

[54] **GROUND SAFE SYSTEM**

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[56] **References Cited**

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Primary Examiner—James D. Trammell

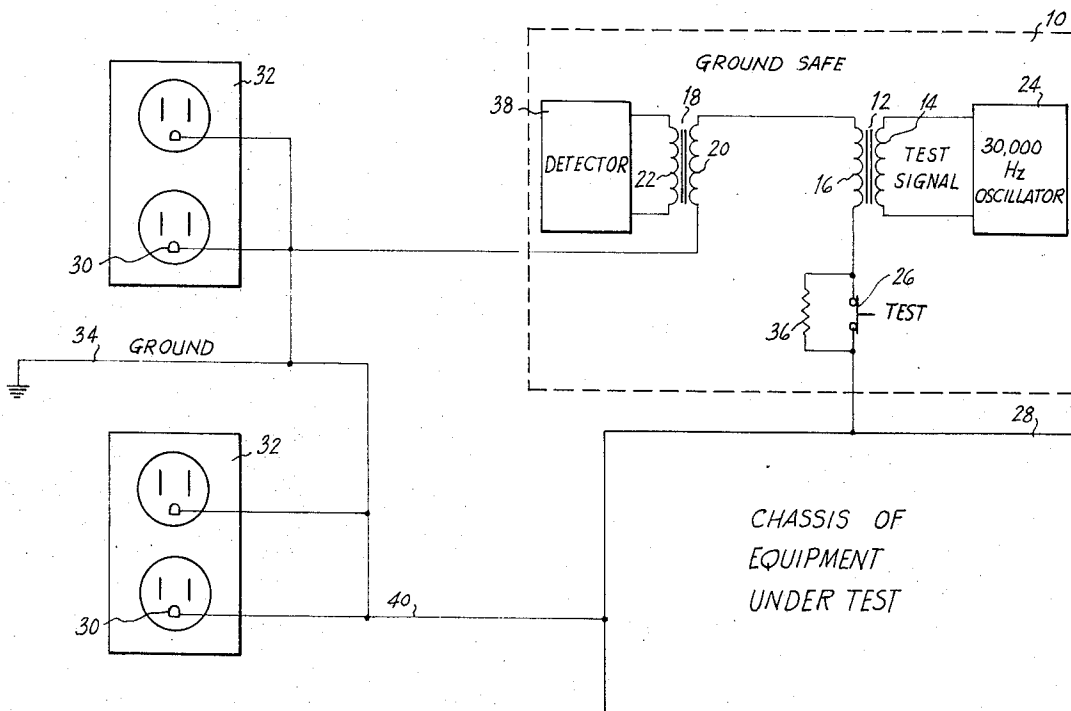
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[57]

ABSTRACT

The chassis of the equipment which is to be monitored is connected in series with a closed switch, the secondary winding of a first transformer, and the primary winding of a second transformer to a ground terminal such as is commonly found in a grounded wall outlet. The primary winding of the first transformer is supplied with a high frequency signal from an oscillator. The secondary winding of the second transformer is connected to a transistorized alarm circuit. As long as the equipment is properly grounded, the high frequency signal will flow through the series circuit and keep the alarm inoperative. If the ground line of the hospital equipment is broken or increases greatly in its resistance, the high frequency signal will be interrupted and this will activate the alarm circuit. The system includes a redundant ground connection to the chassis of the equipment.

