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Doyle

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[54] **FAILURE DETECTION CIRCUIT**

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Related U.S. Application Data

[63] Continuation-in-part of Ser. No. 44,122, June 8, 1970, abandoned.

[52] **U.S. Cl.** **340/251,** 340/256, 340/336

[51] **Int. Cl.**.....**G08b 21/00**

[58] **Field of Search** ..340/248 E, 251, 256, 248, 253, 340/253 B, 412, 213, 336; 315/84, 130, 136

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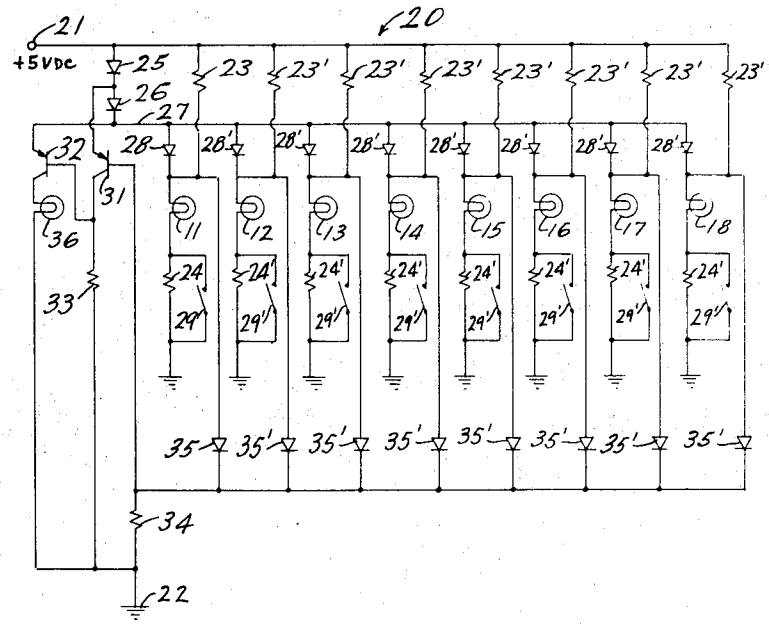
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[57] **ABSTRACT**

A circuit for detecting the failure of one or more of a plurality of incandescent lamps or other electrical devices which are subject to failure. Each device is connected to a power source such that a predetermined low current flows through each good device. The current in each device is normally appreciably lower than the current required to energize the device. A circuit including an isolation diode also connects each device to a common terminal. The voltage on the common terminal changes in the event of a failure of any of the devices causing a current decrease in such device. A voltage change on the common terminal operates an electronic switch to energize an alarm or indicator, such as a warning lamp.

