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ELECTRIC OSCILLATION GENERATING CIRCUIT INCLUDING
A THERMO-RESPONSIVE IMPEDANCE ELEMENT

Filed July 31, 1941

2 Sheets-Sheet 1

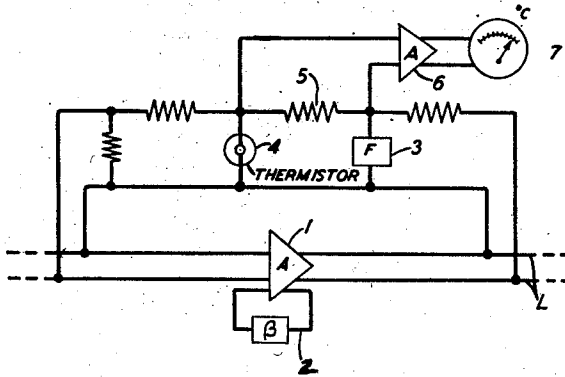


FIG. 1

FIG. 2

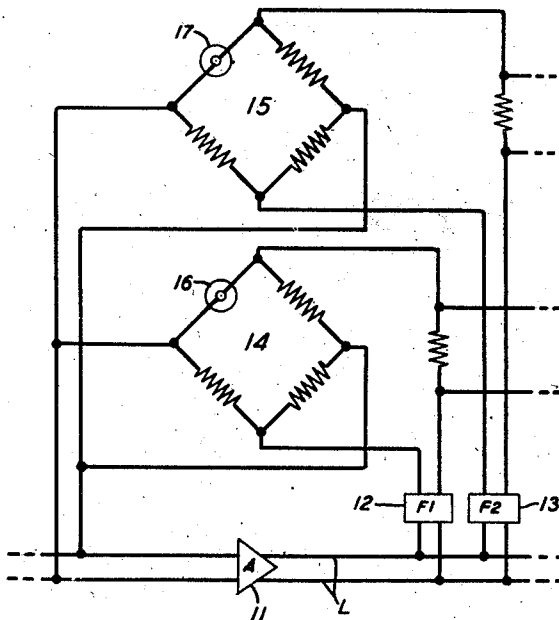
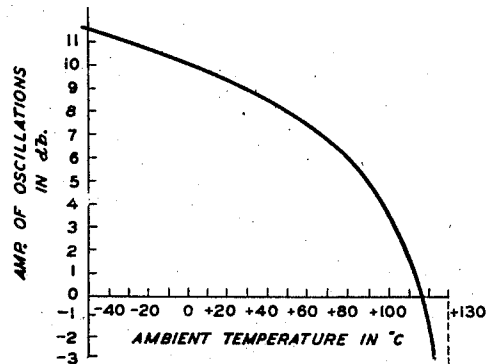


