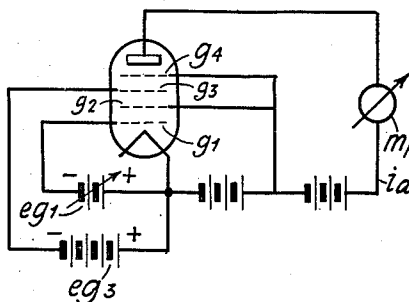


Fig. 2

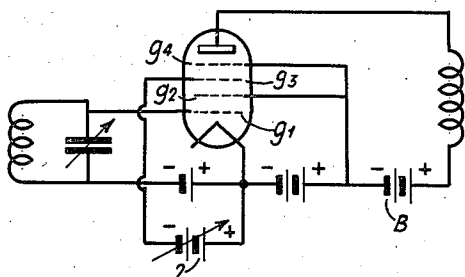


Fig. 3

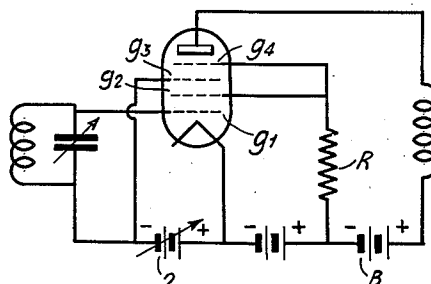
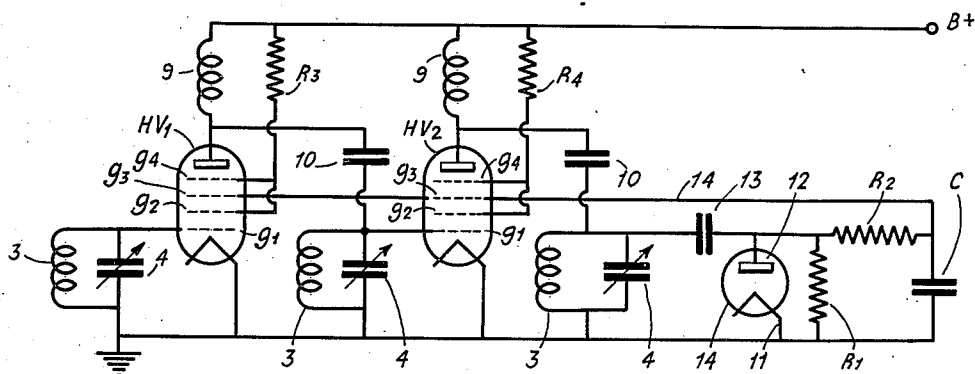


