

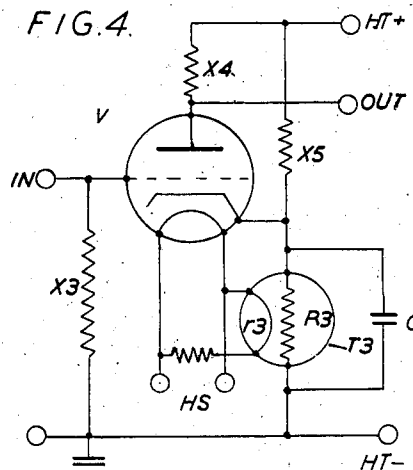
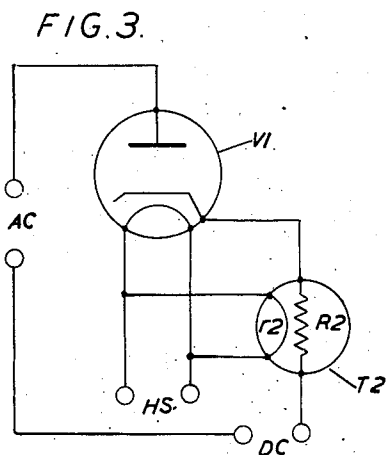
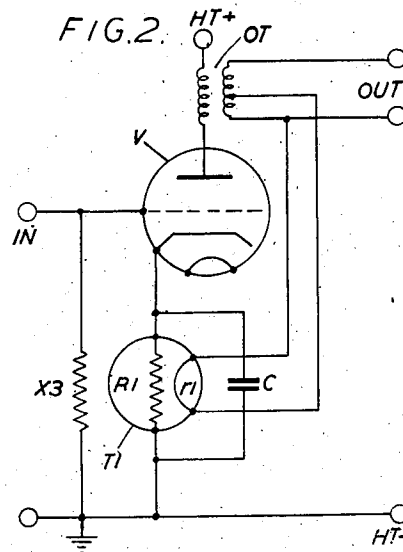
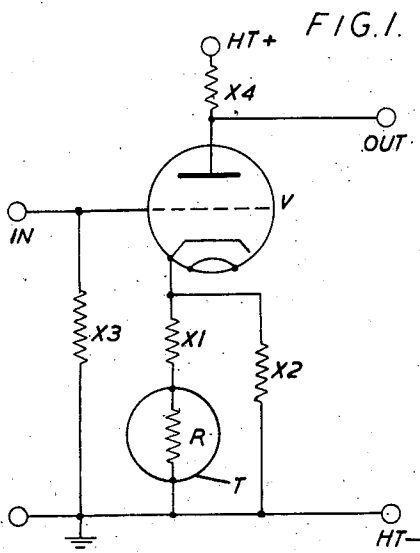
April 26, 1949.

P. K. CHATTERJEA ET AL
THERMISTOR CIRCUIT COMPENSATING FOR
SUPPLY VOLTAGE FLUCTUATIONS

2,468,082

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2 Sheets-Sheet 1



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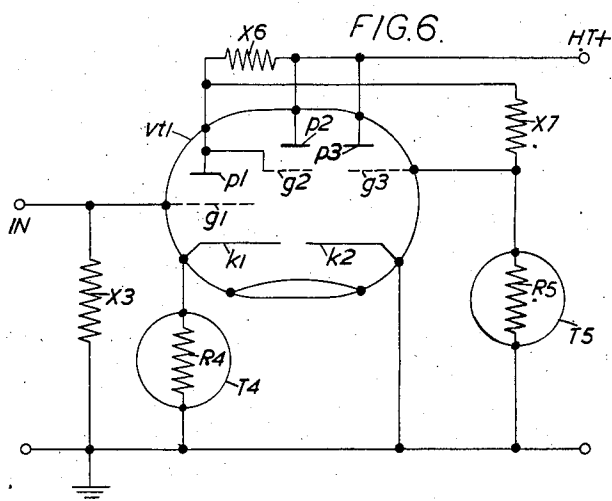
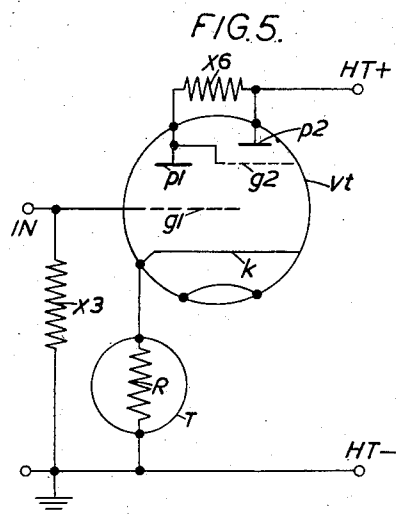
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UNITED STATES PATENT OFFICE