FIG. 3

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2 Sheets-Sheet 2

FIG. 4

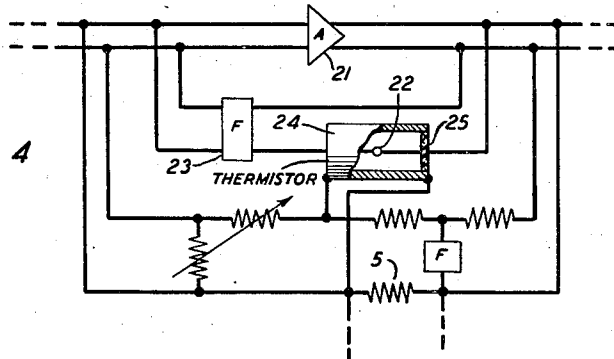


FIG. 5

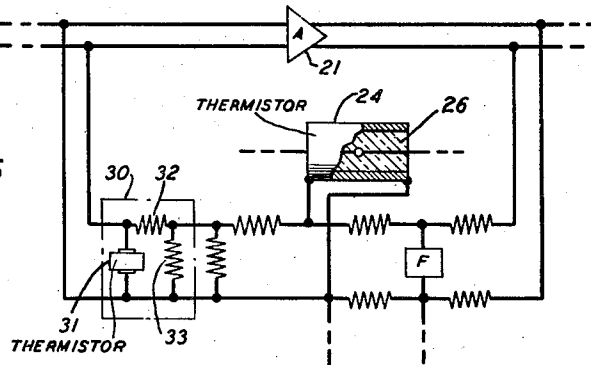
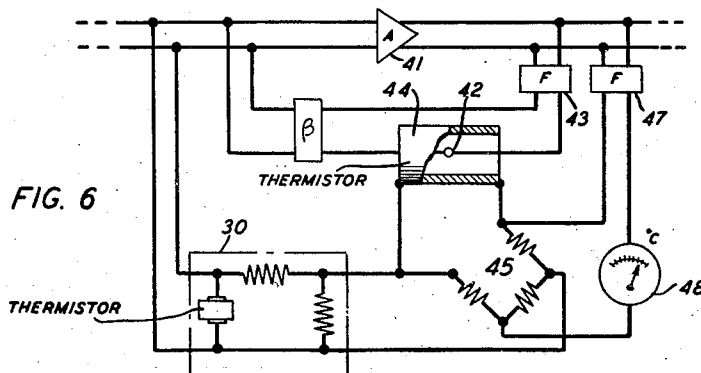


FIG. 6



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ELECTRIC OSCILLATION GENERATING CIRCUIT INCLUDING A THERMORESPONSIVE IMPEDANCE ELEMENT

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Application July 31, 1941, Serial No. 404,771

13 Claims. (Cl. 73-362)

This invention relates to electric circuits employing thermoresponsive impedance elements and, more particularly, to oscillation circuits in which the intensity of oscillation is controlled by a thermosensitive resistance element that is heated by the oscillations generated.

One object of the present invention is to compensate for the variable effect that changes in ambient temperature tend to have upon a thermosensitive impedance element. Another object is to translate the effect of ambient temperature upon a thermosensitive impedance element into an indication or measure of the ambient temperature.

In accordance with a feature of the present invention, an electric wave amplifier is provided with a positive feedback path for the generation of oscillations under the control of a thermosensitive impedance element that is heated by the oscillations generated, and the intensity of oscillation as so controlled is utilized to indicate the temperature of the ambient surrounding the impedance element.

In accordance with another feature a thermosensitive impedance element that is maintained at constant temperature and impedance by oscillations controlled thereby is utilized as a constant or controlled temperature source and, more particularly, as a heater or oven to compensate one or more other thermosensitive elements for changes in ambient temperature.

The nature of the present invention and its various features, objects and advantages will appear more fully from a consideration of the embodiments illustrated in the accompanying drawings and hereinafter to be described. In the drawings:

Figs. 1 and 2 relate to an oscillation generating circuit in which the effect of ambient temperature is translated into a measurement of temperature;

Fig. 3 shows a modification of Fig. 1;

Fig. 4 shows an oscillating amplifier circuit with a thermosensitive control impedance therein that is utilized as a constant temperature source;

Fig. 5 shows a modification of Fig. 4; and

Fig. 6 shows an embodiment of the invention incorporating several of the features of the preceding figures.

If an electric wave amplifier be provided with a positive or regenerative feedback path, oscillations will appear in the transmission loop formed by the feedback path and the amplifier if the transmission loss or attenuation in the loop is not in excess of the gain therein. If no other effect

intervenes the intensity of the oscillations will progressively increase until the amplifier is overloaded and the gain thereof is reduced to equality with the loss of the circuit, whereupon there will be no further change in the intensity of the oscillations. To obtain oscillations of stabilized intensity without overloading the amplifier, it has been proposed heretofore to include in the feedback loop circuit a variable loss element that is variably controlled by the oscillations in such manner that as the oscillation intensity approaches a predetermined value below overload, the total loss in the oscillation loop approaches a value just equal to the gain in the loop. Thus the oscillations are stabilized at the predetermined value, assuming the gain of the amplifier to be stable, for if the oscillation intensity tends to fall the loop loss is automatically reduced and there is a net circuit gain produced which tends to increase the oscillation intensity, whereas any tendency for the oscillation intensity to increase is offset by a concurrent increase in the loop loss.