Fig. 4



INVENTOR
KARL STEIMEL
ERNST KLOTZ
BY *J. E. Scherer*
ATTORNEY

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Fig. 5

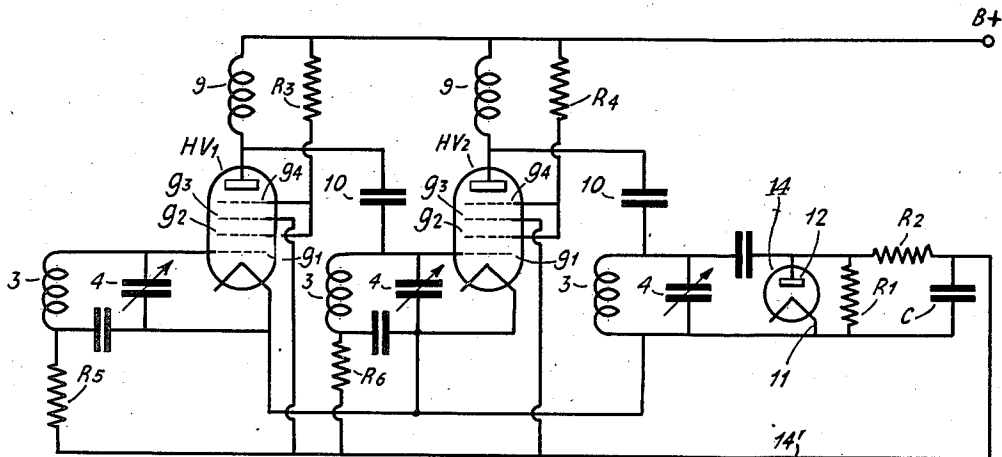


Fig. 6

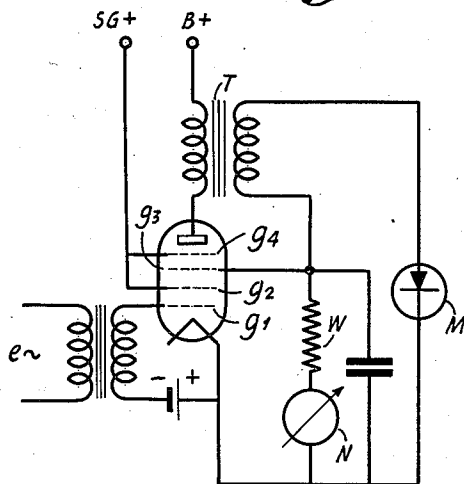
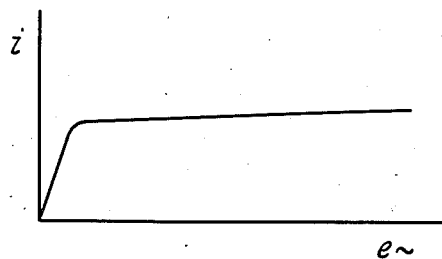


Fig. 7



INVENTOR
KARL STEIMEL
ERNST KLOTZ
BY *H. S. Hoover*
ATTORNEY

UNITED STATES PATENT OFFICE

2,057,857

VARIABLE-GAIN AMPLIFIER ARRANGEMENT

Karl Steimel and Ernst Klotz, Berlin, Germany,
assignors to Telefunken Gesellschaft für
Drahtlose Telegraphie m. b. H., Berlin, Ger-
many, a corporation of Germany

Application December 13, 1933, Serial No. 702,161
In Germany December 27, 1932

13 Claims. (Cl. 250—20)

An object of our invention is to provide a novel amplifying arrangement using a screen grid tube and more especially one in which an auxiliary grid maintained at a negative voltage with respect to the cathode is situated between the screen grid and the anode.

A second object of the invention is to provide in an amplifier as described a second screen grid located between the auxiliary grid and the plate.

A still further object is to adjust the voltage applied to the auxiliary grid, or to both it and the control grid, in accordance with the strength of the incoming signal in such a manner that the output volume of the receiver or amplifier remains substantially constant. Other objects will become apparent to those skilled in the art as the description thereof proceeds. For a better understanding of the invention reference is made to the accompanying drawings, in which,

Fig. 1 is a schematic circuit diagram of an amplifier constructed according to our invention,

Fig. 1a shows certain current characteristic curves of a tube embodying the invention,

Figs. 2 and 3 show arrangements for changing the bias on the grids of an amplifier made according to our invention,

Figs. 4 and 5 show circuit arrangements for securing automatic volume control using tubes made according to our invention,

Fig. 6 shows an audio amplifier arrangement constructed in accordance with our invention, and

Fig. 7 shows the gain control characteristic of the amplifier of Fig. 6.

Screen-grid tubes are known in the prior art which, between the screen grid and the plate, contain an additional grid which, as a general rule, is kept at cathode potential. It is also known in the art that in radio frequency amplifiers equipped with tubes of the said sort, the said auxiliary grid (called also a "collector" grid) is impressed with a regulable voltage, for the purpose of enlarging the resonance curve in local reception. For if a negative biasing voltage is impressed upon the collector grid, a retarding or brake effect is set up in the space between the screen grid and the said collector grid which results in an accumulation of a space-charge in front of the collector grid. Inasmuch as the effect or action of the plate across the collector grid is comparatively large, small voltage variations at the plate will be causative of considerable plate-current variations with the

result that the alternating current resistance assumes small values.