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THERMISTOR CIRCUIT COMPENSATING FOR
SUPPLY VOLTAGE FLUCTUATIONS

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3 Claims. (Cl. 250—27)

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The present invention relates to thermionic valve circuits and in particular makes use of the special properties of the thermally sensitive resistance elements known as thermistors for simplifying the arrangements.

Thermistors have been in use for some years and are characterised by a temperature coefficient of resistance which may be either positive or negative and which is moreover many times the corresponding coefficient for a pure metal such as copper. This property renders thermistors particularly suitable for a variety of special applications in electric circuits.

Various different materials are available for the resistance element of a thermistor, these various materials having different properties in other respects; as one example, a resistance material having a high negative temperature coefficient of resistance comprises a mixture of manganese oxide and nickel oxide, with or without the addition of certain other metallic oxides, the mixture being suitably heat treated.

Thermistors have been employed in two different forms: (a) known as a directly heated thermistor and comprising a resistance element of the thermally sensitive resistance material provided with suitable lead-out conductors or terminals, and (b) known as an indirectly heated thermistor comprising the element (a) provided in addition with a heating coil electrically insulated from the element. A directly heated thermistor is primarily intended to be controlled by the current which flows through it and which varies the temperature and also the resistance accordingly. Such a thermistor will also be affected by the temperature of its surroundings and may therefore be used for thermostatic control and like purposes with or without direct heating by the current flowing through it. An indirectly heated thermistor is chiefly designed to be heated by a controlling current which flows through the heating coil and which will usually, but not necessarily, be different from the current which flows through the resistance element, but this type of thermistor may also be subjected to either or both of the types of control applicable to a directly heated thermistor.

More detailed information on the properties of thermistors will be found in an article by G. L. Pearson in the Bell Laboratories' Record Dec. 1940, page 106.

In the present specification a number of miscellaneous valve circuits will be described embodying the invention which is characterised by connecting the resistance element of a thermistor

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in series with the cathode of a thermionic valve so that the cathode current flows through it.

According to the invention, there is provided an electrical circuit arrangement comprising a thermionic valve and a thermistor having its resistance element connected in series with the cathode of the valve, so that the cathode current flows therethrough.

The invention will be explained with reference to the accompanying drawings in which:

Fig. 1 shows a schematic circuit diagram of a low frequency valve circuit according to the invention;

Fig. 2 shows a circuit for unblocking a quiescent-amplifier;

Fig. 3 shows a protective circuit for a gas filled rectifier valve;

Fig. 4 shows an arrangement for compensating for the effects of changes in the supply voltages for a thermionic valve; and

Figs. 5 and 6 show the invention applied to tuning indicators for radio receiving sets.

In the present specification all resistances not specifically referred to as thermistors are to be supposed to be ordinary resistances whose values are substantially independent of the current flowing through them.

In thermionic valve circuits it is frequently the practice to provide the whole or part of the bias for the control grid by connecting a resistance in series between the cathode and the negative terminal of the plate potential source (which terminal is generally connected to ground). The cathode assumes a positive potential due to the cathode current, and if the control grid is connected to ground through an input circuit in the usual way its potential with respect to the cathode will be negative.