12 Claims, 3 Drawing Figures



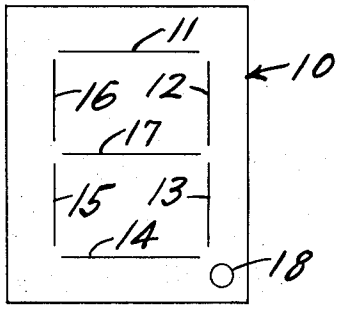


FIG-1-

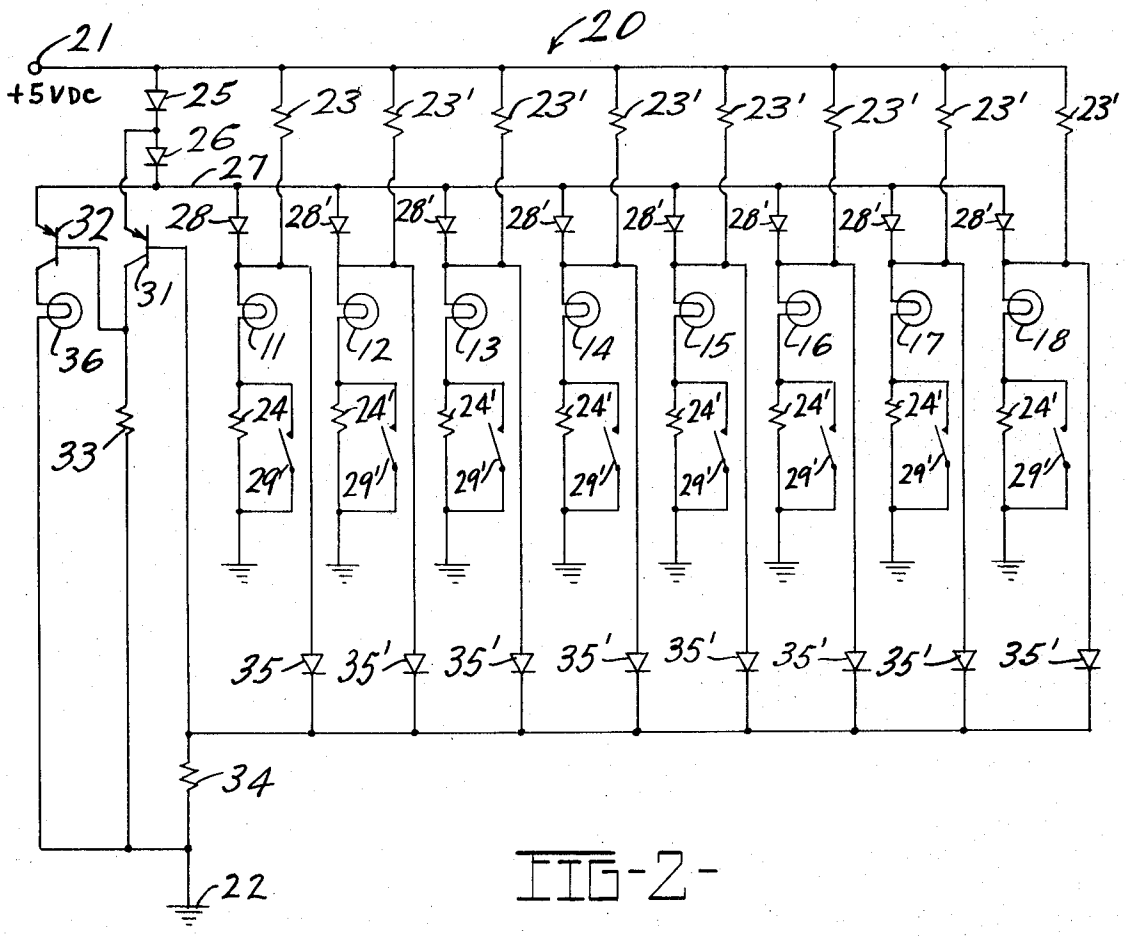


FIG-2-

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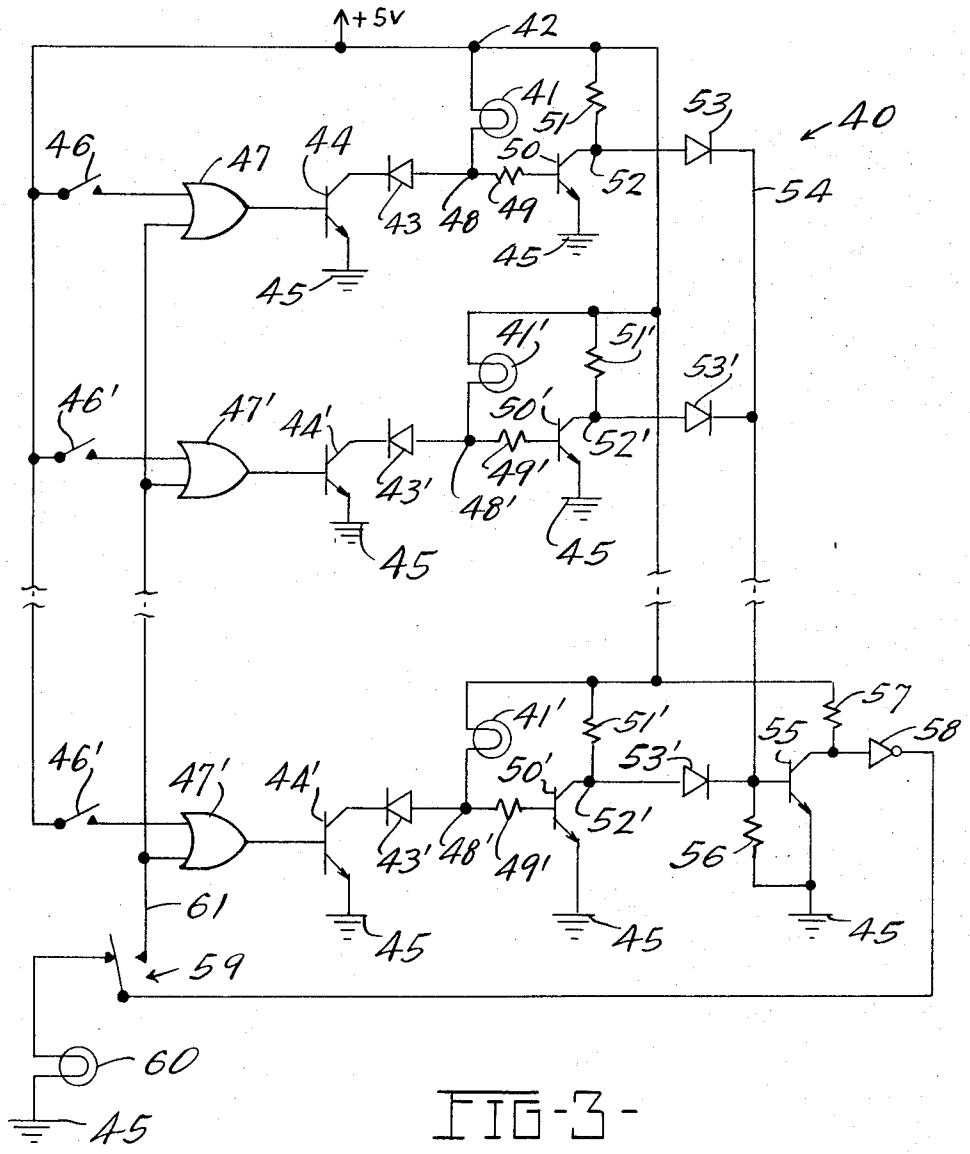