With the building up of a space-charge in front of the collector grid there is associated a change in the current branching or distribution between screen grid and plate. In the presence of zero voltage at the collector grid, the major part of the electron current regulated by the control-grid voltage will flow towards the anode, and only a small portion to the screen grid. The farther the collector-grid voltage is pushed into the negative region, the greater will be the number of electrons that are compelled in front of the collector grid to become reversed and return toward the cathode, and the result is that the screen-grid current grows at the expense of the plate current. If, then, the total electronic current is varied by the signal control grid, it will be seen that in line with what has been stated previously, only a part of this will affect the plate current, and the remainder the screen-grid current; but this means that the slope (mutual conductance) representing the ratio between plate-current change to collector-grid voltage variation is a function of the regulation or value of the collector-grid potential. Now, inasmuch as the gain is essentially a function of this slope, there would result a very simple method of gain regulation, if it were not for the fact that a change in the collector-grid voltage is attended with the drawback above referred to and results in a fall of internal resistance. This shortcoming according to the present invention is obviated as follows:

A four-grid tube is utilized in this manner, that three grids take care of the former mentioned functions of the control grid, screen grid, and collector grid, while the fourth grid constituting another screen-grid is situated between the collector grid and the plate. Now, the system comprising the space-charge in front of the collector grid, collector grid proper, second screen grid, and plate, may again be considered as a normal screen-grid tube. The trans-grid action of the plate potential upon the space-charge built up in front of the collector grid can be rendered very small by the second screen grid, so that the risk of an unduly low internal resistance of the plate circuit is avoided.

The principle hereinbefore described requires the use of at least four grids, though by the introduction of additional grids nothing is altered in the principle before outlined, for instance, by making one of the grids of the multiple kind, by

introducing a space-charge grid for raising the slope, etc.

The characteristic of a tube operating on the above principle is shown in Fig. 1a. The abscissa axis indicates the voltage of the control grid e_{g1} , the ordinate the plate current, i_a . The voltage of the collector or auxiliary grid e_{g3} is the parameter. If the voltage e_{g3} shifts into the negative region, then the slope or transconductance,

$$\frac{di_a}{de_{g1}}$$

decreases. It is seen that a greater change in plate current results from a change in voltage of grid $g3$ than from an equal change in voltage of control grid $g1$. The circuit arrangement employed for plotting the characteristic is represented in Fig. 1.

The arrangement hereinbefore described offers this advantage over others that with the use of appropriately dimensioned tubes, the regulating voltages required for gain control amount to only a few volts, whereas the so-called variable mu tubes serving for the same purpose require regulating potentials up to 40 volts. To make available such high regulating voltages demands high radio frequency amplification and the use of an additional audio amplifying stage, unless recourse is had to plate potential variation in an anode rectifier next above the amplifier. In this latter instance, however, certain artificial circuit schemes are needed for insuring the proper static potential in the amplifier control grid.

In view of the fact that the smallest gains are required when the highest alternating current voltages are impressed upon the control grid of the amplifier stage to be made subject to control, it may be of advantage to insure for this case an increase in the modulating range. This is accomplishable in a simple manner by not only controlling the voltage of the auxiliary grid e_{g3} alone as in (Fig. 2), but also the voltage of the signal control grid e_{g1} (Fig. 3) is shifted into the negative region. If the signal control-grid voltage is made more negative, then also the screen-grid current will decrease. Owing to the diminished voltage drop across the resistance R in the screen-grid lead, there occurs a rise in the screen-grid potential, i. e., the modulation range is enlarged. In this case, as will be seen, regulation of the slope is secured by the auxiliary-grid voltage e_{g3} by a source of variable voltage 2, adjustment of the working point by the control-grid voltage e_{g1} , and adjustment of the modulation range by the "concurrent" screen-grid voltage.

In a great many instances it is desirable to insure automatic regulation or control of the gain, the latter to be a function of the alternating voltage impressed upon the signal control grid. Circuit arrangements of this kind predicated upon a principle as here outlined can be carried into practice in a similar way as with the tubes heretofore employed for these purposes in that the radio frequency amplifier is followed by a rectifier whose direct current component, which is a function of the amplitude of the alternating voltage fed to the rectifier, is used directly or indirectly as a voltage regulator. The ensuing circuit schemes because of the low regulating voltages that are required, can be easily followed up and require only little expenditure of material. Examples of circuit arrangements of this kind are illustrated in Figs. 4 and 5.

