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DEVICE FOR REGULATING THE OUTPUT VOLTAGE OF AMPLIFIERS BY MEANS OF THERMOSENSITIVE RESISTANCES

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Fig. 1

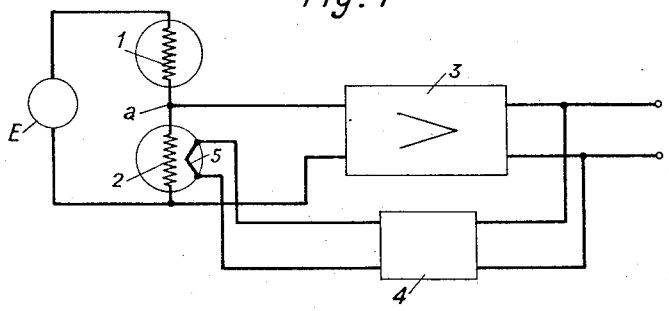


Fig. 2

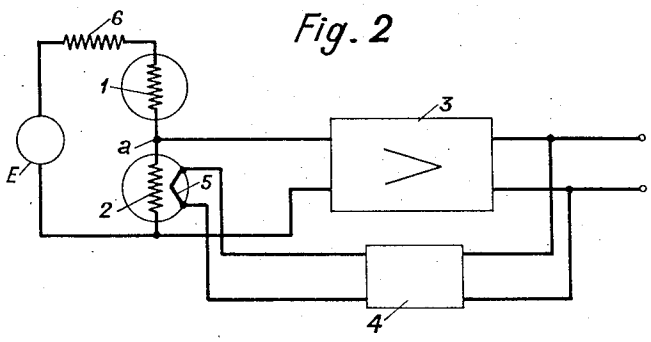
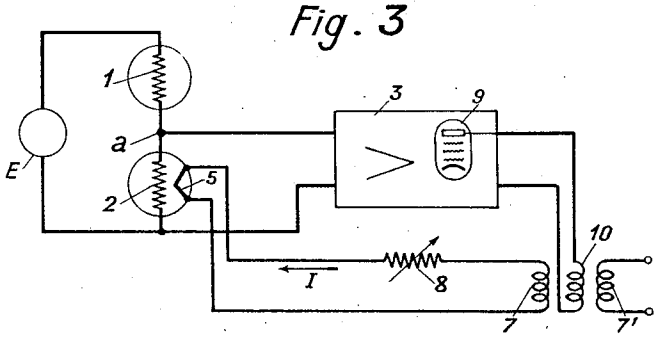


Fig. 3



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DEVICE FOR REGULATING THE OUTPUT VOLTAGE OF AN AMPLIFIER BY MEANS OF THERMOSENSITIVE RESISTANCES

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6 Claims. (Cl. 179—171)

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When it is desired to maintain at a constant level the output voltage of an electronic amplifier, the method commonly used consists in rectifying this voltage and in utilizing the potential difference thus obtained for biasing of a tube having a variable slope. In addition to a certain complication, this method has the drawback of causing the value of the output voltage thus maintained constant to depend on the characteristics of a tube, and to involve a grid characteristic with a large curvature which makes it necessary, in case the harmonics of the input voltage are troublesome, to make this voltage very small.

The purpose of the present invention is to obtain, in a simple manner a regulation, substantially independent of the temperature, of the voltage level at the output of an amplifier by means of elements having a high temperature coefficient as, for example, thermo-sensitive resistances.

It depends mainly on a method for the regulation of the output voltage of an amplifier. It is a characteristic of the method that the input voltage for the amplifier is picked up at the terminals of a thermo-sensitive resistance included in a potentiometer input circuit to the terminals of which the signal to be amplified is applied. Also part of the output voltage of the amplifier is applied to an independent heating winding associated with the thermo-sensitive resistance.

This method also provides for a compensation of the effect of a variation of the ambient temperature on the ratio of the input potentiometer by the presence of a second thermo-sensitive resistance in said potentiometer.

Another object of the present invention is the provision of circuits utilizing the above described method.

Three embodiments of the invention are described in the following specification and illustrated in the accompanying drawings wherein:

Figure 1 shows a circuit arrangement comprising only two thermo-sensitive resistances for obtaining the desired effect:

Figure 2 shows a circuit diagram comprising an additional fixed resistance, and

Figure 3 shows a circuit arrangement for manually controlling the output level of an amplifier.