As is well known, the cathode resistance will act as a feedback connection between the output and the input of the valve, and to prevent feedback when it is not required, it is the practice to shunt the resistance with a by-pass condenser or with a smoothing circuit so that no appreciable alternating potential is developed. This arrangement is quite satisfactory except for amplifiers operating at very low frequencies (say of the order of a few cycles per minute) in which case the necessary condenser has to be so large that the arrangement is impracticable.

Fig. 1 shows how the difficulty may be overcome according to the invention by connecting a directly heated thermistor T in series with the cathode of a valve V. A resistance X_1 is connected in series with the resistance element R

of the thermistor, and a resistance X_2 is connected in parallel with the combination. X_3 is the input grid resistance, and the plate is supplied from the positive terminal HT+ of the high tension source through a resistance X_4 . Signals are applied to the grid across X_3 , and the amplified signals are taken directly from the plate. It will be understood that the valve V may form only one of the stages of an amplifier and may be coupled and supplied in any known way, Fig. 1 showing only one possible arrangement.

The thermistor should have a negative temperature coefficient of resistance. When a constant potential is applied to the control grid, the thermistor will be heated by the corresponding cathode current I and its resistance will decrease to some constant value R. The applied grid bias voltage will evidently be

$$E = \frac{I \cdot X_2 (R + X_1)}{R + X_1 + X_2}$$

If the potential applied to the control grid be increased (that is, made more positive or less negative), the cathode current will be likewise increased, raising the temperature of the thermistor and lowering its resistance. In order that there shall be no feedback it is necessary that the grid bias voltage should be unchanged. It is, therefore, necessary to choose the values of X_1 and X_2 together with the thermistor characteristic so that a constant value of E is obtained over the desired range of variation of I. When this has been done, a fixed grid bias is obtained and there will be no feedback when a low frequency alternating voltage is applied to the control grid.

It may of course happen that one or both of the resistances X_1 and X_2 may not be required, so that the thermistor may be employed alone in series with the cathode. Whether or not either of these resistances is necessary will depend on the characteristics of the thermistor and on the range over which the grid bias voltage must be constant or approximately constant. It will be evident that the resistance X_2 may be connected to shunt the thermistor only and auxiliary biasing means may be provided to assist in adjusting the constant voltage to the desired value.

The circuit of Fig. 1 may be supplemented by the use of a condenser or smoothing circuit connected instead of or in addition to the resistance X_2 , or shunting X_1 or R alone or in other positions. This will give additional freedom in obtaining the desired characteristic.

Moreover, although the valve V is shown for simplicity as a triode, it might have additional electrodes provided with appropriate auxiliary arrangements. When a pentode valve is used the polarising voltage for the screen grid is often obtained by connecting it to an intermediate point on a resistance connected across the high tension supply, a by-pass condenser being connected between the screen grid and ground. At very low frequencies, the by-pass condenser will fall for the reasons already explained, and the earth connection may therefore be replaced by a network including a thermistor generally similar to that shown in Fig. 1 and designed so that the screen grid potential is substantially independent of the potential of the control grid.

On account of the fact that the time taken for the thermistor to heat up is not inappreciable, there will be a small lag in the response to changes in the current. The magnitude of this lag will depend on the thermistor design but will

be practically inappreciable at least up to frequencies of a few cycles per second. The arrangement therefore operates best at very low frequencies where the other methods fail.

According to another feature of the invention, the circuit of Fig. 1 may be employed as a low frequency amplifier in which the action of the thermistor increases the gain. The characteristics of the thermistor, and the values of the associated resistances X_1 and X_2 are chosen so that as the control grid potential is increased or decreased by the applied signal the cathode potential falls or rises respectively; or in other words so that the bias voltage E decreases as the cathode current I increases, and vice versa. This will evidently have the effect of augmenting the change of the potential difference between the control grid and the cathode; in other words the thermistor is acting as an auxiliary amplifier. The reduction in resistance caused by increase in the heating current of a thermistor with a negative temperature coefficient may be very steep and it will generally be easy to meet the above condition. Either or both of the resistances X_1 and X_2 can of course be omitted if not required to obtain an appropriate characteristic.