Fig. 4 shows a circuit arrangement containing a two-stage radio frequency amplifier in which

only the voltage e_{g3} of the auxiliary grids (third grid looking away from the cathode) is regulated. The incoming currents amplified in the amplifier tubes HV1 and HV2 are rectified in a diode 14. The fall of voltage occasioned across resistance $R1$ is fed through a filter $R2C$ and lead 14' to the auxiliary grid $g3$ of each amplifier. In the leads brought to the parallel connected screen grids $g2$ and $g4$ are contained the resistances $R3$ and $R4$ intended to enlarge the modulation range. In the arrangement shown the coils 3 in the control grid circuits may be tuned to the signal frequency by condensers 4, the signal currents being applied to coil 3 of the first amplifier by any means well known to the art. As shown the stages are connected by choke coils 9 in the plate circuits and condenser 10 and the amplified current may be impressed on the plate 12 of the diode detector through a condenser 13, the resistor $R1$ being shunted across the heated cathode 11 and plate 12 of the detector.

Fig. 5 shows the same general circuit arrangement though expanded insofar as also the biasing voltage of the two signal control grids $g1$ is tapped on resistance $R1$, resistors $R5$ and $R6$ being connected between lead 14' and the control grids. In each of the receiver systems shown in Figs. 4 and 5 the diode detector may be coupled to any type of audio frequency net-work, well known to those skilled in the art, for utilizing the audio component of rectified signal currents.

Also for audio frequency purposes the principle here described offers chances for practical application. As an example may be cited a bridge measurement in which the exact balance thereof is insured by the aid of an amplifier. The marked amplitude differences in the vicinity of the zero point and when the bridge balance is markedly disturbed require, as a general rule, readjustment of the measuring ranges of the indicator instruments. By the use of an automatically controlled amplifier stage in conjunction with a rectifier and, for instance, reading of adjustment by measuring the direct current component of the rectifier, these difficulties can be readily obviated. A circuit arrangement along these lines is shown in Fig. 6.

The alternating voltage is impressed upon the control grid $g1$ of the tube. The amplified alternating voltage is fed by way of a transformer T to a rectifier M which furnishes to the resistance W the voltage for the auxiliary grid $g3$. The relation between the direct current i as read in the meter N and the alternating potential e to be amplified is plotted in Fig. 7. The screen grids $g2$ and $g4$ are connected to a common constant voltage source $+SG$.

Having described our invention, what we desire to secure by Letters Patent is:

1. In a device for amplifying alternating currents, the combination of a vacuum tube having a cathode, a signal control grid, an anode, a screen grid located between said control grid and anode, an input circuit connecting said signal control grid and cathode, an output circuit connecting said anode and cathode, means for impressing a positive potential less than that of said anode on said screen grid, an auxiliary grid located between said screen grid and anode and means for impressing a voltage negative with respect to said cathode on said auxiliary grid, an additional screen grid being located between said auxiliary grid and said anode, and means for applying a positive potential to said last named screen grid.

2. In an amplifying device, the combination of a vacuum tube having a cathode, a signal control grid, an anode, a screen grid located between said control grid and said anode, an input circuit connecting said signal control grid and cathode, an output circuit connecting said anode and cathode, an auxiliary grid located between said screen grid and anode, means for applying a negative bias of variable amount to said auxiliary grid, a second screen grid located between said auxiliary grid and anode, and a connection between said screen grids and a positive source of potential arranged to apply substantially the same high voltage to both said screen grids.

3. In an amplifying device for alternating currents, the combination of a plurality of vacuum tube amplifiers connected in cascade, at least one of said stages comprising a tube having a cathode, a signal control grid, a screen grid, an auxiliary grid and a plate arranged in the order named, a signal input circuit connecting said signal control grid and cathode, an output circuit connecting said plate and cathode, a diode detector coupled to said output circuit and a circuit connection between the plate of said detector and the auxiliary grid of said amplifier arranged to control the voltage of said grid in accordance with the amplified voltage applied to said detector.

4. In an amplifying device for alternating currents, the combination of a vacuum tube amplifier having a cathode, a signal control grid, a screen grid, an auxiliary grid, a second screen grid and a plate arranged in the order named, an input circuit connecting said signal control grid and cathode, an output circuit connecting said plate and cathode, means for impressing a positive potential on both of said screen grids, a diode detector comprising a cathode and plate, a connection between the cathodes of said amplifier and detector, a resistor connected to the plate and cathode of said detector and a connection between the end of said resistor connected to said diode plate and the auxiliary grid of said amplifier whereby said grid assumes a negative bias voltage.

