Sept. 11, 1951 P. K. BUYS 2,567,272

CIRCUIT-ARRANGEMENT FOR PROTECTING AMPLIFYING TUBES AGAINST OVERLOADING

Filed June 24, 1947 2 Sheets-Sheet 1

Fig. 1.

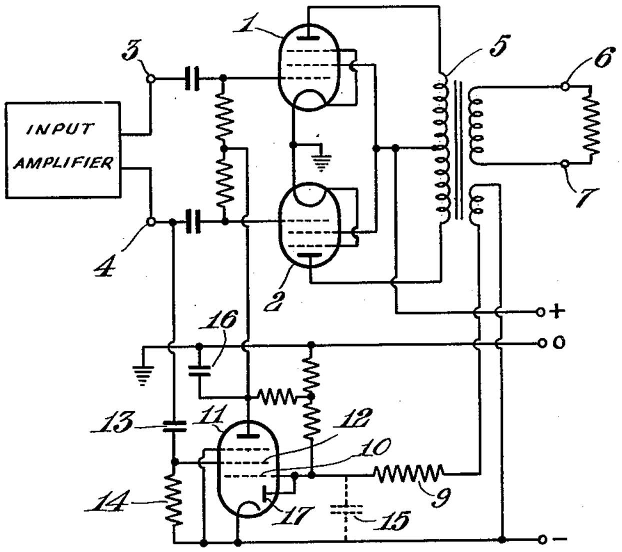



Fig. 2.

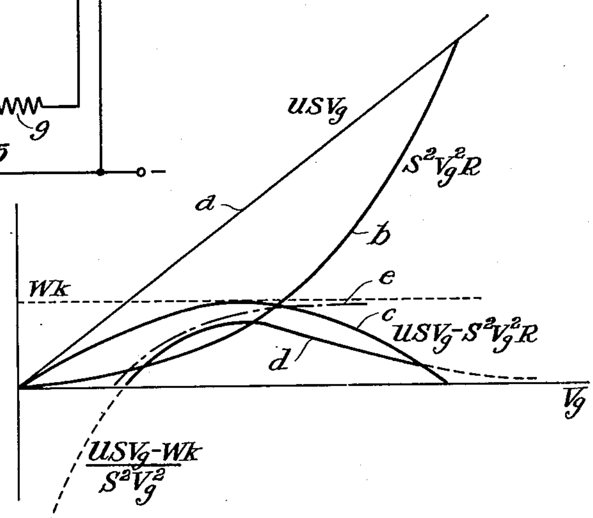
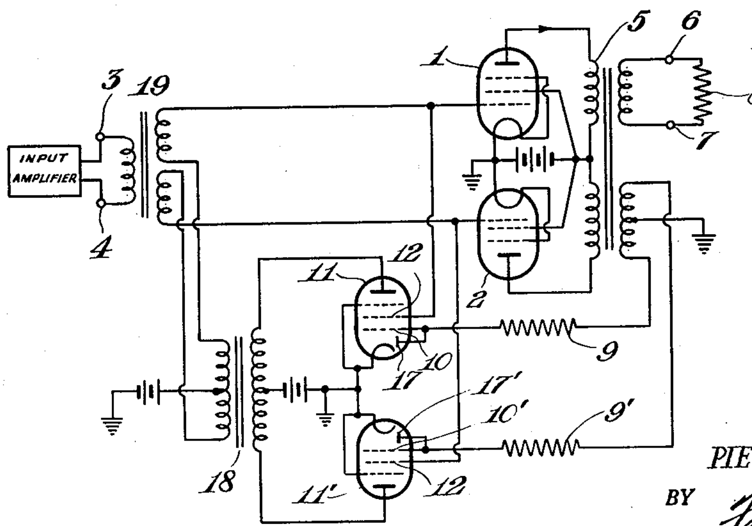



Fig. 3.

