LOW-FREQUENCY AMPLIFIER

Original Filed May 2, 1935

Fig. 1

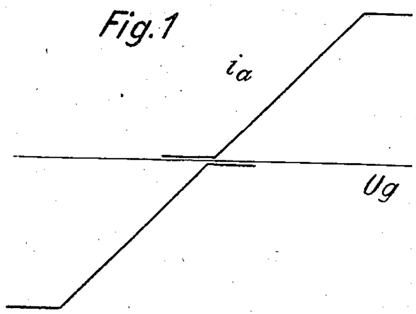



Fig. 2

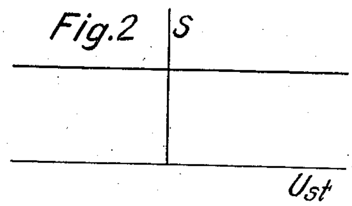



Fig. 3

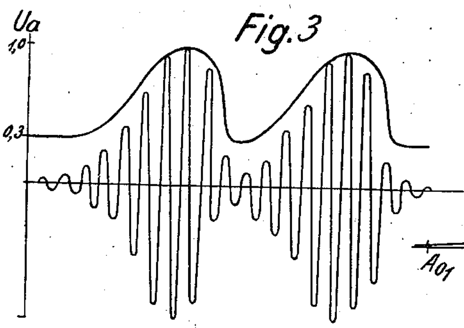



Fig. 4

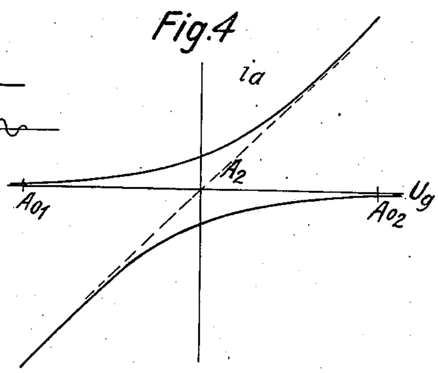
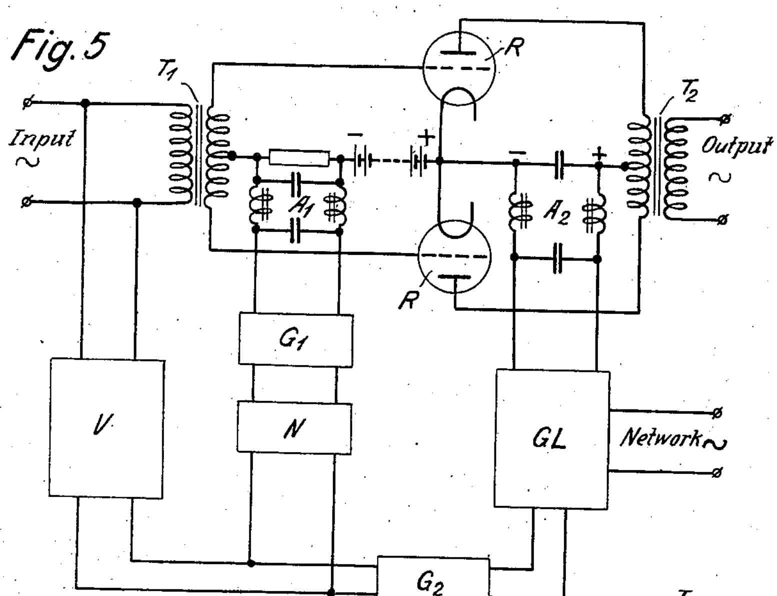



Fig. 5

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# UNITED STATES PATENT OFFICE

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## LOW-FREQUENCY AMPLIFIER

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Original application May 2, 1935, Serial No. 19,469. Divided and this application June 10, 1936, Serial No. 84,437. In Germany July 20, 1934

3 Claims. (Cl. 179—171)

This application is a division of copending application Serial No. 19,469, filed May 2, 1935, for Methods of controlling high frequency transmitters, now Patent No. 2,137,629, issued November 22, 1938, and the invention disclosed in it has for its object to provide means whereby methods such as described in that copending application can be used with advantage in connection with voice frequency amplifiers operating as so-called class B amplifiers of the push-pull or balanced type.

As will be understood from the following description and be particularly pointed out in the appended claims, the main feature of the invention is that in push-pull low frequency amplifiers of the class B type the direct current potential of the anode and the biasing potential of the grid are varied in the rhythm of the average amplitude variations of the voice frequencies, the variation of the anode potential being preferably such that a complete voltage utilization shall be attained. By "voltage utilization" is meant the ratio between the anode alternating voltage and the anode direct voltage and, in accordance with the present invention, by virtue of the alternating control voltage, the linear portion of the tube characteristic is completely utilized.