In the circuit of Figure 1, the source E supplies, through thermo-sensitive resistances 1 and 2, the amplifier 3, part of the output voltage of which is sent, by the network 4, to the heating element 5 of the thermo-sensitive resistance 2. The resistance elements of the two thermo-sensitive resistances 1 and 2 form a potentiometer

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whose middle tap a constitutes one of the input terminals of amplifier 3. To any output voltage variation of the amplifier there corresponds a compensating variation of the resistance 2, whose value varies inversely to its temperature. It is to be noted that the variations both of the source and of the amplifier are compensated.

Thus, if it is assumed that the voltage supplied by the source E decreases, the output voltage of the amplifier decreases likewise; the fraction of this voltage sent to heater 5 of the thermo-sensitive resistance 2 decreases likewise so that the temperature of this thermo-sensitive resistance is lowered while its resistance increases. This causes a modification of the potentiometer ratio in the direction which increases the voltage at the amplifier input terminals and restores the amplifier output to its normal level.

In case the voltage supplied by the source does not vary but the output voltage of the amplifier varies, the method of operation is the same. If the output voltage rises, the heating of the thermo-sensitive resistance 2 becomes more intense, the resistance of said thermo-resistance decreases and a smaller fraction of the input voltage is delivered to the amplifier, the potentiometer ratio varying in an opposite direction to the preceding example.

The thermo-sensitive resistance 1 is provided for securing a compensation of the effect of a given variation of the ambient temperature on the potentiometer ratio. The following calculation will allow a better understanding of the action of this thermo-sensitive resistance.

Let

$$R_1=a_1e^{b'/T} \text{ and } R_2=a_2e^{b''/T}$$

these expressions giving the values of resistances 1 and 2 in terms of the absolute temperature T. In these expressions, a_1 a_2, b' and b'' are constant coefficients.

If the internal resistance of the source E is neglected with respect to the sum of resistances R_1 and R_2, the voltage U at the input of the amplifier is given by the expression

$$U=E\frac{1}{1+R_1/R_2}$$

in which E designates the value of the voltage supplied by the source E.

To reduce the variations of the output voltage as functions of the ambient temperature, which becomes an additional parameter, one may equate the values assumed by the ratio R_1/R_2 at any predetermined limiting temperatures T_1 and T_2.

Let t be the increase in temperature of the thermo-sensitive resistance **2** caused by its heating element **5** for the normal operating point. The condition is:

$$\frac{a_1 e^{b'/T_1}}{a_2 e^{b''/T_1+t}} = \frac{a_1 e^{b'/T_2}}{a_2 e^{b''/T_2+t}}$$

and it is satisfied for

$$b' = b'' \frac{T_1 \times T_2}{(T_1+t)(T_2+t)}$$

The problem is thus solved, theoretically, if a thermo-sensitive resistance **1** is chosen, having the necessary temperature coefficient b'.

This is not always possible and it is just as simple to take two thermo-sensitive resistances of the same type ($b'=b''$) and to arrange, in series, a constant resistance R_1' such as resistance **6** of Figure 2.

To make the input voltages equal at temperatures T_1 and T_2 we must make

$$\frac{R_1' + a_1 e^{b/T_1}}{a_2 e^{b/T_1+t}} = \frac{R_1' + a_1 e^{b/T_2}}{a_2 e^{b/T_2+t}}$$

If R_{01} is the value of R_1 at temperature T:

$$R_{01} = a_1 e^{b/T_1}$$

whence

$$a_1 e^{b/T_2} = R_{01} e^{-b(T_2-T_1)/T_1 T_2}$$

the condition becomes:

$$R'_1 = R_{01} \frac{1 - e^{b(T_2-T_1)(1/(T_1+t)(T_2+t) - 1/T_1 T_2)}}{e^{b(T_2-T_1)/(T_1+t)(T_2+t)} - 1}$$

From which one derives the value R'_1 of the resistance **6** to insert in series to obtain a perfect compensation at temperature T_2.

It is to be noted:

1. That the internal resistance of the generator may be included in the resistance R'_1, while the compensation by a thermo-sensitive resistance of the coefficient b' assumed the internal resistance of the source as being negligible compared with the sum R_1+R_2.

2. That a thermo-sensitive resistance **1** of any type would also give the desired result provided its temperature coefficient is sufficiently high.

It is quite obvious that various modifications of detail may be effected within the scope of the present invention.

Further, the term "thermo-sensitive resistance" used in the present description is to be taken in a very wide sense; it designates any resistance whose value decreases when its temperature increases.

