Sept. 14, 1937. L. H. LYNN **2,093,331**

OSCILLATION GENERATOR

Filed Aug. 1, 1935

Fig. 1.

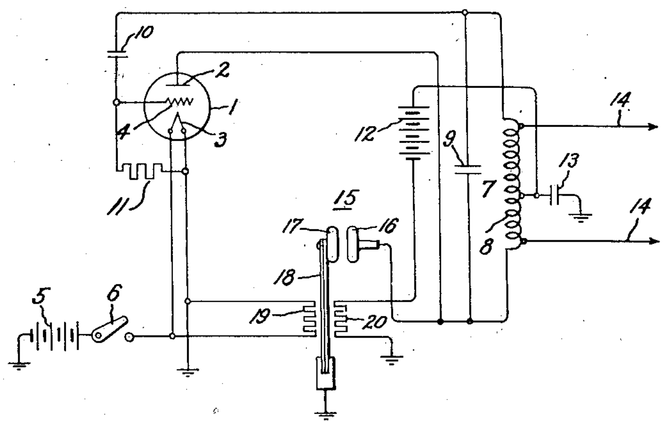


Fig. 4.

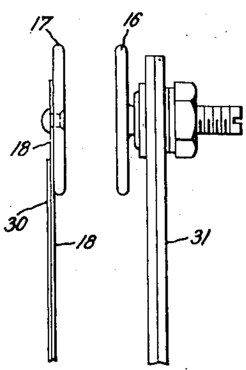


Fig. 3.

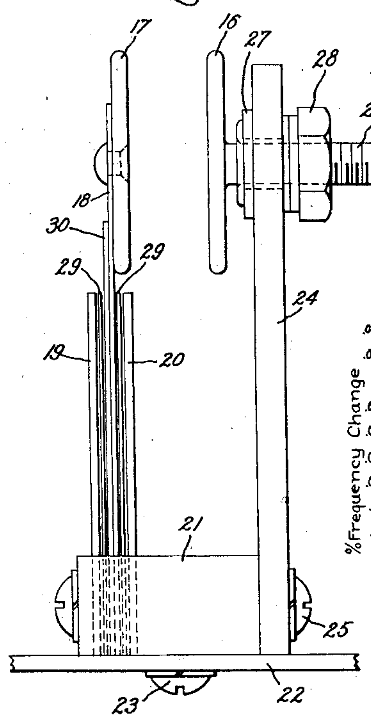
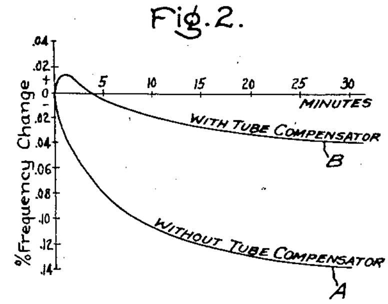


Fig. 2.



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2,093,331

OSCILLATION GENERATOR

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4 Claims. (Cl. 250—36)

My invention relates to electrical networks, and more particularly to networks of the type including an electron discharge tube having a frequency determining circuit connected thereto. My invention is particularly applicable for use in connection with electron discharge oscillators wherein it is desired that the output frequency be maintained substantially constant under all operating conditions.

The conventional electron discharge oscillator usually includes a thermionic device having a control electrode, a cathode and an anode, together with a tunable frequency-determining circuit connected to supply a control potential to the control electrode thereby to maintain the oscillator in a stable operating condition. Such oscillators are designed to generate electrical oscillations of a predetermined frequency and in many applications any deviation from the normal operating frequency is highly objectionable. It has been found that temperature variations in the elements of apparatus of this type cause a wide drift, or change in the frequency of the generated oscillations.

It is an object of my invention to provide a new and improved method of and means for minimizing frequency drift in the output frequency of an electron discharge oscillator.

It has been found that frequency drift in the output frequency of an oscillator of the above-indicated type is primarily attributable to temperature variations within the electron discharge device of the oscillator and to temperature variations of the elements forming the frequency determining circuit.