The variable loss element may, as proposed heretofore, comprise a thermistor, that is, a resistance element having a high temperature coefficient of resistance, disposed in the feedback path and so proportioned that its temperature and resistance are substantially controlled by the heating effect or root mean square value of the oscillations. Then when a stable condition is reached the temperature and resistance of the thermistor are always of a constant value such that the circuit loss is exactly equal to the constant gain of the amplifier, and the oscillations are maintained at a level such as to hold the temperature of the thermistor at that constant value. The oscillation amplitude as so fixed is constant, however, only if the temperature of the thermistor is not affected by changes in the temperature in the ambient surrounding it, but the disturbing effect of ambient temperature changes can be minimized by enclosing the thermistor in an adequate thermal shield or insulating chamber, or by providing a compensating heater, or both, all in a manner well known in the art.

I have perceived that whereas the effect of ambient temperature variations on the oscillation amplitude in a circuit of the kind described has been considered a deleterious effect that should be suppressed, there is an accurate correlation between the ambient temperature on the one hand and the intensity of the oscillations on the other, that is especially well adapted for thermometry

and thermometric control. In accordance with one feature of the present invention, I propose that the oscillation controlling thermistor be exposed to ambient temperature variations and that the intensity of the oscillations be utilized as a measure of the ambient temperature or of changes therein or both. An illustrative embodiment is shown in Fig. 1.

Referring to Fig. 1, there is shown an amplifier 1 comprising one or more stages provided with a negative feedback or beta circuit 2 for stabilizing the gain of the amplifier in a manner well known in the art. The amplifier is provided also with a positive feedback circuit which, as illustrated, may extend from the output terminals of the amplifier 1 to the input terminals thereof. Shunted across the positive feedback path near the input end thereof, that is, near the point of connection to the output of the amplifier 1, is a filter 3 or frequency selective network which cooperates with adjoining series resistors to present comparatively high attenuation for all frequencies transmitted through the positive feedback path except at a predetermined oscillation frequency f . Shunted across the positive feedback path beyond the frequency selective device is a thermistor 4 comprising, for example, a bead of silver sulphide or boron having a high negative temperature coefficient of resistance.

Assuming that initially the temperature and resistance of thermistor 4 are such that the total loss in the positive feedback path at the frequency passed by selective device 3 is less than the gain of amplifier 1, oscillations of frequency f begin to build up in the loop formed by amplifier 1 and the positive feedback path. As the oscillations increase in intensity the power loss in thermistor 4 and the temperature of the thermistor increase also with the result that the resistance of the thermistor is reduced and the shunt loss in the positive feedback path is increased. This process continues until the resistance of thermistor 4 is such that the total loss in the feedback loop at frequency f is equal to the gain at the same frequency. At this point the intensity of the oscillations is stabilized and there is no further change except as other influences may affect the heat supplied to thermistor 4.

Thermistor 4 is exposed to the ambient surrounding it and continually loses heat to it at a rate depending on the ambient temperature. As this heat loss changes, thereby tending to change the temperature and resistance of thermistor 4, there is a compensating change in the intensity of the oscillations generated of such sense and degree as to maintain the transmission equivalent of the loop circuit zero.

The relation between the intensity of oscillation and the ambient temperature in a typical case is illustrated in Fig. 2, where amplitude of oscillation in decibels relative to 1 milliwatt is plotted against ambient temperature in degrees centigrade. This curve is quantitatively accurate for a thermistor having a half temperature of 13°C . in a circuit so proportioned that oscillations would cease if the ambient temperature reached 130°C . It will be noted that in the vicinity of the limiting temperature, i. e., 130°C ., the amplitude of oscillation is a highly critical function of ambient temperature. Assuming that the amplitude of oscillation can be measured with an error of less than one-thousandth of a decibel, the amplitude of oscillation is a measure of the ambient temperature to an accuracy of $\frac{1}{23}$ of a degree at -50°C ., approximately $\frac{1}{50}$ of a degree at $+30^\circ\text{C}$., $\frac{1}{230}$ of a degree at $+110^\circ\text{C}$., and

approximately $\frac{1}{10,000}$ of a degree at a temperature about half a degree below 130°C . where it is assumed the oscillations cease. Since the point at which the oscillations start and stop is a very critical function of the temperature of the thermistor and since the phenomenon is reproducible to as high a degree of accuracy as desired and since the temperature at which this happens can be varied practically at will, this property could conveniently be used to control any manufacturing or other process dependent upon temperature. The critical temperature at which oscillations cease may be fixed at almost any predetermined value. It is a function of the kind, size and shape and thermal properties of the thermistor and its position in the positive feedback loop.

