Oct. 29, 1940. H. P. KALMUS ET AL 2,219,928

STABILIZING MEANS FOR ELECTRIC CIRCUITS

Filed Dec. 29, 1939 2 Sheets-Sheet 1

Fig. 1

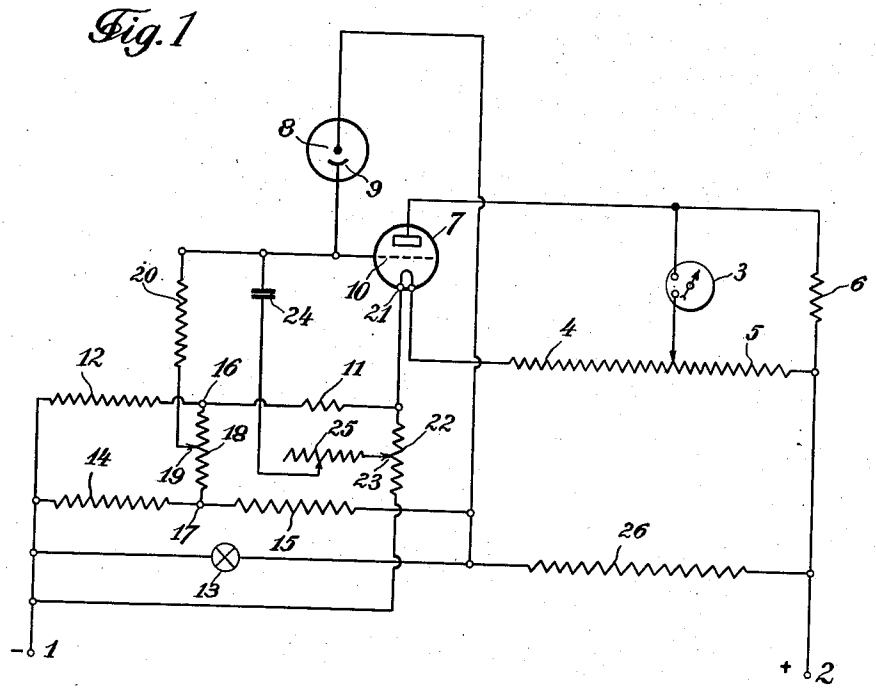

Fig. 2

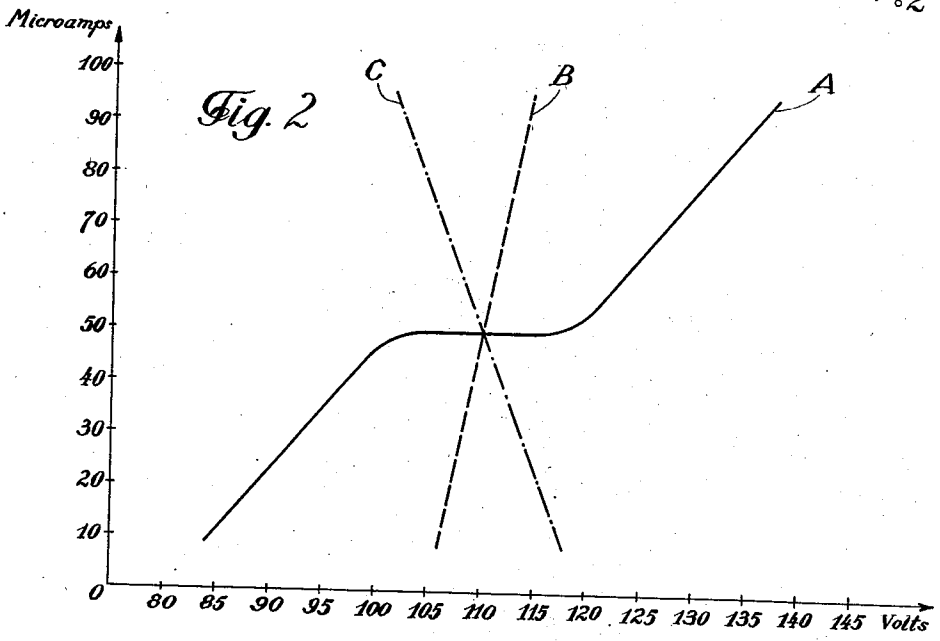

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Fig. 3

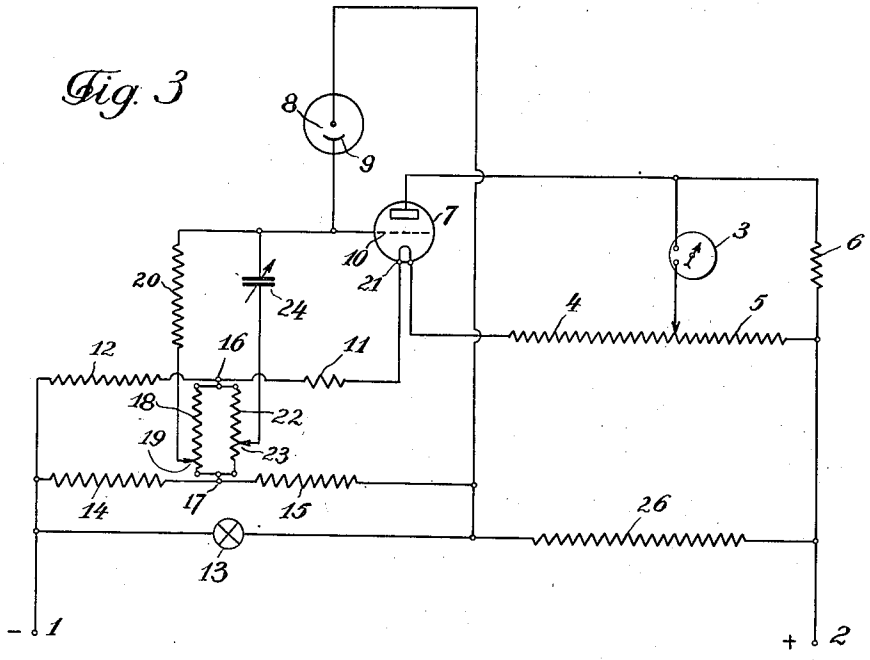
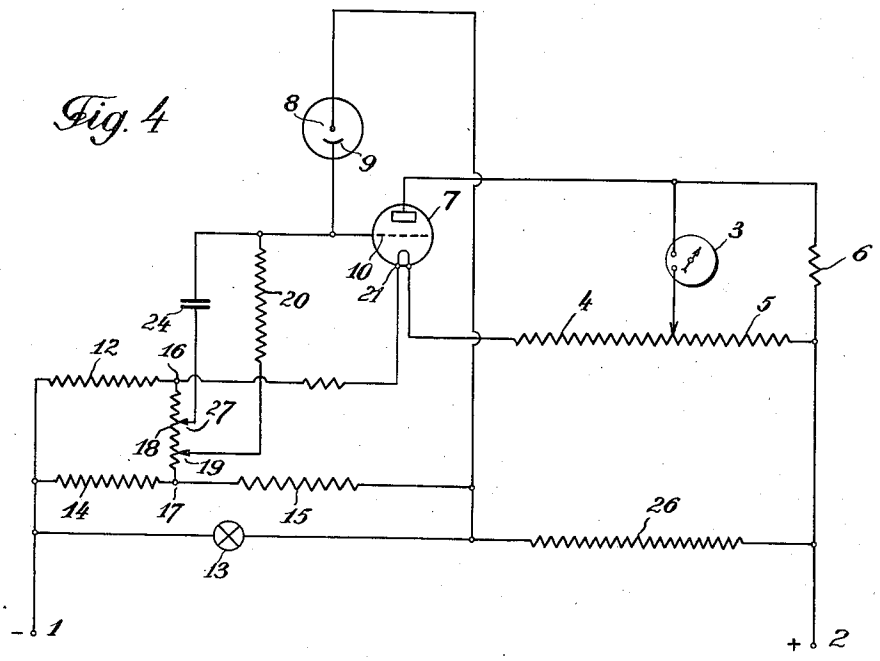


Fig. 4



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STABILIZING MEANS FOR ELECTRIC CIRCUITS

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25 Claims. (Cl. 179—171)

Our invention relates to electric circuits comprising amplifier tubes, and it pertains more especially to the stabilization of circuits of this type.

Electric circuits comprising amplifier tubes operated by a supply voltage are affected by voltage variation in the supply circuit. The reason is that the D. C. plate resistance of amplifier tubes is not constant but depends on the plate voltage, the bias voltage, and the heater current.

When plate voltage, heater voltage, and bias voltage are derived from the supply voltage in the usual way, their percentage change is substantially equal to the percentage change of the supply voltage. In such cases the combined result of increased plate voltage and increased heater voltage i. e. filament current, cannot be fully counterbalanced by the effect of increased bias voltage: For an increased supply voltage there is a drop in D. C. plate resistance; conversely a decreased supply voltage results in an increased D. C. plate resistance.

In some other cases it is not the D. C. plate resistance but the output current or voltage which has to be kept substantially constant; this means that for a certain change in supply voltage a certain specific change in the D. C. plate resistance of the amplifier tube is required. Quite similarly to the first case set forth above, the change of the bias voltage which is derived in the usual manner from the supply voltage is not sufficient to counteract the change in plate voltage to such an extent as to cause the specific D. C. plate resistance change required for keeping the output current or voltage constant.

In some further cases the heater voltage is supplied from a source other than the supply for plate and bias voltages. In such cases the bias voltage change may be closer to the voltage change required for counter-balancing the change in plate voltage, but is not close enough for many purposes where amplifier circuits of high sensitivity and accuracy are required.

It is therefore the main object of our present invention to provide for a stabilized amplifier circuit whose output is independent of changes of the supply voltage.

It is further a special object of our invention to provide for an electric circuit comprising amplifier tubes having a D. C. plate resistance being constant or changing in a predetermined required way in case of supply voltage changes.

It is still a further object to attain this stabilization without provision of a constant supply voltage and without expensive and complicated supply voltage regulating means.

In order to achieve the objects set forth above we propose to keep the percentage change of the grid bias voltage larger than the percentage change of the supply voltage.

