May 17, 1949. J. F. BELL 2,470,425

LOW FREQUENCY DRIFT OSCILLATOR

Original Filed Feb. 13, 1943 2 Sheets-Sheet 1

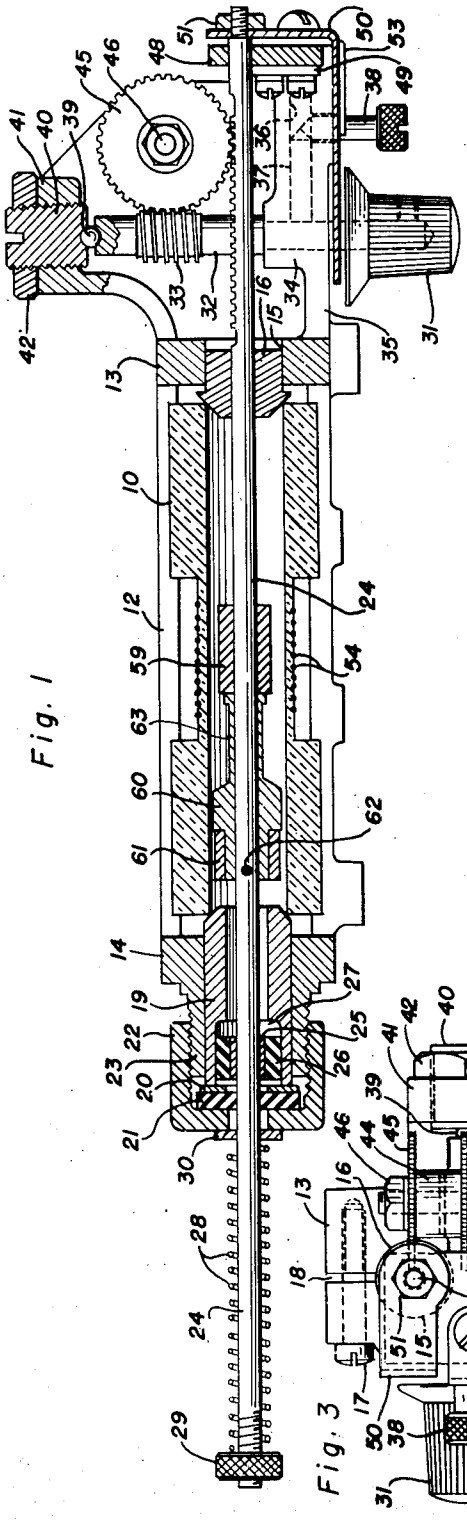


Fig. 1

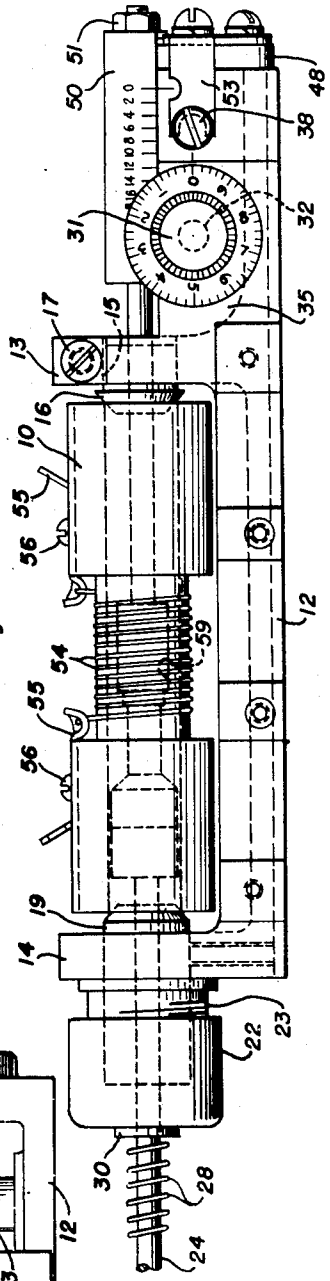


Fig. 2

Fig. 3

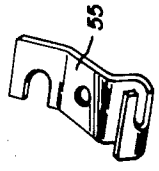


Fig. 4

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Fig. 5