It will be evident that the change in cathode potential must be less than the change in signal potential producing it, otherwise the arrangement will be unstable. This sets a limit to the gain which can be obtained by the means of the thermistor.

It will be evident also that with this arrangement the valve may have additional electrodes polarised in circuits including thermistors as already explained.

The arrangement of Fig. 1 may also be used for reducing the gain or blocking an amplifier when no signals are passing, for the purpose of rendering it quiet in these periods. This is a practice commonly adopted in radio receivers, but the methods used hitherto generally result in asymmetric distortion which occurs on account of the blocking bias which has to be overcome by the signals.

The cathode network in Fig. 1 should be shunted by a by-pass condenser (not shown) and should be chosen so that when there are no incoming signals the valve is biased nearly to the cut-off. As soon as signals at a moderately high level are received, there will be a rectifying effect which will increase the plate current. This will heat the thermistor and if it has a negative temperature coefficient of resistance, its resistance will be decreased and will reduce the blocking bias, still further increasing the plate current until an operating point is reached much farther up the valve characteristic where the curvature is small. It will be seen that the asymmetric distortion will be greatly reduced. It is of course necessary to choose the characteristics of the valve and thermistor so that the arrangement is stable, or in other words so that an increase in cathode current would not by itself, in the absence of signals, produce a change in grid voltage sufficient to maintain the current change. This method is liable still to suffer from some asymmetric distortion, and a preferred arrangement is to use an indirectly heated thermistor, as shown in Fig. 2. The resistance element R_1 of the thermistor T_1 is connected in series with the cathode and is shunted by a by-pass condenser C. Series and/or shunt resistances (not shown) similar to X_1 and X_2 in Fig. 1 may be included if necessary to get the desired characteristic. The

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valve V may be supposed, for example, to be one of the final amplifying stages in a radio receiver, the signals being at voice frequencies and taken from the plate circuit through an output transformer OT. The heating coil r_1 of the thermistor, T_1 is connected across an appropriate portion of the secondary winding (or it may be connected to a suitable third winding or in any other convenient way) so that the thermistor will be heated by the output signals.

The resistance of the element R_1 (together with any additional resistances if used) should be chosen so that the valve is biased nearly to the cut-off when no signals are being received, so that noise originating in the earlier stages is not passed on to the output. When the signals arrive, a small output will at first be obtained which will heat the thermistor and will reduce the resistance of the element. This will reduce the cathode potential, increasing the gain of the valve until the operating point is moved up to a straight part of the valve characteristic, and the full amplification is obtained without asymmetric distortion. When the signals cease, the cathode potential rises again and cuts off the valve. As long as the signals persist, the thermistor does not have time to cool appreciably during the normal fluctuations of the signal voltage and the grid bias will be substantially constant. This arrangement is preferable to the one previously described since it does not depend on rectification for its operation. The thermistor should, of course, have a negative temperature coefficient of resistance.

By a slight variation of this method, the thermistor may be heated from a proportion of the output of any preceding amplifying valve, obtained in any convenient way. This will have the advantage that the response will be somewhat quicker since the full amplitude of the signals is available at once to heat the thermistor, and will not be delayed while the gain of the controlled valve is increasing.

In radio receivers having automatic volume control there is frequently a control valve whose plate current is designed to vary in accordance with the signal level. Advantage may be taken of this for heating the thermistor, and the heating coil r_1 may be connected in series with the plate circuit of the control valve as a further alternative to the arrangement of Fig. 2. It will be evident, therefore, that any arrangement may be adopted by which the thermistor can be heated by signal currents obtained at any convenient place in the amplifier, or by derived currents which depend on the signal level.

In the arrangement of Fig. 2 or in those derived from it, the thermistor may be chosen so that direct heating by the cathode current is appreciable. This will increase the rate of response if the increase in cathode current is sufficiently rapid as compared with the decrease in the thermistor resistance for the total heating power to increase. This will, of course, depend on the characteristics of the valve and thermistor, and if the condition is not fulfilled, so that the power decreases, the response may be retarded.

