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(54) **Title:** METHOD AND APPARATUS FOR ISOLATED THERMAL FAULT FINDING IN ELECTRONIC COMPONENTS

(57) **Abstract:** An apparatus for isolated thermal fault finding in an electronic component comprises; an infra-red (IR) radiation source; means for focussing the IR radiation source into an area on the upper exposed surface of the component under test; a thermal sensor for sensing the heat radiated from the component under test. The apparatus is useful in performing the inventive method for isolated thermal fault finding in an electronic component which comprises; i) focussing a beam of infra-red radiation onto a small area at about the centre of the electronic component; ii) monitoring the temperature of the component of step i) ; and iii) maintaining the temperature of the component of step i) at a predetermined maximum level dictated by the function and/or environmental in which the component is to be used.

METHOD AND APPARATUS FOR ISOLATED THERMAL FAULT FINDING IN ELECTRONIC COMPONENTS

This invention relates to isolated thermal fault finding (ITFF)™ in electronic components and to a novel method and apparatus therefor. For the purposes of this specification, the term "isolated thermal fault finding" should be taken to mean the application of extremes of temperature to an electronic component for the purposes of identifying a weakness or fault therein.

Methods for the detection of faults in electronic components are known. One common such method is known as highly accelerated life testing or HALT in which extreme temperatures, temperature change rates, combinations of temperature and vibration, and other product specific stresses are applied to circuit boards to expose flaws and weak points in a board. In this process the board is subjected to high temperatures within a chamber. The temperature is accelerated at a rate of around 60°C /min between temperatures from as low as about -100°C up to about 200°C. The boards are tested to destruction.

Once destruction has occurred secondary testing is used to isolate the component which has failed in the circuit. This secondary process will generally involve local heating of the board, for example with a hot air gun, and testing of individual heated components for performance. Due to the very small size and close proximity of components on many circuit boards, it is difficult to heat and test components in isolation, thus an element of trial and error is involved in locating the failing component.

A method of isolated thermal stress testing has been proposed in which resistors and thermocouples are adhered to the surface of individual components and power supplied to the resistors to heat the components. This method requires considerable preparation of the circuit board and test apparatus prior to carrying out of the test. One recommended procedure involves cleaning the surface of the circuit with alcohol; applying a thermal epoxy to the surface of the circuit and positioning resistors and thermocouples into the epoxy prior to curing. The resistors are connected in parallel to a variac and a live AC voltage is applied to instigate heating of the resistors and associated circuit components.

It will be appreciated that the above method is both cumbersome to carry out and prone to some error due to the variety of media used to convey heat to the component.

In a first aspect, the present invention provides an apparatus for isolated thermal fault finding in an electronic component comprising;

an infra-red (IR) radiation source;

means for focussing the IR radiation source into an area on the upper exposed surface of the component under test;

a thermal sensor for sensing the heat radiated from the component under test.

By focussing the IR radiation source to a spot on the upper surface of a component the heating effect is considerably more localised than for a heat gun. Since the heating method does not employ direct contact, the method is less cumbersome to carry out and less intrusive of the circuit board thereby greatly simplifying testing of the components.

The IR radiation source is preferably adjustable to allow a chosen heating temperature to be maintained. Conveniently, the thermal sensor may provide feedback to a controller which adjusts the heating intensity of the IR radiation source so as to maintain a relatively constant temperature of the component over a period.

The IR radiation source is conveniently provided in the form of a halogen capsule lamp, preferably, this lamp will have an axial filament. The lamp provides a source of short wave electromagnetic radiation from which the infra-red component may be reflected and focussed. One suitable means of reflecting and focussing the infra-red is through a reflector which has a gold surface. The gold surface absorbs other wavelengths but reflects infra-red radiation. The reflector is suitably shaped to focus the infra-red. A preferred shape for the reflector is elliptical as this enables the infra-red to be focussed into a relatively small spot thus providing rapid heating in a relatively small area.

The reflector may be formed entirely of gold or may be of another material provided with a gold plating or coating. Preferably the reflector comprises aluminium coated at least on its reflective surface with gold.

The lamp and reflector assembly may be carried by a heat sink cup. Preferably the reflector is provided with a flange equipped for mechanical fixing of the heat sink cup. Preferably the reflector is fixed to the heat sink by thermally conducting mechanical fixing devices. This permits heat radiating from the rear of the reflector to be conducted and dissipated through the heat sink cup providing a cooler surface for the manoeuvring and manipulation of the lamp assembly by the user.

Conveniently, an infra-red temperature sensor may be employed as the thermal sensor. In another option, the sensor may comprise a thermocouple. The type and length of thermocouple incorporated may vary with user requirements.

The control circuitry of the apparatus may conveniently be embodied in a housing. The housing may be any desired shape, including but not limited to a rectangular or square box or a dome-shape. Cables connecting the control circuitry to the lamp assembly and the sensor may be housed in flexible tubes to the end of which the lamp assembly and sensor are fixed. These tubes may be used to vary the position of the lamp assembly and/or the sensor to allow selective heating and monitoring of any component in any position. The tubes are preferably configured not only to be manoeuvrable but to hold a position in which they are placed. A single flexible tube may be provided to provide macro positioning of the lamp assembly and sensor and branched tubes leading to each of the lamp assembly and sensor to permit micro positioning of these two component parts relative to each other and the circuit component under test.

In a second aspect, the invention provides an infra-red lamp assembly suitable for use in a novel apparatus as hereinbefore described, the infra-red lamp assembly comprising;

a halogen capsule lamp, positioned centrally of an elliptical reflector, the elliptical reflector having a gold reflective surface and a mounting flange, the mounting flange being connected via metallic mechanical fixing devices to a heat sink cup which carries the lamp and reflector assembly.