In accordance with our present invention we obtain this result by deriving the grid bias voltage from two primary bias voltage sources, both sources of supply voltages being, at the mean value of the supply voltage, equal to each other; but while the percentage change of one of said primary bias voltages is substantially equal to the percentage change of the supply voltage, the percentage change of the other primary bias voltage is larger. Thereby it becomes possible to provide means for deriving from said primary bias voltages a final bias voltage having a percentage change being preferably adjustable within the limits of the percentage changes of said two primary voltages. Thus it is possible to provide for an adjustable final bias voltage the percentage change of which is larger than the percentage change of the supply voltage whereby the D. C. plate resistance of the tube is kept at the required constant value or made to change in a required way when supply voltage changes occur.

Stabilized circuits of the type proposed are of a special importance in highly sensitive and stable bridge circuits, which have to be suitable for the measurement of very small D. C. voltages and/or currents, operated on an unstable supply voltage. This importance is due to the fact that in such cases the indicating element in a bridge comprising amplifier tubes is considerably affected by supply voltage changes.

The manner in which the objects set forth are attained and in which stabilized circuits of the type proposed may be incorporated in bridge circuits for the measurements of very small D. C. voltages and currents e. g. in a photometer circuit for the measurement of very small light values, is shown in the following detailed description and accompanying drawings to which reference will now be made.

Figure 1 is a circuit diagram of a high sensitive photometer using the voltage stabilization proposed by us,

Figure 2 shows curves indicating the meter current plotted against supply voltage, explaining various details of the stabilization method,

Figure 3 is a modification of the circuit shown in Fig. 1, and

Figure 4 is the photometer circuit diagram

shown in Fig. 1 with modified voltage stabilization means.

Referring now more in detail to Fig. 1 the arrangement and operation of the stabilization means shown will be apparent to those skilled in the art. A brief description of it however, will serve to point out the necessity for our invention and may be used in comparing an amplifier circuit embodying it with those not so equipped. Thus as shown in Fig. 1 in the circuit diagram points 1 and 2 are the minus and the plus terminals respectively of a 110 volts D. C. line or of an A. C. rectifier. The microammeter 3 forms in connection with the resistances 4, 5, 6, 26 and the amplifier tube 7 in a way known per se the measuring bridge circuit for measurement of the intensity of light impinging on the photoelectric tube 8. The cathode 9 of this photoelectric tube 8 is connected to the grid 10 of the amplifier tube 7.

Without our proposed stabilization means grid 10 would be biased by the bias voltage supplied by the resistor 11. The voltage across this resistor 11 is subject to the same percentage changes as the supply voltage and therefore this change is insufficient for keeping the D. C. plate resistance constant in case of supply voltage changes. In order to stabilize the circuit the following stabilization means are employed:

The resistor 11 serves as "first primary bias voltage source" giving a "first primary bias voltage" across point 21 of the cathode and point 16 being, at the mean value of the supply voltage, equal to the mean bias voltage, and having in case of supply changes a percentage change being substantially equal to the percentage change of the supply voltage. In accordance with our invention we provide further a "second primary bias voltage source" giving a "second primary bias voltage" being, at the mean value of the supply voltage, equal to the mean bias voltage, and having, in case of supply voltage changes, a percentage change being larger than the percentage change of the supply voltage. In the preferred embodiment shown in the drawing this "second primary bias voltage source" consists of resistors 11, 12, and 14 and supplies a "second primary bias voltage" across point 21 of the cathode and point 17 of the circuit.

As may be seen from the circuit diagram resistor 12 supplying an "additional changing voltage" is arranged in series with resistor 11. The voltage across this resistor 12 is subject to the same percentage changes as the voltage across resistor 11; thus resistors 11 and 12 together supply a "changing voltage" being larger than the "first primary bias voltage" supplied by resistor 11 alone. This resistor 12 is included in the main circuit and therefore the voltage across it has to be held as small as possible, e. g. 10 volts.

In series with this resistor 12 a further voltage source comprising a glow discharge tube 13 is arranged; this glow discharge tube 13 is supplying across its terminals a substantially constant voltage. For our purpose the constant voltage derived from the voltage across this glow discharge tube 13 has to be equal to the voltage across resistor 12 at the mean value of the supply voltage i. e. it has to be 10 volts. As it is difficult and expensive to use glow discharge tubes of such a low voltage we propose to connect parallel with said glow discharge tube two high resistors 14 and 15 forming a voltage divider, and to use resistor 14 as "constant voltage source." As set forth above, at the mean value of the supply voltage the "constant voltage" across this resistor 14 has to be equal to the "additional changing voltage" across resistor 12. As may be seen from the circuit diagram this "constant voltage" across resistor 14 is opposite with respect to both the "first primary bias voltage" across resistor 11 and the "additional changing voltage" across resistor 12 and thereby also opposite with respect to the "changing voltage" across both resistors 11 and 12.

Across points 16 and 17 a high resistance potentiometer 18 is connected and the adjustable tap 19 of this potentiometer 18 serves as source for the "final bias voltage" for grid 10. Resistor 20 serving as load for the photo-electric tube 8 is inserted in the connection between tap 19 and grid 10.