To measure the oscillation amplitude any of a large number of available devices may be used. In Fig. 1 the measurement is made by applying the voltage drop across the series resistor 5 that is disposed between elements 3 and 4 to an amplifier 6 which leads to a meter 7 that is calibrated in degrees of temperature.

The amplifier 1 in Fig. 1 may be used for purposes other than that of generating local oscillations. Thus the amplifier 1 may be part of a telephone repeater interposed in a transmission line L for relaying speech or multiplex telephone signals, for example. In this case, of course, the frequency chosen for the oscillation circuit should not lie within any of the signal frequency bands, and the signals should not be allowed to reach thermistor 4 with sufficient intensity to affect it substantially. The locally generated oscillations will in part be transmitted over the line L together with the signals and at a remote point, as, for example, a distant attended repeater station, it may be diverted and its amplitude translated into an indication of the temperature recorded by meter 7.

The embodiment of the invention shown schematically in Fig. 3 in part illustrates the fact that more than one oscillation generating loop may be associated with the same amplifier. A feature of this embodiment is that the amplifier need not have constant gain, and the gain in fact may be permitted to vary over a wide range as, for example, where the amplifier comprises a telephone repeater amplifier with provision for automatic gain adjustment responsive to changes in the transmission equivalent of the transmission line.

Amplifier 11 in Fig. 3 is embraced by two positive feedback paths which have respective filters 12 and 13 for fixing the frequency of oscillations and for excluding from the feedback circuit thermistors all amplifier output currents except those of the respective oscillation frequencies. In each feedback path there is disposed a variable loss element comprising a four-terminal resistance bridge 14, 15, one of the four resistance arms of which is constituted by a thermistor 16, 17, which corresponds with thermistor 4 of Fig. 1. Each bridge is so proportioned that at some temperature slightly above that expected in normal operation the thermistor resistance is such that the bridge is balanced thereby introducing infinite loss in the feedback path. At lower ambient temperatures the bridge is unbalanced and the transmission loss reduced to the point where oscillations can occur through the feedback loop. As in Fig. 1, the oscillations are stabilized at a value such that the loss introduced by the bridge under the control of the bridge thermistor is equal to the gain of the amplifier 11 at the oscillation frequency. As in the example previously described, the resist-

ance of the thermistor 16, 17, tends to change with ambient temperature, but the concurrent change in the intensity of the oscillations and their heating effect on the thermistor continually maintains the transmission equivalent of the loop circuit at zero.

To render the thermistor temperature and the oscillation amplitude substantially independent of the gain of the amplifier 11 it is only necessary that the bridge be nearly balanced at all times. The high feedback circuit loss associated with approximate bridge balance may be offset by increasing the gain of the amplifier 11. It will be appreciated that with the bridge almost exactly balanced, a very slight change in the temperature of the thermistor will give rise to a great percentage or decibel change in the loss interposed by the bridge circuit which is a part of the positive feedback path. A very slight increase or decrease in amplitude of the oscillations is sufficient to cause this very slight change in the temperature of the thermistor which in turn is enough to make a large decibel increase or decrease in the loss interposed by the bridge circuit. It is possible, therefore, to control the amplitude of the oscillations and the temperature of the thermistor as closely as wished even though the gain of the amplifier or the loss of the positive feedback circuit or both vary between wide limits, for example, 30 decibels, because just a very slight change (which is smaller the higher the bridge balance and the higher the amplifier gain) in the oscillation amplitude and temperature of the thermistor would be required to restore equilibrium, that is, equality of gain and loss.