As well as finding application in the novel apparatus previously described, it is to be understood that an infra-red lamp assembly may find application in any application requiring the localised heating of an article to a relatively high temperature. Such potential applications include but are not limited to; solder melting, curing of adhesives, drying of inks and cutting applications. The skilled addressee will understand that the heating power of the lamp can be easily increased by use of a capsule lamp with a higher power rating. Equally the scale of the components can be adjusted to suit the chosen application without departing from the novel principles described.

In a third aspect the invention provides a reflector for use in an infra-red lamp assembly as hereinbefore described, the reflector comprising a gold coated, aluminium, elliptically shaped cup having an aperture positioned centrally of the ellipse for receiving a halogen capsule lamp and a mounting flange extending rearwardly therefrom, the mounting flange having one or more apertures for receiving mechanical fixing devices.

In a fourth aspect the invention comprises a method for isolated thermal fault finding in an electronic component comprising;

i) focussing a beam of infra-red radiation onto a small area at about the centre of the electronic component;

ii) monitoring the temperature of the component of step i) ; and

iii) maintaining the temperature of the component of step i) at a predetermined maximum level dictated by the function and/or environment in which the component is to be used and monitoring the performance of the component.

In a fifth aspect, the invention provides an apparatus for thermal fault finding in an electronic component comprising:

a substrate of conductive material of less than about 225 min in area having mounted in a heat conductive manner thereon, a resistor and a thermocouple, the resistor and thermocouple being electrically connectable to a controller for providing a controlled current to the resistor and reading the output of the thermocouple.

The apparatus is conveniently provided in the form of a square pad. Preferably, the thermocouple contacts the centre of the pad and the resistor is in the form of a track which arches around the thermocouple. The pad is adhered to the component to be tested and current supplied to the resistor to heat the component via the conductive substrate. The small size of the pad enables good and fast, localised heating of the component and the proximity of the thermocouple (heat sensor) to the heat source and component permits accurate monitoring of the temperatures achieved by the component during test.

Control of testing can be effected in much the same manner as for the first embodiment of the invention, the resistor being substitutable for the infra-red lamp and the thermocouple as the heat sensor. A control system similar to that described for the first aspect of the invention may be easily adapted for use with the apparatus in accordance with the fifth aspect.

For the purposes of exemplification one embodiment of the invention will now be further described with reference to the following Figures in which:

Figure 1 illustrates an infra-red lamp assembly according to the present invention focussing a spot of infra-red radiation onto a test component;

Figure 2 illustrates the reflector of the infra-red lamp assembly of Figure 1;

Figure 3 illustrates an apparatus according to the present invention embodying the lamp assembly and reflector of Figures 1 and 2;

Figure 3a illustrates a slight variation in design for the embodiment of Figure 3;

Figure 4 illustrates the control circuit of the embodiment of Figure 3;

Figure 5 illustrates an apparatus according to the fifth aspect of the present invention;

Figure 6 illustrates a wiring diagram for a suitable control circuitry for an apparatus according to the invention and similar to that disclosed in Figure 3a wherein the sensor is a thermocouple;

Figure 7 illustrates a wiring diagram for a suitable control circuitry for an apparatus according to the fifth aspect of the invention and as illustrated in Figure 5.

As can be seen from the figures, lamp assembly 4 comprises a reflector 9 which has a reflector portion 22 and a flange portion 23. The reflector has a central channel 24 for receiving halogen capsule lamp 14. The flange 23 of the reflector 9 is fixed to ceramic lamp socket 15 by means of crinkle washer 18, nuts 17 and button head screws

19 which cap spacers 16 at both ends. Spacers 16 extend through ceramic socket 15 to the rear end of heat sink cup 8. The mechanical fixing devices 16, 17 and 19 are generally metallic and conduct heat from the rear of reflector 9 to the heat sink cup 8 which is black and metallic and thereby dissipates heat from the back of the reflector 9 providing a relatively cool surface of the heat sink cup 8 by which the lamp assembly can be manoeuvred.

The reflector 9 is elliptically shaped in cross section and reflects infra-red radiation from halogen capsule lamp 14 from its gold surface and focusses a spot of infra-red radiation 21 onto the surface of an electronic component 22.

The apparatus in Figure 3 comprises a base 1 on the surface of which is carried a display and control panel 11 for displaying and adjusting the temperature of the component under test. Whilst the base is shown as a dome shaped in this embodiment the skilled addressee will understand this not to be essential and any other shape may be used, for example, plate-like, box-like, cylindrical, etc. Extending from the centre of the domed base is a flexi-arm 2 through which is carried a cable for providing power to lamp assembly 4 and thermal sensor assembly 3. In the embodiment shown, the main flexi-arm 2 branches via three way adaptor 10 to provide two extended arms 2a and 2b for carrying thermal sensor assembly 3 and infra-red lamp assembly 4. This arrangement permits infra-red lamp assembly 4 and sensor assembly 3 to be positioned independently of each other and of main flexi-arm 2. Whilst the controller is shown as encased in the base in this embodiment, it is to be understood that the controller may be provided separately from the base, the base and controller being electrically connected by a connector lead as illustrated in Figure 3a.

The thermal sensor assembly 3 generally comprises a swivel joint 5 which provides a further degree of freedom for movement of the sensor 7 which is carried by a sensor disc 6. The circuitry controlling sensors assembly 3, lamp assembly 4 and display unit 11 is illustrated in Figure 4. The apparatus shown in Figure 3 is provided with power from a mains power supply 12 via power input cable 13.

The temperature controller shown in Figure 4 contains a set of pre-programmed parameters such as temperature ramp rate (the rate at which the temperature rises and falls) and PID settings. The temperature controller monitors the temperature via the infra-red sensor 7 and controls a dimmer module which alters the voltage input to the transformer which changes the voltage output to the halogen capsule lamp 14.

In operation, the operator aligns the lamp 14 and sensor 7 at the device which is to be heated, inputs a point temperature to the temperature controller and initiates cycling of the system whereby the apparatus automatically heats the device to the set temperature and then maintains that temperature until it receives additional input.