If an extra resistance (not shown) be connected between the cathode and the positive high tension terminal HT+, the cathode may derive its bias from the potentiometer so formed, and the resistance and thermistor may be so chosen that the potentiometer current is large compared with the cathode current, so that the variations of the latter will have no appreciable effect on the cath-

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ode potential. The extra resistance may alternatively be the resistance element of a second indirectly heated thermistor having a positive temperature coefficient of resistance and having its heating coil connected in series or in parallel with r_1 . This will produce a more rapid change in the cathode potential when the signals are first received.

More than one valve may be controlled at the same time in the manner of Fig. 2 and its variations, by connecting the heating coils of all the thermistors in series or in parallel.

The process of unblocking a valve in the manner described in connection with Fig. 2 may be regarded as an extreme or limiting case of contrast expansion. It will, therefore, be easily appreciated that by suitably choosing the valve and thermistor characteristics together with the values of the associated resistances (if any), true contrast expansion can be obtained; in other words, the gain of the valve may be made to increase smoothly at any desired rate as the level of the incoming signals rises, and vice versa. If the thermistor has a positive temperature coefficient, contrast contraction will evidently be obtained.

Fig. 3 shows a different application of the invention to a gas-filled rectifier valve V_1 . It is well known that if relatively large currents are drawn from gas-filled rectifiers, there is considerable liability of damage when switching on unless the cathode is properly heated up before the plate supply is connected. Accidental damage from this cause may be avoided by connecting a thermistor resistance element R_2 in series with the cathode of the gas-filled valve V_1 as shown in Fig. 3. The heating coil r_2 of the indirectly heated thermistor T_2 is shown connected in parallel with the cathode heater of the valve V_1 to the source of heating current HS. These may however obviously be in series if desired, and auxiliary series and/or shunt resistances may be included to proportion the heating currents as may be necessary. The alternating current supply AC is connected to the plate and cathode of V_1 in series with R_2 and the direct current output terminals DC. The thermistor T_2 should have a negative temperature coefficient of resistance and when it is cold, R_2 will be large, and will limit the current which would flow through the valve if the alternating current were switched on before the heating supply HS. When the supply HS is switched on, the thermistor is heated at the same time as the cathode, and its resistance begins to fall. When it has reached its maximum temperature its resistance will be low and will permit the normal current to be drawn from the valve. It is necessary however, that the rate of heating of the thermistor should be lower than that of the cathode particularly at first, so that its resistance will always be high enough to prevent dangerous currents until the cathode is fully hot. One way of ensuring a suitable delay would be to connect another directly or indirectly heated thermistor with a negative temperature coefficient in series with r_2 , or one with a positive temperature coefficient in parallel therewith, so that T_2 would not begin to be heated appreciably until the second thermistor had become hot.

It will be evident that T_2 could be chosen so as to be heated appreciably also by the cathode current: and it might be preferable to use a directly heated thermistor in place of T_2 , the connection shown in Fig. 3 to the heating coil r_2 being, of course, omitted. This would tend to

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produce automatically the desired delay in heating the thermistor since the cathode current would at first be very small and would, therefore, take a long time to raise the temperature of the thermistor. The heating rate would, of course, increase considerably afterwards, but the slow early period could be made to last during the major portion of the cathode heating time.

Fig. 4 shows another embodiment where the invention is applied to the compensation of the effects of supply voltage variations on a thermionic valve V. The cathode potential is obtained from a potentiometer comprising a resistance X_5 and the resistance element R_3 of an indirectly heated thermistor T_3 connected across the high tension supply, the thermistor connecting the cathode to ground. The heating coil r_3 of the thermistor is connected in parallel with the cathode heater of the valve to the heating source HS. X_4 is the plate circuit resistance and X_3 is the input grid resistance, the output being taken from the plate. The input and output circuits and other details are conventional and can be arranged in any other way.

The thermistor should have a positive temperature coefficient of resistance and should be so chosen that when the power supplies have normal voltages, the grid bias voltage has the proper value. Auxiliary biasing batteries or other means (not shown) may be employed if necessary.