The operation of the stabilization means described and the method of adjusting these means are the following:

As set forth above, at the mean value of supply voltage the voltage across resistor 11 is 4 volts, across resistor 12 10 volts, and across resistor 14 also 10 volts. Therefore at the mean value of supply voltage the "first primary bias voltage" across point 21 of the cathode and point 16 is 4 volts from resistor 11 and the "second primary vias voltage" across point 21 and point 17 is 4 volts from resistor 11, plus 10 volts from resistor 12, minus 10 volts from resistor 14, which makes also 4 volts. Now, if the supply voltage drops by e. g. 1 percent the "first primary bias voltage" i. e. the voltage across resistor 11 decreases also by 1 per cent i. e. by 0.04 volt to 3.96 volts; the "second primary bias voltage" composed of the voltages across resistors 11, 12 and 14 however, decreases in the following way: the voltage across resistor 11 decreases also by one percent i. e. by 0.04 volt to 3.96 volts, the voltage across resistor 12 also by one percent i. e. by 0.1 volt to 9.9 volts, but the voltage across resistor 14 remains constant 10 volts. Thus the "second primary bias voltage" will decrease to 3.96 volts plus 9.9 volts minus 10 volts which makes 3.86 volts i. e. by much more than 1 percent. Actually this latter drop is 3.5 percent. Therefore, if tube 7 were biased by the "second primary bias voltage" across point 21 and point 17, as a result of one percent supply voltage drop the D. C. plate resistance would be decreased considerably.

Thus the effect on the D. C. plate resistance has become reversed: As long as point 16 was used as bias source, a supply voltage drop caused increased D. C. plate resistance which resulted in a downward shifting of the needle of the microammeter 3; now point 17 being the source causes decreased D. C. plate resistance resulting in an upward shifting of the needle.

In order to have the possibility to adjust the bias voltage change needed the adjustable tap 19 of the high resistance potentiometer 18 across points 16 and 17 is used as bias source: In shifting the tap 19 from one end towards the other, any desired bias change within wide limits can be obtained. It is easy, therefore, to set the tap 19 to a position so that the D. C. plate resistance becomes constant and independent of supply voltage changes. As a result, the meter needle shifts neither downward nor upward even if the voltage supply to the bridge may change.

In Fig. 2 the meter deflection in microamperes is plotted against supply voltage for a certain illumination which produces, at 110 volts supply

voltage, a meter current of 50 microamperes. Curve A shows that the range of effectiveness of the stabilization is almost plus and minus 10 volts from an average supply voltage of 110 volts for which the potentiometer 18 has been set. Curve B shows the condition when no compensation was used i. e. when tap 19 of the potentiometer was set to point 16. Curve C shows an equally undesirable condition of over-compensation i. e. when tap 19 of potentiometer 18 was set to the point 17.

As may be seen from this diagram the final correct position of tap 19 must be between these two extreme positions. In order to find this correct position and to adjust the stabilization the following way is proposed:

1. Set potentiometer tap 19 to point 16. Decrease the supply voltage and observe whether meter 3 shows a downward deflection.

2. Set potentiometer tap 19 to point 17. Decreased supply voltage should result in an upward deflection of meter needle.

3. Shift the tap 19 step by step until the meter needle is not deflected by supply voltage changes.

Setting the tap 19 at the point found as above described by trial will result in a final bias voltage compensating the effect of supply voltage changes on the amplifier tube, and thereby stabilizing the bridge circuit.

These stabilizing means are sufficient for compensating supply voltage changes, when none of the changes involved has a time lag as against the other changes. However, only two of the changes mentioned namely the changes in bias and plate voltage occur simultaneously with the change in supply voltage, while the third i. e. the change in filament temperature is delayed. This temporary lag is due to the cathode requiring a certain time to attain its changed temperature. Therefor our "static" stabilization is only sufficient as long as supply voltage changes are slow or at least not too sudden: Very rapid supply voltage changes, however, cause a temporary deflection of the meter needle.

As the filament of directly heated tubes is very thin, the time lag of temperature changes during which the needle is deflected, is therefor very short. Proper damping of the meter further reduces this effect of sudden supply voltage changes. Nevertheless, in most locations, the supply voltage variations due to loads being switched on and off the supply line, are so sudden and frequent that the needle fluctuations may become disturbing.

In order to overcome this effect the "static" stabilization described above is supplemented by a further stabilizing compensation, the action of which may be termed as being "dynamic."

As at the first instant after sudden supply voltage change, the filament is still at its previous temperature, i. e. substantially no change in filament temperature has yet occurred, the plate voltage change only has to be compensated. We propose therefor to retard the effect of bias voltage change on the grid after sudden supply voltage changes, preferably in conformity with the lag in change of filament emission, until the cathode filament reaches a temperature corresponding to the changed supply voltage. This retarding effect may be attained in accordance with our present invention by producing a temporary shift of the bias voltage as supplied to the grid 10. This temporary shift is obtained by a "temporary additional voltage" made to act upon the grid, the magnitude of which temporary additional voltage is smaller than the magnitude of the change of the final bias voltage as supplied by tap 19 and the direction of which temporary additional voltage is opposite to the direction of the change of the final bias voltage. In most cases it is sufficient if the magnitude of this temporary additional voltage is ranging between the magnitude of the change of the final bias voltage as supplied by tap 19 and the magnitude of the change of the first primary voltage as supplied by point 16.