As can be seen from Figure 5, the apparatus comprises a square piece of alumina substrate 1,typically measuring about 10 mm x 10 mm. Arranged parallel to sides of the square substrate in an arched fashion is a resistive track 2. Positioned centrally of the substrate and the track is a thermocouple pad 3. The resistive track 2 terminates in two termination pads 4a and 4b which connect with wiring 5a, 5b leading to a controller circuit (not shown). The thermocouple pad 3 is also electrically connected to control circuitry via connector 6. A suitable controller circuit is illustrated in Figure 7.

A technical specification for a preferred embodiment of the infra-red lamp assembly of the present invention is summarised in Table 1 below.

INFRA RED LAMP ASSEMBLY	
Electrical Data	
Input:	0-12 volts (AC/DC), 3-6.5 Amps
Maximum Output:	35-75 Watts
Heating Geometry and Data	
Smallest Spot-Size:	4 mm
Working Distance:	20-30 mm (4 mm Spot)
Maximum Temperature	600°C (approximately)

Miscellaneous Information	
Life Expectancy:	Average Lamp Life 2000 hours (this will vary depending on the working environment)
Lead Length:	LL03- (300 mm standard) LL-500 (500 mm) LL-1000 (1000 mm)
Maximum Working Temperature	250°C
Safety:	The halogen lamps are UV stop bulbs and low voltage
Mechanical Fundamentals:	
IR Reflector and the 12 Volt 35 Watt capsule lamp	Basic Elliptical shape (focuses the energy into a spot) including a mounting flange at the base that has 2 x 4.2 mm holes 22 mm apart. Made from aluminium, coated in Gold to ensure the maximum of Infra Red energy produced by the 12 Volt 35 Watt capsule lamp (Short Wave energy source) is reflected (theoretically 99%) and concentrated into a 4mm spot. Dimensions of reflector 43mm diameter at end, flange 32 mm, central orifice 12 mm.
Heat Sink Back Cup	Unwanted heating occurs at the reflector by reflected radiation and convection from the device being heated, and from the ceramic socket which is heated by conduction from the Halogen Capsule Lamp. The unwanted energy is transferred by conduction through the metal fittings to the black heat sink back cup where the energy is radiated away and the assembly remains mildly warm and safe to touch during operation. Dimensions of cup 34 mm diameter, length 12 mm. 2 x 4.2 mm holes 22 mm apart at closed end.
Fittings	
M3 Nuts, Screws and Spacers	Used to fit the assembly together and conduct unwanted energy to the heat sink back cup.
M3 Crinkle washer	Acts like a spring to prevent damage to the ceramic socket as that area expands during operation

A technical specification for a preferred embodiment of the isolated thermal fault finding apparatus of the present invention is summarised in Table 2 below.

ISOLATED THERMAL FAULT FINDING DEVICE	
Electrical Data	
Input:	110/230 Volts AC, 1 Amp

Output:	0-11.8 volts ac, 3-6.5 Amps
Heating Geometry and Data	
Spot-size/Working Distance:	4 mm/20-30 mm
Maximum Temperature:	up to 200°C (depending on IC size and PCB density)
Miscellaneous Information	
Life Expectancy:	Average lamp life 2000 hours (this will vary depending on the working environment)
Temperature sensor:	Non contact Infra Red, gives accurate reading of ± 5°C, easy to position
Key Switch:	Adding extra security, only key holders can use the system, 2 positions Standby (left) and Cycle (right)
Maximum PCB Dimensions:	24" x 24"
Power Controller:	This is the heart of the system and works in conjunction with the IR Temperature Sensor and the Infra Red Lamp assembly to precisely heat an individual component to a specific temperature
Safety:	The halogen lamps are UV stop bulbs and low voltage

A technical specification for an alternative, preferred apparatus of the present invention is summarised in Table 3 below.

ISOLATED THERMAL FAULT FINDING APPARATUS	
Electrical Data	
Input	110/230 Volts AC, 1 Amp
Output	0-11.8 volts ac, 3-6.5 Amps
Heating Geometry and Data	
Spot-Size/Working Distance	4 mm/20-30 mm
Maximum Temperature	up to 200 °C (Depending on IC size and PCB density)
Miscellaneous Information	
Life Expectancy	Average Lamp Life 2000 hours (This will vary depending on the working environment)
Temperature Sensor	K Type contact thermocouple, gives accurate reading of ±5 °C, easy to position

Key Switch	Adding extra security, only key holders can use the system, 2 positions Standby (Left) and Cycle (Right)
Maximum PCB Dimensions	24" x 24"
Power Controller	This is the heart of the system and works in conjunction with the Thermocouple and the Infra-Red Lamp assembly to precisely heat an individual component to a specific temperature.
Safety	The halogen lamps are UV stop bulbs and low voltage

A technical specification for a preferred embodiment in accordance with the fifth aspect of the invention is summarised in Table 4 below.

ISOLATED THERMAL FAULT FINDING APPARATUS	
Electrical Data	
Input	110/230 Volts AC, 0.5 Amp
Output	0-11.8 volts ac, 0.75-6.5 Amps
Heating Geometry and Data	
Working Area	Variable
Maximum Temperature	up to 200 °C (Depending on IC size and PCB density)
Miscellaneous Information	
Life Expectancy	N/A
Temperature Sensor	K Type contact thermocouple, gives accurate reading of ±5 °C, easy to position
Key Switch	Adding extra security, only key holders can use the system, 2 positions Standby (Left) and Cycle (Right)
Maximum PCB Dimensions	24" x 24"
Power Controller	This is the heart of the system and works in conjunction with the Thermocouple and the Thermal Pad assembly to precisely heat an individual component to a specific temperature. Thermal Pad assembly can be used inside and outside of a chamber.
Safety	Low voltage

A technical specification for a preferred embodiment of a thermal pad for use in accordance with the fifth aspect of the invention is summarised in Table 5 below. In this embodiment, the thermal pad comprises the previously discussed IR radiation source.