It is a further object of my invention to provide in combination with an electron discharge oscillator, means for varying the tuning of the frequency determining circuit in accordance with the temperature within the discharge device to which it is connected whereby variations in the output frequency of the oscillator are minimized.

An additional object of my invention is to provide a compensating means of the above character which operates to compensate against frequency change caused by fluctuations in the temperature of the elements forming the frequency determining circuit.

Variations in the temperature within the tube may be attributed to two predominant factors. One such factor is the heating of the cathode of the tube during the starting period of the oscillator circuit and the second factor which influences the temperature within the control tube is the magnitude of the average current flowing in the anode circuit of the oscillator.

It is, therefore, an additional object of my invention to provide in combination with an oscillation generator including a frequency determining circuit connected to an electron discharge control tube having a cathode, means for varying the tuning of the frequency determining circuit in accordance with the temperature of the cathode of the electron discharge tube thereby to minimize frequency drift in the output frequency of the generator.

A still further object of my invention is to provide in apparatus of the above-indicated character means for varying the tuning of the frequency determining circuit in accordance with variations in the magnitude of the average current flowing in the anode circuit of the oscillator.

In accordance with my invention compensation for frequency drift caused by temperature variations within the tube is obtained by providing an auxiliary variable condenser connected in shunt with a portion, or all, of the frequency determining circuit, which may be actuated to vary the tuning of the circuit in accordance with the amount of energy supplied to the cathode to heat the same and in accordance with the magnitude of current in the anode circuit.

In the specific embodiment of my invention illustrated and described hereinafter the variable condenser comprises a stationary electrode and a movable electrode mounted on the thermostatic element. The thermostatic element is energized to vary the capacity between the stationary and movable electrodes in accordance with the temperature within the oscillator tube by a pair of heating resistances connected respectively in the cathode heater circuit and the anode circuit of the tube. The thermostatic element is of course influenced by the ambient temperature of the air or other media surrounding the thermostatic element and the tube and, in this manner, further compensates for frequency drift occasioned by variations in the temperature of the frequency determining elements.

A more specific object of my invention is to provide compensating means for the purpose described above, which comprises a variable condenser connected in shunt with the frequency determining circuit of the oscillator and including a movable electrode which is mounted on a thermostatic element, the latter element being energized by a pair of resistances connected respectively in the anode and cathode circuits of the oscillator.

The novel features which I believe to be characteristic of my invention are set forth with particularity in the appended claims. My invention itself, however, both as to its organization and the method of operation, together with further objects and advantages thereof, may best be understood by reference to the following specification taken in connection with the accompanying drawing, in which Fig. 1 illustrates a circuit arrangement having my invention embodied therein and which operates in accordance with the method to be described hereinafter; Fig. 2 illustrates the operating characteristics of the circuit shown in Fig. 1; Fig. 3 is a side view of an element of the circuit shown in Fig. 1, and Fig. 4 is a detailed view of a modification of the element shown in Fig. 3.

Referring to Fig. 1 of the drawing I have shown my invention as applied to an electron discharge tube oscillator of a type well known in the art.

The oscillator comprises an electron discharge tube 1 having an anode 2, a cathode 3, and a control grid 4. The tube 1 is shown as being of the directly heated cathode type, although it will be understood by those skilled in the art that a tube of the indirectly heated cathode type may be employed with but a slight modification of the circuit arrangement shown. The cathode 3 of the tube 1 is energized from a suitable source of low voltage shown in the form of a battery 5, which may be connected or disconnected from the cathode heater circuit by a circuit interrupting device 6.

The tunable frequency determining circuit of the oscillator is indicated at 7 and consists of an inductance 8 shunted by a condenser 9. One terminal of the tuned circuit 7 is connected to the control grid 4 of the tube 1 through a circuit lead which includes a grid condenser 10. A grid leak resistor 11 is connected between cathode 3 and grid 4. The anode circuit of the oscillator includes the lower portion of the inductance 8 and a suitable source of high voltage 12 shunted by a high frequency by-pass condenser 13. The anode circuit is connected between the anode 2 and the cathode 3 of the discharge device 1 in the manner illustrated and a portion of the oscillatory energy developed in this circuit may be conducted to a utilizing circuit (not shown) by means of the circuit leads 14.

