

March 29, 1966

G. A. VOGT ETAL

3,243,572

PROPORTIONALLY CONTROLLED CRYSTAL OVEN

Filed Feb. 10, 1964

2 Sheets-Sheet 1

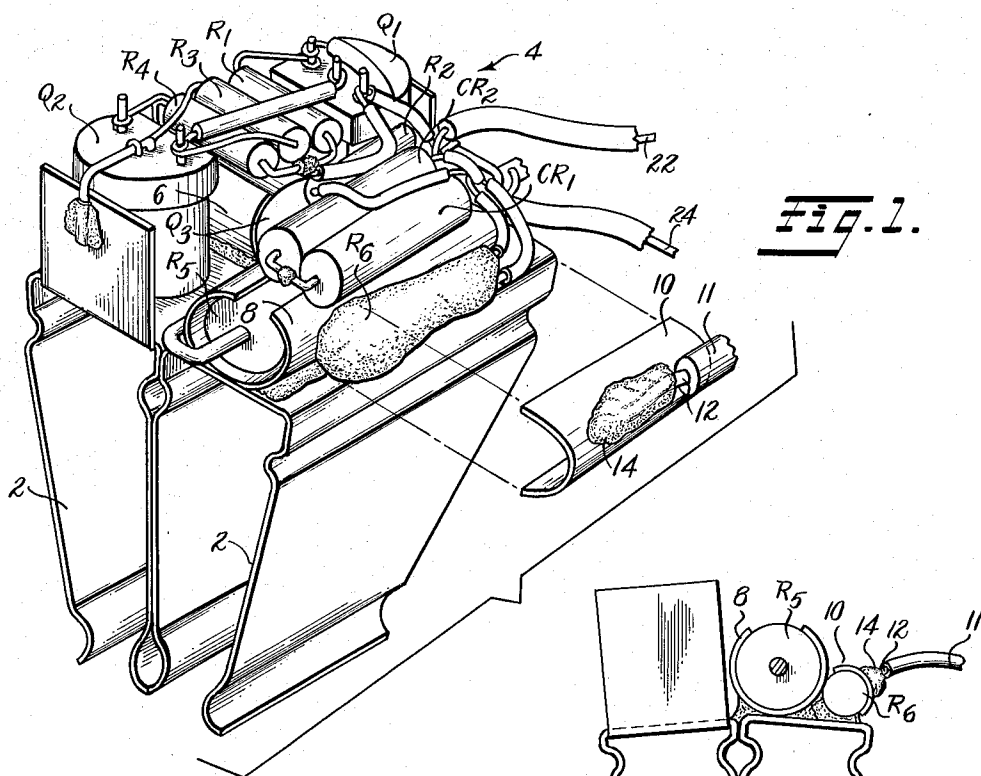


Fig. 1.

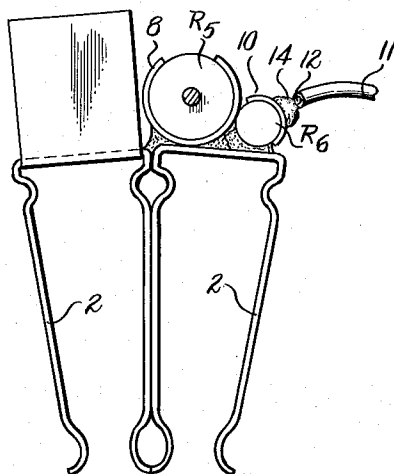


Fig. 2.

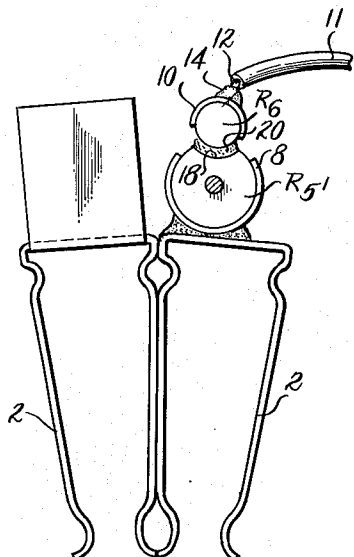


Fig. 3.