THERMAL PAD	
Electrical Data	
Input	0-12 volts (AC/DC), 3/4 Amps
Maximum Output	8 Watts
Heating Geometry and Data	
Heating Area	10 x 10 mm
Maximum Temperature	180 °C
Miscellaneous Information	
Life Expectancy	N/A
Lead Length	1000 - 2000 mm
Maximum Working Temperature	210 °C
Safety	Low voltage
Mechanical Fundamentals	The substrate is made of Alumina, which is extremely flat, giving you an excellent surface to surface contact. Meaning efficient transfer of energy. The resistive track, termination pads and thermocouple pads are all screen printed onto one side of the substrate. The flying leads and thermocouple are soldered or brazed to the pads and then coated to insulate the terminations. The thermocouple is centrally positioned to give the hottest reading of the device.
Attachment	The Thermal pad can be attached with heat conductive adhesive or thermal tape (eg Kapton ™ or PTFE tape)

The thermal pad is able to operate in an environment held at a negative temperature for example inside a HALT chamber, to perform a task commonly referred to as a "Band Aid Fix". An example of this task is as follows. A PCB is tested in a HALT chamber at -40°C. Device "A" falls at -20°C and at -30°C device "B" fails. One needs to know if device "B" failed because of the failure of device "A" or if its failure is independent of device "A"'s failure. By placing the thermal pad onto device "A" its temperature can be maintained above -20°C. It will therefore remain working while the rest of the PCB's temperature is lowered meaning that if device "B" fails, it is not due to the failure of device "A".

It is to be understood that the foregoing represents just some embodiments of the invention and other embodiments occurring to the skilled reader may not fall outside of the true scope of the invention as claimed.

CLAIMS

1. Apparatus for isolated thermal fault finding in an electronic component comprising;

an infra-red (IR) radiation source;

means for focussing the IR radiation source into an area on the upper exposed surface of the component under test;

a thermal sensor for sensing the heat radiated from the component under test.

2. Apparatus as claimed in claim 1 further comprising a temperature controller for adjusting the heating effect of the IR radiation source.

3. Apparatus as claimed in claim 2 wherein the temperature controller responds to input from the thermal sensor to maintain a constant temperature of the component under test.

4. Apparatus as claimed in any preceding claim wherein the controlling circuitry for the IR radiation source, thermal sensor and temperature controller are housed in a base unit.

5. Apparatus as claimed in any preceding claim wherein the IR radiation source is a halogen capsule lamp.

6. Apparatus as claimed in claim 5 wherein the halogen capsule lamp has an axial filament.

7. Apparatus as claimed in claim 5 or claim 6 wherein the halogen capsule lamp has a power rating of 12 volts / 35-75 watts.

8. Apparatus as claimed in any preceding claim wherein the means for focussing

the IR radiation source comprises a metallic reflector.

9. Apparatus as claimed in claim 8 wherein the metallic reflector has a gold reflective surface.

10. Apparatus as claimed in claim 9 wherein the gold reflective surface is coated on an aluminium body.

11. Apparatus as claimed in any one of claims 8 to 10 wherein the reflector has a basic elliptical cross-section for focussing the IR source into a spot.

12. Apparatus as claimed in claim any one of claims 8 to 11 wherein the reflector comprises a mounting flange for mounting by metallic mounting means.

13. Apparatus as claimed in claim 12 wherein the reflector is mechanically mounted by means of the mounting flange and metallic fixing devices to a heat sink cup for dissipating heat generated within the IR radiation focussing means.

14. Apparatus as claimed in any preceding claim wherein the IR radiation source and focussing means are provided on a first flexible arm and the thermal sensor is provided on a second flexible arm to allow independent manipulation of the thermal sensor and the IR radiation source.

15. Apparatus as claimed in claim 14 wherein the first and second flexible arm branch from a third flexible arm which extends from a base unit.

16. Apparatus as claimed in claim 15 wherein the base unit is dome shaped.

17. An infra-red lamp for use in isolated thermal fault finding of electronic components comprising;

a halogen capsule lamp, positioned centrally of an elliptical reflector, the elliptical reflector having a gold reflective surface and a mounting flange, the mounting flange being connected via metallic mechanical fixing devices to a heat sink cup which carries the lamp and reflector assembly.

18. An infra-red reflector for use in an infra-red lamp comprising; a gold coated aluminium, elliptically shaped cup having an aperture positioned centrally of the ellipse for receiving a halogen capsule lamp and a mounting flange extending rearwardly therefrom, the mounting flange having one or more apertures for receiving mechanical fixing devices.

19. A method for isolated thermal fault finding in an electronic component comprising;

i) focussing a beam of infra-red radiation onto a small area at about the centre of the electronic component;

ii) monitoring the temperature of the component of step i) ; and

iii) maintaining the temperature of the component of step i) at a predetermined maximum level dictated by the function and/or environment in which the component is to be used.

20. An apparatus for thermal fault finding in an electronic component comprising:

a substrate of conductive material of less than about 225 min in area having mounted in a heat conductive manner thereon, a resistor and a thermocouple, the resistor and thermocouple being electrically connectable to a controller for providing a controlled current to the resistor and reading the output of the thermocouple.

21. An apparatus as claimed in claim 20 further comprising a temperature controller for adjusting the heating effect of the resistor.

22. An apparatus as claimed in claim 21 wherein the temperature controller responds to input from the thermocouple to maintain a constant temperature of the component under test.

23. Apparatus as claimed in any of claims 20 to 22 wherein the substrate comprises alumina .

24. Apparatus as claimed in any of claims 20 to 23 wherein the substrate is a square of not more than 10 mm x 10 mm in size.

25. Apparatus as claimed in any of claims 20 to 24 wherein the thermocouple is positioned centrally of the substrate and the resistor is provided in the form of a track which arches around the thermocouple.

26. A method for isolated thermal fault finding comprising:

i) using the apparatus of any of claims 20 to 25 to heat an electrical component,

ii) monitoring the temperature of the component of step i) using the thermocouple and

iii) maintaining the temperature of the component at a predetermined maximum level dictated by the function and/or environment in which the component is to be used.