In the operation of the above-described circuit and with the cathode 3 of the device 1 heated to its normal electron emission temperature, if a voltage be impressed on the tuned circuit 7, electrical oscillations are produced therein having a frequency determined by impedance constants of the circuit. A portion of the energy developed by such oscillations is impressed on the control grid 4 of the tube 1 through the circuit lead including the grid condenser 10 and functions to maintain the circuit in a stable oscillatory condition. The operation of the oscillator described above is well understood in the art and a further explanation thereof is therefore deemed to be unnecessary.

In certain applications it is desirable to employ a control oscillator which is capable of producing electrical oscillations of substantially constant frequency under all operating conditions. One such example is that of a radio transmitter wherein a master oscillator, which may be of the type described above, is used to control the carrier frequency generated by the transmitter. It has been found that drift in the output frequency of electron discharge tube oscillators is largely attributable to temperature variations within the oscillator control tube and to temperature variations of the elements of the frequency determining circuit. Variations in the temperature within the tube cause warping of the elements of the tube thereby resulting in a change in the interelectrode capacity between the tube elements and an attendant change in the resonant frequency of the frequency determining circuit connected between the tube elements. In like manner variations in the temperature of the frequency determining elements produce variations in the impedance characteristics thereof whereby the natural frequency of the circuit in which they are connected is varied.

In accordance with my invention frequency drift in the output frequency of apparatus of the above-described type is minimized by the provision of means responsive to variations in the temperature existing within the tube, and to variations in the ambient temperature of the media surrounding the frequency determining circuit elements for varying the tuning of the frequency determining circuit. This means is shown as including a small auxiliary condenser 15 having its two electrodes 16 and 17 connected across a portion of the frequency determining circuit, one of the electrodes being movable with respect to the other electrode in response to the movement of a thermostatic element 18 which is energized by a pair of heating resistances 19 and 20 connected respectively in the cathode and anode circuits of the tube 1.

The operation of the above-described arrangement to produce the desired compensating action is as follows:—During the starting period of the apparatus and following a closure of the circuit interrupting device 6 to energize the cathode heater circuit, the cathode 3 of the tube 1 starts to heat up to its normal electron emission temperature. The heat generated by the cathode raises the temperature of the media within the tube and the temperature of the elements therein. This increase in the temperature of the elements causes the latter to be physically displaced with respect to each other thereby to change the capacity shunting the frequency determining circuit 7 and thereby alter the output frequency of the oscillator. However, closure of the circuit interrupting device 6 causes a simultaneous energization of the heating winding 19 which results in a flexure of the bi-metallic element 18 thereby to move the movable electrode 17 of the condenser 15 with respect to the fixed electrode 16 and change the capacitance thereof. This change in the capacity of the condenser 15 tends to compensate for the variation in capacity caused by the warping of the tube elements and by a proper calibration of the movement of the electrodes of condenser 15, the compensating action may be adjusted to prevent any appreciable change in the frequency of the oscillations generated by the oscillator during the starting period.

Following an initiation of the operation of the oscillator, anode current flows between the anode 2 and the cathode 3 of the tube and through the anode circuit of the oscillator. This current may be varied in magnitude in several different ways. For example, if the oscillator be embodied in a radio transmitting system and the control oscillator is keyed to produce coded impulses of control current, the anode current of the oscillator will fluctuate between zero and a normal value during each keying operation. Such fluctuations in the anode current tend to vary the mean value of heat energy developed within the tube by the anode current and are accordingly attended with variations in the temperature within the tube which cause undesired changes in the inter-electrode capacity between the tube elements. The effect of such capacity changes in producing undesired variations in the output frequency of the oscillator has been previously described. In accordance with my invention the above-noted undesired temperature variations are compensated for by energization of the heating resistance 20 connected in the anode circuit of the oscillator to produce a flexure of the bi-metallic element 18 which is proportional to the average current flowing in the anode circuit. Thus, assuming an increase in the average anode current such that a decrease in the output frequency of the oscillator is produced, heat generated by the increased current through the resistance 20 causes the element 18 to be flexed further to the left to decrease the capacitance value of the condenser 15 and thereby change the tuning of the resonant circuit 7 to increase the output frequency of the oscillator.