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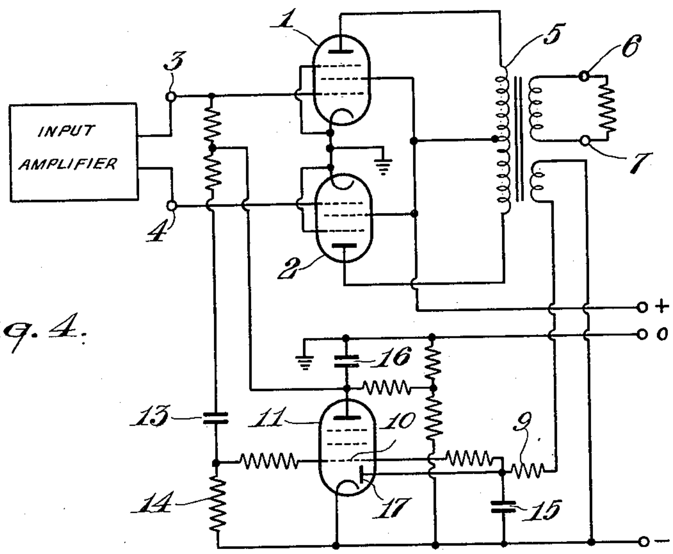


Fig. 4.

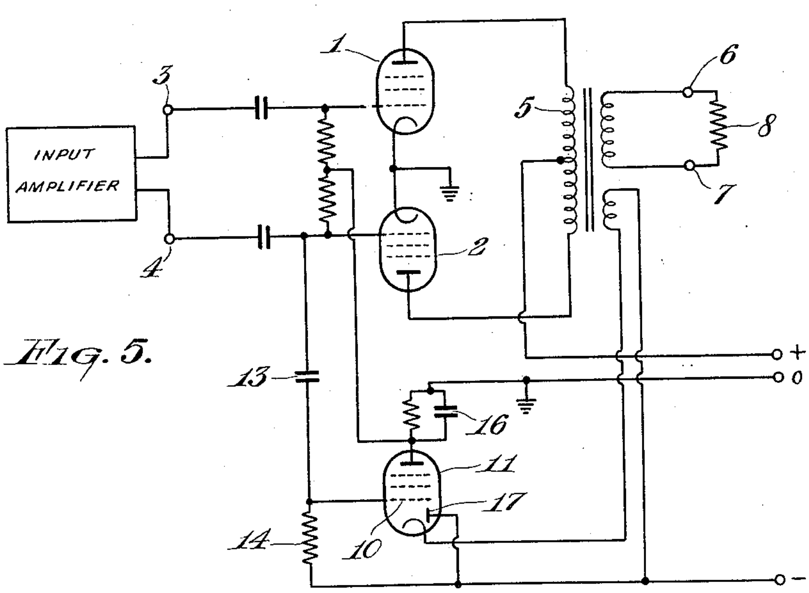


Fig. 5.

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## CIRCUIT ARRANGEMENT FOR PROTECTING AN AMPLIFYING TUBE AGAINST OVERLOADING

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8 Claims. (Cl. 179—171)

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This invention relates to a circuit-arrangement for protecting an amplifying tube, which is loaded by an impedance in class AB-, B- or C-setting, from overloading and, more particularly, of push-pull connected final tubes in class B-setting. As is well known with amplifying tubes in any of the aforesaid settings there is a risk of overloading of the tubes if the load impedance is too low.

This applies, for instance, to amplifiers for radio-relay exchanges, in which the load of the amplifier varies in accordance with the number of listening subscribers or in the case of short-circuits.

In order to obviate overloading provision is made according to the invention, for controlling the effective input voltage in accordance with the value of the load impedance. This control is governed by the difference between a voltage taken from the input circuit of the tube to be protected and from the input circuit of an amplification stage preceding this tube respectively, and a voltage taken from the output circuit of the said tube.

In the present case the term "control" should be understood to mean control in the widest sense that is to say any control as a result of which the effective voltage supplied to the grids of these tubes (i. e. the voltage which occurs during that part of the cycle of the alternating grid voltage during which anode current passes through the tube) has a smaller amplitude than it would be the case without control.

In order that the invention may be clearly understood and carried into effect, it will now be explained more fully with reference to the accompanying drawings in which several embodiments thereof are represented by way of example.