FIG-3-

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FAILURE DETECTION CIRCUIT

CROSS-REFERENCE TO RELATED APPLICATION

This is a continuation-in-part of my copending application Ser. No. 44,122, filed June 8, 1970, now abandoned.

BACKGROUND OF THE INVENTION

This invention relates to detector circuits and, more particularly, to a circuit for detecting the failure of one or more of a plurality of incandescent lamps or other electrical devices which are subject to failure.

Incandescent lamps and other light sources are commonly used as a source of information. In aircraft, for example, an annunciator panel is positioned near the pilot. In the event of the occurrence of a monitored condition, such as low fuel, landing gear down, low oil pressure, etc., an associated indicator lamp is energized to give the pilot a warning. If, however, a lamp fails, the pilot may not be notified of the occurrence of a critical condition. Similarly, light sources are commonly used in segment type readout devices found in various instruments. By energizing preselected combinations of the light sources, the numbers zero through nine or other symbols can be formed. In devices of this type, the failure of one or more of the light sources may result in an erroneous indication. If, for example, a segment readout device is energized to indicate the number 7 and the upper light source fails, the readout device will actually indicate the number 1. A false indication of this type can lead to numerous problems, particularly since the readout device appears to give a valid reading.

In the past, there has been no satisfactory circuit for simultaneously and continuously monitoring a plurality of indicator lamps, neon lamps, light emitting diodes, relays, or other similar devices. A plurality of devices of this type are generally tested by simultaneously energizing all of the devices and noting if any device has failed. However, such a test will not indicate the failure of a device after the test is completed.

SUMMARY OF THE INVENTION

According to the instant invention, a circuit is provided for continuously monitoring a plurality of electrical devices which are subject to failure, such as incandescent lamps, neon lamps, light emitting diodes, relays and the like, to detect the failure of one or more of the devices. In the event of a failure, a warning lamp, a relay, or some other suitable alarm is energized. The circuit is designed to cause a reference current to continuously flow through each device. In one embodiment, the current also flows through a series resistor which is selected to limit the reference current to a level appreciably lower than the current required to energize the device. The device is energized by closing a switch to short out the series resistor. In the event of a failure of one or more of the devices, the current in the failed device decreases below the reference value. A current decrease in any device to less than the reference value is sensed by an electronic switching circuit which energizes the alarm.

