United States Patent

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[54] **ON-OFF HEATER CONTROL**
2 Claims, 5 Drawing Figs.

[52] U.S. Cl. 219/497, 219/499, 219/501
[51] Int. Cl. H05b 1/02
[50] Field of Search 219/499, 501, 497

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ABSTRACT: An On-Off heater control consisting of a switching-type, proportional, temperature regulating control circuit comprising a temperature sensing bridge and differential amplifier which has an output voltage which is a function of input temperature, a triangular voltage function generator, and a comparator and saturating DC amplifier for driving the heating elements.

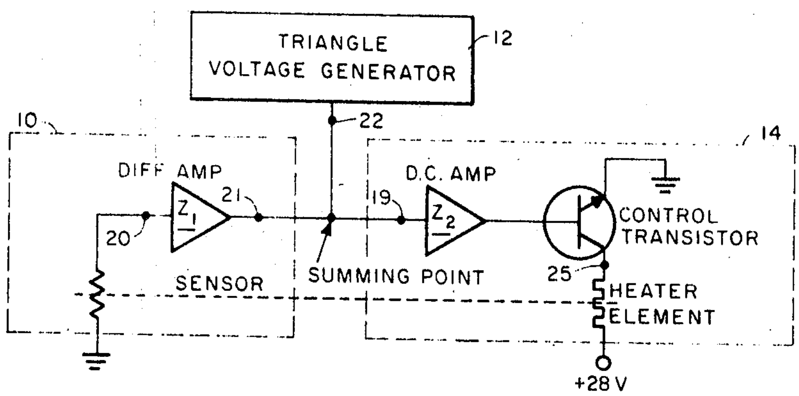


FIG. 1

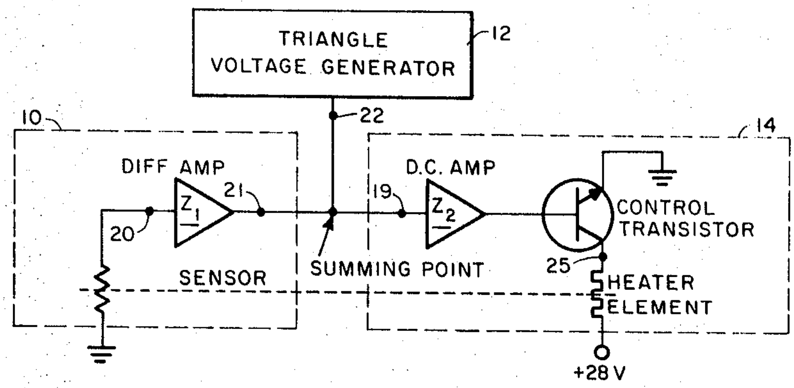


FIG. 2

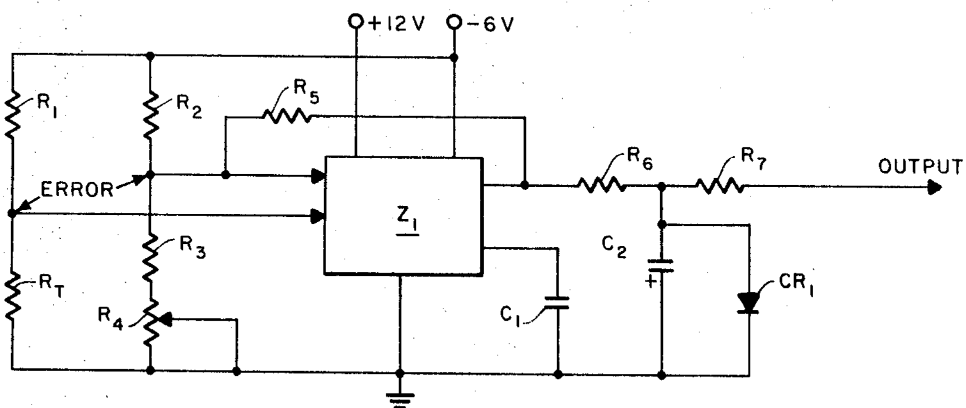
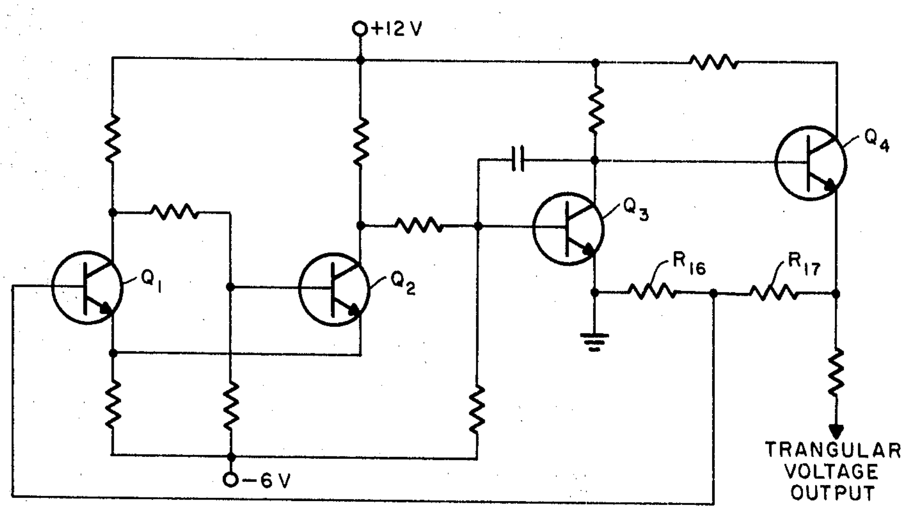


