

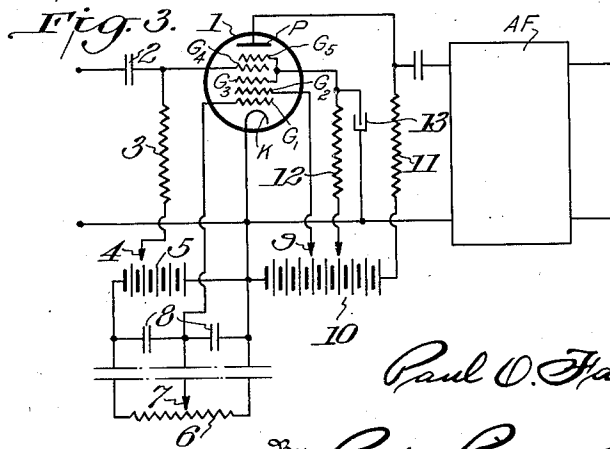
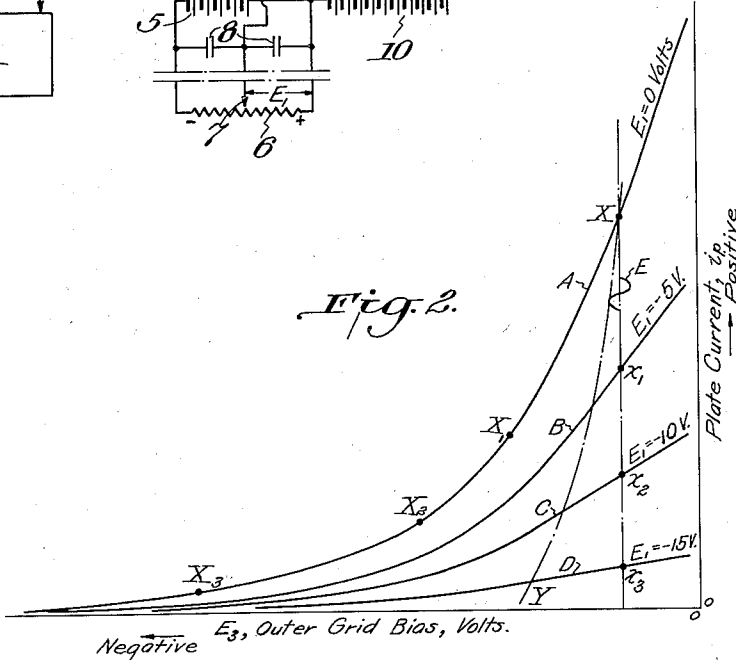
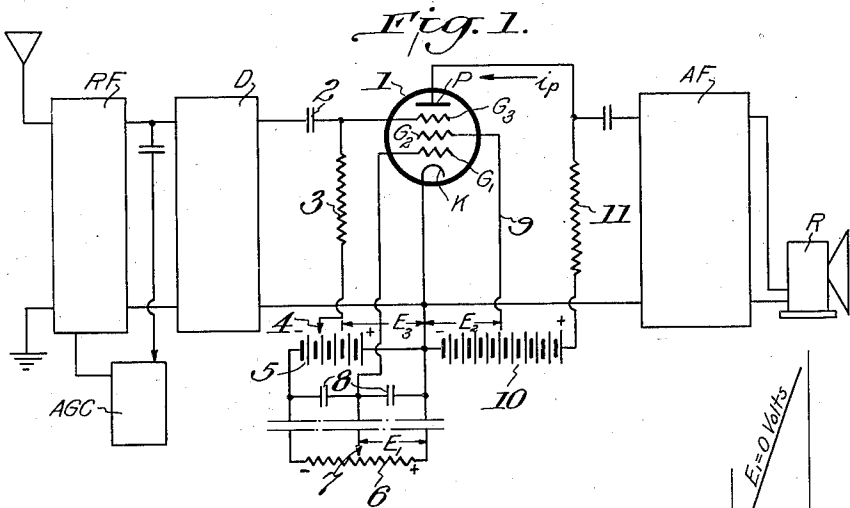
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AUDION AMPLIFIER

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2,006,099

AUDION AMPLIFIER

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4 Claims. (Cl. 250—20)

This invention relates to amplifying systems and particularly to arrangements suitable for controlling the gain or output level of a voice frequency amplifier by means of a direct current control voltage.

The invention is especially useful in connection with the problem of controlling the audio output level of a radio receiving system of the automatic gain control type from a point remote from the audio amplifier. Various methods have been proposed as a solution to this problem and, in my copending application Serial No. 671,771, filed May 18, 1933, I have described and claimed a method of audio level control which contemplates the control of radio gain in a stage following the automatic gain control system. Other methods involving the use of gain control attenuators or passive networks such as potentiometers involve expensive impedance adjusting networks or, alternatively, complicated and expensive motor systems if the actual control point is located remote from the audio amplifier. Some attempts have been made to control the gain of an audio amplifier stage by varying the direct current bias between the signal input grid and the cathode of a vacuum tube but this method leads to considerable distortion of the output audio wave for large signal input voltages and high negative grid biases. The use of a space-charge tube has also been attempted as one solution to this audio volume control problem, i. e., the signal input was applied to an outer negatively polarized grid while an inner grid polarized with a variable direct current potential positive to the cathode was used to control the gain of the stage. This latter method suffered from the distortion introduced when the positive potential on the space charge grid was lowered to obtain a substantial reduction in gain, and was also inadequate from the standpoint of obtaining a sufficiently wide range of control.