In a second embodiment, each device is connected in parallel to a power source. A diode having a predetermined forward voltage drop and a transistor switch are connected in series with each device and the power source. Each device is energized by closing an associated one of the transistor switches. The junction between each device and the series diode is connected to the control element of an electronic switch which senses a decrease in a minimum reference current through the device and such control element. The electronic switch can be connected to energize an alarm or to energize all of the devices which have not failed, thereby indicating the location of any failures.

Accordingly, it is a primary object of the invention to provide a circuit for continuously monitoring a plurality of electrically conducting devices for detecting the failure of one or more of such devices.

Another object of the invention is to provide a circuit for monitoring and detecting the failure of one or more lamps in a device having a plurality of indicator lamps.

Other objects and advantages of the invention will become apparent from the following detailed description, with reference being made to the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a front elevational view of a segment type readout device;

FIG. **2** is a detailed schematic circuit diagram of a detector circuit constructed in accordance with one preferred embodiment of the present invention; and

FIG. **3** is a detailed schematic circuit diagram of a detector circuit constructed in accordance with a second preferred embodiment of the present invention.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

According to the present invention, a circuit is provided for detecting and indicating the failure of one or more of a plurality of electrical devices. The devices may be, for example, light sources, such as incandescent lamps, neon lamps and light emitting diodes, or relay windings and the like. In the following detailed description, two circuits are described connected for monitoring a plurality of incandescent lamps in a segment type readout device. It is, of course, obvious that the circuits may be used to monitor other electrical devices and, therefore, it is not intended to limit the circuits to this particular use.

Referring now to FIG. **1**, the front of a typical seven segment readout device **10** is shown in detail. The readout device **10** is designed to mount in the front of a panel, such as a computer control panel or on the front of a direct reading voltmeter, for selectively indicating any number zero through nine. The readout device **10** is provided with eight incandescent lamps, **11** through **18**, for illuminating the seven segments and a decimal point, respectively. Various numbers are formed by energizing combinations of the lamps, for example, the number 1 is formed by energizing the lamps **12** and **13** and the number 7 is formed by energizing the lamps **11**, **12** and **13**. It can be seen that if the lamp **11** fails, the number 7 will erroneously appear as the number 1. Thus, if the readout device has no lamp failure indicator, an instrument operator may rely upon erroneous data.

Turning to FIG. **2**, a circuit **20** is shown connected to the eight lamps **11** through **18** for detecting the failure

of any one or more of the lamps. A suitable power source is connected between a positive terminal 21 and a negative ground terminal 22. For the purposes of this discussion, it will be assumed that the power source is a five volt direct current source, although it is not intended that the invention be limited to a power source of this type or voltage. It will also be assumed that the lamps 11 through 18 each require three to five volts at twenty to fifty milliamperes for operation.

The lamp 11 is connected through a resistor 23 to the positive terminal 21 and through a current limiting resistor 24 to the ground terminal 22. The lamps 12 through 18 are each similarly connected to the positive terminal 21 and the ground terminal 22, with corresponding resistors labeled 23' and 24'. The value of the resistor 24 is selected to limit the current through the lamp 11 to a value appreciably below the current required to energize the lamp 11, for example, one or two milliamperes.

A diode 25 and a diode 26 are connected in series between the positive terminal 21 and a terminal 27. The terminal 27 is then connected through a diode 28 to the lamp 11, and similarly through a plurality of parallel diodes 28' to the lamps 12 through 18. Thus, the series diodes 25, 26 and 28 are in parallel with the resistor 23. The value of the resistor 23 is selected to be such that the current flowing through it will be less than the current through the resistor 24, so that the diode 28 will provide a clamping function. A switch 29 is provided in parallel with the resistor 24 for selectively energizing the lamp 11. When the switch 29 is closed, the resistor 24 is shorted and one side of the lamp 11 is connected directly to the ground terminal 22. Current for operating the lamp 11 is then provided through the series diodes 25, 26 and 28. The voltage applied to the lamp 11 will equal the voltage applied between the terminals 21 and 22 less the forward voltage drop of the three diodes 25, 26 and 28. Thus, if the diodes have a forward voltage drop of 0.6 volts, 3.2 volts will appear on the lamp 11 when the switch 29 is closed and the lamp 11 will be energized. When the switch is open or closed the voltage at the top of the lamp will remain approximately 0.6 volts below the voltage on the line 27 (due to the clamping action of the diode 28).