INVENTORS

Gunther A. Vogt

JOHN C. ALDERMAN, JR.

BY

Bacon & Thomas

ATTORNEYS

March 29, 1966

G. A. VOGT ET AL

3,243,572

PROPORTIONALLY CONTROLLED CRYSTAL OVEN

Filed Feb. 10, 1964

2 Sheets-Sheet 2

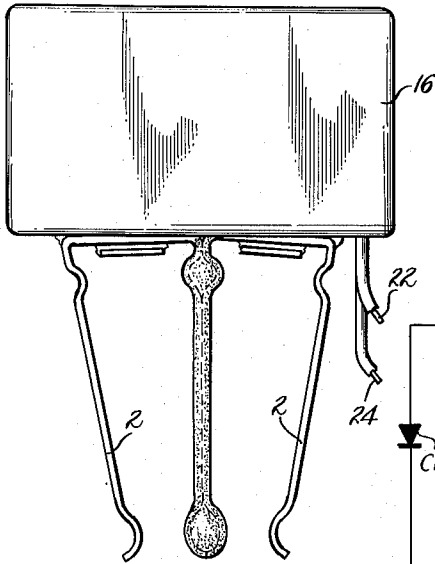


Fig. 4.

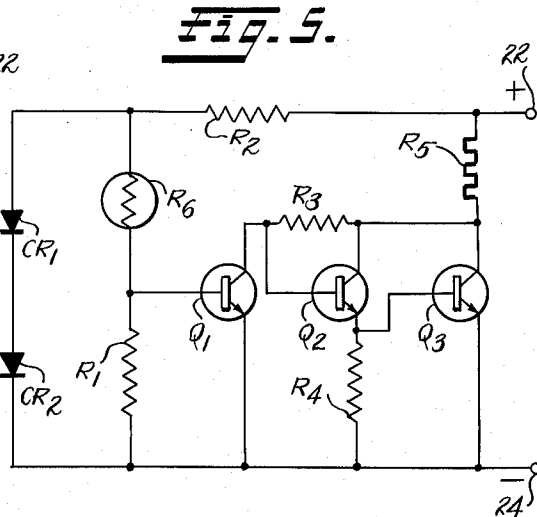


Fig. 5.

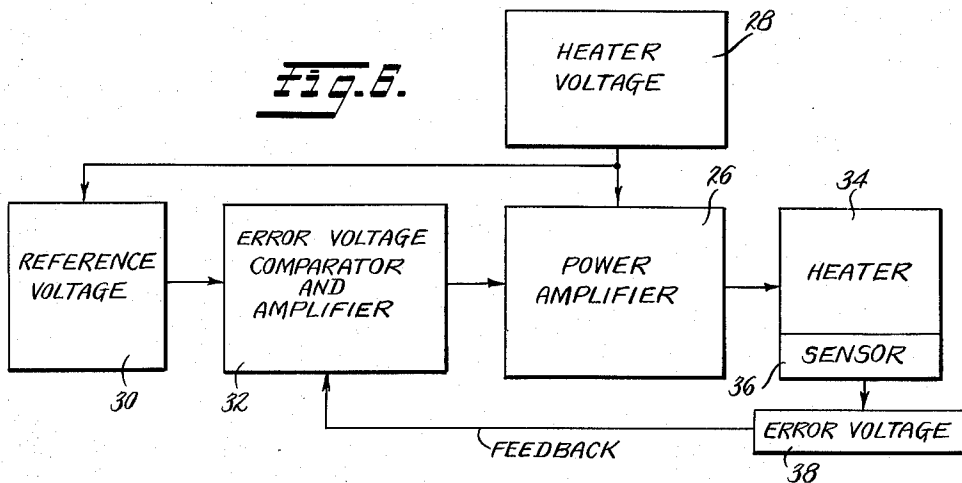


Fig. 6.

INVENTORS

Günther A. Vogt
JOHN C. ALDERMAN, JR.