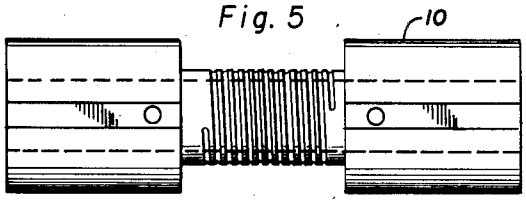


Fig. 6

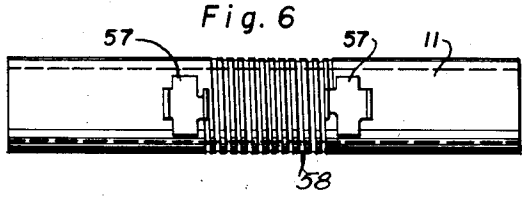


Fig. 7

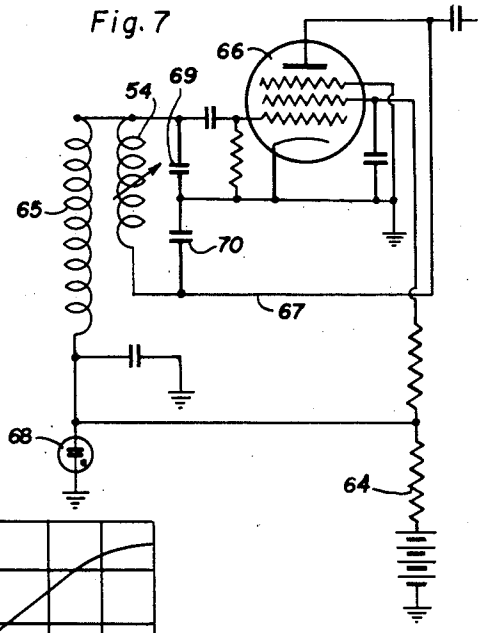


Fig. 9

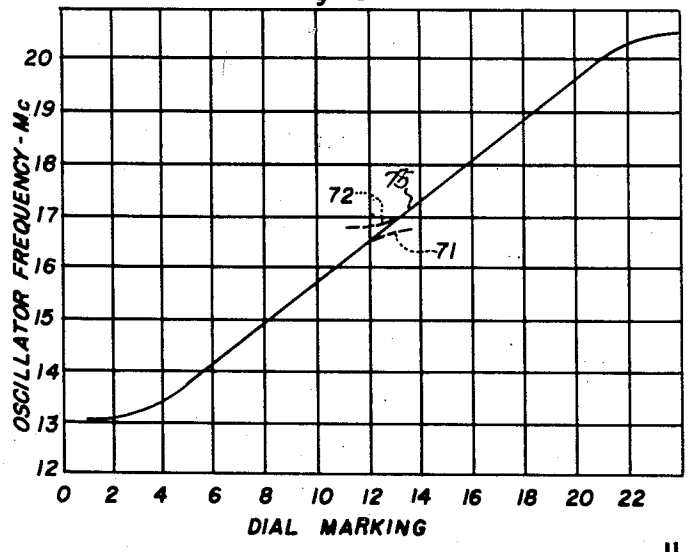


Fig. 8

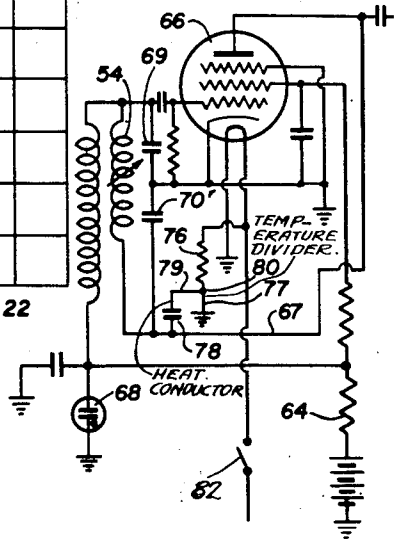
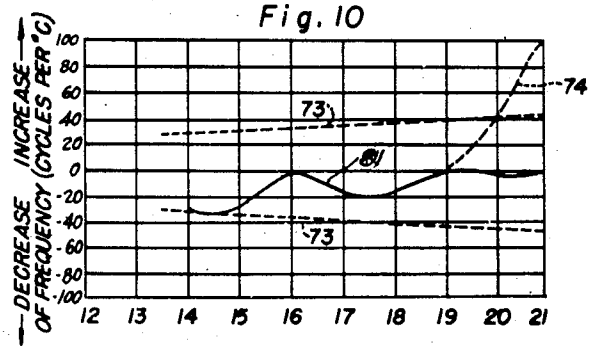