A solid state switching circuit including a pair of PNP transistors 31 and 32 is also connected between the positive terminal 21 and the ground terminal 22. The emitter of the transistor 31 is connected to the junction between the series diodes 25 and 26, which is at a voltage equal to the voltage on the line 27 plus the forward voltage drop of the diode 26. The collector of the transistor 31 is connected through a resistor 33 to the ground terminal 22 and the base is connected through a resistor 34 to the ground terminal 22. The base of the transistor 31 is also connected through a diode 35 to the common junction between the lamp 11, the diode 28 and the resistor 23. Similarly, the base of the transistor 31 is connected through a plurality of diodes 35' to the lamps 12 through 18. The diodes 35 and 35' form an AND-circuit for applying a current to the base of the transistor 31. The transistor 31 is normally in the on state since the current flowing through the resistor 34 is flowing into its base. The resistor 23 is of a value to cause a current flow greater than the current flowing through the resistor 34. The current flowing through the resistor 23 normally has as its ground path the light 11 and resistor 24. In this condition the diode 35 is back biased preventing current to flow into the resistor 34. When light 11, or any other light 12 through 18, fails, all of the current flowing through the resistor 23 flows through the diode 35 into the resistor 34. Since the current flowing through the resistor 23 is normally greater than the current flowing through the resistor 34 all of the current through the resistor 34 is diverted away from the base of the transistor 31, thereby turning it off. This current is generated by the voltage drop across the resistor 34 (approximately 3.5 volts). In the event of a failure of any of the lamps, such as lamp 11, the current through resistor 34 is switched through the diode 35 and the resistor 23, and does not flow into the base of the transistor 31, thereby causing the transistor 31 to go into a nonconducting state. For this gating function to take place the current through the resistor 23 is greater than the current through the resistor 34.

The transistor 32 has an emitter connected to the terminal 27 and a base connected to the collector of the transistor 31. The collector of the transistor 32 is connected through a suitable alarm, such as a warning lamp 36, to the ground terminal 22. As long as the transistor 31 conducts, the current flowing through the resistor 33 will pass through the transistor 31 and the base of transistor 32 will not have any drive current, thus causing the transistor 32 to be in a nonconducting state. When the failure of one or more of the lamps 11 through 18 biases the transistor 31 into a nonconducting state, the current flowing through the resistor 33 will flow into the base of the transistor 32, switching the transistor 32 into a conducting state. It is apparent that other types of alarms, such as an audible alarm or a relay, may be connected either in series with, in parallel with, or in place of the warning lamp 36.

Turning now to FIG. 3, a second detector circuit embodiment 40 is shown in detail. As in FIG. 2, the detection circuit elements for one device are labeled with whole numbers and corresponding elements for other devices are labeled with corresponding prime numbers. In this embodiment, a plurality of indicator lamps 41 are each connected to a positive terminal 42. Each lamp is also connected in series through a diode 43 and an NPN transistor 44 to a negative or ground terminal 45. The diode 43 may be a single diode or a series of diodes selected to have a predetermined forward bias voltage drop. If, for example, a conventional 5-volt power source is connected between the positive terminal 42 and the ground terminal 45, the diode 43 may be selected to have a 1.4-volt forward bias voltage drop. Whenever a transistor 44 conducts, 3.6 volts will appear across the associated lamp 41 to illuminate the lamp. The positive terminal 42 is also connected through a switch 46 and an OR gate 47 to the base of the transistor 44. When the switch 46 is closed, the gate 47 applies a positive voltage to the base of the transistor 44, causing the transistor 44 to conduct to illuminate the lamp 41.

A junction 48 between the lamp 41 and the diode 43 is connected through a resistor 49 to the base of an NPN transistor 50. The collector of the transistor 50 is connected through a resistor 51 to the positive terminal 42, while the emitter is connected to the ground terminal 45. Three distinct voltages may appear on the