FIG. 3



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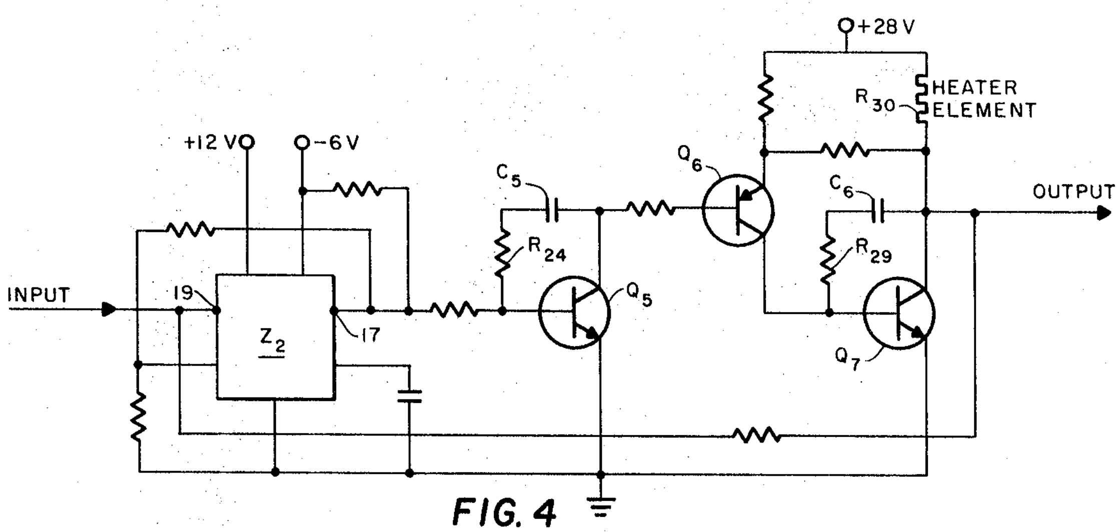