Fig. 10



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UNITED STATES PATENT OFFICE

2,470,425

LOW-FREQUENCY DRIFT OSCILLATOR

John F. Bell, Chicago, Ill., assignor to Zenith Radio Corporation, a corporation of Illinois

Original application February 13, 1943, Serial No. 475,779. Divided and this application October 20, 1944, Serial No. 559,618

1 Claim. (Cl. 250—36)

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This invention relates to a low frequency drift oscillator having a variable tuned circuit, the present application being a division of my copending application Serial No. 475,779 which has issued to United States Letters Patent No. 2,437,345 granted to me on March 9, 1948, and assigned to the same assignee as the present application.

One of the objects of the invention is to provide an improved low frequency drift variable tuned circuit and particularly an oscillator circuit which maintains a practically constant frequency notwithstanding considerable variations of temperature.

A further object of the invention is to provide an improved stable frequency tuned circuit including a variable inductor which has a very low change of inductance with change of temperature.

A further object of the invention is to provide an improved stable frequency tuned circuit including a variable inductor in which the ratio of change of inductance with change of temperature is substantially proportional to the inductance for which the inductor may be set.

A further object of the invention is to provide an improved tuned circuit including a variable inductor in which the ratio of change of inductance with change of temperature is small and is substantially proportional to the inductance for which the inductor may be set, together with capacitor means having a temperature co-efficient, that is, a ratio of change of capacity with change of temperature, which substantially corrects for changes of inductance and capacitance with temperature to provide a tuned circuit having substantially negligible frequency drift with changes of temperature.

A further object of the invention is to provide an improved tuned circuit which can be tuned to any desired frequency within an extended range of frequencies and which will maintain any desired frequency to which it may be tuned within close limits notwithstanding considerable change of temperature.

Other objects, advantages and capabilities of the invention will appear from the following description of a preferred embodiment thereof, taken in conjunction with the accompanying drawings, in which:

Figure 1 is a longitudinal sectional view of my improved variable inductor;

Fig. 2 is a side elevation thereof;

Fig. 3 is an end elevation thereof;

Fig. 4 is a perspective view of one of the clips to which the inductor coil is connected;

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Fig. 5 is a plan view of the coil and a form in which it may be mounted;

Fig. 6 is a similar view showing another coil form;

Fig. 7 is a wiring diagram of an oscillator circuit in accordance with my invention;

Fig. 8 is a similar diagram illustrating compensating means for initial drift due to heating up of the tube;

Fig. 9 is a frequency-dial marking curve of the oscillator shown in Fig. 7 or Fig. 8; and

Fig. 10 is a frequency drift-frequency curve showing the negligible drift of my improved circuit.

My invention includes an improved variable inductor which is arranged to have a relatively low drift of inductance in all its settings and in which the drift of inductance with temperature change is substantially proportional to the inductance for which the inductor is set within its operating range. I find that if such an inductor is incorporated as the variable element of a variable tuned circuit, the frequency drift has a straight line relation to temperature change and can be corrected by capacitor means having a suitable temperature coefficient.

My invention includes a tuned circuit embodying such an inductor and such capacitor means. My improved variable inductor, and consequently the tuned circuit, are arranged for accurate reproduction of tuning so that the same frequency may be attained accurately when the tuning means of the inductor is located in the same dial position.

My improved inductor is illustrated in detail in Figs. 1 to 6. The materials of which it is made are selected so that no changes of parameter result when the temperature of the inductor is raised or lowered and then returned to initial temperature. The metal parts of the inductor fulfill this requirement to a high degree. The coil forms 10 and 11 are of dielectric material selected to meet this requirement. I find that a coil form 10 of steatite has satisfactory expansion properties. Likewise, the coil form 11 of glass meets these requirements. Other dielectric substances have the same properties but the two mentioned have proved to be perfectly satisfactory.

My improved inductor comprises a main frame or base 12 which is preferably of metal, cast iron being a suitable material. The coil form 10 is mounted between two upstanding lugs 13 and 14 which extend upwardly from the base 12. The

lug 13 is provided with an opening 15 which receives a metal bushing 16 having a coned face against which one end of the form 10 abuts as shown in Fig. 1.