BY

Bacon & Thomas

ATTORNEYS

1

2

3,243,572

PROPORTIONALLY CONTROLLED CRYSTAL OVEN

Gunther A. Vogt, 1628 Brandywine Drive, and John C. Alderman, 612 Preston Place, both of Charlottesville, Va.

Filed Feb. 10, 1964, Ser. No. 343,870
4 Claims. (Cl. 219-210)

This invention relates to crystal ovens for holding frequency control crystals, or the like, at a substantially uniform operating temperature irrespective of changes in ambient temperature.

The oven of the present invention comprises generally one or more spring clips adapted to embrace the usual housing of a frequency control crystal or group of crystals, in good thermal contact therewith so as to assume the same temperature as the crystal housing, with a minimum loss of time and to transfer heat thereto efficiently and rapidly. A complete control circuit is mounted on and carried by the clip assembly and consists of a heater element, a temperature sensing device in heat conductive relation to both the heater and ambient conditions and a control circuit. The temperature sensing device is preferably a thermistor. As is known, a thermistor is a device, the resistance of which decreases as temperature increases. The thermistor senses temperature changes brought about by the heater and/or ambient conditions and by virtue of its resistance characteristics controls an amplifier supplying current to the heater.

It is, therefore, an object of this invention to provide a crystal oven device having means for sensing both the temperature of the crystal and ambient temperature and including control circuits, all of which are mounted in compact relation and in heat conductive relation to a crystal to be controlled.

Another object is to provide a crystal oven of the type set forth wherein a thermistor is at least partially imbedded in a heating resistor so as to be rapidly responsive to changes in temperature of the resistor.

Still another object of the invention is to provide a crystal oven of the type set forth wherein heat dissipated by the power output component of an amplifier is also conducted to the crystal to be heated thereby.

Other and additional objects and advantages will become apparent to those skilled in the art as the description proceeds with reference to the accompanying drawings wherein:

FIG. 1 is a perspective view, on an enlarged scale, of a crystal oven device embodying the present invention;

FIGS. 2 and 3 are end views, as seen from the left of FIG. 1, but with parts being omitted for clarity of illustration, and illustrating alternative physical arrangements of certain components;

FIG. 4 is a view similar to FIGS. 2 and 3 but showing a completed crystal oven device;

FIG. 5 is a schematic circuit diagram of the control circuit; and

FIG. 6 is a block diagram of the units comprising the control circuit.

Referring first to FIG. 1, numerals 2 indicate spring clip devices adapted to be placed in snug embracing relation to the usual housing in which frequency control crystals are mounted. The clips are of suitable metal having good heat conductivity and are preferably soldered together in good mutual heat conductive relation. It is to be understood, however, that a single clip could be used within the scope of the invention. Heat sensing and control components comprising a control circuit designated generally at 4 are mounted on the clip assembly. The components include a heater resistor R5, a thermis-

tor R6 in heat conducting contact with the resistor R5, and a power output transistor Q3 firmly mounted in a clip 6 soldered or otherwise mounted on the clip assembly 2 so as to be in good heat transferring relation therewith. The heater resistor R5 is mounted in the clip 8 as shown. The thermistor R6 is adhesively secured to the clip 2 and in contact with the clip 8 so as to be responsive to heat transmitted through clip 2.

An ambient temperature sensing means may be clipped or adhered to the thermistor R6 and comprises a heat conductive member 10 adapted to embrace an outer portion of thermistor R6 and including a heat conductor 12 soldered, at 14, to the shield 10 so as to be in intimate heat conducting relation to the thermistor. The portion 12 may be a simple copper wire, with or without insulation 11, extending to any desired location where it is exposed to and responsive to ambient temperature conditions. The region into which the end of conductor 12 extends may be referred to as a remote location even though it may be physically quite close to the oven described herein and in fact may be within the body of a "potting" material 16 (FIG. 4), which may be employed to enclose the entire control circuit of FIG. 1 in the finished product.