In the embodiment shown in Fig. 1 a voltage proportional to the output voltage is applied to the first grid, and a voltage proportional to the input is applied to the second grid of an auxiliary tube. The two voltages are in phase-opposition and their value is such that, if the final tubes are adequately loaded, the auxiliary tube does not carry anode current, even if the voltage taken from the output increases. It does, however, if this voltage decreases. The anode current may be rectified and may influence the negative grid bias and consequently the mutual conductance of the final tubes and /or of one or more preceding amplifying tubes, as a result of which the effective input voltage of the final tubes decreases.

In the embodiment shown in Fig. 3, the circuit-arrangement of which is similar to that in Fig. 1, the effective voltage applied to the grids of final tubes 1 and 2 is reduced due to a voltage obtained from the anode circuit of two auxiliary tubes 11 and 11'.

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In a variant of the two embodiments shown in Fig. 4 a rectified portion of the output voltage influences, according to the invention, the mutual conductance of an auxiliary tube 11, the input voltage being fed to a control-grid of this tube.

The embodiment shown in Fig. 5 is different from that shown in Fig. 1 inasmuch as one of the voltages is operative in the cathode circuit, the other is the grid circuit of the auxiliary tube 11.

The circuit-arrangements shown in Figs. 1, 3, 4 and 5 will now be explained more fully.

The input voltage is fed through terminal 3, 4 to the control-grids of the two final tubes 1 and 2 operating in class B-setting (Fig. 1). The anode circuit of these tubes comprises an output transformer 5, the secondary part of which is loaded by loads which are connected to terminals 6, 7 together represent a load resistance 8.

A voltage is taken from the second secondary winding of transformer 5 and supplied through a resistance 9 to a grid 10 of an auxiliary tube 11.

The input voltage is supplied to a grid 12 of this tube through a condenser 13 and a resistance 14. The phase-displacements owing to this condenser 13 and resistance 14 and those due to the resistance 9 and a condenser 15 provided, if required, in the circuit connected to grid 10 are such that in the case of a purely ohmic character of load 8 the voltages set up at grids 10 and 12 are in phase-opposition. Usually only small phase displacement are allowed. The amplitudes of these voltages and the bias of grids 10 and 12 are chosen to be such that with the maximum permissible value of load 8 the grids just do not carry grid current.

Moreover, the ratio between the amplitudes of these voltages is such that at maximum load their control effects on the anode current practically neutralize one another, so that the auxiliary tube either does not carry anode current or carries a constant anode current.

If the load increases excessively due to diminution of the resistance 8, which involves a decrease of the voltage induced on the second secondary winding, current pulses will occur in the anode circuit of the auxiliary tube. As a result thereof a rectified voltage is set up across a smoothing condenser 16 which voltage influences the negative grid bias of final tubes 1 and 2 in a manner such that the grids become more negative (C-setting) and the mean anode current of the final tubes decreases again. If, however, the load becomes smaller than the maximum permissible value, due to an increase of resistance 8, the amplitude of the anode current pulses will not increase, since owing to the grid current occurring a voltage drop is produced across resistance 9, owing to which the grid 10 becomes more negative and the anode current is limited in a known manner. If required, this effect may be increased by providing a diode 17 which is connected to the grid 10.

From the displacement of the working points of final tubes 1 and 2 distortions will accrue, which can be obviated by controlling by means of the voltage produced across condenser 16 not the bias of the final tubes, but the mutual conductance and consequently the amplification factor of amplifying tubes (not shown) preceding the final stage, as a result of which the effective input voltage of the final tubes decreases if the load becomes too low.

The operation of the circuit-arrangement shown in Fig. 1 will now be explained hereinafter with reference to the characteristic curves shown in Fig. 2.

In Fig. 2 the curve *a* illustrates the power of the final amplifying tubes 1 and 2 obtained from the anode supply with a direct voltage U, as a function of the alternating voltage $Vg$ supplied to the control-grid; this power is equal to $USVg$. Curve *b* represents the power $S^2Vg^2R$ supplied to the load impedance R, curve *c* representing the power $USVg-S^2Vg^2R$ dissipated in tubes 1 and 2.

In this expression S represents the mutual conductance, $Vg$ the alternating grid voltage of the tubes.