The bushing 16 is rigidly held in desired adjusted position by means of a binding screw 17 which extends through a slot 18 in the upper end of the lug 13 as shown in Fig. 3. The other end of the form 10 abuts against the coned end of a sleeve 19 which is slidably mounted in an opening in the lug 14. The sleeve 19 abuts against a washer 20 carried by a gasket 21 of rubber or other insulating material. The gasket 21 is held compressed by means of an internally threaded cap 22 which is mounted on a threaded nipple 23 extending from the lug 14 away from the form 10.

A slug shaft 24 is slidably mounted in the bushing 16 and in a bearing 25 carried by an annulus 26 of compressed rubber or other dielectric located in an enlargement 27 in the sleeve 19 remote from the form 10.

The slug shaft 24 is biased towards the left as viewed in Fig. 1 by means of a coil spring 28 which abuts against a nut 29 threaded on the end of the shaft 24 and against a washer 30 of insulating material which abuts against the face of the cap 22. It is to be noted that the shaft 24 is electrically connected to the base 12 through the bushing 16, but the shaft is insulated from the lug 14 to avoid an electrical loop constituted by the shaft 24 and the frame 12 which would result in excessive losses and uncertain operation.

The shaft 24 is arranged to be moved axially by means of a knob 31 which is mounted on a shaft 32 which carries a worm 33. The shaft 32 is rotatably mounted in a bearing 34 formed on a web 35 which extends upwardly from the frame 12. The web 35 is provided with a bore 36 which extends into the opening of the bearing 34. The bore 36 contains a pressure pin 37 adapted to be forced against the shaft 32 by means of a set screw 38 threaded into the web 35, the pin 37 and the set screw 38 having cooperating coned ends as shown in Fig. 1. By means of the set screw 38, a desired degree of friction may be applied to the shaft 32 so that it maintains the desired position in which the shaft 32 is moved by the knob 31.

The inner end of the shaft 32 is supported by means of a ball 39 received in a recess in the end of the shaft 32 and in a recess carried by a plug 40 which is threaded into a boss 41 carried by the frame 12.

The plug 40 is locked in position by means of lock nut 42. The shaft 32 has a shoulder which abuts against the inner side of the bearing 34.

The worm 33 meshes with a worm gear 43 rigidly carried by a sleeve 44 which also rigidly carries a pinion 45 at the level of the shaft 24. The sleeve 44 is rotatably mounted on a post 46 which projects upwardly from the base 12. The pinion 45 meshes with a rack 47 formed on the right-hand end of shaft 24 as viewed in Fig. 1. Consequently, rotation of the knob 31 effects axial movement of the shaft 24 in one direction or the other.

At the right-hand end of the inductor as viewed in Fig. 1, the base 12 is provided with an upstanding lug 48 which has an opening through which the right-hand end of the shaft 24 extends. A key plate 49 adjustably mounted on the lug 48 bears against the shaft 24 to limit lateral and rotary motion thereof. Beyond the lug 48 the shaft 24 is reduced and threaded to receive

a scale 50 of rectangular form and a securing nut 51.

The longitudinal member of the scale 50 is provided with suitable divisions and numerals which are arranged to cooperate with an index mark 52 on the web 35. Also mounted on the lug 48 is an angular resilient clip 53 which cooperates with the set screw 38 to prevent accidental loss or loosening thereof.

The coil form 10 shown in Figs. 1, 2 and 5, is suitably of steatite or similar material, and it may be of generally dumbbell form. The coil 54, which is relatively short, is tightly wound in a helical groove formed in the central part of the form 10, its ends being soldered to clips 55 which are mounted on the enlarged ends of the form 10 by means of screws 56.

To avoid excessive drift due to expansion and contraction of the coil 54 with temperature changes, I prefer to make this coil of invar wire which is copper coated and preferably also silver coated to provide a low resistance layer. The coil 54 is tightly wound upon the form 10 at a low temperature so that it is always in firm contact with its groove in the form. The expansion of the coil 10 is consequently the expansion of the material of which the form 10 is made.

As shown in Fig. 6, I may employ a class form 11 upon which are mounted clips 57 for connection of the ends of the coil. Between these clips the coil is provided with a helical groove 58 for the reception of the tightly wound coil 54.

The shaft 24 carries an iron slug 59 and a conductive slug 60. To attain my objects of keeping inductance drift with temperature low, and keeping the drift proportional to the inductance, I employ these two slugs so as to get a large travel of the slug shaft. I use the term "slug" to designate generally a body movable relative to the coil to effect a change of its inductance.