In the accompanying drawing

Figs. 1 to 4 are diagrams relating to the operation of arrangements constructed in accordance with the invention. Fig. 5 is a diagrammatic representation of such an arrangement.

The ideal characteristic of a push-pull low frequency amplifier in class B connection has the shape represented in Fig. 1. The slope of this characteristic is a straight line, as will be seen from Fig. 2. With respect to a half-wave of the control frequency the energy conditions may be considered as follows:

If one places the operating potential, i. e., momentary plate voltage $U_a$, over the threshold potential, i. e., the voltage at which a slope occurs in the anode current-anode voltage characteristic, the saturation voltage $U_s$, then for example, when $U_a=10U_s$, the potential utilization

$$h=1-\frac{U_s}{U_a}=0.9=90\%$$

With a current utilization

$$j=\frac{J_a}{I_a}=1.6$$

adapted for the purpose if the working point is located in the zero point of the characteristic and if $h=90\%$ as mentioned above the efficiency $\eta=72\%$.

This efficiency is derived by means of the well known formula $\eta=\frac{1}{2}.J.h.\cos\varphi$ wherein J represents the ratio between the anode alternating current and the anode direct current and $h$ the ratio between the anode alternating voltage and the anode direct voltage. This formula may be found in vol. II of the book "Elektronenrohren," by Barkhausen, page 117. In the above formula $J_a$ represents the anode alternating current and $I_a$ the corresponding anode direct current. With the alternating grid potential decreasing, the efficiency likewise decreases in linear relation with the envelope of the voice frequency current. Similarly to high frequency amplifiers, the voltage utilization at small values of input voltage in the case of audio frequency class B amplifiers increased by varying the continuous anode voltage and the continuous grid voltage in the rhythm of the average amplitude variations. The continuous anode voltage cannot be varied from zero up to the full value 1 but can start only from a certain at rest value, such as 0.2 or 0.4. This at rest value depends upon the tubes used, as the characteristic curves worked upon must all run parallel with each other. In Fig. 3 an example of amplitude variations is shown which are produced for instance by speech and correspond to the curve of the continuous anode voltage with an at rest value 0.3. The continuous grid potential is regulated in such a manner that in case the voice frequency input potential is half the value between zero and maximum, the working point is located at the zero point of the characteristic for half the continuous anode potential. If voice alternating potential is supplied then with an increasing anode potential, the grid potential is increased towards the negative side by a negative increment $D\Delta U_a$ whenever the anode potential is increased by a positive increment $\Delta U_a$.

In reality the characteristics of push-pull amplifiers are not so ideal as shown in Fig. 1 but have for instance the shape represented in Fig. 4. Such shapes of the characteristic are liable, in the case of small control amplitudes, to cause effective distortions with respect to loudness ratios and sound. In addition, such a class B amplifier is, in the case of small control amplitudes, very sensitive to variations of the continuous anode voltage and grid voltage. The working point in this case is liable to be easily displaced into the negative part of the characteristic by irregular changes in the bias and anode supply potential. This results in a shifting of the characteristics of the tubes relative to each other so that small control amplitudes will not be amplified at all. The active alternating grid voltage $U_{st}$ is formed by the difference $U_{st}=DU_a-U_g$, where D is the "durchgriff" of the tube, $U_a$ is the operating plate voltage and $U_g$ is the grid potential. This word "durchgriff" is a familiar German term meaning the throughgrip of the plate of the electron tube on the electrons between the grids and the cathode which may be expressed as the reciprocal of the amplification factor. If $U_g$ is small then $U_{st}$ depends very much upon $DU_a$ and thus upon the continuous anode voltage $U_a$.

By the described method of controlling simultaneously the continuous anode and the grid bias potential in dependence upon the voice frequency amplitude to improve the voltage utilization, it follows that the displacement of the active working point resulting from anode potential variations, in the case of small voice frequency amplitudes will no longer cause failure of amplification. This may be learned from the foregoing formula $U_{st}=DU_a-U_g$ since under these conditions a decrease of the grid bias $U_g$ does not cause a further decrease of the anode potential below the rest value of the continuous anode potential of 0.3 $U_a$ indicated by way of example.

It has been learned by experiment that the sensitivity of the B-amplifier circuit with respect to anode voltage variations is approximately the same whether the potential amplitudes at the grid of the push-pull connection are large or small in the above described arrangement.