27. An apparatus substantially as described herein and with reference to the Figures 1, to 4, 5, 6 or 7.

28. An infra-red lamp substantially as described herein and with references to the Figures 1 and 3.

29. An infra-red reflector substantially as described herein and with reference to the Figures 1 to 3.

30. A method substantially as described herein and with reference to the Figures 1 to 4.

FIG. 1

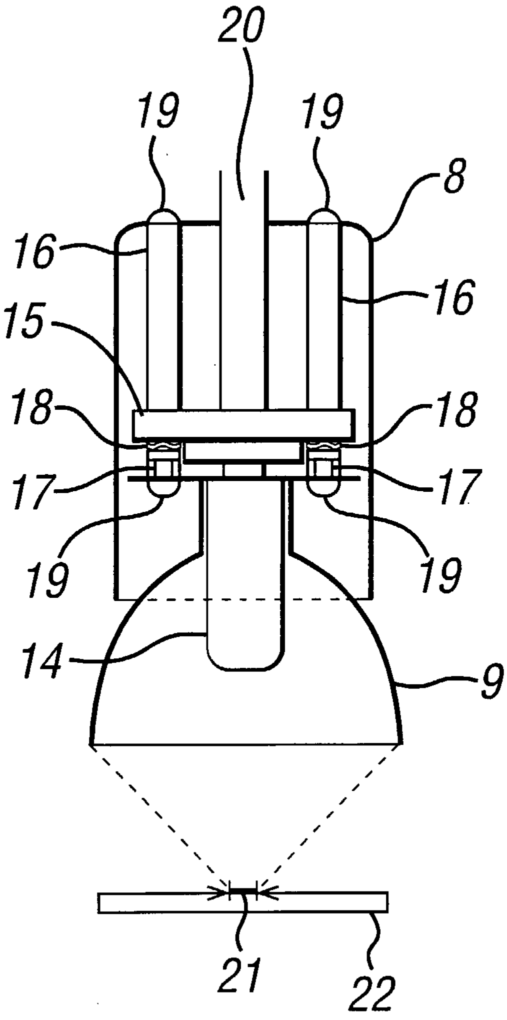


FIG. 2

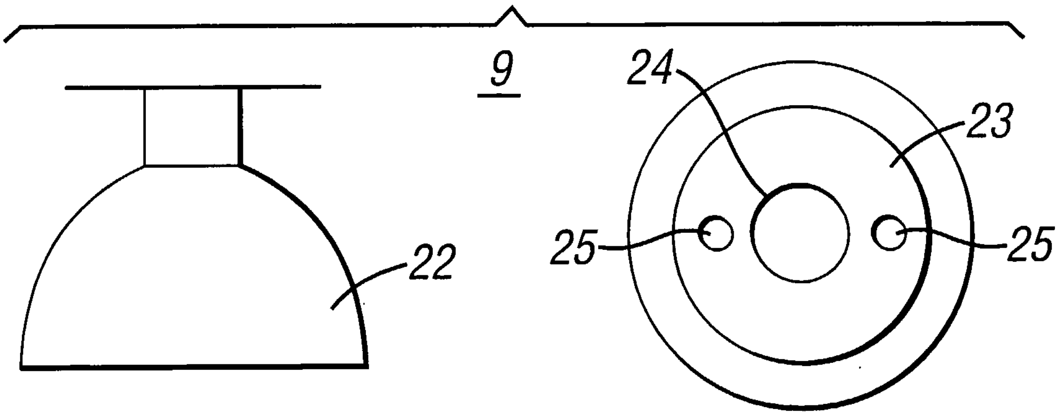


FIG. 3

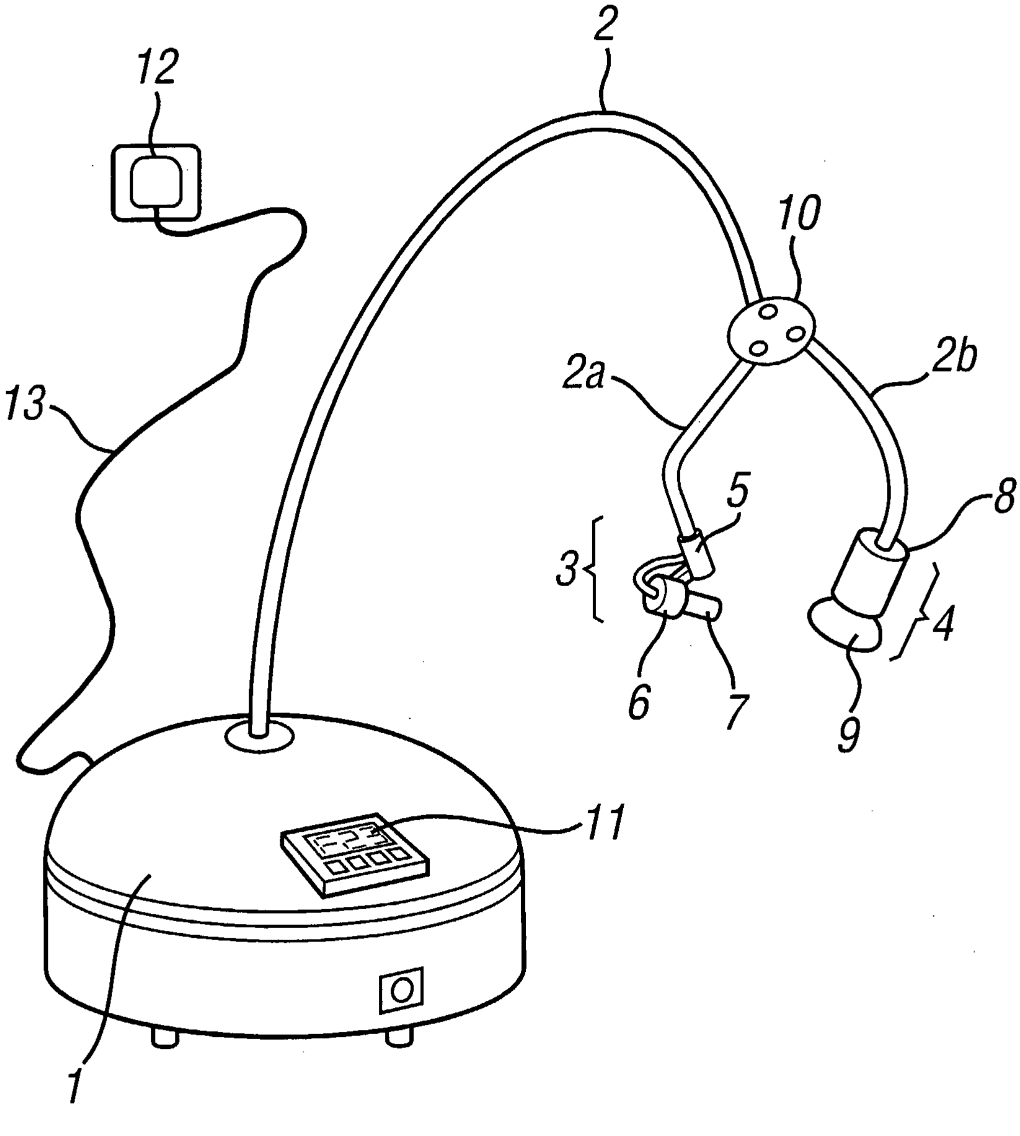
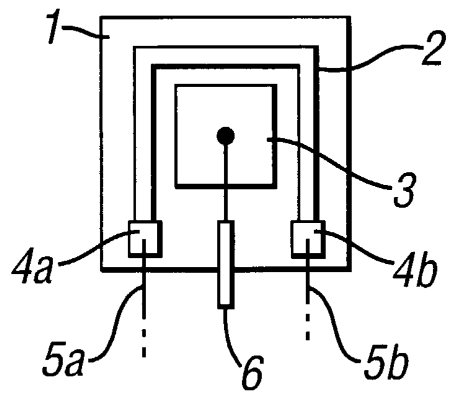