It should be noted that an appreciable time lag occurs between a change in the temperature within the tube and a warping of the tube elements to conform to such change. This of course, means that instantaneous variations in the anode current do not produce corresponding instantaneous changes in the inter-electrode capacity between the tube elements. However, if the anode current is being varied over wide ranges, as for example, by keying the oscillator, the amount of heat energy dissipated within the tube assumes a mean value considerably lower than that which would obtain if the anode current were maintained constant at a normal operating value. This means that the average temperature is lower and the displacement between the elements is different. It will be seen, therefore, that changes in the inter-electrode capacities between the tube elements are produced by changes in the average value of the anode current as contrasted to instantaneous current variations. The operation of the condenser 15 is such that changes in the capacity thereof are in accordance with, and are proportional to, the average value of the anode current. Thus, as the instantaneous value of anode current fluctuates, the heat energy developed by the resistance 20 is varied in accordance with the wattage input to the resistance, which is, in turn, determined by the average current flowing through the resistance. The temperature increase of the element 18 due to the heat developed by resistance 20 is proportional to the heat energy output of this resistance and, since the amount of flexure of the element attributable to the heat produced by resistance 20 is proportional to this temperature increase, it will be seen that the capacity of the condenser 15 is varied in accordance with the average value of the anode current.

From the foregoing description it will be apparent that the thermostatic element energizing resistance 19 is effective to minimize frequency drift in the output frequency of the oscillator during the period when the oscillator is being started and until it reaches a stable operating condition. After the oscillator has attained a normal operating condition the heat energy generated by the resistance 20 produces a flexure which varies in accordance with the average current flowing in the anode circuit of the oscillator. The total heating effect produced by the two resistances 19 and 20 is such that the element 18 is flexed in accordance with the temperature within the tube 1 and the capacitance of the condenser 15 is accordingly varied in accordance with the temperature within the tube 1.

The thermostatically actuated auxiliary condenser 15 may be designed to perform an added compensating function, viz: that of compensating for variations in the impedance characteristics of the resonant circuit elements 8 and 9 due to changes in the ambient temperature of the media surrounding these elements. In this connection it will, of course, be understood that the elements 8 and 9 are located in close physical proximity to the thermostatic element 18 in such manner that the ambient temperature of the media surrounding the element 18 and the associated resistances 19 and 20 will be substantially the same as that of the media surrounding the elements 8 and 9. Thus, as this ambient temperature rises the overall temperature of the element 18 is raised irrespective of the heat energy being supplied by the resistances 19 and 20. The element 18 is flexed in response to such an elevation in the temperature thereof thereby producing a variation in the capacitance of condenser 15 which tends to compensate for changes in the natural frequency of the resonant circuit 7 resulting from the variations in temperature of the media surrounding the elements 8 and 9.

The effect of employing my improved compensating arrangement in connection with an oscillator of the type described above is best illustrated by reference to Fig. 2 wherein I have shown curves plotted from data taken from tests run on a spcific installation. In this figure variations in the frequency output of an oscillator from its normal operating frequency are plotted against time; the curve A being plotted from data taken on an uncompensated oscillator and the curve B being plotted from data taken during the operation of the same oscillator when equipped with my improved compensating arrangement. From these curves it will readily be seen that the deviation in the frequency of the output of the oscillator equipped with a compensating device arranged in accordance with my invention is at all times substantially less than the deviation in frequency of an uncompensated oscillator.