Suppose now that the voltage of the high tension supply should for some reason increase. This will tend to increase the plate current and also the potentiometer current, increasing the value of R_3 and raising the cathode potential so that the effective grid bias is made more negative. This will tend to reduce the plate current, and by proper choice of the thermistor characteristics the two effects may be made to neutralise one another so that the plate current is unaltered by the change. The reverse action will take place if the supply voltage decreases.

Similarly, if the voltage of the cathode heating source increases, this will also increase R_3 and the consequent tendency for increase of the plate current due to the higher temperature of the cathode may be neutralised. In this case it may be necessary to connect suitable series and/or shunt resistances to r_3 that illustrated being a series resistance r_4 .

The neutralising effect may be increased by replacing resistance X_5 by a second thermistor having a negative temperature coefficient of resistance, the heating coil being connected in series or in parallel with r_3 .

It may not be necessary to compensate simultaneously for changes in both the supply sources. If the high tension source only is to be compensated, then the thermistor T_3 will be replaced by a directly heated thermistor, the heating coil connections being of course omitted. Alternatively, X_5 may be omitted, in which case compensation of the heating source only will be obtained. Furthermore, if simultaneous compensation of both sources is required, it may be preferable to connect an extra directly heated thermistor in series with T_3 , and to choose T_3 so that it is not appreciably affected by the changes in the cathode current. Compensation will then be obtained with separate thermistors for the two sources.

Another entirely different application of the invention is to the type of cathode ray tube tuning indicator which is now commonly supplied with radio broadcast receiving sets, and which has come to be known by the term "magic eye."

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In this type of indicator a geometrical pattern appears on a fluorescent electrode or screen; the area of the pattern depends on the level of the signal applied to the device and reaches a maximum when the set is accurately tuned to the station it is desired to receive.

The difficulty which has hitherto been experienced with this type of indicator is that it lacks sensitivity, and does not operate over a sufficiently wide range of incoming signal levels. For example, when tuning to a strong station which is close by, the indicator will be fully operated by the sidebands before the carrier wave is properly tuned in; and in the case of a distant and/or weak station, it may be found that practically no effect can be produced on the indicator.

Thermistors may be used to remedy these difficulties in a simple way. Fig. 5 shows a magic eye V_i of the ordinary type comprising a valve section and an indicator section which share the same cathode k . The valve section comprises a control grid g_1 , and a plate p_1 , and the indicator section consists of a control electrode g_2 which is connected to p_1 , and a fluorescent plate or electrode p_2 on which the indicating pattern appears. The plate p_2 is directly connected to the positive terminal HT+ of the high tension source and the plate p_1 is connected thereto through a high resistance X_6 . The control grid g_1 is earthed through the grid resistance X_3 , and a directly heated thermistor T having a positive temperature coefficient of resistance has its resistance element R connected in series with the cathode k .

The usual method of operating the magic eye will be briefly described. The fluorescent area on the electrode p_2 depends on the potential of the control electrode g_2 with respect to the cathode, being increased when this potential increases. The potential of p_1 depends on the plate current of the valve section of the device and will be lower than that of the plate voltage supply source by the potential drop in the high resistance X_6 .

The valve section is so biased that when no signal is applied to the control grid g_1 the plate current is large so that the plate voltage is low. This allows only a small area of the electrode p_2 to become fluorescent. A negative voltage proportional to the incoming signal level (usually derived from the automatic volume control voltage) is applied to the control grid g_1 . This raises the plate voltage by reducing the plate current and so raises the voltage of the control electrode g_2 and consequently also increases the fluorescent area.

According to the invention, the cathode k is biased positively with respect to the control grid g_1 by connecting the resistance element R of the thermistor T in series with it. With no input signal and the plate current at a maximum, the thermistor will be hot and will have a high resistance which should be chosen so that the proper bias is obtained. When a negative signal is applied to the control grid g_1 , as already explained, the plate current is decreased and this will decrease the resistance of the thermistor. The combined effect is to decrease the cathode potential so that the effective signal voltage applied to the control grid g_1 is reduced. In other words, a contrast contraction has been produced. Thus the sensitivity of the device may be designed for incoming signals of low level without producing overloading of the indicator for high

level signals, or in other words the effective range of the device has been increased.

