

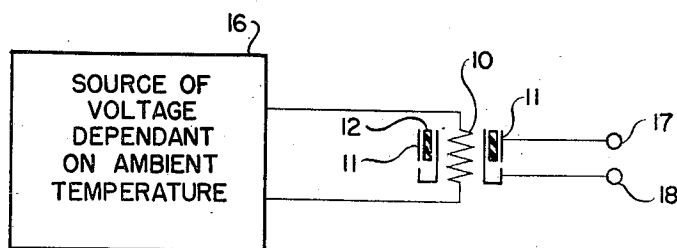
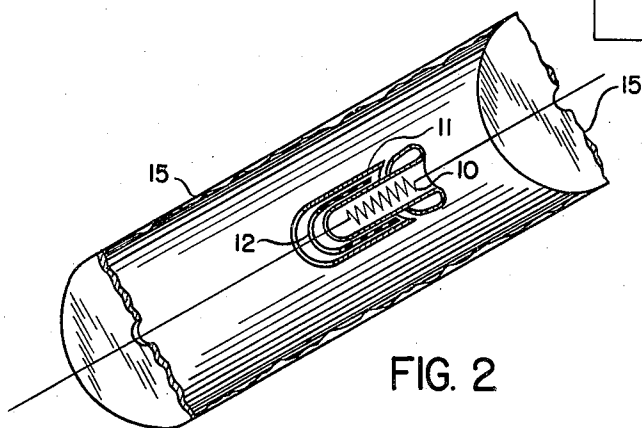
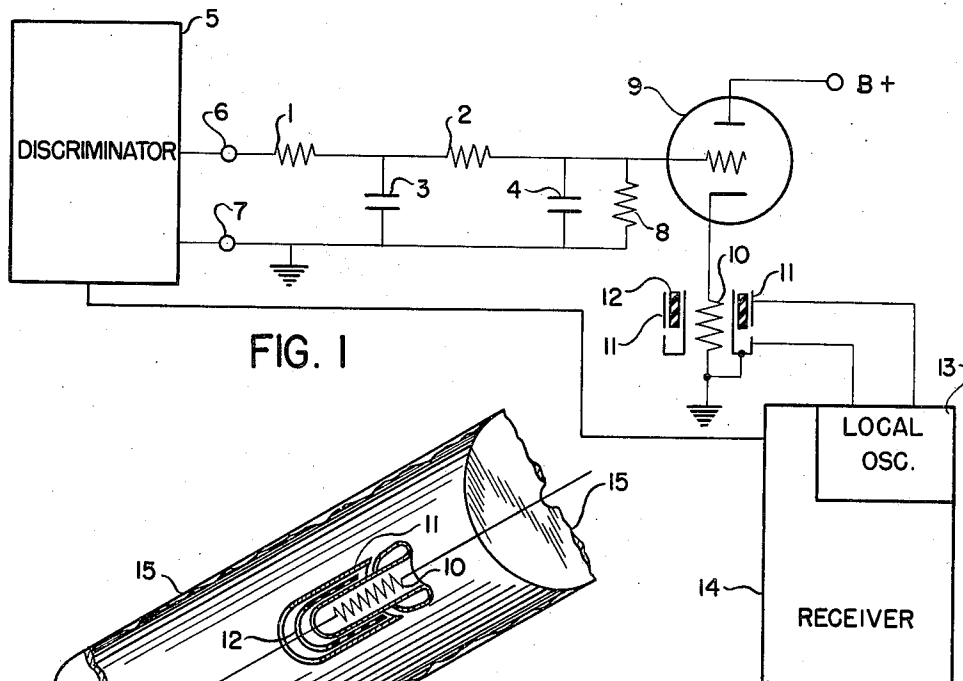
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AUTOMATIC FREQUENCY CONTROL CIRCUIT

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AUTOMATIC FREQUENCY CONTROL
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1

This invention relates to new and useful improvements in automatic capacitance varying circuits.

