

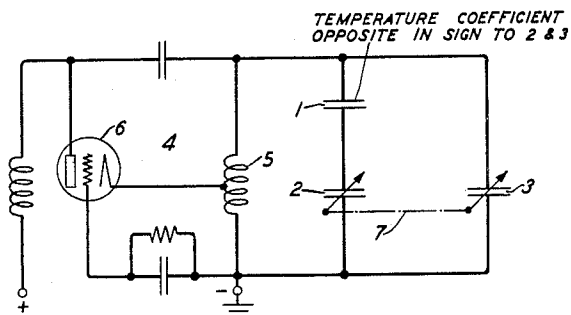
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K. D. SMITH

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TEMPERATURE COMPENSATING MEANS

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INVENTOR
K. D. SMITH
BY
G. H. Heydt.
ATTORNEY

UNITED STATES PATENT OFFICE

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TEMPERATURE COMPENSATING MEANS

Kenneth D. Smith, White Plains, N. Y., assignor
to Bell Telephone Laboratories, Incorporated,
New York, N. Y., a corporation of New York

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This invention relates to variable condensers and more particularly to temperature compensated variable condensers adapted for use in oscillator circuits.

Various means have been suggested in the prior art for maintaining constant the various circuit parameters which are made component parts of oscillators where the frequency is to be kept constant. Crystals having a constant natural period at substantially constant temperatures have been used. However, where the oscillator must provide a wide range of frequencies and must not shift appreciably in frequency as the temperature changes, some means must be provided to either individually maintain constant with temperature all the circuit parameters or to compensate collectively for their variations. Condensers and inductors per se may be individually temperature compensated by means provided in the prior art represented, for example, by United States Patent 1,616,622 to J. W. Horton issued February 8, 1927, 1,722,083 to J. C. Gabriel et al. issued July 23, 1929, and 2,185,355 to G. Peterson issued January 2, 1940. Tube capacitances also vary with temperature and even though the principal components of the frequency determining circuits have been carefully compensated these tube capacitance variations as well as other parasitic capacitance variations cause an undesirable frequency drift with changing temperature.

It is an object of this invention to provide a simple means for temperature compensating variable condensers as well as variable frequency oscillators adjusted by variable condensers throughout their adjustable ranges.

The foregoing object is attained by connecting in parallel with the variable condenser a second variable condenser mechanically linked to the first variable condenser and having a substantially similar law of variation and inserting a fixed condenser in series with the second condenser, the fixed condenser having a temperature coefficient opposite in sign to the two variable condensers.

A simple schematic of a Hartley type oscillator 4 has been selected to be shown in the annexed drawing as an example of a specific application of this invention. As is well known the principal frequency determining network comprises inductor 5 and condenser 3, it being assumed for the moment that condensers 1 and 2 are not in the circuit. Tube 6 is shown as a triode but may be any other multielectrode tube commonly used in oscillators of this type. Moreover, other types of oscillators may be substituted such as, for example, the Colpitts oscillator, the tuned grid or tuned plate regenerative oscillator or an electron coupled oscillator, all of which are

well known to the electronic art provided, however, their adjustable element is a variable condenser.

Inductor 5 and variable condenser 3 should be carefully made mechanically so that their magnitudes will vary consistently with changes in temperature or they may be individually temperature compensated, although not necessarily so. For example, assume that inductor 5 is individually temperature compensated but condenser 3 is not so compensated. In such a case the frequency will shift as the temperature changes due to changes in capacitance. Since condenser 3 is the adjustable element it follows that whatever compensation is employed it must correctly compensate over the entire adjustable range and should take into account capacitance changes in the vacuum tube as well as such other stray capacitance variations as may appear in the particular oscillator assembly. To simplify the explanation of this invention, it is assumed that all the stray circuit capacitances are effectively included in the residual capacitance of condenser 3.

This invention solves this problem in a very simple manner by employing an auxiliary variable condenser 2 connected in series with a fixed condenser 1. These two series-connected condensers are then connected in parallel with the first variable condenser 3 which, of course, must have a different capacitance range than when used alone in order to give the desired over-all capacitance range. The two variable condensers 2, 3 are mechanically ganged together by shaft 7 in essentially the same manner as is done for gang tuning condensers in radio receivers.

The temperature coefficient of the fixed condenser must be opposite to that of the two ordinary variable condensers. The construction of such condensers is well known and need not be discussed in detail as it forms no part of this invention. However, it is the inherent property of some condensers made with ceramic insulation to have a temperature coefficient opposite in sign to ordinary air condensers. This is particularly true where the insulation is made with titanium dioxide.

It will be apparent that if a condenser having a given temperature coefficient is connected in parallel with another having a coefficient of opposite sign that the latter will tend to compensate for the changes taking place in the former so that the net capacitance does not vary with temperature. Fixed capacity ceramic condensers with relatively large temperature coefficients are available and, in accordance with this invention, such a condenser 1 of appropriate size is connected in series with the auxiliary ganged vari-

able condenser 2. With this arrangement the compensating effect of fixed condenser 1 is made effective throughout the adjustable range of condenser 3.