Since the power dissipated in the tubes should, at the most, be equal to the permissible anode dissipation $Wk$, i. e. $Wk=WSVg-S^2Vg^2Rk$, it follows that the limit value $Rk$ of resistance R is

$$Rk=\frac{USVg-Wk}{S^2Vg^2}$$

Curve *d* in Fig. 2 represents this limit value as a function of $Vg$, the dotted part relating to such values of $Rk$ which cannot be realized physically. At values of R smaller than $Rk$, i. e. the range in the $R-Vg$ area between curve *d* and the $Vg$-axis, the tubes are consequently overloaded.

By taking the measures according to the invention it is ensured that at any value of the load resistance the effective voltage $Vg$ is kept beyond the range located between the $Vg$-axis and this curve *d*.

If, in effect, the effective alternating grid voltage is proportional, as is the case in Fig. 1, to the positive difference between a voltage $C_1Vg$ proportional to the grid voltage $Vg$ of the final tubes and a voltage $C_2SVgR$ taken from the output, than, as a voltage $Vi$ to be amplified and supplied to the input circuit of the final stage, $Vg=Vi-C_3(C_1Vg-C_2SVgR-C_4)$, where $C_1$ to $C_4$ are constants, so that

$$Vg=\frac{Vi+C_3C_4}{1+C_1C_3-C_2C_3SR}$$

i. e. as a function of R a hyperbola, represented by the dot-and-dash curve *e* in Fig. 1. By a proper choice of constants $C_1$ to $C_4$ curve *e* may be located as closely as possible above curve *d*.

A further embodiment of the invention is shown in Fig. 3, in which corresponding circuit elements bear the same reference numerals as in Fig. 1. In this circuit arrangement provision is made of two push-pull connected auxiliary tubes 9 and 9′ to the grids 10 and 10′ of which the voltage proportional to the output voltage, and to the grids 12 and 12′ of which the voltage proportional to the input voltage of final tubes 1 and 2 is supplied.

The anode circuit of these tubes comprises a transformer 18, on the secondary winding of which a negative feedback voltage is induced if the voltage across the output circuit of the amplifier is too low owing to an excessively small value of load resistance 8.

The secondary winding of transformer 18 is connected in series with the secondary winding of the input transformer 19, so that the voltage supplied to the grids of tubes 1, 2 is reduced by the voltage produced across the first-mentioned winding, as a result of which the effective voltage set up at the grids decreases.

It is pointed out that in the circuit-arrangement shown in Fig. 2 a decrease of the voltage supplied to the grids also occurs if the input voltage is excessively high or if it is not sinusoidal.

In the circuit-arrangement shown in Fig. 3 the input voltage $Vi$ must not exceed a definite value. The adjustment is, however, simpler than in the circuit-arrangement shown in Fig. 1, since there is less need of taking phase-displacements into account.

In the circuit-arrangement shown in Fig. 4 the voltage proportional to the output voltage is supplied to the diode 17 through a resistance 9.

Across condenser 15 a voltage is set up which influences the mutual conductance of the auxiliary tube 11, by controlling the bias of grid 10.

The voltage to be amplified, which is fed to tubes 1, 2, is supplied to this grid or to another grid of the auxiliary tube 11.

The voltage which is produced across condenser 16 and, similarly to the circuit-arrangement of Fig. 1, increases again according as the difference between the input and the output voltage increases, again influences e. g. the mutual conductance of amplifying tubes (not further described) preceding the final stage.

Instead of causing the output voltage to influence the mutual conductance of the auxiliary tube 11 according to Fig. 4, the input voltage may be used for this purpose. In this case the polarity of rectifier 17 is required to be reversed.

In the circuit-arrangement shown in Fig. 4 the control is not affected if the amplifier is loaded by a complex impedance, in contradistinction to the circuit-arrangements shown in Figs. 2 and 3, in which strong control occurs even at a small complex load. This circuit-arrangement has, however, a limitation in that the control depends to some extent upon the curve form of the incoming signal.

Fig. 5 represents, by way of example, one embodiment of the invention in which one of the voltages is operative in the cathode circuit of auxiliary tube 11. Otherwise the circuit-arrangement is entirely identical with that of Fig. 1 and has the same reference numerals. Similarly one of the voltages may be introduced with the cathode-circuit in the circuit-arrangements shown in Figs. 3 and 4.