In radio receivers which are selectively tuned to transmissions on particular carrier frequencies it is frequently desirable to employ automatic apparatus for controlling the accuracy and the constancy of tuning. In receivers of the super-heterodyne type wherein tuning is accomplished by varying the frequency of a local oscillator automatic frequency control can be accomplished by automatic control of the frequency of the local oscillator. This, in turn, can be accomplished by automatic control of the capacitance in the tank circuit of the local oscillator.

Circuits are known which depend for their operation on what is known as a variable reactance tube. This type of control circuit does not directly employ either a capacitor or an inductor whose value can change in response to changes in a control voltage. Instead, certain conventional components are arranged so that the circuit as a whole produces the desired effect. For certain purposes, such, for example, as to provide greater ease of repair because its mode of operation is obvious and can be readily understood by repairmen, the existence of a single circuit element which is directly capable, in itself, of offering values of reactance which vary in accordance with changes in a control voltage has certain advantages.

Moreover, such a single circuit element might be small, compact, inexpensive, sturdy, dependable, and readily manufactured, whereas reactance tube circuits lack these attributes either partially or entirely.

It is an object of this invention to provide automatic control circuits for varying the capacity of a capacitor in a predetermined manner in response to control voltage changes.

It is a further object of this invention to provide an automatic frequency control circuit including such an automatically variable capacitor connected to the tank circuit of the local oscillator of a receiver to be automatically tuned.

Other objects, features and advantages of this invention will become apparent from the following description of this invention taken in connection with the drawings in which:

Fig. 1 is a circuit diagram of one embodiment of this invention;

Fig. 2 is a schematic representation of a cross section of the type of variable capacitor employed in the circuits of this invention; and

Fig. 3 is a block diagram of another embodiment of this invention.

2

Referring more particularly to Fig. 1, the portion of the circuit comprising elements 1, 2, 3 and 4 is a filter circuit. Elements 1 and 2 are resistors, and elements 3 and 4 are capacitors. These parts are arranged so that capacitors 3 and 4 are in shunt across the input voltages fed to this filter circuit while resistors 1 and 2 are in series between the input and output of the filter. In this respect, elements 1, 2, 3 and 4 are arranged as a conventional resistor-capacitor alternating current filter. In the present circuit the filter is intended to eliminate audio components which may reach the input and accordingly this portion of the control circuit is designated, for all purposes in this application, as the audio filter. Input terminals 6 and 7 of the audio filter are connected across the output terminals of a discriminator shown in Fig. 1 as block 5. When the device is in operation, the discriminator will, at any instant of time, supply voltages between terminals 6 and 7 which will include a direct current component. This component, unless it is of zero magnitude, will have some finite positive or negative value.

Across the output of this filter there is connected a grid resistor 8. Grid resistor 8 is grounded at one end and its other end is connected to the grid of vacuum tube 9 which may be a triode. The plate of vacuum tube 9 is connected to an energizing source of direct current voltage and; therefore, as is well known, the current drawn by vacuum tube 9 will depend on the voltage relationship between the grid and the cathode as well as upon the value of this energizing voltage. The voltage relationship between the grid and cathode of tube 9 depends, in part, on the value of resistor 10 through which the cathode of vacuum tube 9 is connected to ground. The resistance of resistor 10 is selected so that the voltage drop across it raises the cathode of vacuum tube 9 above ground potential and biases vacuum tube 9 at a bias value substantially midway between zero bias and cut-off for the particular vacuum tube used. As a result of this selection of resistance and of the energizing voltage, direct current voltage changes which are impressed on the grid of tube 8 within the range of voltages offered by the discriminator will cause changes in the current drawn by tube 9. The current through tube 9 will remain unidirectional but will change in magnitude whether these direct current voltage changes are negative-going or positive-going. These changes in the current drawn by tube 9 will lead to corresponding changes in the current passing through resistor 10 inasmuch as this element is in series with tube 9.