If condenser 2 were not made variable and condenser 1 were selected to properly compensate condenser 3 at maximum capacitance, it is clear that condenser 1 would overcompensate the lower capacitance adjustments of condenser 3. However, by making auxiliary condenser 2 variable it reduces the compensating effect of condenser 1 as the capacitance of condenser 3 is reduced. It has been found that if condenser 2 is made to obey the same law as condenser 3 and the relative magnitudes are properly chosen to give the desired over-all capacitance range and temperature compensation at one capacitance adjustment, compensation within acceptable limits achieved for the entire adjustable range.

A refinement can be made, however, by simply giving the plates of condenser 2 a special shape to follow the required actual temperature variation law of the entire oscillator or condenser assembly. An example of how this may be done in a practical embodiment may be illustrated by assuming an oscillator assembly with a temperature coefficient of -25 cycles per million cycles per degree centigrade, which is to be compensated over a frequency ratio of 2 to 1. It is evident that the total necessary capacitance variation will be in the ratio of 1 to 4, because the tuning capacity ratio is inversely proportional to the square of the frequency ratio tuned. Also, the effective temperature coefficient of capacity before compensation is $+50$ parts per million per degree, because of this same inverse square relationship. It is, therefore, necessary to provide compensation for a system in which the total capacitance varies in a ratio of 1 to 4 as, for example, 100 to 400 micro-microfarads, and in which the capacitance coefficient before compensation is $+50$ parts per million per degree centigrade.

It can be shown by analysis that to achieve compensation the following relation must exist:

$$\alpha \frac{C_1 C_2}{C_1 + C_2} = -\beta C_3$$

where

α = the temperature coefficient of the series combination of condensers 1 and 2.

β = temperature coefficient of condenser 3.

C_1, C_2, C_3 = capacitances of condensers 1, 2 and 3, respectively

For convenience, let

$$\frac{C_1 C_2}{C_1 + C_2} = C_4$$

then $\alpha C_4 = -\beta C_3$ is the relation which must be satisfied. Of course the necessary values of C_1 and C_2 to give the desired product αC_4 will depend on the temperature coefficients of C_1 and C_2 , as well as their values, so in order to obtain a numerical solution it will be assumed that C_1 is a fixed condenser of 100 micro-microfarads having a temperature coefficient of -400 parts per million per degree centigrade, and that C_2 is a variable condenser of similar construction to C_3 , and having a temperature coefficient of $+50$ parts per million per degree centigrade. Perhaps the simplest procedure is to plot graphically the values of αC_4 versus C_2 for this combination, and to determine from this curve the necessary value of

C_2 for each value of C_3 . Then from C_3, C_2 and C_1 the total tuning capacitance for each value of C_2 is computed.

The table shows values of C_1, C_2, C_3, C_4 and C (the total tuning capacity) which give accurate compensation on the above assumptions. Here the value of C_2 is always less than C_3 , so that the plates of one section of a two-section ganged condenser can be re-shaped to form C_2 .

TABLE

Capacity in micro-microfarads

C_3	C_1	C_2	C_4	C
65	100	49	35	100
75	100	56	37	112
100	100	65	39.5	139.5
150	100	88	47	197
200	100	114	53.3	253.3
300	100	176	64	364
334	100	201	66	400

Although the invention has been described assuming that the inductor 5 is compensated, it is evident that if it is not compensated the entire frequency determining network of the oscillator including stray capacitances will have a definite temperature coefficient for each frequency setting of the variable condenser 3. In such a case compensation can still be effected in accordance with this invention by properly shaping the plates of condenser 2 as described in the specific example given above.

What is claimed is:

1. Means for temperature compensating a variable condenser throughout its capacity range, comprising a second variable condenser substantially similar to and mechanically ganged with said first-named variable condenser, a fixed condenser having a temperature coefficient opposite in sign to that of the two variable condensers connected in series with the second condenser, and means connecting the two series-connected condensers in parallel with the variable condenser.

2. Means for temperature compensating the frequency determining network of an oscillator having a variable condenser as the adjustable part thereof comprising a second variable condenser mechanically ganged with said first-named variable condenser, a fixed condenser having a temperature coefficient opposite in sign to the over-all temperature coefficient of said oscillator, said fixed condenser being connected in series with said second variable condenser, and means connecting the two series-connected condensers in parallel with said first-named condenser.

3. Means for temperature compensating a variable condenser throughout its capacity range comprising a second variable condenser mechanically coupled with the first-named variable condenser, a fixed condenser having a temperature coefficient opposite in sign to that of the said two variable condensers, specially shaped plates for the said second condenser adapted to provide in cooperation with the fixed condenser a substantially exact temperature compensation for the first-named variable condenser, and means connecting the second variable condenser in series with the fixed condenser and the resulting series-connected condensers in parallel with the first-named variable condenser.

KENNETH D. SMITH.