On the other hand, the effect of ambient temperature on amplitude of oscillations is rather similar to what happens in the circuit of Fig. 1. The reason for this is that by virtue of the properties of the self-oscillating circuit, the resistance of the thermistor must equal a specified fixed value to the end that the loss equal the gain, hence if the ambient causes this thermistor resistance to vary, the amplitude of the self-oscillations will automatically increase or decrease to such an extent as automatically to compensate thereby keeping the value of resistance unchanged.

The two thermistors 16 and 17 in Fig. 3 may be made responsive to ambient temperature changes in different locations. Thus, thermistor 16 may be exposed to the ambient within a repeater station while thermistor 17 is exposed to the outside temperature. The critical temperature at which oscillations cease could be different in the two cases. Means may be provided as in Fig. 1 to obtain a measure of the oscillation amplitude in each of the feedback loops and the oscillations transmitted over the line L could be used for telemetering, alarm, control purposes and the like.

I have perceived further that in a thermistor stabilized oscillation generator such as described with reference to Figs. 1 and 3, the oscillation controlling thermistor, even though it be exposed to wide variations in ambient temperature, maintains a constant temperature to a high degree of accuracy. In accordance with an important feature of the present invention, I utilize the oscillation controlling thermistor as a constant temperature source and, more particularly, as a radiant heater or oven of constant or controlled temperature. In the embodiment of the invention illustrated in Fig. 4, the constant temper-

ature heater or oven is utilized to compensate a second thermoresponsive element for changes in ambient temperature.

Referring to Fig. 4 there is shown schematically an amplifier 21 of constant gain that is provided with a positive feedback path for the generation of oscillations stabilized under the control of a thermistor 24. This feedback path is the same as that illustrated in Fig. 1 in circuit configuration and method of operation but differs in respect of the shape of the thermistor 24. For the purposes at hand, thermistor 24 is constructed in the form of an elongated hollow cylinder with terminals soldered or otherwise attached to the opposite ends thereof. To promote uniformity of current distribution and temperature the end faces may be sputtered with metal and for the same purpose the walls of the cylinder may be made fairly thin.

Inasmuch as the gain in the oscillation circuit of Fig. 4 is constant there is only one value for the resistance of thermistor 24 that will satisfy the conditions for stability, that is, that the loss in the circuit at the oscillation frequency be equal to the gain. Likewise, there is only one temperature at which the resistance of thermistor 24 assumes the critical value. Hence, despite all other influences that tend to affect the temperature of thermistor 24, the latter will remain invariable provided the thermistor is not externally heated to a temperature higher than that at which oscillations cease. Likewise, if the open ends of the cylinders are closed by heat insulating material, thereby tending to inhibit the dissipation of heat from the thermistor, the oscillation amplitude is automatically reduced to a value such that with the reduced supply of heat from this source the thermistor assumes and maintains the predetermined temperature.

It will be noted that the temperature of thermistor 24 depends on the amount of fixed loss in the positive feedback path and that it can therefore be adjusted over a range of values by adjusting the resistance elements in the feedback path. The thermistor temperature can accordingly be set to various predetermined temperatures with a high degree of reproducibility.

Although a variety of uses for a constant temperature source such as the one here disclosed, will occur to those skilled in the art, I propose in accordance with a further feature of the present invention to utilize the constant temperature thermistor 24 as a radiant or thermal conduction heater or shield for a thermosensitive device, such as a second thermistor, that is adversely influenced by changes in ambient temperature. The thermistor to be protected is shown as a bead 22 which is supported, as for example by its lead wires, at the geometric center of the thermistor 24 where it is exposed to the constant temperature radiation from the latter. The heat capacity of thermistor 24 is large enough compared to that of bead 22 that in effect the thermistor 24 constitutes a chamber or oven providing a constant ambient temperature. Although the bead 22 is surrounded by air and influenced by the temperature of the latter, the air surrounding the bead is heated by thermistor 24 to a substantially constant temperature that is not substantially affected by changes in the heat transmission to the relatively cool air at the end of the cylinder. If thermistor 24 is provided with closed insulating ends 25 to form a completely closed chamber, the movement of

cool air to the vicinity of the bead 22 may be suppressed. Thermal conduction from thermistor 24 to the enclosed element 22 is a constant factor and may be the principal effect in some modifications of the invention. Thus thermistor 24 may be in thermal contact with the bead 22, as illustrated in Fig. 5, with the space between the two filled with solid glass 26. The entire assembly may then be suitably mounted, as in an evacuated envelope, for example.