Capacitor 11 is placed near enough to resistor 10 so that these two elements, for reasons explained hereinafter, will tend to have the same temperature.

Dielectric spacer 12 is located between the opposed plates of capacitor 11. It is composed of a material whose dielectric constant varies in response to temperature changes. This property of spacer 12 causes the capacity of capacitor 11 to be sensitive to temperature changes. Since this trait is to serve a useful purpose, herein, spacer 12, in particular, must be physically related to resistor 10 so that it will tend to follow its variations in temperature. Some dielectric materials are available whose dielectric constants increase with rises in temperature whereas others are available whose dielectric constants decrease therewith. They are referred to respectively as having positive or negative temperature coefficients of dielectric constant. It is obvious that a capacitor, of the kind described herein, which uses a spacer having a positive temperature coefficient will have its capacity increased by increases in its temperature. Such a capacitor is described as having a positive temperature coefficient of capacity. Capacitors which are heat sensitive in the manner described herein and whose heat sensitive spacers are of a ceramic material are readily procurable and are used in precision instruments to compensate for ambient temperature change effects.

The plates of capacitor 11 are connected into the tank circuit of local oscillator, block 13, of a superheterodyne receiver, block 14. In practice, discriminator 5 as well as the entire control circuit shown in detail herein may be physically included in a complete receiver so that this automatic frequency control is an integral part of it. The function of the discriminator and its relationship to the RF portion of the receiver are conventional, and it is deemed unnecessary to describe it in detail herein. The term "tank circuit" as used herein and, in particular, in the claims, is intended to refer to the tunable resonant circuit of local oscillator 13 which, as will become apparent from the explanation which follows, is variably tuned by changes in the capacitance of capacitor 11.

Referring now more particularly to Fig. 2, convenient shapes for the plates of capacitor 11 and a convenient arrangement of these plates with respect to each other, to spacer 12, and to resistor 10 are shown. Capacitor 11, as indicated therein, has concentric, substantially cylindrical plates with resistor 10 fitting within the inner plate and spacer 12 fitting concentrically between the inner and the outer plate. This entire assembly may be placed within a hollow conductive shield 15. The use of shield 15 is advisable since capacitor 11 is to be used as an oscillator tank circuit element. In this use its outer plate will carry high RF voltages. Shield 15 will tend to avoid RF feedback to preceding and adjacent circuits. Shielding this same plate from resistor 10, which is accomplished by the construction of the inner plate of capacitor 11 shown in the drawing, also has a beneficial effect in that it tends to preserve the Q of the oscillator tank circuit.

Prior to placing this apparatus into operation, the local oscillator should be tuned and the receiver should be aligned while the direct current voltage on the grid of vacuum tube 9 is at zero value. This condition can be achieved by

grounding the grid. By following this procedure, undesirable complications which might arise if the discriminator is misaligned can be avoided.

Preferably capacitor 11 should supply all of the capacitance needed in the tank circuit of the local oscillator. When, because of this, there is no other capacitor in the tank circuit and when capacitor 11 itself is not adjustable, the local oscillator may be tuned by varying the value of the inductance which is used in the tank circuit. This inductance may be varied by any conventional means such as by varying the permeability of its core.

Thereafter, in operation, when the receiver which employs this automatic frequency control becomes detuned, a positive or negative direct current voltage, due to the action of the discriminator, will appear on the grid of tube 9. As indicated above, direct current changes within a predetermined range above or below zero will cause changes in the current flow through vacuum tube 9 and resistor 10. Resistor 10, in addition to being selected to effect a proper bias of vacuum tube 9, is selected to have such characteristics that its temperature is appreciably altered by such changes in the current through it. Moreover dielectric spacer 12 of capacitor 11, due to the proximity of capacitor 11 to resistor 10 and also due, in particular, to the design indicated herein, has these temperature changes quickly communicated to it.

In this application the close physical association between resistor 10 and capacitor 11 which results in ready communication of heat changes from resistor 10 to spacer 12 will be referred to as "thermal contact."