An object of the invention is to provide novel methods and circuit arrangements for controlling the gain of an audio amplifier by adjustment of a direct current bias applied to a grid other than the signal grid. More particularly, an object is to provide an audio amplifier including a tube having at least two negatively polarized grids with an intervening positive grid and an outside anode, and circuits for impressing the signal voltage on one negative grid and an adjustable gain control bias upon the other negative grid.

These and other objects and advantages of the invention will be apparent from the following

specification when taken with the accompanying drawing, in which:

Fig. 1 is a somewhat schematic diagram of a radio receiver including an audio amplifier stage embodying the invention;

Fig. 2 is a curve sheet showing the plate current flow in the amplifier tube for different values of the negative bias applied to the gain control grid; and

Fig. 3 is a fragmentary circuit diagram of another embodiment of the invention.

In the drawing, the reference character RF identifies a radio amplifier including one or more tube stages for amplifying a desired signal at the received carrier frequency and/or an intermediate frequency. The gain of the amplifier may be controlled automatically by a gain control system AGC to maintain an approximately constant radio input to the detector stage D.

The tube 1 of the audio stage working out of the detector has at least three grids serially arranged between cathode K and the plate P, and the audio output of the detector is impressed upon the outer or third grid G₃ through an appropriate coupling, such as that provided by condenser 2. The grid G₃ is placed at a desired negative potential E₃ with respect to cathode K by a circuit including a bias resistance 3 and a tap 4 which is adjustable along a direct current source 5, here shown diagrammatically for purposes of illustration as a battery. The resistance 6 of a potentiometer is shunted across the current source 5 and the tap 7 is connected to the inner grid G₁ to place a negative bias on that grid. As indicated by the breaking away of the leads to the potentiometer, this gain control unit may be located at some distance from the controlled tube. Condensers 8 are provided to by-pass the leads for signal frequencies when the potentiometer is located at a remote control point, thus insuring that there will be no pickup and transmission of undesired currents of audible frequencies to the controlled stage. The intermediate grid G₂ is maintained at a desired positive potential E₂ with respect to the cathode by a tapped connection 9 to the plate current source, battery 10. The plate circuit includes a resistance 11 or other appropriate impedance to which a succeeding audio amplifier AF is coupled, the amplifier AF working into a loud speaker or other appropriate form of reproducer R.

The method of operation and advantages of the invention will be apparent from a consideration of the family of curves showing the relation of plate current, i_p , to the signal grid bias, E₃. Curve

A is the plate current grid bias characteristic obtained when the bias voltage E_1 on the inner grid was reduced to zero, and this will be recognized as having the general form of the characteristic of the usual amplifier tubes. Curves B, C and D are characteristic curves obtained when the voltage E_1 on the inner grid had values of -5 , -10 and -15 volts, respectively. Point X on curve A is the normal operating point for maximum gain and, as is well known, the stage gain may be reduced by making the signal grid bias E_3 more negative, for example by shifting the operating point to one of the positions indicated by X_1 , X_2 , X_3 . The stage gain for an impressed signal voltage E is proportional to the transconductance or slope of the curve at the operating point.

$$\frac{di_p}{dE_3}$$

while the distortion of the signal is proportional to

$$\frac{d^2i_p}{dE_3^2}$$

and to the higher order derivatives. Inspection of curve A shows that the curvature at operating points for reduced stage gain is substantially greater than the curvature at the point X and it is therefore apparent that the distortion increases when the bias E_3 on the signal grid is adjusted to reduce the stage gain.

The operating point may be shifted to another curve by adjustment of the negative bias E_1 on the inner grid and, if bias E_3 remains fixed, the operating point will move downward along the ordinate through point X to the curve B, C, etc. for the selected value of the inner grid bias E_1 . The series of operating points x_1 , x_2 , x_3 thus obtained by adjustment of E_1 are located at portions of curves B, C, D, respectively, which have less slope and less curvature than curve A at point X. For purposes of comparison, the points X_1 , X_2 and X_3 were located at those regions on curve A at which the slope was the same as that of curves B, C, D at points x_1 , x_2 , x_3 , respectively. The stage gain for small inputs will therefore be the same when operating at either of the pairs of points, X_1 , x_1 or X_2 , x_2 , etc., but the distortion is substantially less when a fixed signal grid bias is used and the gain is controlled by adjustment of the inner grid bias E_1 .

So long as the operating point is shifted along curve A by adjusting the signal grid bias, a decrease in transconductance is obtainable only with an increase in distortion, while by shifting the operating point across the family of curves by different bias voltages E_1 , the transconductance is decreased with an actual decrease in distortion, since the curvature of successive curves decreases for increasing values of E_1 .