I use powdered iron of such characteristics that, upon temperature change, the inductance always returns to its initial value upon the return of the temperature to its initial value. When such iron is utilized, the permeability is sufficiently high to make the slug of satisfactorily small diameter. The slug 59 may suitably consist of this powdered iron cemented to slug form by a suitable binder such as a thermal setting plastic. The slug 59 is suitably cemented to the shaft 24.

The slug 60 consists primarily of copper. To minimize the drift at one position of adjustment of the shaft 24, I provide at the outer end of this slug an annulus 61 of metal having a smaller thermal expansion than that of copper. Various metals having different thermal expansions may be used to attain any desired correction of drift which may be necessary. In the present embodiment of the invention the annulus 61 may suitably be of invar or of other similar metal having a very small thermal expansion. The composite slug 60 is secured to the shaft 24 by means of a pin 62. Annulus 61 is plated with copper and preferably also with silver, so that it has high frequency electrical properties of cooper or silver.

While I have referred to the element 60 as a slug, it must be understood that only the outer surface layer is effective electrically, and at high frequencies this layer is extremely thin. Thus, the invar annulus 61 has no electrical function. It merely provides a support for the copper or silver surface and imparts to the copper or silver cylinder a much lower thermal expansion than that which the cylinder would have if unsup-

ported. The slug 60, 61 may be hollow or it may have a core which is non-metallic. Since this slug has a conductive surface, currents are induced on this surface due to the field of the coil, which currents set up opposing fields which in effect decrease the apparent inductance of the coil. Therefore, as the slug 60, 61 is inserted further into the coil, the portion of the conductive surface lying in the coil becomes greater, and hence the apparent inductance of the coil decreases.

The shaft 24 is suitably of stainless steel. The portion of the shaft between the two slugs 59 and 60 may be plated or coated with a non-magnetic metal of high conductivity such as copper or silver, or both. Instead of so coating this portion of the shaft, I may provide a sleeve extension 63 of the slug 60 which extends up to the slug 59. When the shaft 24 is thus coated it has substantially no effect upon the electrical qualities of the coil 54.

The slugs 59 and 60 are in such spaced relation that as one leaves the coil 54 electrically, the other enters the coil electrically. Actually the slugs are spaced slightly less than the physical length of the coil. It is to be noted that the slug 60 is shown with a slight conical formation on its inner end, but the ends of the slugs may be varied in shape to some extent without affecting the operation of the inductor provided the spacing of the slugs is made correct as hereinafter explained.

The electrical properties of my improved inductor can best be understood with reference to a tuned circuit in which it is incorporated. In Fig. 7 I show a wiring diagram of a Colpitts oscillator including the coil 54 tuned by the slugs 59 and 60 to determine the frequency of oscillation.

The B battery is connected through a resistor 64 and through a choke coil 65 to the grid side of the coil 54, the other side thereof being connected to the plate of the tube 66 by a conductor 67.

A voltage regulator tube 68 which may suitably be a VR–150 tube, is connected to the common point of the resistance 64 and choke coil 65 and to ground so as to establish substantially constant voltage on the plate of the tube 66.

The grid-to-ground condenser 69 may suitably be several times larger than the plate-to-ground condenser 70. Last said condenser may have a value of around 100 $\mu\mu$ farads. The condenser 70 may suitably be a ceramic condenser having a suitable temperature coefficient, usually a negative temperature coefficient, sufficient to correct for frequency drift due to changes in capacity in the circuit with temperature and due also to changes of inductance in the inductor including the coil 54. This inductor has only a slight change of inductance with temperature change and that change of inductance with temperature change is substantially proportional to the inductance for which the inductor is set. Consequently, this slightly change of inductance can be compensated for, together with drift due to capacity, by a condenser 70 of correct temperature coefficient.

The correct temperature coefficient to be selected for the condenser 70, can be determined empirically in the manner set forth in United States Letters Patent No. 2,371,790 granted to me on March 20, 1945, and assigned to the same assignee as the present application. In short, the method consists in installing a condenser 70 of

known temperature coefficient and determining the frequency, with one setting of the slug shaft at two considerably different ambient temperatures.

From the frequency change it can be determined that an additional change of capacity of determined amount in capacitor 70 would bring the drift to zero. To this change of capacity is algebraically added the actual change introduced by the condenser 70 and from this result it is a matter of elementary calculation to determine that the condenser 70 should, for correction of ambient temperature, have a definite temperature coefficient. Correction for ambient temperature drift is thus attained by substituting a condenser 70 of the same capacity and having the desired temperature coefficient.