As a means for producing this "temporary additional voltage" we may use a condenser 24, one terminal of which is connected to grid 10 and the other terminal to a point in the circuit the voltage of which changes, in case of supply voltage changes, by a value adapted to cause the aforesaid temporary additional voltage to act upon the grid. Thus, for instance, in the embodiment of our invention shown in Fig. 1 the other terminal of condenser 24 is connected to the adjustable tap 23 of the additional potentiometer 22. This additional potentiometer 22 is connected across points 1 and 21 thereby being adapted to supply for the first instant after a sudden supply voltage change a temporary additional voltage of the required magnitude. By adjusting tap 23 we find the correct magnitude of this temporary additional voltage. While the filament approaches its new temperature the condenser 24 is discharged through resistor 20 and the grid 10 assumes its bias from the tap 19 of potentiometer 18. Thus, the position of the tap 23 of the potentiometer 22 determines the magnitude of this temporary additional voltage, while the value of the time constant of condenser 24 and resistor 20 determines the duration of this change. We prefer to make both adjustable so that the effect of this time delay in temperature changes of the filament can be correctly compensated.

It is also possible to use separate means adapted to adjust the time constant of said bias retarding means as to be substantially equal to the time constant of change of filament emission of the tube; thus e. g. a variable resistor 25 may be inserted in series with condenser 24 and used as means to adjust the time constant of the delay described above.

We want further to point out that it is not necessary to connect the potentiometer 22 across points 1 and point 21 of the cathode as shown in Fig. 1. Figs. 3 and 4 show that other connections giving in most cases satisfactory results are also possible: Thus in Fig. 3 the high resistance potentiometer 22 is connected parallel to the potentiometer 18 across points 16 and 17; in Fig. 4 a circuit diagram is shown in which no second potentiometer besides the main potentiometer 18 is provided for, but the voltage needed for "dynamic" compensation, is supplied by tap 27 positioned on the main potentiometer 18 between tap 19 and the end of the potentiometer connected to point 16. As pointed out above it is only of importance that for the instant after the sudden supply voltage change the grid 10 assumes a potential nearer to point 16 than the potential determined by tap 19: In all embodiments of our invention this purpose is fully attained.

In using both the "static" and "dynamic" compensation for stabilization as proposed by us, it is possible to operate electric circuits, comprising amplifier tubes, directly on supply lines even

though the voltage of such lines be subject to wide and sudden variations.

Without further analysis, the foregoing will so fully reveal the gist of our invention that others can by applying current knowledge readily adapt it for various applications without omitting features, that, from the standpoint of the prior art, fairly constitute essential characteristics of the generic or specific aspects of this invention, and therefore such adaptations should and are intended to be comprehended within the meaning and range of equivalency of the following claims.

What we claim as new and desire to secure by Letters Patent is:

1. In an electric circuit an amplifier tube, a supply voltage circuit for said tube, said supply voltage being subject to changes, two sources of primary grid bias voltage, said sources giving voltages being at the mean value of the supply voltage equal to each other, the percentage change of one of said primary bias voltages being in case of supply voltage changes substantially equal to and the percentage change of the other of said bias voltages being larger than the percentage change of said supply voltage, and means for deriving from said primary bias voltages a final bias voltage having a percentage change between the percentage changes of said two primary voltages.

2. In an electric circuit an amplifier tube, a supply voltage circuit for said tube, said supply voltage being subject to changes, two sources of primary grid bias voltage, said sources giving voltages being at the mean value of the supply voltage equal to each other, the percentage change of one of said primary bias voltages being in case of supply voltage changes substantially equal to and the percentage change of the other of said bias voltages being larger than the percentage change of said supply voltage, and means for deriving from said primary bias voltages a final bias voltage having a percentage change adjustable within the limits of the percentage changes of said two primary bias voltages.

3. In an electric circuit an amplifier tube, a supply voltage circuit for said tube, said supply voltage being subject to changes, a first source of primary grid bias voltage, the percentage change of said first bias voltage being in case of supply voltage changes substantially equal to the percentage change of said supply voltage, a second source of primary grid bias voltage, the percentage change of said second bias voltage being in case of supply voltage changes larger than the percentage change of said supply voltage, said two sources giving voltages being at the mean value of the supply voltage substantially equal to each other and to the mean bias voltage, and means for deriving from said primary bias voltages a final bias voltage having a percentage change adjustable within the limits of the percentage changes of said first and second bias voltages.

4. In an amplifier circuit an amplifier tube, a supply voltage circuit for said tube, said supply voltage being subject to changes, two sources of primary grid bias voltage, said sources supplying voltages being at the mean value of the supply voltage equal to each other, the percentage change of one of said primary voltages being in case of supply voltage changes substantially equal to and that of the other primary voltage being larger than the percentage change of said supply voltage, and a potentiometer connecting said primary voltage sources, the adjustable tap of said potentiometer being the source of the final bias voltage, said final bias voltage thereby having a percentage change adjustable within the limits of the percentage changes of said primary voltages.

5. In an amplifier circuit an amplifier tube, a supply voltage circuit for said tube, said supply voltage being subject to changes, two sources of primary grid bias voltage, said sources supplying voltages being at the mean value of the supply voltage equal to each other, the percentage change of one of said primary voltages being in case of supply voltage changes substantially equal to and that of the other primary voltage being larger than the percentage change of said supply voltage, and a potentiometer connecting said primary voltage sources, the adjustable tap of said potentiometer being the source of the final bias voltage, said adjustable tap being so positioned that the D. C. plate resistance of the tube is kept at a substantially constant value despite supply voltage changes.