It will be observed from the curves of Fig. 2 that during the starting period of the apparatus, corresponding to a time interval of approximately four minutes for the equipment tested, the compensating device over-compensates for the frequency change caused by the warping of the tube elements. Over-compensation would, of course, be unnecessary if compensation were 100% efficient from the moment of initial energization of the oscillation generator throughout the entire operation period. When the mass of the thermostatic element 18 is less than the mass of the elements in discharge device 1, the temperature of the former rises more rapidly than that of the latter and hence over-compensation takes place. If the oscillation generator be properly compensated for normal operation, a large amount of over-compensation occurs during the initial energization period. If the oscillation generator be properly compensated for the initial energization period under-compensation occurs to a marked degree during normal operation. It is, therefore, desirable to strike some compromise between these two extremes in order that the percent deviation over the entire period of operation be minimized as much as possible.

Referring to Fig. 3 of the drawing I have illustrated an auxiliary condenser which is particularly adaptable for discharging the compensating functions described in the preceding paragraphs. The condenser is shown as comprising a pair of electrodes 16 and 17, the latter electrode being movable with respect to the former in response to the flexure of the bi-metallic element 18 upon which it is mounted. The element 18 is mountd on a supporting base 21 which is shown as being mounted on a panel 22 by means of a screw 23. In order to permit the condenser 15 to be readily adjusted to secure the correct initial adjustment of the frequency determining circuit 7, the electrode 16 is adjustably mounted adjacent the movable electrode 17 on a supporting member 24 which is fixedly mounted on the base 20 by means of a screw 25. The adjustable connection between the supporting member 24 and the electrode 16 comprises a threaded stud 26 extending from the electrode 16 and a pair of nuts 27 and 28 threaded on the stud 25 and positioned on either side of the support 24.

The heating coils 19 and 20 are indicated as being located on either side of the bi-metallic element 17 in close physical proximity thereto. Preferably the heating coils are insulated from the element 18 by thin mica strips 29 mounted on the member 21 and extending on either side of the element 18. If desired, the entire assembly may be surrounded with a layer of asbestos or other heat insulating material to insure a good transfer of the generated heat to the element 18.

In the construction and operation of a condenser suited to the purpose described above, it has been found that stray mechanical vibrations produce vibrations of the movable element 17 which cause frequency pulsations in the output frequency of the oscillator. In order to eliminate this undesired vibration of the electrode 17 a second bi-metallic element 30 may be positioned directly adjacent the element 18, and having a surface thereof in frictional contact with a surface of the element 18. The element 30 should be biased against the element 18 to insure a good frictional engagement between the surfaces of the two elements. In addition, the temperature flexure characteristics of the two elements 18 and 30 should be identical and they should be so arranged that the free ends thereof move in the same direction under like changes in temperature. With this composite structure, mechanical vibrations which tend to produce vibrations of the electrode 17, are substantially prevented by the damping effect created by the frictional engagement between the two elements 18 and 30. Since the two elements are identical in their flexure characteristics, the compensating action is not interfered with.

In designing elements 17 and 30 of sufficient sensitivity to produce the desired compensating action with a low power input to the resistances 19 and 20 it has been found to be necessary to use elements which are over sensitive to changes in the ambient temperature of the media surrounding the element. In other words, such ambient temperature changes produce an over-compensation and cause an undesired frequency variation in the output frequency of the oscillator. This undesired feature can, of course, be obviated by increasing the power input to the resistances 19 and 20 and making the elements 19 and 30 less sensitive to temperature variations. However, it is desirable to maintain the power input to the two named resistances as low as possible in order to minimize the current consumption of the oscillator unit. This over-compensating effect is particularly undesirable when the apparatus is located in a surrounding media having a very low temperature.