In Fig. 9 I have shown a graph of oscillator frequency against dial markings derived from such a circuit. The part of the curve corresponding to between 0 and 12 on the dial marking corresponds to the movement of the iron slug from the position shown in Fig. 1, that is, when it is fully inside the coil 54, to a position in which it just emerges from this coil. Change of frequency has a straight-line relation to dial marking for the greater parts of its length, but adjacent the 16½ mc. point, the curve tends to flatten out as shown by the dotted line 71.

The slope of the curve depends primarily upon the diameter of the slug. If the slug 59 were made of larger diameter, the straight-line part of the curve between 13½ mc. to 16½ mc. would be steeper. The same applies to the conductive slug 60 with respect to the portion of the curve between about 17 mc. and 20 mc. The diameters of the two slugs are thus correlated so that they provide two portions of the curve of the same slope.

Correct alignment of the two curves is attained by accurate spacing of the two slugs. Thus, if the slug 60 were moved slightly to the right, portion of the curve of Fig. 9 between 17 mc. and 20 mc. would be moved downwardly on this figure. Correct spacing places the two portions of the curve in alignment. It is to be noted that below around 17 mc. point, the upper part of the curve, due to the slug 60 alone, tends to flatten out as shown by the dotted line 72. The two dotted lines 71 and 72 combine to form the complete straight line designated as 75.

It is to be understood that it is within the scope of my invention to construct an inductance in which the inductance varies non-linearly in a desired fashion upon adjustment of the two relatively movable parts thereof. That is, as set forth above, the two slugs 59 and 60 may be made of such relative diameters, various sections of each of the two slugs 59 and 60 may be made of different relative diameters, and the spacing between the two slugs 59 and 60 may be such as to obtain a very large variety of non-linear curves of induction upon change in adjustment of the two relatively movable parts.

In Fig. 10 I have shown the frequency drift of a circuit as described above, expressed in cycles, against the frequency expressed in megacycles. From this curve, it is obvious that the frequency drift lies within the limits of ±0.01% of the frequency for a variation of ±47.5° C., these limits being indicated by the dotted lines 73 on Fig. 10.

It is to be noted that when the slug 59 is within the coil 54, the frequency diminishes 20 cycles per temperature rise of one degree centigrade.

As the iron slug is withdrawn from the coil, the frequency drift increases slightly and then it decreases until at a point where the slug 59 is almost out of the coil, the frequency drift is 0. As the slug 60 is drawn into the coil, the frequency drift decreases somewhat and then increases. The dotted line 74 represents the frequency drift curve obtained with the slug 60 completely of copper. Since this curve provides excessive increase of frequency with temperature increase between 20 and 21 mc., undoubtedly due to expansion of the copper slug, I modified the slug 60 by replacing a substantial part of its outer end by the invar element 61 and I find that with this invar element, the frequency drift between 19 and 21 mc., is practically zero.

It must be emphasized that the full line curve 81 shown in Fig. 10 can, for all practical purposes, be regarded as a straight line. The drift there indicated, amounting to less that 30 cycles in about 15,000,000 cycles for each degree centigrade, is negligible for all practical purposes. The dial may be set to a desired frequency with the aid of the vernier scale on the knob 31 with an accuracy of about one kilocycle. At the worst part of the curve shown in Fig. 10, one kilocycle corresponds to drift due to 30° C., so that the maximum frequency drift is of substantially the same order as the accuracy of setting the dial and its effect is completely negligible. The dial can be set to a desired position and a station of the corresponding wave length can be received with a frequency shift of the circuit of less than 30 cycles in about 15 kilocycles for each degree centigrade change in temperature conditions.

It has been explained that the condenser 70 having an appropriate temperature coefficient, substantially compensates for drift due to changes of capacity and inductance due to change of ambient temperature. If desired, the tuned circuit may be also corrected for frequency changes due to warming up of the tube 66. This is done in the manner described in detail in my aforesaid Patent No. 2,371,790, and it will therefore be referred to only briefly herein with reference to Fig. 8.