6. In an electric circuit an amplifier tube, a supply voltage circuit for said tube, said supply voltage being subject to changes, a first source for primary bias voltage having in case of supply voltage changes a percentage change being substantially equal to the percentage change of said supply voltage, a second source of primary grid bias voltage, said second source giving a voltage composed of two voltages supplied by two voltage sources, one of these sources supplying a changing voltage being larger than said first primary bias voltage, and the other of these sources supplying a substantially constant voltage being opposite with respect to said changing voltage, said constant voltage being equal to the difference between said changing voltage at the mean value of said supply voltage and the first primary bias voltage, and means for deriving from said primary bias voltages a final bias voltage having a percentage change being between the percentage changes of said primary voltages.

7. In an electric circuit an amplifier tube, a supply voltage circuit for said tube, said supply voltage being subject to changes, a first primary bias voltage source, the percentage change of said first bias voltage being in case of supply voltage changes substantially equal to the percentage change of said supply voltage, a second primary bias voltage source, said second primary bias voltage source giving a voltage composed of two voltages supplied by two voltage sources, one of these sources supplying a changing voltage being larger than and being subject to the same percentage changes as said first primary bias voltage, and the other of these sources supplying a substantially constant voltage being opposite with respect to said changing voltage, said constant voltage being equal to the difference between said changing voltage and said first primary bias voltage at the mean value of said supply voltage, and means for deriving from said primary bias voltages a final bias voltage having a percentage change being between the percentage changes of said primary voltages.

8. In an amplifier circuit an amplifier tube, a supply voltage circuit for said tube, said supply voltage being subject to changes, a first primary bias voltage source giving a voltage being at the mean value of the supply voltage equal to the mean bias voltage and having in case of supply voltage changes a percentage change being substantially equal to the percentage change of said supply voltage, a source of changing voltage being

larger than said first primary bias voltage, in series with said changing voltage source a source of substantially constant voltage, said constant voltage being equal to the difference between said changing voltage and the first primary bias voltage at the mean value of the supply voltage, the free terminal of said constant voltage source serving as second source of primary bias voltage, and means for deriving from said first and second primary bias voltages a final bias voltage having a percentage change being between the percentage changes of said primary voltages.

9. In an amplifier circuit an amplifier tube, a supply voltage circuit for said tube, said supply voltage being subject to changes, a first primary bias voltage source giving a voltage being at the mean value of the supply voltage equal to the mean bias voltage and having in case of supply voltage changes a percentage change being substantially equal to the percentage change of said supply voltage, a second primary bias voltage source giving a second primary bias voltage composed of two voltages supplied by two voltage sources arranged in series, one of these sources supplying a changing voltage being larger than and being subject to the same percentage changes as said first primary bias voltage, and the other of these sources supplying a substantially constant voltage being opposite with respect to said changing voltage, said constant voltage being equal to the difference between said changing voltage and said first primary bias voltage at the mean value of said supply voltage, and a potentiometer connecting said primary voltage sources, the adjustable tap of said potentiometer being the source of the final bias voltage, said final bias voltage having a percentage change adjustable within the limits of the percentage changes of said primary voltages.

10. In an amplifier circuit an amplifier tube, a supply voltage circuit for said tube, said supply voltage being subject to changes, a first primary bias voltage source giving a voltage being at the mean value of the supply voltage equal to the mean bias voltage and having in case of supply voltage change a percentage change being substantially equal to the percentage change of said supply voltage, a second primary bias voltage source, said second primary bias voltage source giving a second primary bias voltage composed of two voltages supplied by two voltage sources arranged in series, one of these sources supplying a changing voltage being larger than, and subject to the same percentage changes as said first primary bias voltage, and the other of these voltage sources comprising a glow discharge tube supplying a substantially constant voltage being opposite with respect to said changing voltage, said constant voltage being derived from the voltage across the terminals of said glow discharge tube and being equal to the difference between said changing voltage and said first primary bias voltage at the mean value of said supply voltage, and means for deriving from said first and second primary bias voltages a final bias voltage having a percentage change being between the percentage changes of said primary voltages.

11. In an electric circuit an amplifier tube, a supply voltage circuit for said tube, said supply voltage being subject to changes, a first primary bias voltage source giving a first primary voltage being at the mean value of the supply voltage equal to the mean bias voltage and having in case of supply voltage changes a percentage change being substantially equal to the percentage change of said supply voltage, in series therewith a source of additional changing voltage being subject to the same percentage changes as said first primary bias voltage, in series with said additional changing voltage source a source supplying a substantially constant voltage being opposite with respect to said additional changing voltage, said constant voltage being, at the mean value of the supply voltage, substantially equal to said additional voltage, the free terminal of said constant voltage source serving as second primary bias voltage source giving a second primary bias voltage, and means for deriving from said first and second primary bias voltages a final bias voltage having a percentage change being between the percentage changes of said primary voltages.

12. In an electric circuit an amplifier tube, a supply voltage circuit for said tube, said supply voltage being subject to changes, a first primary bias voltage source giving a voltage being at the mean value of the supply voltage equal to the mean bias voltage and having in case of supply voltage changes a percentage change being substantially equal to the percentage change of said supply voltage, a source of additional changing voltage in series with said first primary bias voltage source, said additional changing voltage being subject to the same percentage changes as said first primary bias voltage, a further voltage source comprising a glow discharge tube, supplying a substantially constant voltage being opposite with respect to said additional changing voltage, arranged in series with said changing voltage source, said constant voltage being derived from the voltage across the terminals of said glow discharge tube and being at the mean value of the supply voltage equal to said additional changing voltage, the free terminal of said constant voltage source serving as second primary bias voltage source and a potentiometer connecting said first and second primary bias voltage sources, the adjustable tap of said potentiometer being the source of the final bias voltage, said adjustable tap being so positioned that the D. C. plate resistance of the tube is kept at a substantially constant value despite supply voltage changes.