FIG. 3 illustrates a modified assembly arrangement wherein the heater resistor R5' is provided with a longitudinal groove or channel 18 substantially complementary to the outer surface of a portion of the thermistor R6. The latter is nested within the groove 18 and adhesively secured therein by means of any suitable heat conductive adhesive material 20. In this form the thermistor is more sensitive to temperature changes in the resistor and responds thereto more rapidly than in the assembly arrangement shown in FIG. 2.

FIG. 1 also illustrates a pair of conductors 22 and 24 for conducting D.C. power to the crystal oven, as will be described. The conductors 22 and 24 may be referred to as "terminals" of the circuit which will be described.

FIG. 5 is a schematic diagram of the circuit and shows the electrical relationships of the components shown in FIG. 1. FIG. 6 is a block diagram showing the principal component parts of the circuit, identified at least in part by their functions rather than actual physical position or relationship. Referring first to FIG. 6 the circuitry includes a power amplifier 26, comprising transistors Q2 and Q3 and resistors R3 and R4. A supply voltage 28 supplies direct current of suitable voltage to the terminals 22 and 24. That voltage is supplied to the power amplifier and to a reference voltage network comprising diode rectifiers CR1 and CR2 along with resistor R2. As can be seen from FIG. 5, voltage applied to the terminals 22 and 24 causes current to flow through resistor R2 and the rectifiers and develops a reference voltage drop across the rectifiers. The reference voltage network is identified in FIG. 6 by numeral 30 and the reference voltage developed thereby is applied to components constituting an error voltage comparator and amplifier 32. This unit comprises thermistor R6 and resistor R1 along with transistor Q1, the output of which is applied to the power amplifier 26. The output of the power amplifier is conducted through heater 34 which comprises the heating resistor R5 and actually includes the "heat sink" (conventional) associated with transistor Q3. FIG. 6 includes a block 36 identified as "sensor." Actually, this represents the physical position and function of thermistor R6 in sensing the temperature of the heater. As a result of temperature changes in R6 an error voltage is developed (numeral 38) and is, in effect, fed back to the error voltage comparator, as will be described.

Referring now to FIG. 5, a D.C. voltage is applied to the terminals 22 and 24 and current flows through resistor

R2 and the diode pair CR1 and CR2. The voltage drop across the diode pair becomes a reference voltage E_{ref} . The ratio of the impedance of the diode pair to resistor R2 is very small, on the order of 5×10^{-3} , to minimize changes in reference voltage upon variations of the input voltage applied to terminals 22 and 24. The reference voltage developed across the diodes is applied across the voltage divider R6-R1. At a predetermined operating temperature the ratio of R6 to R1 is such that the voltage across R1 maintains transistor Q1 at a quiescent operating point. However, as the temperature changes; for example, increases, the resistance of thermistor R6 decreases as does the voltage drop across it and, therefore, a larger proportion of the reference voltage is dropped across R1 and, therefore, the input to transistor Q1 changes in a direction to bias Q1 further into conduction and thus increase its collector current by a factor equal to the gain of the transistor. The increased collector current from Q1 flowing through R3 decreases the current available to the base of Q2, which lowers the flow of current from the emitter of Q2. The voltage at the base of Q3 is approximately constant so a reduction in current through the emitter of Q2 will also reduce the current in the base of Q3 (since the current in R4 is constant). The collector current of Q3 is therefore reduced and the heat output of R5 is reduced. Since the input voltage at terminal 22 and 24 multiplied by the current drawn by the device is the heating power, it can be seen that the heating power of the circuit has been reduced, thus permitting heat losses to the ambient surroundings, which results in a cooling of R6 and a restoring of equilibrium to the voltage divider circuit R1-R6, and the system is returned to its initial operating condition. As previously pointed out, Q3 is in intimate heat conductive contact with the clip assembly and so its heat loss is also utilized to heat the clip. In the event of a decrease in operating temperature, the reverse of the above holds true.