5. An audio amplifier including a tube having input and output circuits, said tube having at least a cathode, anode, a positive screen grid, a signal grid, and a gain control grid, said screen grid being disposed between the signal and gain control grids, means for varying the negative bias of the gain control grid over a range of values to regulate the gain of the amplifier and a source of audio signals connected to the signal grid.

6. In combination with a source of wave energy, an amplifier having at least three grids, one of the grids being a positive screen, the other grid being a gain control grid, and the remaining grid being coupled to the said wave source, said gain control grid being disposed between the screen and plate, said tube having an effective plate current-wave grid voltage characteristic whose slope depends on the bias of said gain control grid, the potential range of the wave grid available for waves being substantially independent of the gain control grid bias, and means for varying the bias of the gain control grid over a range of negative values to regulate the flow of current in the plate circuit of said tube, impedance means in circuit with the positive screen whereby the screen voltage increases when said gain control grid bias is increased.

7. In combination with a source of audio sig-

nals, an amplifier having at least three grids, one of the grids being a positive screen, the other grid being a gain control grid, and the remaining grid being coupled to the said signal source, said gain control grid being disposed between the screen and plate, said tube having an effective plate current-signal grid voltage characteristic whose slope depends on the bias of said gain control grid, the potential range of the signal grid available for signals being substantially independent of the gain control grid bias, and means for varying the bias of the gain control grid over a range of negative values in response to variations in the signal amplitude to regulate the flow of current in the plate circuit of said tube.

8. Amplifier arrangement with regulable gain in which one or more tubes comprising cathode, anode and at least four grids are used, with this characteristic feature that at least two grids are at a negative potential with respect to the cathode, that at least two additional grids have a positive potential with reference to the cathode, and that one of the two negative grids is located between cathode and one positively biased grid, while the second negative grid is located between the two positively biased grids, and with the additional feature that the alternating voltage to be amplified is fed to that one of the two negative grids which is located close to the cathode.

9. Amplifier arrangement with regulable gain in which one or more tubes comprising cathode, anode and at least four grids are used, with this characteristic feature that at least two grids are at a negative potential with respect to the cathode, that at least two additional grids have a positive potential with reference to the cathode, and that one of the two negative grids is located between cathode and one positively biased grid, while the second negative grid is located between the two positively biased grids and with the additional feature that the amplifier includes means for varying the negative bias voltages of the two negative grids jointly.

10. Amplifier arrangement with regulable gain in which one or more tubes comprising cathode, anode and at least four grids are used, with this characteristic feature that at least two grids are at a negative potential with respect to the cathode, that at least two additional grids have a positive potential with reference to the cathode, and that one of the two negative grids is located between cathode and one positively biased grid, while the second negative grid is located between the two positively biased grids, and with the additional feature that means is coupled between the negative grids and the anode whereby the adjustment of the negative biasing voltage of both of the negative grids is effected in dependence upon the amplitude of the alternating voltage impressed upon the amplifier.

11. Amplifier arrangement with regulable gain in which one or more tubes comprising cathode, anode and at least four grids are used, with this characteristic feature that at least two grids are at a negative potential with respect to the cathode, that at least two additional grids have a positive potential with reference to the cathode, and that one of the two negative grids is located between cathode and one positively biased grid, while the second negative grid is located between the two positively biased grids.

12. A method of regulating the amplification of signal waves which consists in impressing the waves upon the signal grid of an amplifier tube

having an effective plate current-signal grid voltage characteristic whose slope is dependent upon the potential of a gain control grid, separating the signal and gain control grids by a positive screening field which wholly surrounds the gain control grid, and varying the bias of said gain control grid.

13. Amplifier arrangement with regulable gain in which one or more tubes comprising cathode, anode and at least four grids are used, with this characteristic feature that at least two grids are at a negative potential with respect to the cath-

ode, that at least two additional grids have a positive potential with reference to the cathode, and that one of the two negative grids is located between cathode and one positively biased grid, while the second negative grid is located between the two positively biased grids, a resistor in the circuit of one of said positively biased grids, and means for varying the negative bias of at least one of the negative grids.

KARL STEIMEL. 10
ERNST KLOTZ.