13. In an electric circuit an amplifier tube, a supply voltage circuit for said tube, said supply voltage being subject to changes, two sources of primary grid bias voltage, said sources giving voltages being at the mean value of the supply voltage equal to each other, the percentage change of one of said primary bias voltages being in case of supply voltage changes substantially equal to and the percentage change of the other of said bias voltages being larger than the percentage change of said supply voltage, means for deriving from said primary bias voltages a final bias voltage having a percentage change between the percentage changes of said two primary voltages, and means for retarding the effect of changes in said final bias voltage on the grid after sudden supply voltage changes until the cathode reaches a temperature corresponding to the changed supply voltage.

14. In an electric circuit an amplifier tube, a supply voltage circuit for said tube, said supply voltage being subject to changes, two sources of primary grid bias voltage, said sources giving voltages being at the mean value of the supply voltage equal to each other, the percentage change of one of said primary bias voltages being in case of supply voltage changes substan-

tially equal to and the percentage change of the other of said bias voltages being larger than the percentage change of said supply voltage, means for deriving from said primary bias voltages a final bias voltage having a percentage change being between the percentage changes of said two primary bias voltages, and means for retarding the effect of changes in said final bias voltage on the grid after sudden supply voltage changes in conformity with the lag in change of filament emission until the cathode reaches a temperature corresponding to the changed supply voltage.

15. In an electric circuit an amplifier tube, a supply voltage circuit for said tube, said supply voltage being subject to changes, two sources of primary grid bias voltage, said sources giving voltages being at the mean value of the supply voltage equal to each other, the percentage change of one of said primary bias voltages being in case of supply voltage changes substantially equal to and the percentage change of the other of said bias voltages being larger than the percentage change of said supply voltage, means for deriving from said primary bias voltages a final bias voltage having a percentage change between the percentage changes of said two primary voltages, a resistor inserted in the connection between the final bias voltage source and the grid, and means for retarding the effect of changes in said final bias voltage on the grid after sudden supply voltage changes until the cathode reaches a temperature corresponding to the changed supply voltage.

16. In an electric circuit an amplifier tube, a supply voltage circuit for said tube, said supply voltage being subject to changes, two sources of primary grid bias voltage, said sources giving voltages being at the mean value of the supply voltage equal to each other, the percentage change of the first of said primary bias voltages being in case of supply voltage changes substantially equal to and the percentage change of the second of said bias voltages being larger than the percentage change of said supply voltage, means for deriving from said primary bias voltages a final bias voltage having a percentage change being between the percentage changes of said two primary voltages, a resistor inserted in the connection between the final voltage source and the grid, a potentiometer, a connection between the tap of said potentiometer and the grid of the tube, and a condenser inserted in said connection.

17. In an electric circuit an amplifier tube, a supply voltage circuit for said tube, said supply voltage being subject to changes, two sources of primary grid bias voltage, said sources supplying voltages being at the mean value of the supply voltage equal to each other, the percentage change of one of said primary voltages being in case of supply voltage changes substantially equal to and the percentage change of the other primary voltage being larger than the percentage change of said supply voltage, a potentiometer connecting said primary voltage sources, said potentiometer having two adjustable taps, the first of them being the source of the final bias voltage, said final bias voltage having a percentage change adjustable within the limits of the percentage changes of said primary voltages, and the second of said taps being positioned between said first tap and the end of the potentiometer connected to the first primary bias voltage source, and a condenser inserted in a connection between the grid and said second potentiometer tap.

18. In an electric circuit an amplifier tube, a supply voltage circuit for said tube, said supply voltage being subject to changes, two sources of primary grid bias voltage, said sources giving voltages being at the mean value of the supply voltage equal to each other, the percentage change of one of said primary bias voltages being in case of supply voltage changes substantially equal to and the percentage change of the other of said bias voltages being larger than the percentage change of said supply voltage, means for deriving from said primary bias voltages a final bias voltage having a percentage change being between the percentage changes of said two primary bias voltages, means for retarding the effect of changes in said final bias voltage on the grid after sudden supply voltage changes in conformity with the lag in change of filament emission until the cathode reaches a temperature corresponding to the changed supply voltage, and means adapted to adjust the time constant of said retarding means as to be substantially equal to the time constant of change of filament emission of said tube.

19. In an electric circuit an amplifier tube, a supply voltage circuit for said tube, said supply voltage being subject to changes, two sources of primary grid bias voltage, said sources giving voltages being at the mean value of the supply voltage equal to each other, the percentage change of the first of said primary bias voltages being in case of supply voltage changes substantially equal to and the percentage change of the second of said bias voltages being larger than the percentage change of said supply voltage, means for deriving from said primary bias voltages a final bias voltage having a percentage change being between the percentage changes of said two primary voltages, a resistor inserted in the connection between the final voltage source and the grid, a potentiometer, a connection between the tap of said potentiometer and the grid of the tube, and a condenser in series with a variable resistor inserted in said connection.