In fact, it is obvious that, through experimentation with the use of dielectric materials and of various designs, capacitors based on the broad operating principle of capacitor 11 might be devised which would have a wide variety of responses to changes in temperatures. While it is preferable for this control circuit that the capacitor be appreciably affected by changes in temperature, that is, that its coefficient of capacity be large, it is not essential that these changes necessarily be either in the direction of increases or of decreases with particular respect either to increases or decreases in temperature. For, if, in a particular control circuit, it is found that changes in the value of capacity go in the opposite direction to that which is necessary to retune the local oscillator, the connections between the discriminator circuit and terminals 6 and 7 need only be reversed to correct this condition.

Obviously, in the actual construction of frequency control circuits in accordance with this invention, the component elements should be selected to have values which will tend to cause the circuit to have maximum usefulness. For example, in a preferred embodiment, the capacitance of capacitor 11 comprises a large percentage of all the capacitance of the tank circuit, the resonant frequency of which it is to control, and its temperature coefficient of capacitance has a high value. For, when these conditions obtain, the device has broad usefulness in that it has a wide frequency range of control.

In said preferred embodiment, moreover, the portion of the circuit which includes resistor 10 and capacitor 11 is designed to operate at a steady state temperature which is relatively high with respect to anticipated ambient temperatures. When this condition obtains, this device is least

5

affected by changes in ambient temperature. Obviously, however, the steady state operating temperature should be no higher than is consistent with good engineering practice, and allowance should be provided, in addition, for the greatest temperature rises which might be expected under extreme control conditions.

In said preferred embodiment, resistor 10 is arranged with respect to the inner plate of capacitor 11 and to spacer 12 for ready heat transfer to them; provision is made for ready dissipation of heat from spacer 12 and the outer plate of capacitor 11 to the surrounding air; and all of these parts are selected to have small capacity for the retention of heat; that is, to have small thermal capacity. When these conditions obtain, this automatic frequency control circuit has a relatively fast corrective action and a minimum of thermal inertia.

Referring now more particularly to Fig. 3, block 16 represents a component having an electrical output which varies in a predetermined manner with changes in ambient temperature. The output of block 16 is connected directly across resistor 10 and causes a certain normal or steady state electrical current at a certain predetermined "normal" or average ambient temperature, which current may either increase or decrease when the ambient temperature either drops or rises.

The plates of capacitor 11 are connected to terminals 17 and 18 whereby capacitor 11 may be connected to any desired external circuit.

Thus for each change in the capacity of capacitor 11 caused directly by a change in ambient temperature (heating or cooling of the unit by the surrounding air instead of by resistor 10) this circuit may provide a boost aiding the direct change. On the other hand due to the large transformation in the magnitudes of ambient temperature changes, as measured near to resistor 10, which are caused by this device, the direct effects on the value of capacitor 11 may be of a negligible order of magnitude. If they are negligible, it may be entirely feasible to devise block 16 so that it supplies a current which decreases with ambient temperature rises. Although the temperature of resistor 10 will then tend to be effected in opposite directions directly by the surrounding air and indirectly by the circuit action, and though the two tendencies will be opposing rather than aiding, yet one of them will be negligible. The direction of change in the capacity of capacitor 11 does not depend on whether block 16 provides an increasing or decreasing electrical flow for a given ambient temperature change. For, as explained above, spacer 12 may be selected to have either a positive or a negative temperature coefficient of dielectric constant. This increases the number of equivalent alternate arrangements and the number of different useful element combinations.

Obviously the over-all effective response of the value of capacitor 11 to temperature changes may be closely controlled over a wide range in various ways and its effective ambient temperature coefficient of capacitance may be precisely set at any desired value over a wide range. Available control parameters which suggest themselves are the value of the resistance of resistor 10, the rate of change of current flow for changes in ambient temperature, and the magnitude of the nominal or steady state current.