In the circuit-arrangements as described in the foregoing a voltage proportional to the grid voltage of the final tubes is supplied to the auxiliary tube. As an alternative, however, the characteristic curve *d* in Fig. 2 may be closely approximated by supplying, instead of a voltage proportional to the voltage applied to the grids of tubes 1, 2, a voltage which is proportional to the output voltage of one of the amplifying tubes preceding the final tubes or proportional to the input voltage $V_i$ of the final stage.

What I claim is:

1. An overload protection circuit for an amplifying system having a source of desired signals, an amplifier stage adapted for operation in class AB, B or C coupled to said source and a load impedance coupled to the output of said amplifier stage, comprising an electron discharge tube having cathode, input and output electrodes defining an input circuit and an output circuit, means coupled to said amplifier stage to derive a first potential proportional to the output voltage of said amplifier stage, means to apply said first potential to the input circuit of said discharge tube, rectifier means coupled to the input circuit of said discharge tube to limit the amplitude of said first potential to a given value, means coupled to said source to apply a second alternating potential to the input circuit of said discharge tube, means coupled to the output circuit of said discharge tube to derive therefrom a control voltage at amplitude values of said first potential below said given value, and means to vary the amplitude of said desired signals at the output of said amplifier stage proportional to the value of said control voltage.

2. An overload protection circuit for an amplifying system having an input stage providing a source of desired signals, an amplifier stage adapted for operation in class AB, B or C coupled to said input stage and a load impedance coupled to the output of said amplifier stage, comprising an electron discharge tube having cathode, input and output electrodes defining an input circuit and an output circuit, means coupled to said amplifier stage to derive a first alternating potential proportional to the output voltage of said amplifier stage, means to apply said first alternating potential to the input circuit of said discharge tube, rectifier means coupled to the input circuit of said discharge tube to limit the amplitude of said first alternating potential to a given value, means coupled to said input stage to derive a second alternating potential proportional to the amplitude of said desired signals, means to apply said second alternating potential to the input circuit of said discharge tube, means coupled to the output circuit of said discharge tube to derive therefrom a control voltage at amplitude values of said first alternating potential below said given value, and means to vary the amplitude of said desired signals at the output of said amplifier stage proportional to the value of said control voltage.

3. An overload protection circuit for an amplifying system having an input stage providing a source of desired signals, an amplifier stage adapted for operation in class AB, B or C coupled to said input stage and a load impedance coupled to the output of said amplifier stage, comprising an electron discharge tube having cathode, input and output electrodes defining an input circuit and an output circuit, means coupled to said amplifier stage to derive a first alternating potential proportional to the output voltage of said amplifier stage, means to apply said first alternating potential to the input circuit of said discharge tube, rectifier means coupled to the input circuit of said discharge tube to limit the amplitude of said first alternating potential to a given value, means coupled to said input stage to derive a second alternating potential proportional to the amplitude of said desired signals, means to apply said second alternating potential to the input circuit of said discharge tube, means coupled to the output circuit of said discharge tube to derive therefrom a unidirectional control voltage at amplitude values of said first alternating potential below said given value, and means to vary the amplitude of said desired signals at the output of said amplifier stage proportional to the value of said unidirectional control voltage.

4. An overload protection circuit for an amplifying system having an input stage providing a source of desired signals, an amplifier stage adapted for operation in class AB, B or C coupled to said input stage and a load impedance coupled to the output of said amplifier stage, comprising an electron discharge tube having cathode, input and output electrodes defining an input circuit and an output circuit, means coupled to said amplifier stage to derive a first alternating potential proportional to the output voltage of said amplifier stage, means to apply said first alternating potential to the input circuit of said discharge tube in a given phase, rectifier means coupled to the input circuit of said discharge tube to limit the amplitude of said first alternating potential to a given value, means coupled to said input stage to derive a second alternating potential proportional to the amplitude of said desired signals, means to apply said second alternating potential to the input circuit of said discharge tube in phase opposition to said given phase, means coupled to the output circuit of said discharge tube to derive therefrom a unidirectional control voltage at amplitude values of said first alternating potential below said given value, and means to vary the amplitude of said desired signals at the output of said amplifier stage proportional to the value of said unidirectional control voltage.