20. In an electric circuit an amplifier tube, a supply voltage circuit for said tube, said supply voltage being subject to changes, a first primary bias voltage source giving a first primary bias voltage being at the mean value of the supply voltage equal to the mean bias voltage and having in case of supply voltage changes a percentage change being substantially equal to the percentage change of said supply voltage, a source of additional changing voltage in series with said first primary bias voltage source, said additional changing voltage being subject to the same percentage changes as said first primary bias voltage, a further voltage source comprising a glow discharge tube, arranged in series with said additional changing voltage source and supplying a substantially constant voltage being opposite with respect to said additional changing voltage, said constant voltage derived from the voltage across the terminals of said glow discharge tube and being at the mean value of the supply voltage equal to said additional changing voltage, the free terminal of said constant voltage source serving as second primary bias voltage source giving a second primary bias voltage, a main high resistance potentiometer connecting said primary bias voltage sources, the adjustable tap of said main potentiometer being the source of the final bias voltage, said final bias voltage thereby having a percentage change adjustable

within the limits of the percentage changes of said primary bias voltages, a resistor inserted in the connection between said final bias voltage source and the grid, an additional high resistance potentiometer being connected across two such points of said circuit as to be adapted to produce at the tap of the additional potentiometer a temporary additional voltage, the magnitude of which temporary additional voltage is ranging between the magnitude of the change of said final bias voltage and the magnitude of the change of said first primary bias voltage in case of such sudden supply voltage change, a connection between said tap of the additional potentiometer and the grid of the tube, and a condenser inserted in said connection.

21. In an electric circuit an amplifier tube, a supply voltage circuit for said tube, said supply voltage being subject to changes, two sources of primary grid bias voltage, said sources giving voltages being, at the mean value of the supply voltage, substantially equal to each other, the percentage change of one of said primary bias voltages being, in case of supply voltage changes, substantially equal to and the percentage change of the other of said bias voltages being larger than the percentage change of said supply voltage, means for deriving from said primary bias voltages a final bias voltage having a percentage change being between the percentage changes of said two primary bias voltages, means for retarding the effect of changes in said final bias voltage up on the grid after sudden supply voltage changes in conformity with the lag in change of filament emission until the cathode reaches a temperature corresponding to the changed supply voltage.

22. In an electric circuit an amplifier tube, a supply voltage circuit for said tube, said supply voltage being subject to changes, two sources of primary grid bias voltage, said sources giving voltages being, at the mean value of the supply voltage, substantially equal to each other, the percentage change of one of said primary bias voltages being, in case of supply voltage changes, substantially equal to and the percentage change of the other of said bias voltages being larger than the percentage change of said supply voltage, means for deriving from said primary bias voltages a final bias voltage having a percentage change being between the percentage changes of said two primary bias voltages, means for producing for the first instant after a sudden supply voltage change a temporary additional voltage on the grid, the magnitude of which temporary additional voltage is smaller than the magnitude of the change of said final bias voltage in case of such sudden supply voltage change.

23. In an electric circuit an amplifier tube, a supply voltage circuit for said tube, said supply voltage being subject to changes, two sources of primary grid bias voltage, said sources giving voltages being, at the mean value of the supply voltage, substantially equal to each other, the percentage change of the first of said primary bias voltages being, in case of supply voltage changes, substantially equal to and the percentage change of the second of said bias voltages being larger than the percentage change of said supply voltage, means for deriving from said first and second primary bias voltages a final bias voltage having a percentage change being between the percentage changes of said two primary bias voltages, means for producing for the first instant after a sudden supply voltage change a temporary additional voltage on the grid, the magnitude of which temporary additional voltage is ranging between the magnitude of the change of said final bias voltage and the magnitude of the change of said first primary bias voltage in case of such sudden supply voltage change.

24. In an electric circuit an amplifier tube, a supply voltage circuit for said tube, said supply voltage being subject to changes, two sources of primary grid bias voltage, said sources giving voltages being, at the mean value of the supply voltage, substantially equal to each other, the percentage change of one of said primary bias voltages being, in case of supply voltage changes, substantially equal to and the percentage change of the other of said bias voltages being larger than the percentage change of said supply voltage, means for deriving from said primary bias voltages a final bias voltage having a percentage change being between the percentage changes of said two primary bias voltages, a condenser connected to said grid and being adapted to produce for the first instant after a sudden supply voltage change a temporary additional voltage on the grid, the magnitude of which temporary additional voltage is ranging between the magnitude of the change of said final bias voltage and the magnitude of the change of said first primary bias voltage in case of such sudden supply voltage change.

25. In an electric circuit according to claim 4, means for retarding the effect of changes in said final bias voltage upon the grid after sudden supply voltage changes in conformity with the lag in change of filament emission until the cathode reaches a temperature corresponding to the changed supply voltage, said means comprising an additional high resistance potentiometer being connected across two such points of said circuit as to be adapted to produce at the tap of the additional potentiometer a temporary additional voltage, the magnitude of which temporary additional voltage is ranging between the magnitude of the change of said final bias voltage and the magnitude of the change of said first primary bias voltage in case of such sudden supply voltage change, a connection between said tap of the additonal potentiometer and the grid of the tube, and a condenser inserted in said connection.

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