The control obtained is quite like that obtained with filamentary cathodes by adjustment of the heating current and is, in fact, based upon a variation of the electron stream in which the signal grid G_3 is located. The positively polarized grid G_2 attracts electrons from the cathode K and those electrons which are thus attracted and pass through the grid G_2 are in turn drawn toward the plate P by the more positive potential of the plate. But the number of electrons which can reach the region of the grid G_2 is controlled by the inner grid G_1 . So far as concerns the control action of the signal grid G_3 , the electron source is not the cathode K but is a virtual cathode which may be considered as existing in the region of the grid G_2 .

While this type of control may be obtained with the usual pentode tubes having an outer grid of relatively "coarse mesh" or long pitch, a grid G_3 of relatively fine mesh is preferably employed to obtain higher maximum gain for the signal frequencies and, if desired, one or more turns may be omitted from this grid winding to obtain a variable mu characteristic.

For a control over a wide range of input voltages, it may be desirable to increase the signal grid bias E_3 , as E_1 is increased to lower the gain, and at any appropriate rate with respect to the adjustment of E_1 . The locus of the operating points when both bias voltages are varied may be, for example, as indicated by the dotted line XY. When used as an audio stage in a receiver of the automatic gain control type, it is not necessary, in general, to make any adjustment of the bias on the signal grid since the input to the detector will be maintained approximately constant by the automatic gain control system and the adjustment of the bias on the inner grid provides a sufficient range of control to bring the receiver output to any desired level.

As shown in Fig. 3, the controlled stage may include a tube 1' of the type known commercially as "2A7", which tube is ordinarily used as an oscillator-first detector combination in superheterodyne receivers. This type of tube includes five grids, the grids G_3 and G_5 being connected within the tube and brought out to a single tube terminal. Except that the signal voltage is applied to grid G_4 , the circuit connections are, or may be, substantially as shown in Fig. 1, and will not be again described in detail. Grids G_3 , G_5 are connected to a desired point of positive potential on the source 10 through a resistance 12, and the grids are by-passed to the cathode for all signal frequencies by a condenser 13. While the resistance 12 is not essential, it is desirable to employ one of such value that the reduction in space current flow to these grids as the control bias E_1 is made more negative increases the cathode to grid voltages (by the decreased potential drop across resistance 12) to effect a further reduction in the curvature of the i_p vs E_4 characteristic.

As in the case of the Fig. 1 circuit, the bias voltage E_4 on the signal Grid G_4 may be made somewhat more negative as the gain control bias E_1 is increased negatively.

It is apparent that the invention may be applied as well to the control of gain in a radio frequency stage. It is of particular advantage, however, for the remote control of gain in an audio amplifier such as might be used in a radio receiver employing automatic gain control, in a public address system or in an electrical system for phonographic reproduction. The tube structure beyond the virtual cathode formed by the inner negatively polarized grid and the adjacent positively polarized grid may be of any desired type to constitute a triode, tetrode or other type of amplifier.

I claim:

1. In the operation of an amplifier stage including a tube having a cathode cooperating with a signal grid and anode, the method of reducing the transconductance of the tube from signal grid to anode without increasing the distortion introduced into the amplified output of the tube, comprising the establishing of a positive or accelerating field between the signal grid and cathode, controlling the electron flow from said cathode to the region of the positive field and signal grid

by a negative field adjacent said cathode, initially impressing on the signal grid such a negative bias which results in substantially maximum amplification and increasing the signal grid bias in a negative sense as the negative field is increased in magnitude to reduce the stage gain.

2. An amplifier stage comprising a vacuum tube having a cathode, a positively polarized anode and three grid electrodes between said cathode and anode, means impressing a negative bias on the outermost and innermost of said three grids, means polarizing the intervening grid positive with respect to said cathode, circuit connections impressing a signal voltage between the outer of said grids and cathode, an output circuit between said anode and cathode, means for adjusting the negative bias on the inner negative grid, a fourth grid located between the outermost of said grids and anode, a direct current circuit between said fourth grid and cathode including a resistance and a current source establishing a positive potential on said fourth grid; said resistance having a magnitude such that space current flow in said direct current circuit produces a substantial potential drop across the

same when the negative potential on said inner grid is adjusted for maximum gain.

3. An amplifier stage comprising a tube having a cathode cooperating with a signal grid and an anode to form an amplifier, an input circuit connected between said signal grid and cathode, an output circuit between said anode and cathode, means for controlling the gain of the stage and comprising a pair of oppositely polarized electrodes located between said cathode and signal grid, and means including a potentiometer located at a point remote from said tube and a contact adjustable therealong for adjusting the potential between one of said electrodes and the cathode.

4. The combination defined in claim 3 in which said potentiometer is connected to said tube by a pair of long leads and a capacitor having a low impedance to the signal frequencies to be amplified is connected across said leads adjacent said tube whereby undesired induction currents picked up by said leads are prevented from reaching said electrodes.

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