terminal 48: approximately 5 volts will appear on the terminal 48 when the transistor 44 is nonconducting and the lamp 41 is good; 1.4 volts plus the forward voltage drop of the transistor 44 will appear on the terminal 48 while the transistor 44 is conducting and the lamp 41 is illuminated; and zero volts will appear upon the terminal 44 in the event of a failure of the lamp 41. So long as at least 1.4 volts appear on the terminal 48, the transistor 50 is biased into a conducting state by a low current flowing through the lamp 41, the resistor 49 and the base of the transistor 50. A junction between the resistor 51 and the collector of the transistor 50 will be near the potential on the ground 45 when the transistor 50 conducts. All of the current flowing through the resistor 51 will flow through the transistor 50 to the ground 45. The terminals 52 and 52' for each transistor 50 and 50' are connected through an isolation diode 53 or 53' to a common terminal 54. When a lamp failure causes the transistor 50 to stop conducting, the current flowing through the resistor 51 flows through a diode 53, the terminal 54 and the base of a transistor 55. As long as all of the transistors 50 and 50' conduct, no current will flow through the terminal 54. However, in the event of a failure of one or more of the lamps 41 or 41' causing one or more of the transistors 50 or 50' to stop conducting, the current flowing through the resistors 51 or 51' will be applied through one or more of the diodes 53 or 53' to the common terminal 54 and the base of the transistor 55.

The common terminal 54 is connected to the base of an NPN transistor 55 and through a bias resistor 56 to the ground terminal 45. The collector of the transistor 55 is connected through a resistor 57 to the positive terminal 42 and to the input of a conventional inverter-amplifier 58. The amplifier 58 will have a high output whenever the terminal 54 is passing current due to a failure of one or more of the lamps 41 and 41'. The output of the amplifier 58 is connected through a switch 59 to either an alarm, such as an incandescent lamp 60, or to a buss 61. When the switch 59 connects the output of the amplifier 58 to the lamp 60, the lamp 60 will be illuminated in the event of a failure of one or more of the lamps 41 and 41'. The buss 61 is connected in parallel to a second input of each of the OR gates 47 and 47'. When the output of the amplifier 58 is connected to the buss 61 and one or more of the lamps 41 or 41' fails, all good lamps 41 and 41' will be illuminated. Thus, any of the lamps which fail may be readily located. In a modified embodiment, the switch 59 can be eliminated and the output of the amplifier 58 connected directly to the buss 61. In this case, a failure of any one of the lamps 41 and 41' will automatically illuminate all of the good lamps. Thus, the lamps 41 and 41' form an alarm to indicate both the failure of one of such lamps and the location of the failure.

It will be appreciated that the values of the various circuit components may be selected such that the alarm is energized when the current in any of the monitored lamps or other monitored devices decreases below a preselected level. The components of FIG. 2 may, for example, be selected to energize the alarm in the event that the current in any lamp drops below one milliampere. This current may be considerably lower with the circuit of FIG. 3. Should any lamp or the connection to any lamp have an abnormally high resistance, the circuit will operate to give an alarm even though there is not a total failure of the lamp. It will also be appreciated that other arrangements of the detector circuit may be used and that the detector circuit may be used for monitoring any number of electrical devices other than incandescent lamps without departing from the spirit and the scope of the appended claims.

What I claim is:

1. A circuit for detecting the electrical failure of any of a plurality of electrical devices each of which requires a predetermined current to operate comprising, in combination, a plurality of resistors, means connecting a different one of said resistors in series with each of the devices, means for causing currents less than the predetermined currents to flow through the devices, the current through any device decreasing to below such lesser currents in the event of a failure of such device, said current causing means causing currents to flow through each series resistor and device when such device is not operating, a plurality of switch means for selectively shorting each of said resistors for selectively increasing the current in each device to the predetermined operating current, an alarm, and switch means for energizing said alarm in response to such a decrease in the current through any of the devices.

2. A circuit for detecting the electrical failure of any of a plurality of electrical devices each of which requires a predetermined current to operate comprising, in combination, means for causing currents less than the predetermined operating currents to flow through the devices, the current through any device decreasing to below such lesser currents in the event of a failure of such device, an alarm, first switch means for energizing said alarm in response to such a decrease in the current through any of the devices, a plurality of second switch means, each of said second switch means having a predetermined voltage drop when closed, means connecting a different one of said second switch means in series with each of the devices for selectively energizing the devices, and means connecting the junctions between each of the devices and the connected second switch means to said first switch means for energizing said alarm.