In order to retain the advantages of low power consumption and sufficient sensitivity of the elements 18 and 30 to produce the desired compensating action, it is advantageous to mount the electrode 16 on a thermostatic element 31 in the manner illustrated in Fig. 4. The element 31 should possess a temperature flexure characteristic such that movements of the free end thereof for predetermined temperature variations are substantially less than the movements of the electrode 17 for like temperature variations. Obviously the element 31 should be arranged in such a way that the free end thereof moves in the same direction as the elements 18 and 30 in response to like temperature changes. In this manner the over-compensating effect caused by the high sensitivity of the elements 18 and 29 is neutralized by a movement of the electrode 16 in response to flexure of the element 30. By a proper selection of the length and physical properties of the element 30 the device may be calibrated so that no over-compensation occurs due to the high sensitivity of the elements 18 and 29. It will of course be understood that a fourth bi-metallic element may be used to prevent vibration of the element 31 in the same manner that the element 30 prevents vibration of the element 18.

It has been found from experience that frequency drift in the output frequency of an oscillator equipped with my improved compensating arrangement is substantially reduced, and that once the compensating device has been properly calibrated it operates faithfully to perform the desired compensating action under widely divergent conditions of oscillator operation.

Although I have described my improved compensating device as being used in connection with an electron discharge oscillator, it will of course be understood by those skilled in the art that it may have utility in connection with other types of networks in which a determining circuit is connected to an electron discharge device. While I have described my improved compensating arrangement as including means for compensating for variations in the average value of the anode current, it will be realized that in certain applications where the anode current is maintained substantially constant this element of the apparatus may be omitted, since the necessity for its inclusion is eliminated.

While I have shown a particular embodiment of my invention, it will of course be understood that I do not wish to be limited thereto since many modifications in the structure may be made, and I contemplate by the appended claims to cover all such modifications as fall within the true spirit and scope of my invention.

What I claim as new and desire to secure by Letters Patent of the United States is:

1. In combination, an electron discharge device including a cathode and an anode, a tunable frequency determining circuit connected to said device, an auxiliary variable condenser having relatively movable electrodes, a thermostatic element for producing relative movement between said electrodes, and means including a pair of resistances connected respectively in circuit with said

cathode and in circuit with said anode for energizing said element to vary the tuning of said frequency determining circuit in accordance with variations in the temperature within said device.

2. In an oscillatory circuit of the class having an electron discharge device, a power supply circuit therefor, and a frequency determining circuit connected thereto, said discharge device including an anode and a cathode, the combination with said discharge device and said frequency determining circuit of an auxiliary variable condenser having relatively movable electrodes connected in said frequency determining circuit, a thermostatic element for producing relative movement between said electrodes, said thermostatic element being positioned in proximity to the elements of said frequency determining circuit to compensate for variations in ambient temperature, means responsive to variations in the cathode heating current of said discharge device for producing a false ambient about said thermostatic element, and means responsive to variations in average plate current flowing through said discharge device for producing a false ambient about said thermostatic element.

3. In combination, an electron discharge device including a cathode, an anode element, and a grid element, a source of heating current operatively connected to heat said cathode, a voltage source operatively connected to supply a voltage to said anode, a tunable frequency determining circuit operatively connected to said cathode and at least one of said elements, an auxiliary variable condenser separate from said discharge device and having relatively movable electrodes, a thermostatic element for producing relative movement between said electrodes, and means for energizing said thermostatic element to vary the tuning of said frequency determining circuit in accordance with variations in the temperature within said device, said means including means connected to said cathode heating source and means connected in series with said anode and said anode voltage source.

4. In combination, an electron discharge device including a cathode, an anode element, and a grid element, a source of heating current operatively connected to heat said cathode, a tunable frequency determining circuit operatively connected to said cathode and at least one of said elements, an auxiliary variable condenser separate from said discharge device and having relatively movable electrodes, a thermostatic element for producing relative movement between said electrodes, and means for energizing constantly during the initial heating of said cathode to the electron emission temperature said thermostatic element by current supplied from said cathode heating source, said electrodes, said thermostatic element, and said means being so arranged that the tuning of said circuit is changed to compensate for change in the inter-electrode capacity of said discharge device caused by warping of electrodes therein when the temperature of said cathode is raised from cold condition to said electron emission temperature.

LAMBERT H. LYNN.