Thermistor bead 22 may itself be an oscillation controlling element in another feedback loop around the amplifier 21. It may be used, for example, in accordance with the teachings of Mallinckrodt Patent 2,231,542, February 11, 1941, to modulate locally generated oscillations in accordance with the average intensity of signal current relayed by the amplifier so that the total power output of the amplifier is substantially constant. Filter 23 in this feedback path limits the oscillations to the predetermined pilot frequency while thermistor 22 receives a fixed fraction of the signal and pilot output of the amplifier and operates to vary the loss and therefore the intensity of the pilot oscillations. The intensity of the oscillations generated in the first-mentioned feedback path and applied to thermistor 24 may be so small as to have no significant effect on thermistor bead 22 in which case it may be disregarded. Otherwise, these oscillations may be excluded from the second feedback path by judicious selection of circuit impedances or by filtering. Filter 23 may be a piezoelectric crystal and supported within the constant temperature thermistor 24 to stabilize the oscillation frequency.

Inasmuch as thermistor 24 is influenced by the ambient temperature, the intensity of the oscillations in its feedback path can be translated into a measure of temperature. A resistor 5 connected in the feedback path may be utilized as indicated in Fig. 1 for the purposes of temperature measurements.

In the modification of the invention illustrated in Fig. 5, additional means are provided for varying the loss in the oscillation generating feedback path as a function of temperature but not as a function of the oscillation amplitude. The apparatus provided for this purpose may comprise, as shown, a pi-network of resistance elements of which one shunt arm is a thermistor 31 that is exposed to variations in ambient temperature but which is so proportioned that its temperature and resistance are substantially unaffected by the current flowing through it. The loss-temperature characteristic of the combination 30 may be fashioned almost at will by proper selection of the temperature-resistance characteristic of thermistor 31 and the relative magnitudes of its associated resistors. Thus the loss-temperature characteristic may be so proportioned that the intensity of the oscillations in the feedback loop is the same at all ambient temperatures. In this case, then, the temperature of thermistor 24 is variable and remains a fixed number of degrees above the ambient temperature. Again the characteristic may be such that the temperature of thermistor 24 is any prescribed function of the ambient temperature. More particularly, should it be found in a particular instance of practice in accordance with Fig. 4 that better compensation would be obtained if the temperature of thermistor 24 increased somewhat near the low end of the ambient temperature range, the combination 30 of

Fig. 5 could be so selected and adjusted as to reduce the loss inserted at low temperatures, thereby raising the temperature of thermistor 24.

Unit 30 of Fig. 5 is in the form of a pi-pad terminating in the input of the amplifier. Assuming this termination is a constant resistance R and that the thermistor 31 has a negative temperature characteristic, I have observed that if the series arm 32 of the pi has a suitable positive temperature coefficient, the impedance of the combination is a constant resistance practically independent of temperature over a moderate range (-40° to $+160^{\circ}$, or -32° to $+125^{\circ}$ F., for example). Further, by making the shunt arm 33 of the pi a resistance of appropriate value and independent of temperature, the impedance looking into this end of unit 30 is also R. Over a moderate range of temperatures then, the unit 30 constitutes a constant resistance pad the attenuation of which varies with temperature, or in effect a variable attenuator without contacts. A plurality of such constant resistance units can be operated in tandem and the total attenuation at any temperature within the operating range is the algebraic sum of the attenuations of the individual sections.

Fig. 6 shows a constant-output repeater amplifier that incorporates various features of the invention hereinbefore described. The repeater is of a type adapted for use in conjunction with the pilot generating terminal described with reference to Fig. 4 or in a system such as disclosed in J. H. Bollman Patent 2,231,558, February 11, 1941, in which the gain of the repeater amplifier is controlled by the joint action of signals and modulated pilot transmitted over the line. The signal and pilot output of the repeater amplifier 41 is applied to a gain controlling thermistor bead 42 in a negative feedback circuit through a band-pass filter 43. The elements of the negative feedback circuit are so proportioned in a manner known in the art that the total output intensity of the signal and modulated pilot remains substantially constant for a wide range of signal and pilot input to the amplifier.