3. In combination with a plurality of electrical devices, a circuit for detecting the failure of any of said devices comprising a power source, a plurality of resistors, each of said resistors connecting a different one of said devices to said source whereby a predetermined low current flows through each good device, said low current in each device being lower than the current required to energize such device, means including a plurality of isolation diodes for connecting the junctions between said resistors and said devices to a common terminal whereby a first voltage appears on said terminal when all of said devices are good and a second voltage appears on said terminal upon the failure of any of said devices, an alarm, and switch means connected to said terminal and responsive to a change from said first voltage to said second voltage for energizing said alarm.

4. The combination of claim 3, wherein said switch means comprises a first transistor having a control electrode connected to said terminal, means for biasing said first transistor into a conducting state when the first voltage is applied to said control electrode and into

a nonconducting state when the second voltage is applied to said control electrode, and a second transistor having an input connected to said first transistor and an output connected to said alarm, said second transistor conducting to energize said alarm when said first transistor is nonconducting.

5. The combination of claim 3 and including means for selectively energizing each of said devices.

6. The combination of claim 5, wherein said means for selectively energizing each of said devices includes a plurality of current limiting resistors, means connecting a different one of said current limiting resistors in series with each of said devices, a plurality of switches, and means connecting a different one of said switches in parallel with each of said current limiting resistors whereby the closure of each switch energizes a different one of said devices.

7. The combination of claim 4, wherein said devices are incandescent lamps.

8. In combination with a plurality of electrical devices, a circuit for detecting the failure of any of said devices comprising a power source, a plurality of first switch means, a predetermined current flowing through each of said first switch means when closed, means connecting each of said devices and a different one of said first switch means in series, means connecting all of said series connected devices and first switch means in parallel to said power source whereby said devices are selectively energized by selectively closing said first switch means, an alarm, second switch means for energizing said alarm, means connecting said second switch means to the junctions between each of said devices and said first switch means, said second switch means energizing said alarm in response to a decrease in current through any of the junctions between said devices and said first switch means to below the predetermined current through said first switch means when such first switch means is closed.

9. The combination of claim 8, wherein said second switch means includes a plurality of electronic switches having input, output and control electrodes, means connecting said input and output electrodes to said power source, means connecting a different one of said control electrodes to each of the junctions between said devices and said first switch means, each of said electronic switch means changing state in response to a decrease in the current through the connected junction to below said predetermined current, a common terminal, and means connecting said output electrodes to said common terminal whereby the current through said common terminal is changed upon a failure of one or more of said devices, and means responsive to the current through said terminal for energizing said alarm.

10. A circuit for detecting the electrical failure of a device which requires a predetermined current to energize comprising, in combination, means for causing a current lower than the predetermined current to flow through the device, the current through the device decreasing to below such lower current in the event of a failure of the device, an alarm, switch means for energizing said alarm in response to such a decrease in the current through the device, a resistor, means connecting said resistor in series with the device, the current to the device being caused to flow through said resistor when the device is not energized, and switch means for selectively shorting said resistor to increase the current in the device to the predetermined energizing current for selectively energizing said device.

11. In combination with a plurality of incandescent lamps, a circuit for detecting the failure of any of said lamps comprising a power source, a plurality of first switch means, each of said first switch means having a predetermined voltage drop when closed, means connecting each of said lamps and a different one of said first switch means in series, means connecting all of said series connected lamps and first switch means in parallel to said power source whereby said lamps are selectively energized by selectively closing said first switch means, an alarm including all of said lamps, second switch means for energizing said alarm, and means connecting said second switch means to the junctions between each of said lamps and said first switch means, said second switch means energizing said alarm in response to a decrease in voltage on any of said junctions between said lamps and said first switch means to below the predetermined voltage drop of said first switch means whereby, when one or more of said lamps fail, the remaining good ones of said lamps are all energized.

12. The combination of claim 11, wherein said second switch means includes a plurality of electronic switches having input, output and control electrodes, means connecting said input and output electrodes to said power source, means connecting a different one of said control electrodes to each of the junctions between said devices and said first switch means, each of said electronic switch means changing state in response to a decrease in the voltage on the connected junction to below said predetermined voltage drop, a common terminal, and means connecting said output electrodes to said common terminal whereby the voltage on said common terminal is changed upon a failure of one or more of said devices, and means responsive to the voltage on said terminal for energizing said alarm.

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