FIG. 4

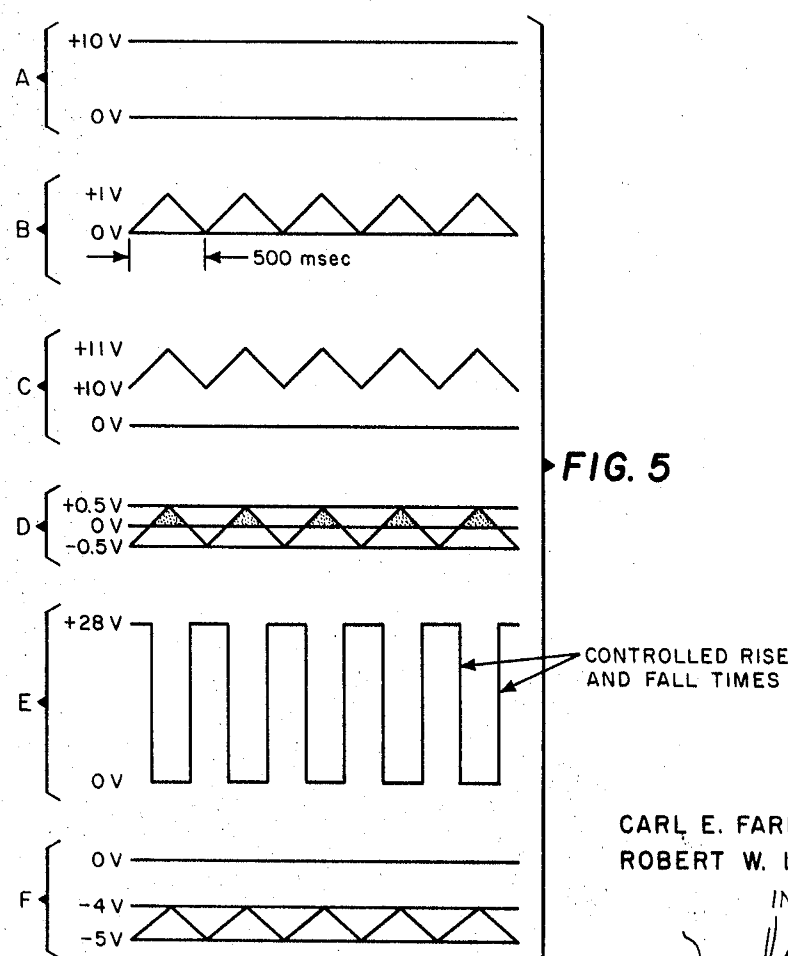

FIG. 5

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ON-OFF HEATER CONTROL

The invention herein described may be manufactured and used by or for the Government of the United States of America for governmental purposes without the payment of any royalties thereon or therefor.

There has been a need for a temperature regulator of the proportional-type, but without the disadvantage of high heat dissipation and thus reduced efficiency. Where sensitive circuits are nearby, the usual switching-type of regulator, while having low heat dissipation, is unsatisfactory because rapid switching causes Radio Frequency Interference (RFI).

The unique characteristics of the present invention are high efficiency, with very little power being dissipated in the control element, combined with a switching arrangement which prevents the generation of Radio Frequency Interference, allowing its use near sensitive receiver circuitry.

Other objects and many of the attendant advantages of this invention will become readily appreciated as the same becomes better understood by reference to the following detailed description when considered in connection with the accompanying drawings wherein:

FIG. 1 is a block diagram of the heater control circuit,

FIG. 2 shows the differential amplifier circuit portion of FIG. 1,

FIG. 3 is a circuit diagram of the triangle circuit of FIG. 1,

FIG. 4 shows a circuit diagram for the comparator and DC amplifier circuit of FIG. 1,

FIG. 5 illustrates the voltage at various points in the control circuit.

The present invention is comprised of three circuit units as shown in the block diagram of FIG. 1, to perform the necessary control functions: A temperature sensing bridge and differential amplifier circuit 10; a triangular voltage function generator 12; and a comparator and saturating DC amplifier circuit 14 to drive the heating element.

Resistance elements R_1 and R_T make up the signal portion of the bridge network shown in FIG. 2, with R_T being a thermistor having a positive temperature coefficient. Resistors R_2, R_3 and R_4 make up the comparator portion of the bridge network. The error signal at points 16 and 17 is connected to an integrated circuit Z_1 differential amplifier whose output is a function of this error signal. R_5 is the feedback resistor for the differential amplifier Z_1. Capacitor C_1 is for frequency compensation of the differential amplifier. Resistors R_6 and R_7 make up the load for differential amplifier Z_1 with capacitor C_2 used for filtering. Diode CR_1 protects polarized capacitor C_2 from reverse voltage.

The relative values of resistors R_1, R_1, R_3, R_4 and R_5 and thermistor R_T determine the circuit sensitivity in detecting temperature changes and are selected to provide the required gain for the control loop.

The triangle voltage generator circuit 12 is shown in FIG. 3 and is made up of a Schmitt Trigger consisting of transistors Q_1 and Q_2, an integrator transistor Q_3, and an emitter follower transistor Q_4. The control for the Schmitt Trigger is provided by the voltage developed at resistors R_{16} and R_{17}. The output of the Schmitt Trigger is a square wave voltage. This square wave is integrated and a resulting triangular voltage as shown in FIG. 5B is the output of this circuit.

The comparator and DC amplifier circuit 14 is shown in FIG. 4 and is made up of 2 gain stages, amplifier Z_2 and control transistor Q_5, and emitter followers, transistors Q_6 and Q_7. When amplifier Z_2 is driven positive the output at point 17 furnishes enough base current for transistor Q_5 to saturate. Collector current in transistor Q_5 is the base current for transistor Q_6 which also saturates. The collector current of transistor Q_6 is the base current for transistor Q_7 which also saturates. Therefore the positive input voltage at point 19 saturates transistors Q_5, Q_6 and Q_7. A negative input voltage at 19 will present a back bias for the base-emitter junction of transistor Q_5. This prevents a base current from flowing in transistor Q_5 which prevents a base current from flowing in transistor Q_7. Therefore a negative input voltage at 19 cuts off transistors Q_5, Q_6 and Q_7.