The amplifier is provided also with a positive feedback path adapted to generate oscillations at a frequency determined by the filter 47 at the input end of that path. Interposed in the positive feedback path is a variable loss element comprising a resistance bridge 45, one arm of which is a hollow cylindrical or other appropriately shaped thermistor 44 corresponding to thermistor 24 of Fig. 4. Alternatively the thermistors may be shaped and positioned with thermistor 42 constituting an enclosure for a thermistor 44 of bead form, especially if the latter is maintained at a temperature materially higher than that of the ambient. The resistance bridge 45 is so proportioned as described with reference to Fig. 3 that the oscillation amplitude is substantially unaffected by the gain variation experienced by amplifier 41, hence the thermistor 44 is maintained at a substantially constant temperature and is adapted to serve as a compensating radiant heater for thermistor 42. The compensating network 30 of Fig. 5 may be included in the positive feedback path, if necessary, to supplement the compensating effect of the radiant heater thermistor 44. The oscillation amplitude varies as a function of the ambient temperature to which thermistor 44 is exposed and a meter 48 in the positive feedback path may be so calibrated as to translate the amplitude fluctuations into a measure of the ambient temperature.

Although the invention has been described largely in terms of several embodiments, it will be understood that in some respects these embodiments are only illustrative and that the invention is susceptible of application in a variety of other forms within the spirit and scope of the appended claims.

What is claimed is:

1. In combination, an oscillation generating loop circuit including amplifying means and a loss controlling thermosensitive impedance element that is substantially affected in temperature and impedance by the oscillations traversing said loop, the parameters of said loop circuit being so proportioned that the impedance and temperature of said element are maintained substantially independent of changes in ambient temperature, means to be actuated as a function of said ambient temperature, and means for controlling said last-mentioned means in accordance with the intensity of said oscillations.

2. In combination, an electric wave amplifier having a positive feedback loop adapted for the generation of oscillations, a thermoresponsive resistor, means connecting said resistor in loss controlling relation in said loop, said resistor being so proportioned as to be substantially affected in temperature and resistance by the oscillations traversing said loop, and an ambient temperature indicator controlled by said oscillations.

3. In combination, an oscillation circuit, an oscillation-controlled thermosensitive impedance element connected in loss controlling relation in said oscillation circuit, said element being exposed to the temperature modifying effect of an ambient, and a thermometric indicator controlled in accordance with the intensity of the oscillations in said circuit.

4. In combination, an amplifier having a positive feedback loop for the generation of oscillations, an oscillation heated thermosensitive impedance element variably controlled in dependence on the intensity of the generated oscillations and disposed in loss adjusting relation in said loop, said element being so proportioned as to stabilize the intensity of said oscillations at any ambient temperature within a range of ambient temperatures, and means for recognizing changes in ambient temperature comprising a device controlled in accordance with the intensity of said oscillations.

5. In combination, an electric wave amplifier of variable gain, a positive feedback loop for said amplifier adapted for the generation of oscillations, a variable loss unit in said loop comprising a bridge circuit including a thermosensitive impedance element exposed to variations in ambient temperature and variably heated in accordance with the intensity of said oscillations, said impedance element being so proportioned that the intensity of said oscillations is substantially independent of the gain variations of said amplifier, and means utilizing changes in the intensity of said oscillations as a measure of changes in said ambient temperature.

6. An oscillation generator including an oscillation intensity stabilizer, said stabilizer comprising a current-dependent thermosensitive impedance element and circuit means for passing the generated oscillations through said element, and means for varying the stabilized intensity of said oscillations as a function of ambient temperature, said last-mentioned means comprising a second thermosensitive impedance element elec-

trically connected to said oscillation generator, said second element being exposed to variations in said ambient temperature and proportioned to be substantially unaffected by said oscillations.