FIG. 5



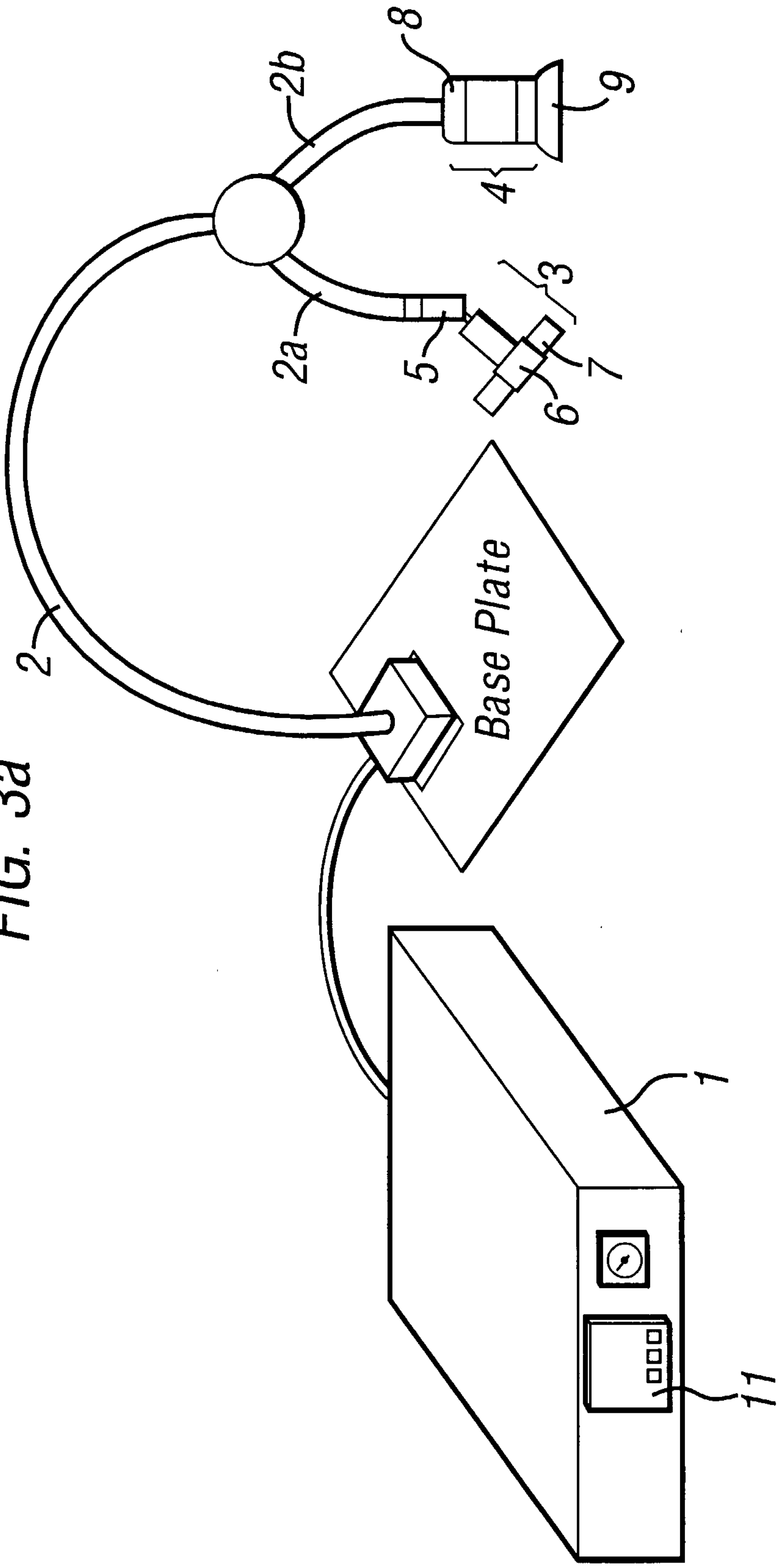
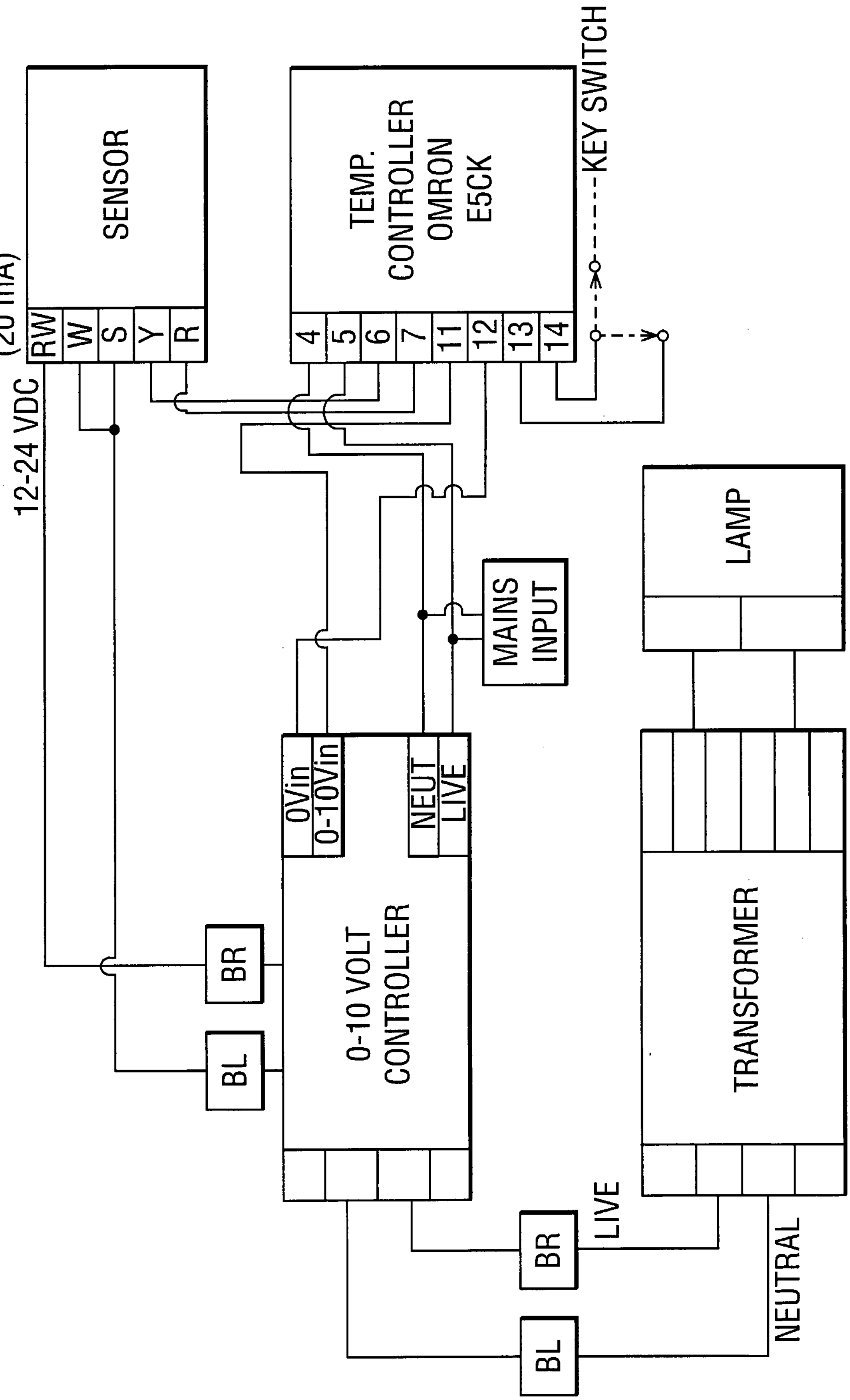