As already explained in connection with the earlier embodiments, the thermistor may be supplemented by the use of series and/or shunt resistances such as X_1 and X_2 (not shown in Fig. 5) to secure a suitable characteristic.

Since the variations of the cathode potential will affect also the indicating part of the device, it may be preferable in some cases to provide it with a separate cathode separately biased in any convenient way, so that the valve current and the beam current become independent of one another.

The range of sensitivity may be still further increased by providing the magic eye with a beam or beams having two separate control electrodes one much more sensitive than the other. This is shown in Fig. 6. The tuning indicator V_1 has a valve section k_1 , g_1 , p_1 as in Fig. 5, and two indicator sections having a common cathode k_2 separate from k_1 . There are two plates p_2 and p_3 and two corresponding control electrodes g_2 and g_3 of which g_2 is connected to p_1 as before, and g_3 is connected to a tapping point on a potentiometer connected between p_1 and earth. The potentiometer comprises a resistance X_7 and the resistance element R_5 of a directly heated thermistor T_5 . The cathode k_1 has the resistance element R_4 of a directly heated thermistor T_4 connected in series as in Fig. 5. T_4 and T_5 should both have a positive temperature coefficient of resistance.

The plates p_2 and p_3 are both connected to the positive terminal HT+ and could actually be represented by different areas in the same electrode.

The section p_2 , g_2 operates in the manner described in connection with Fig. 5, and should be designed principally for the lower level signals. Section p_3 , g_3 will be less sensitive because the control electrode is subjected to only a fraction of the voltage of p_1 , and moreover, as this voltage is reduced when the signal level increases, the potentiometer ratio decreases due to the cooling of the thermistor T_5 . Both effects operate to make the section p_3 , g_3 relatively insensitive so that it will not be easily overloaded by high level signals.

As already explained, series or shunt resistances may be combined with T_5 as may be required. Similar results would be obtained by giving T_5 a negative temperature coefficient and interchanging it with X_7 ; or X_7 could be replaced by a third directly heated thermistor having a negative temperature coefficient.

In one frequently used form of the magic eye, the fluorescent electrode is circular, and the control electrode is shaped like a cross and is centrally placed, so that a quadriform clover leaf pattern is produced. By dividing the cross into two parts represented by g_2 and g_3 , respectively, in Fig. 6, the two pairs of clover leaves could be separately controlled, one pair only being appreciably affected by weak stations and the other pair being used for strong stations which overload the sensitive pair.

In all the embodiments of the invention described above, the minimum of detail has been shown for simplicity; although in general triode valves have been shown, they may have additional electrodes which may be biased in any convenient way. Many of the auxiliary arrange-

ments shown are conventional and may be varied as may be found desirable.

What is claimed is:

1. In an electronic device including a thermionic valve having a cathode, grid and anode, a source of electrical potential having its positive side connected to said anode, and a source of electrical energy for heating said cathode connected thereto; means for compensating for variations in said source of energy comprising an indirectly heated thermistor having a resistance element and a thermistor heater associated therewith, means connecting said element between the cathode and the negative side of said source of potential to provide a self-biasing arrangement, and means connecting the thermistor heater to said source of electrical energy to be heated thereby.

2. An electronic device according to claim 1, wherein said compensating means also compensates for variations in the voltage from said source of potential, said resistance element having a high temperature coefficient of resistance with a positive characteristic.

3. An arrangement for compensating for the effects of supply voltage changes on the operation of a thermionic valve including a thermionic valve having a cathode, grid, and anode, a supply voltage source connected to supply the operating voltages for said valve, a thermistor of the indirectly heated type with a positive temperature coefficient of resistance, said thermistor having a heating coil and resistance element, said resistance element being connected in series between the cathode of said valve and the negative terminal of the voltage source of said valve, and an auxiliary resistance connected between the positive terminal of said voltage source and said cathode whereby a voltage divider is formed, and a cathode heating source, the heating coil of said thermistor being connected to said cathode heating source to be heated by current therefrom.

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