From the above it is seen that the present invention provides a means and method for automatically regulating the output voltage of an amplifier, consisting in picking up the input voltage for the amplifier at the terminals of a resistance element having a negative temperature coefficient and having an independent heating circuit, the resistance forming part of a voltage divider supplied by the source to be amplified and in applying part of the voltage output of the amplifier to the heating circuit of the resistance element.

Means have also been provided for compensating the effect of variations of the ambient temperature and circuits for securing the desired result described.

Under such conditions, the heating circuit of the thermo-sensitive resistance is energized by a current which is proportional to the output voltage of the amplifier, so that the input voltage varies in a direction inverse to the output voltage thus tending to keep the latter constant.

The constancy of the output voltage is of course greater as the resistance variation of the thermo-sensitive resistance as a function of temperature increases. Now the coefficient of resistance variation of the thermo-sensitive resistance depends, to a fairly large extent, on the temperature to which the thermo-sensitive resistance is raised, i. e. in the present case, on the amount of current flowing through its heating circuit.

A further modification of the invention makes it possible to modify at will the output voltage of the amplifier without displacing the operating point of the thermo-resistance selected in conformity with its construction. Thus, whatever value may be selected for the output voltage, the thermo-sensitive resistance will be able to operate at its optimum point.

In this modification, the internal output resistance of the amplifier is high compared to the resistance in its output circuit and almost its whole load consisting of the heating circuit of the thermo-sensitive resistance. An adjustable resistance is connected in series with said thermo-sensitive resistance to vary the output voltage of the amplifier.

This modification is shown in Figure 3 wherein the current source E is connected through a voltage divider consisting of resistance 1, which is a resistance sensitive to the ambient temperature, and of the thermo-sensitive resistance **2**, connected to the input terminals of amplifier **3**. The last stage of the amplifier is constituted by an electronic tube having an internal impedance much larger than its load impedances, for example, a pentode **9**. The transformer **10** comprises two secondary windings **7** and **7'**, one of which **7'** energizes the supply circuit and the other of which **7** supplies the heating circuit **5** of the thermo-sensitive resistance **2**. The transformer **10** is designed in such a manner that for the normal input voltage and the normal output current, the current I flowing through the heating circuit **5** of the thermo-sensitive resistance **2** raises the latter to a temperature at which the resistance variation caused by a variation of the current I is large. A variable resistance **8** is connected in series in the heating circuit **5** of the thermo-sensitive resistance **2**.

Under such conditions, the load of the transformer T being assumed as consisting mainly of the heating circuit of the thermo-sensitive resistance, for a voltage of the source E and a given amplification coefficient for the amplifier, a variation of the resistance **8** does not appreciably change the current flowing through it, and, therefore the temperature of the thermo-sensitive resistance, but allows an adjustment of the output voltage.

The resistance **8** being set at a desired value, a variation of the voltage of E or of the amplification coefficient will cause a current variation in transformer T in such a direction that the resistance of the thermo-sensitive resistance **2** will be modified so as to oppose said variation and, consequently, to keep the output voltage constant.

While I have above described the principles of my invention in connection with specific apparatus, it is to be understood that this description is made only by way of example and not as a limitation on the scope of the invention as set forth in the objects of my invention and the accompanying claims.

I claim:

1. A device for automatic gain regulation of an amplifier having input and output signal terminals, comprising a voltage divider, said divider including two thermo-sensitive resistances having negative temperature coefficients, one of said thermo sensitive resistances comprising an insulated heater for its indirect heating, a source of signal voltage connected to said voltage divider, means connecting input terminals of said amplifier to spaced apart points on said voltage divider, a circuit for supplying current to said heater and means coupling said circuit to the output signal terminals of said amplifier, whereby the temperature of said one resistance is increased in response to an increase in amplified signal voltage at said amplifier output terminals.

2. A device according to claim 1, wherein the input terminals of said amplifier are connected across the ends of said heated resistance.

3. A device according to claim 1, wherein said one resistance which is heated has a negative temperature coefficient of resistance of substantially greater value than the temperature coefficient of resistance of the other thermosensitive resistance.

4. A device according to claim 1, wherein the output stage of the amplifier has a high internal

resistance and wherein the circuit for supplying current to said heater includes an adjustable resistance, whereby adjustment of said adjustable resistance permits the output signal voltage of said amplifier to be adjusted to a desired level.

5. A device according to claim 1, wherein the voltage divider includes a third resistance of value remaining substantially the same at different ambient temperatures, said resistance being connected in series, in said voltage divider.

6. A device according to claim 5, wherein an appreciable portion of said third resistance consists of the internal resistance of said signal voltage source.

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