FIG. 3a

FIG. 4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TEMP. CONTROLLER OMRON E5CK
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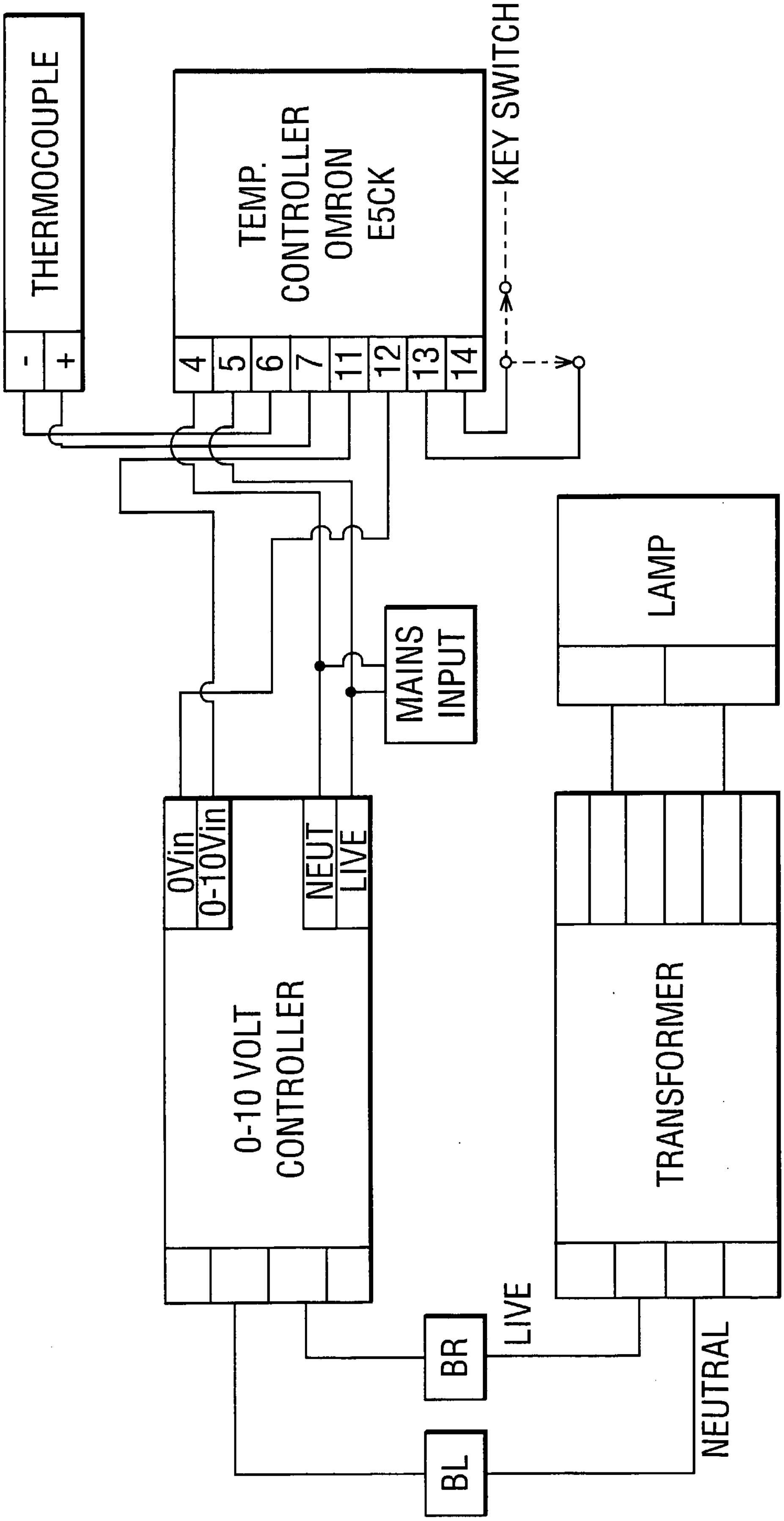
FIG. 6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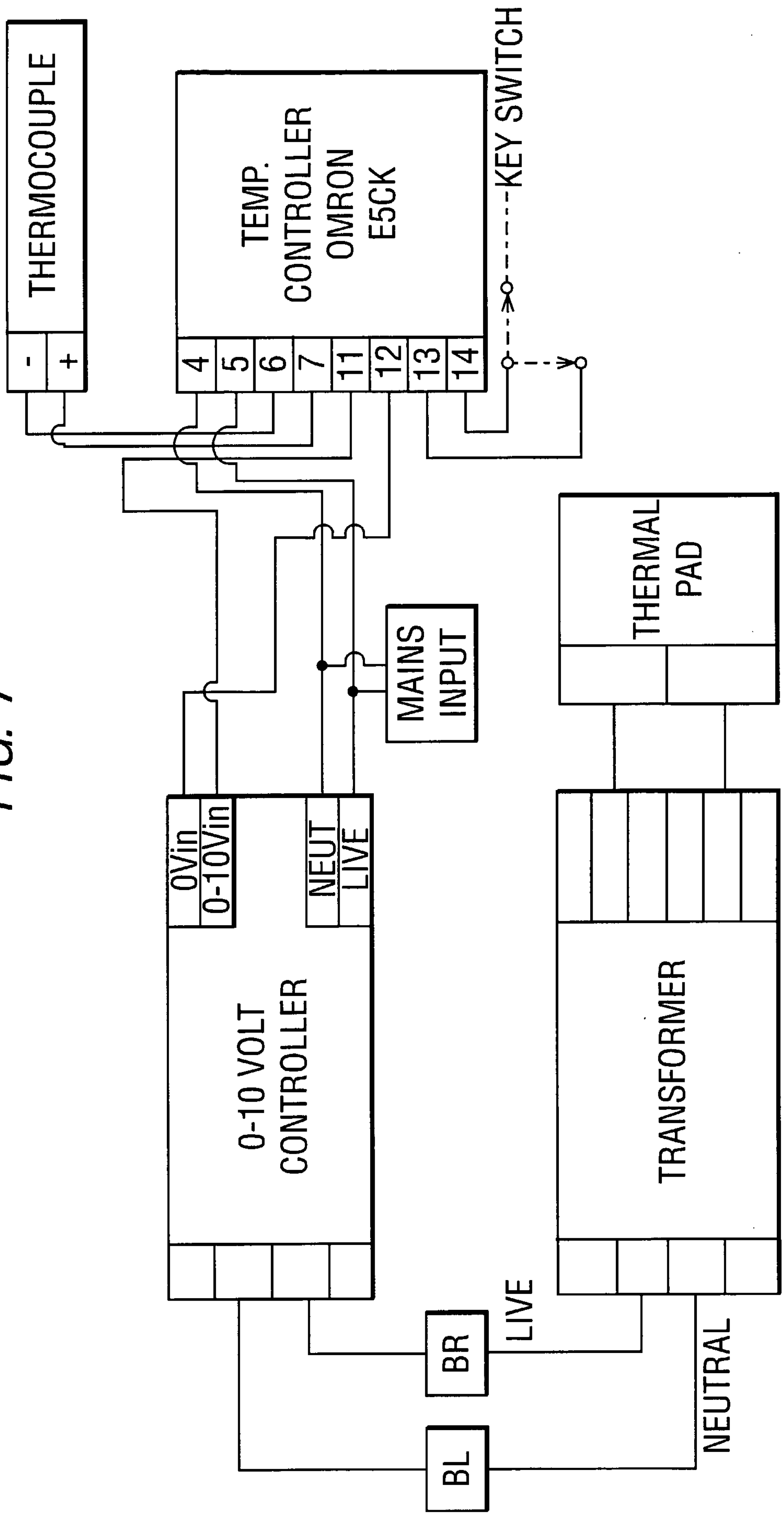
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FIG. 7