7. In combination, a circuit including a thermosensitive control element, and means for compensating for the effect that changes in ambient temperature tend to have on said control element comprising an electric wave amplifying element, an electrically continuous loop transmission circuit comprising said amplifying element and wave feedback means connected to said amplifying element for the generation of self-sustained electrical oscillations therein, means for automatically limiting the intensity of the said generated oscillations to a value below overload of said amplifying element, said limiting means comprising an oscillation-controlled thermovisible resistance element connected in loss controlling relation in said loop transmission circuit whereby said resistance element tends to assume a fixed temperature and resistance irrespective of the said changes in ambient temperature, said resistance element being disposed as a heater for said control element.

8. In combination, a circuit including a thermosensitive control element, and means for compensating for the effect that changes in ambient temperature tend to have on said control element, said compensating means comprising an oscillation generating loop circuit and means for automatically limiting the intensity of the generated oscillations to a value below overload, said loop circuit comprising an amplifying element and a feedback circuit therefor, and said limiting means comprising a current-dependent thermosensitive resistance element connected in loss controlling relation in said feedback circuit whereby said resistance element tends to assume a fixed temperature and resistance irrespective of the said changes in ambient temperature, said resistance element being disposed as a heater for said control element, said resistance element being the only oscillation controlling element in said loop circuit that substantially affects the loss therein as a function of variations in oscillation amplitude or ambient temperature.

9. In combination, a circuit including a thermosensitive control element, and means for compensating for the effect that changes in ambient temperature tend to have on said control element, said compensating means comprising an amplifying element and a feedback circuit connected thereto to form an oscillation generating loop circuit and means for automatically limiting the intensity of the generated oscillations, said limiting means comprising a current-dependent thermosensitive resistance element connected in loss controlling relation in said feedback circuit whereby said resistance element tends to assume a fixed temperature and resistance irrespective of the said changes in ambient temperature, said resistance element being disposed as a heater for said control element, and a thermoresponsive impedance element that is disposed in loss controlling relation in said loop circuit and substantially unaffected in temperature by the oscillations generated.

10. In combination, a thermosensitive electric circuit element the operation of which tends to be disturbed by changes in ambient temperature, a thermoresponsive resistor constituting a chamber enclosing said element, and means comprising an oscillation generator for passing heating current through said thermoresponsive resistor,

said oscillation generator including current-dependent variable impedance means comprising said thermoresponsive resistor for stabilizing the intensity of the generated oscillations at a value below overload whereby the intensity at which said oscillations are stabilized varies with ambient temperature to maintain the resistance of said thermoresponsive resistor substantially constant.

11. In combination, a chamber comprising a hollow thermoresponsive resistor, a thermosensitive electric circuit element to be shielded against the influence of changes in ambient temperature, said element being disposed within said chamber, and means for regulating the temperature of the said chamber comprising an oscillation generating loop circuit and oscillation-dependent variable resistance means for automatically stabilizing the intensity of the generated oscillations at a value below overload, said stabilizing means comprising said thermoresponsive resistor and means connecting said thermoresponsive resistor in loss controlling relation in said loop circuit.

12. In combination, a chamber comprising a hollow thermoresponsive resistor, a thermosensitive impedance element the impedance of which tends to be substantially affected by changes in ambient temperature, said element being disposed within said chamber, an oscillation generating circuit, and means for maintaining the tempera-

ture of said chamber substantially constant irrespective of changes in ambient temperature, said last-mentioned means comprising means for passing through said chamber a heating current the strength of which is dependent on the intensity of the generated oscillations, whereby the resistance of said thermoresponsive resistor is substantially dependent on the intensity of the said oscillations, and said thermoresponsive resistor being connected to said oscillation generating circuit to stabilize the intensity of said oscillations at a value below overload.

13. In combination, a chamber comprising a hollow thermoresponsive resistor, an electrical oscillation generator, means for electrically heating said thermoresponsive resistor by the passage of current therethrough, means for varying the said electrical heating in dependence on the ambient temperature, and means for limiting the intensity of the generated oscillations to a value below overload dependent on the resistance of said thermoresponsive resistor, all of the aforesaid means comprising circuit means coupling said thermoresponsive resistor to said oscillation generator, and a thermosensitive electrical element disposed in the said chamber and thereby protected from the adverse influence of changes in ambient temperature.

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