5. An overload protection circuit for an amplifying system having a source of desired signals, a push-pull amplifier stage adapted for operation in class AB, B or C coupled to said source and a load impedance coupled to the output of said amplifier stage, comprising an electron discharge tube having cathode, first control grid, second control grid and output electrodes, means coupled to said amplifier stage to derive a first alternating potential proportional to the output voltage of said amplifier stage, means to apply said first alternating potential to the first control grid of said discharge tube, rectifier means coupled to the first control grid of said discharge tube to limit the amplitude of said first alternating potential to a given value, means coupled to said source to apply a second alternating potential to the second control grid of said discharge tube, means coupled to the output electrode of said discharge tube to derive therefrom a unidirectional control voltage at amplitude values of said first alternating potential below said given value, and means to vary the amplitude of said desired signals at the output of said amplifier stage proportional to the value of said control voltage.

6. An overload protection circuit for an amplifying system having a source of desired signals, a push-pull amplifier stage adapted for operation in class AB, B or C coupled to said source and a load impedance coupled to the output of said

amplifier stage, comprising a pair of electron discharge tubes coupled in push-pull and each having cathode, first control grid, second control grid and output electrodes, means coupled to said amplifier stage to derive a first alternating potential proportional to the output voltage of said amplifier stage, means to apply said first alternating potential to the first control grid of each of said discharge tubes, rectifier means coupled to the first control grids of said discharge tubes to limit the amplitude of said first alternating potential to a given value, means coupled to said source to apply a second alternating potential to the second control grids of said discharge tubes, means coupled to the output electrodes of said discharge tubes to derive therefrom a control voltage at amplitude values of said first alternating potential below said given value, and means to vary the amplitude of said desired signals at the output of said amplifier stage proportional to the value of said control voltage.

7. An overload protection circuit for an amplifying system having a source of desired signals, a push-pull amplifier stage adapted for operation in class AB, B or C coupled to said source and a load impedance coupled to the output of said amplifier stage, comprising an electron discharge tube having cathode, input and output electrodes, means coupled to said amplifier stage to derive a first alternating potential proportional to the output voltage of said amplifier stage, rectifying means coupled to the input electrode of said discharge tube, means to apply said first alternating potential to said rectifying means to limit the amplitude of said first alternating potential to a given value and to apply a bias voltage proportional to the amplitude of said first alternating potential to the input electrode of said discharge tube, means coupled to said source to apply a second alternating potential to the input electrode of said discharge tube, means coupled to the output electrode of said discharge tube to derive therefrom a unidirectional control voltage at amplitude values of said first alternating potential below said given value, and means to vary the amplitude of said desired signals at the output of said amplifier stage proportional to the value of said control voltage.



8. An overload protection circuit for an amplifying system having a source of desired signals, a push-pull amplifier stage adapted for operation in class AB, B or C coupled to said source and a load impedance coupled to the output of said amplifier stage, comprising an electron discharge tube having cathode and input electrodes defining a cathode-input electrode circuit and having an output electrode, means coupled to said amplifier stage to derive a first alternating potential proportional to the output voltage of said amplifier stage, means to inject said first alternating potential into the cathode-input electrode circuit of said discharge tube, rectifier means coupled to said cathode-input electrode circuit to limit the amplitude of said first alternating potential to a given value, means coupled to said source to apply a second alternating potential to the input electrode of said discharge tube, means coupled to the output electrode of said discharge tube to derive therefrom a unidirectional control voltage at amplitude values of said first alternating potential below said given value, and means to vary the amplitude of said desired signals at the output of said amplifier stage proportional to the value of said control voltage.

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## REFERENCES CITED

The following references are of record in the file of this patent:

UNITED STATES PATENTS

| Number | Name | Date |
|---|---|---|
| 2,118,287 | Koch | May 24, 1938 |
| 2,252,049 | Terman | Aug. 12, 1941 |
| 2,293,528 | Barco et al. | Aug. 18, 1942 |
| 2,343,207 | Schrader et al. | Feb. 29, 1944 |
| 2,413,348 | Hammond, Jr. | Dec. 31, 1946 |