According to another feature of the invention, the $DU_a$ compensation is accomplished in a non-linear form to compensate for the curvature of the characteristic at its lower end, in order to diminish the distortion of loudness ratios and sound caused by the characteristic curvature. In other words, since because of the curvature of the characteristic, signals of low amplitude are not linearly amplified, the grid bias must be made less negative at a greater rate with respect to the decrease in anode potential than on the linear portion of the characteristic when the slope is diminishing, as shown in the drawing. This insures that the points at which the average amplitude is a minimum the signal will still be amplified properly. It is obvious that if the slope increased it would be necessary to decrease instead of increase the rate at which the grid becomes less negative in order to compensate the distortion. The particular values of this non-linear correction differs for every tube characteristic so no absolute rule of construction is laid down. However, it is clear that any person skilled in the art can design a circuit suitable for the purpose, dependent upon particular tubes used.

By this manner of controlling the grid bias, each control amplitude of the voice frequency has a different working point on the curved portion of the characteristic. This mode of eliminating distortions has the advantage that the elimination can be effected in the class B amplifier itself or that owing to such special circuit arrangement a substantial distortion cannot occur.

In accordance with a further step of the invention the correction of distortion of voice frequencies in such a B-amplifier may be effected by a non-linear displacement of the working point by means of the grid without altering the continuous anode voltage. As mentioned above, the anode voltage has a certain minimum value, for example, 0.3 $U_a$. Since the distortion occurs only at smaller amplitudes below this minimum value, it is possible when operating below said minimum value to effect a counterdistortion by a corresponding control of the grid potential. Within this range it is not necessary to compensate the variation of the anode potential, but it is merely necessary to provide for the large and small control amplitudes to be as far as possible free from distortion. The influences set up by the slope of the characteristic are compensated by a non-linear control of the direct grid potential, whereby the non-linear dependency with respect to the grid direct potential is obtained by virtue of an amplifier N. The grid and plate potentials of the two push-pull connected tubes are always so displaced that the operating point is maintained in the zero point. The plate and the grid potentials of both tubes are always varied in the same direction, whereby the grid potentials become more negative, when the plate potentials become more positive.

This will be understood from Fig. 5. The push-pull tubes are designated R. The voice frequencies are in a well known manner conveyed over the transformer $T_1$ and on the grid side directly to the push-pull tubes R and are also conducted through an amplifier V to the push-pull arrangement, the amplifier V belonging to the novel control arrangement by which the grid voltage as well as the anode voltage are influenced. N is a non-linear amplifier which, according to the foregoing, serves for compensating the curvature of the characteristics. Connected to the output of the non-linear amplifier is a rectifier $G_1$, which through a smoothing means $A_1$, such as a filter circuit, acts to control the grid bias. In the output of V another rectifier $G_2$ is disposed by which the anode voltage is controlled. In the case represented it is intended to derive the anode voltage from the alternating current network by means of a grid control rectifier GL. In this case the grid of GL is controlled by the rectifier $G_2$. The controlled anode voltage is then fed over a smoothing link $A_2$ to the anode circuit of the push-pull arrangement.

What is claimed is:

1. The method of controlling a push-pull low frequency amplifier in class B connection having a grid controlled anode potential supply source, which comprises, using the average amplitude variations of the low frequencies to vary the direct current potential of the anodes of the amplifier in the same sense as the direction of average amplitude varies by controlling the grid voltage of said grid controlled anode supply source, simultaneously varying the grid biasing potential of both tubes in a sense opposite to the change in said anode potential to increase the average efficiency of said amplifier and maintain distortion at a substantial minimum and further controlling said grid biasing potential to compensate for curvature in the amplifier characteristic by effecting a non-linear displacement of the working point.

2. An arrangement for controlling a low frequency push-pull class B amplifier employing vacuum tubes having cathodes, grids and anodes for amplifying low frequency variable amplitude waves comprising an anode supply rectifier, means responsive to the average amplitude variations of the low frequencies controlling said rectifier to control the direct current potential on the anodes, means responsive to said ampli-

tude variations for simultaneously varying the bias potential of both said grids in the direction opposite to the variation in anode potential and means for controlling said grid bias to effect a non-linear displacement of the working point of said amplifier to compensate for amplifier distortion.

3. An arrangement for controlling a low frequency push-pull class B amplifier employing vacuum tubes having cathodes, grids and anodes, for amplifying waves, comprising a variable output rectifier for supplying anode potential, means responsive to average amplitude variations of the low frequencies for controlling the output of said rectifier directly as the variation of said average amplitude, other means responsive to said amplitude variations for simultaneously varying the bias potential of said grids in a sense opposite to said plate potential variation and amplifying means for controlling said other means to produce a non-linear variation of said grid bias to compensate for curvature of said vacuum tube characteristic.

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