Amplifier Z_2 is used as a high gain voltage comparator. The input at point 19 (noninverting connection) is the sum of the bridge DC amplifier output and the triangular voltage wave output, FIG. 3. Whenever the combined input voltage at point 19 is positive, the voltage at point 17 drives toward +12 volts. Conversely, when the combined input at point 19 is negative, point 17 drives toward −6 volts. Due to the additional gain of transistors Q_5 and Q_6, transistor Q_7 is correspondingly either full on or full off. Feedback networks formed by resistor R_{29} and capacitor C_6 and resistor R_{24} and capacitor C_5 slow the switching transition down sufficiently to avoid the generation of Radio Frequency Interference due to fast current transients, and insure loop frequency stability.

Referring to the block diagram of FIG. 1, when the thermistor sensor R_T is colder than the reference resistor R_1, the error voltage at point 20 is positive and point 21 is at +10 volts for example, such as shown in FIG. 5A. The voltage at point 22, the output of triangle circuit 12, is a constant repetitious triangular voltage of +1 volt. The summation of the voltage at points 21 and 22 is as shown in FIG. 5C, for example.

This voltage at point 19, the input of the DC amplifier Z_2, keeps it on and the control transistor is saturated. The current in the heater element resistance R_{30}, produces heat which in turn is sensed by the sensor thermistor bridge network of FIG. 2.

As the sensor is heated the error signal is reduced until the error is 0 volts at point 20 (i.e. the bridge network is balanced). The voltage at point 21, the output of the differential amplifier, is now −0.5 v., for example. The summation of voltages at points 21 and 22 will then be +0.5 v. as shown in FIG. 5D, and as shown in FIG. 5E at point 25.

The shaded area in FIG. 5D is where the heater R_{30} is turned on and the white area is where it is turned off.

When the thermistor sensor R_T is hotter than the reference resistor R_1, the error at point 21 is negative and point 21 is a −5 v. The summation of voltages at points 21 and 22 is as shown in FIG. 5F.

This negative voltage at point 19, the input of the DC amplifier, keeps the control transistor off and zero current flows in the heater element resistance R_{30}. The actual temperature change required to drive the heater duty cycle from full on to full off depends on the bridge DC amplifier gain which can be made quite high, resulting in very tight temperature control.

The temperature regulator is a proportional controller because the power (not the voltage) supplied to the heater element is proportional to the temperature deviation. The proportional power occurs because the heater voltage is pulsewidth modulated. The time off to the time on is continuously variable causing proportional power control vs. temperature input up to the full output capability of the heating element.

The power dissipation in the control transistor is small because it is operated in a switching mode. Radio Frequency Interference (RFI) is avoided by two precautions: First, the power switching transition is constrained to occur in 1 millisecond rather than the fractional microsecond range normally used. The transition is still fast enough to maintain high efficiency through low total power dissipation. Second, the pulse repetition frequency is held to a very low value such that significant harmonics fall in the sub audio range. The repetition frequency is made high enough that thermal flicker and control loop instabilities are avoided, however. A Fourier analysis of this trapezoidal waveform shows that the spectral energy distribution is all concentrated at very low frequencies, giving the desired result.

What we claim is:

1. A proportional temperature regulating control circuit which prevents the generation of radio frequency interference, comprising:

a. a temperature sensing circuit means having an output voltage which is a function of input temperature, said temperature sensing circuit means comprising:

1. a resistance bridge network, one leg of which is a thermistor which is exposed to temperature changes from said heating element, the output of said bridge network being an error signal,
2. the output of said bridge network being connected to an integrated circuit differential amplifier whose output which is a function of the error signal input is a function of the temperature sensed by said thermistor,

b. a triangle voltage function generator for producing a repetitious pulse waveform voltage at its output, said voltage function generator producing a triangular waveform voltage,

c. a heating element,

d. a comparator and switching means having its input connected to the summed outputs of said temperature sensing circuit means and said voltage function generator, said comparator and switching means comprising high gain voltage amplifier whose output is fed to control transistor means, and feedback network means for slowing down switching transition to avoid generation of radio frequency interference due to fast current transients and insure loop frequency stability, the output of said comparator and switching means connected to said heating element for driving the heating element, and heat generated in said heating element producing input temperature which is sensed by said temperature sensing circuit means,

e. said summed outputs of the temperature sensing circuit means and the voltage function generator having a pulse repetition frequency in which significant harmonics fall in the subaudio range and also avoid thermal flicker sufficient to maintain low power dissipation,

f. a positive voltage at the summed outputs of said temperature sensing circuit means and said voltage function generator being fed to said high gain voltage amplifier means driving the amplifier positive and saturating said control transistor means to allow current to flow in said heater element, a negative voltage at said summed outputs switching said control transistor means to off condition preventing current from flowing in said heater element, the heater voltage being pulsewidth modulated resulting in the power supplied to said heater element being proportional to the temperature deviation sensed by said temperature sensing circuit means.

2. A device as in claim **1** wherein said voltage function generator comprises a square wave voltage generator whose output is integrated to provide a triangular wave voltage.