For this result, I connected in parallel with the heater element of the discharge device 66, a resistor 76, which resistor is connected to ground by a lead 77, so that both the resistor 76 and the heater of device 66 start to heat up together when switch 82 is closed. Instead of the single capacitor 70 as in Figure 7, I employ a capacitor 70' having a capacitor 78 connected in parallel thereto through a ground connection, the two capacitors having the same total capacity as a capacitor 70 of Figure 7. The temperature coefficients of the two capacitors 70', 78 are such that their combined change in capacity with change in temperature is that of the single capacitor 70.

The capacitor 78 is connected to ground through a lead 74 and a portion of lead 77, the lead 79 being connected to lead 77 at point 80. The lead 77 is preferably much larger than lead 79. The lead 77 is arranged so that it serves as a temperature divider, that is, it is a heat conductor analogous to the slide wire of a voltage divider, temperature being regarded as analogous to voltage. In other words I provide a temperature gradient along conductor 77. At its upper end which is connected to resistor 76, the temperature of conductor 77 is at a maximum, and at its lower end which is connected to ground, or to the chassis supporting the circuit elements,

the temperature is substantially that of the chassis. Intermediate points on conductor 77 have intermediate temperatures which increase from the lower to the upper end. The position of the point of connection 80 on conductor 77 determines the maximum temperature which the capacitor 78 obtains, and the length of the conductor 79 determines approximately the rate at which capacitor 78 heats up when switch 82 is closed, conductor 79, hence, acting as a heat conductor to conduct heat from the temperature divider lead 77 to capacitor 78. The point 80 and the effective length of conductors 79 are determined in a manner set forth in my aforesaid Patent No. 2,371,790 so that the capacitor 78 heats up as a discharge device 66 heats up, and at a rate which compensates for the change of frequency due to the change of temperature of the device 66 during heating. With this compensating system, the frequency remains substantially constant from the instant when device 66 first becomes effective to the normal operating temperature of the device.

It is to be noted that on increase of temperature, the cast iron frame 12 between the post 46 and the lug 13 expands, thus tending to move the coil form 10 to the left relative to the slugs, thus increasing the frequency. The much lesser expansion of the material of the coil form 10 tends to have the same effect. The expansion of the stainless steel shaft 24 tends to move the slugs 59 and 60 to the left, as viewed in Fig. 1. The stainless steel shaft is selected of material which has a thermal expansion intermediate those of the base 12 and the form 10, and such that the expansion of the base 12 and the form 10 are offset to some extent by the expansion of the shaft 24.

The expansion of the portion of the shaft 24 between its point of engagement with the pinion 45 and the effective slug, that is, the slug which is cooperating with the coil 54, is somewhat less than the sum of the expansion of the frame between the pin 46 and the abutment 13 and the expansion of the half of the coil form 10 between this abutment and the coil. Consequently, an increase of temperature has the effect of pulling the iron slug 59 out of the coil 54 to a slight extent, thus tending to increase the frequency. The expansion of the shaft 24 is selected so that this slight net movement of the slug 59 relative to the coil 54 substantially balances the effect of the simultaneous expansion of the iron slug 59 and the coil 54.

Since these materials have excellent expansibility and contractibility with change of temperature, the rate of change of inductance with temperature change resulting from these factors is highly constant at any setting of the inductance.

I may, by proper selection of thermal expansions and dimensions of the coil form, frame and slug shaft, make the drift of inductance with change of temperature, when the slug 59 is cooperating with the coil, substantially zero. In practice, it is not necessary to compensate to this extent because I find that if the inductance drift with temperature change is made small, it is substantially proportional to the inductance setting, and it can be balanced by a temperature compensating condenser. Since I prefer to use such a condenser to compensate for drift due to changes of capacity of the circuit with change of temperature, it is convenient to employ a condenser of appropriate temperature coefficient to correct for both the residual drift of the induct-

ance and the drift of capacity due to change of temperature.

Expansion of the iron slug with increase of temperature tends to decrease the frequency in the case of most iron slug compositions. This effect, however, is minimized since the slug **59** is relatively small. My employment of an iron slug and a slug of conductive metal enables me to have a relatively large travel of the slug shaft, which materially reduces the drift of inductance in frequency due to temperature change.

Expansion of the coil **54** with increase of temperature tends to decrease the frequency. This effect is kept at a minimum by employing, in effect, a coil which has a very low expansibility. In fact, it has the expansibility of the form which is quite low, compared with that of most normal metals. The invar coil **54** is wound upon the form at a very low temperature and under substantial tension. This tension is retained at all times with the result that the wire of the coil is firmly seated in its groove at all times.