It is obvious that the embodiment of this invention shown in Fig. 3 may be used to increase the effectiveness of a compensating capacitor in

6

temperature compensated circuits where the maximum obtainable coefficient is not great enough, in itself, to make changes in ambient temperature result in complete compensation.

In practice resistor 10 and capacitor 11, 12 will constitute a unitary structure comprising a single element. In this element heat changes occurring in the resistor portion will produce heat changes in the condenser portion and for the purpose of the claims this relationship is defined as thermal contact between the two portions.

What I claim is:

1. In an electrical circuit, an element comprising a resistor and a capacitor in thermal contact with each other, said capacitor having at least two opposing plates and dielectric spacing means, said spacing means being composed at least in part of material having a dielectric constant the value of which is affected by temperature changes, means for supplying electrical energy to said resistor including means for varying the amount of said electrical energy whenever the capacity of said capacitor ceases to be substantially that of a predetermined value, and an external circuit connected to plates of said capacitor.

2. In an electrical circuit, an element comprising a resistor and a capacitor in thermal contact with each other, said capacitor having at least two opposing plates and dielectric spacing means, said spacing means being composed at least in part of material having a dielectric constant the value of which is affected by temperature changes, means for supplying electrical energy to said resistor and for varying the amount of said electrical energy in response to ambient temperature changes within a predetermined temperature range, and an external circuit connected to plates of said capacitor.

3. In an electrical circuit, an element comprising a resistor and a capacitor in thermal contact with each other, said capacitor having at least two opposing plates and dielectric spacing means, said spacing means being composed at least in part of material having a dielectric constant, the value of which is affected by temperature changes, a circuit tuned to a predetermined frequency, means for supplying to the tuned circuit voltages including a component at said predetermined frequency means for supplying electrical energy to said resistor, including means for varying the amount of said energy when any change occurs in the relationship of the frequency of said component to the tuning of said circuit, and an external circuit connected to plates of said capacitor.

4. In an electrical circuit, an electrical device having at least an anode, a cathode and a control grid, an input circuit for feeding a varying voltage to said control grid, means for energizing said electrical device, an element comprising a resistor and a capacitor in thermal contact with each other, said resistor being in series with said anode and said cathode, said capacitor having at least two plates and dielectric spacing means, said spacing means being composed of material whose dielectric constant is affected by temperature changes, and an external circuit connected to plates of said capacitor.

5. In an electrical circuit, an electrical device having at least an anode, a cathode and a control grid, an input circuit for feeding varying voltage to said control grid, means for energizing said electrical device, an element comprising a resistor and a capacitor in thermal contact with each other, said resistor connected between said cathode and ground, said capacitor having at least two

7

plates and dielectric spacing means, said spacing means composed of material having a temperature coefficient of dielectric constant of relatively large value, and an external circuit connected to plates of said capacitor.

6. In a radio receiver, a local oscillator, a frequency discriminator, an electrical device having at least an anode, a cathode, and a control grid, an input circuit for feeding varying voltage from said discriminator to said control grid, means for energizing said electrical device, an element comprising a resistor and a capacitor, said resistor being in series with the anode and cathode, said capacitor having at least two plates and dielectric spacing means composed at least in part of material the value of whose dielectric constant is affected by heat, said local oscillator having a tank circuit with which said capacitor is connected.

7. In a radio receiver as in claim 6, said resistor being connected to said cathode and to ground.

8. In a radio receiver, a local oscillator, a frequency discriminator, an electrical device having at least an anode, a cathode and a control grid, an RF filter circuit having its input terminals connected to the output of said discriminator and its output terminals between said control grid and said cathode, means for energizing said electrical device, an element comprising a resistor and a

8

capacitor in thermal contact with each other, said resistor being in series with the anode and the cathode, said capacitor having at least two plates and dielectric spacing means being composed at least in part of material the value of whose dielectric constant is affected by heat, said local oscillator including a tank circuit with which said capacitor is connected.

9. In a radio receiver, according to claim 8, and in which said resistor is connected to said cathode and to ground.

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