The foregoing description sets forth the manner in which this circuit compensates for the tendency of the temperature of a crystal to vary due to changes in ambient temperature but since the power of the heater, the biasing of the transistors and the reference voltage are all dependent on the stability of the input voltage, one would expect variations of input voltage to result in temperature variations. However, one of the unique features of this circuit is its compensation for input voltage variations. The value of the reference voltage developed across CR1 and CR2 was initially assumed to be substantially invariant. However, it does vary by an amount equal to the change in input voltage multiplied by the ratio of the reference voltage to the voltage drop across R2 and is actually quite small. The new reference voltage, after a change in input voltage, is applied to voltage divider R1-R6 and thus to the input of Q1 and the bias on Q1 is changed by an amount proportional to the change in reference voltage while the output of Q1 changes by a factor including the gain of that stage. Thus, the output of the amplifier is again changed by an amount equal to the output of Q1 multiplied by the amplification factor in the power stages. By referring again to the circuit functions described heretofore, it will be seen that the changes in input voltage result in power changes at the heater which are equal in numerical value but of opposite polarity to the change in power due to the change in input voltage.

From the above it can be seen that, considering both thermal and voltage compensation, there is a compromise value for the ratio of the impedance of the diode pair to R2, since the former requires an absolute minimum and the latter some value which will result in an amplified voltage for the correct numerical value at the heater.

To provide the optimum in compensation for both

voltage and thermal changes the circuit configuration is designed to provide optimum voltage compensation while the physical arrangement of the components is designed to provide optimum thermal compensation. The latter is accomplished by use of the ambient sensor, already described as comprising elements 10, 12 and 14. This permits the thermistor to sense ambient changes with a minimum time lag so that the circuit can respond with the necessary corrections in minimal time. The degree of ambient compensation may be controlled by proper selection of the sensor assembly 10-14 and by arranging the conductor 12 in a suitable manner.

In actual embodiments of the device described, the body of material 16, shown in FIG. 4, was approximately $\frac{3}{8}$ " square and $\frac{3}{8}$ " high and consumed only about $\frac{1}{4}$ watt power.

While a limited number of embodiments of the invention have been shown and described herein, it is to be understood that the same are merely illustrative of the principles involved and that other forms may be resorted to within the scope of the appended claims.

We claim:

1. In a crystal oven device; a spring clip structure adapted to removably embrace a crystal housing in heat conductive relation thereto; temperature control means carried by said structure and including a heating resistor in heat conductive relation to said clip structure; said control means including circuit means for controlling the flow of current through said resistor and including a thermistor arranged with a portion thereof in heat conductive relation to said resistor, another portion of said thermistor being exposed to ambient temperature.

2. A crystal oven as defined in claim 1 wherein said resistor is provided with a recess therein; said portion of said thermistor being nested in said recess.

3. A crystal oven as defined in claim 1 including a heat conducting member engaging said other portion of said thermistor and having a heat conductive element extending outwardly therefrom to a predetermined region remote from said thermistor, to render said thermistor responsive to the ambient temperature in said remote region.

4. In a crystal oven device; heat conducting spring clip support means adapted to removably and frictionally engage a crystal housing in heat conductive relation; voltage input means and means on said support connected thereto for developing a reference voltage; a power amplifier on said support and connected to said voltage input means; a heater controlled by said amplifier and mounted on said support means in heat conducting relation thereto; a voltage comparator on said support and including means for developing a second voltage proportional to the temperature of said heater; means applying said reference voltage to said comparator for comparison with said second voltage; and means responsive to the difference between said second voltage and said reference voltage for controlling the operation of said power amplifier.

References Cited by the Examiner

UNITED STATES PATENTS

1,423,742	7/1922	Silverman	219-535
2,386,903	10/1945	Lutomirski	219-209
2,484,585	10/1949	Quinn	338-25
2,797,296	6/1957	Fowler et al.	219-536
2,840,679	6/1958	Hart	219-450
2,955,185	10/1960	Cox	219-209
3,079,484	2/1963	Shockley et al.	219-501
3,158,821	11/1964	Sulzer	219-210

RICHARD M. WOOD, *Primary Examiner*.

C. L. ALBRITTON, *Assistant Examiner*.