The tendency toward increase of frequency resulting from the relative displacement between the coil **54** and the slug **59** owing to the expansion of the coil form **10**, the frame **12** and the shaft **24**, is arranged so that it substantially nullifies the tendency towards decrease of frequency resulting from the simultaneous expansion of the coil **54** and the slug **59**. While this result can be conveniently attained by selecting a shaft **24** of correct thermal expansion, it is obvious that the effect involves the thermal expansion of the coil form **10** and the frame **12** and the same result can be obtained by selecting material for the coil form **10** or material for the frame **12** so that the three elements **10**, **12** and **24** will provide the small displacement of the slug **59** relative to the coil **54** necessary effectively to nullify the frequency change resulting from expansion of the slug **59** and the coil **54**.

Expansion of the slug **60** tends to increase the frequency with rise of temperature. During the first part of the travel of the slug this tendency minimizes a tendency toward opposite drift, but a slug **60** completely of copper gives excessive increase of frequency with rise of temperature when the slug is more than half way into the coil. As shown by the portion of the dotted line **74** above the upper dotted line **73** in Fig. 10, the frequency drift exceeds 0.01% of the frequency for a change of temperature of ±47.5° C. when more than about three-quarters of the slug **60** is within the coil. By substituting the portion **61** of low thermal expansion for part of the slug **60**, it will be seen that the frequency drift when more than about one-third of the slug **60** is within the coil, is reduced to not more than 0.001% of the frequency for a change of temperature of 47.5° C., a drift which is substantially negligible.

It will be understood that although I have referred to invar as a prime example of metal having substantially no thermal expansion, it is well known in the arts that many other metals and alloys have the same or similar property, and they may be used instead of invar in the relations herein stated. It will be understood that in some cases a lesser degree of correction than that provided by the invar element **61** is necessary and that the element **61** may in such cases be made of a metal which has a substantial thermal expansion somewhat less than that of copper. It will also be understood that the length of the element **61** and its position on the slug **60**, **61** is determined by the position in the tuning range where the correction it provides is necessary.

It must also be understood that it is within the scope of the present invention to provide a slug such as **60**, **61**, to correct for a reduction of frequency with rise of temperature, and in such cases an element **61** may be provided at the proper position on the slug **60**, **61**, which has a greater thermal expansion than that possessed by the body **60** of the slug.

While it is preferred in the embodiment of the invention illustrated to employ two slugs **59** and **60**, it will of course be apparent that each slug exercises its individual tuning effect and it is within the scope of my invention to employ a single iron slug **59** or a single composite slug **60**, **61** to provide an inductor having a lesser tuning range.

Although the invention has been described in connection with specific details of preferred embodiments thereof, it must be understood that such details are not intended to be limitative of the invention except in so far as set forth in the accompanying claim.

I claim:

An oscillator circuit comprising a tunable inductor, capacitor means, and an electron discharge device having a heater element, said inductor being arranged to have low inductance drift with temperature changes and one which is substantially proportional to the inductance in all settings of the inductor, said capacitor means including two capacitors having temperature coefficients which compensate for changes of capacity and inductance in said oscillator circuit due to changes of ambient temperature, a resistor heater, means for supplying current to said heater element and to said resistor heater simultaneously, a temperature divider conductor extending from said heater resistor, and a heat conductor lead extending from one of said capacitors to an intermediate point on said temperature divider conductor, said intermediate point of connection of the heat conductor lead and said temperature divider conductor and the effective length of the heat conductor lead being such that heat is transferred from said resistor heater to the capacitor connected to the heat conductor lead at a rate and to an extent to provide capacity change in the circuit to compensate for changes in the frequency which would otherwise result from changes of parameters due to the heating up of the tube.

JOHN F. BELL.

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2,407,360	White	Sept. 10, 1946

Certificate of Correction

Patent No. 2,470,425. May 17, 1949.

JOHN F. BELL

It is hereby certified that errors appear in the printed specification of the above numbered patent requiring correction as follows:

Column 4, line 28, for the word "class" read *glass*; column 5, line 65, for "slightly" read *slight*;

and that the said Letters Patent should be read with these corrections therein that the same may conform to the record of the case in the Patent Office.

Signed and sealed this 18th day of October, A. D. 1949.

[SEAL]

THOMAS F. MURPHY,
Assistant Commissioner of Patents.

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