5 Claims, 2 Drawing Figures



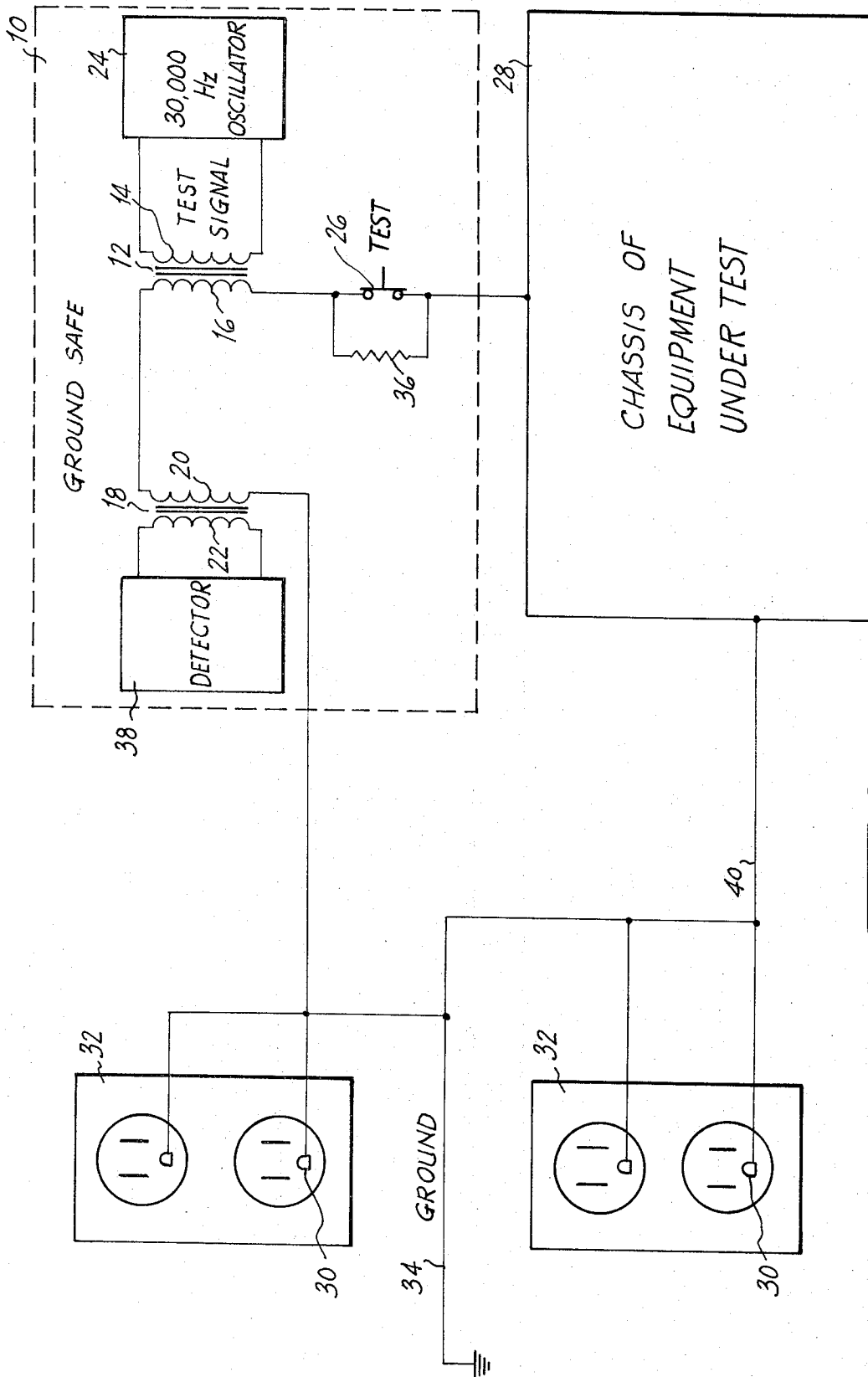


Fig. 1.

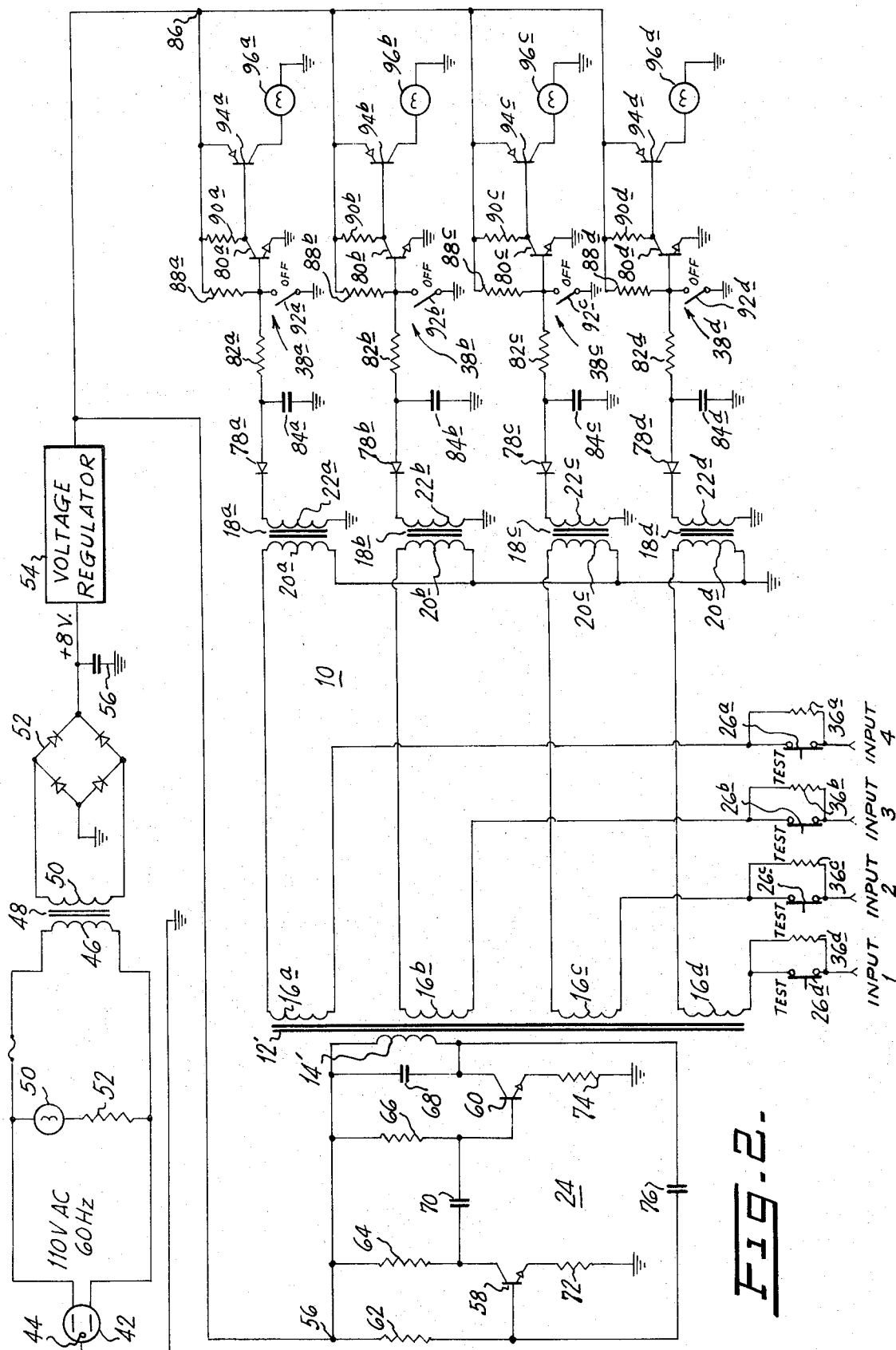


FIG. 2.

GROUND SAFE SYSTEM

BACKGROUND OF THE INVENTION

The present invention relates to systems for monitoring the ground connection to the chassis of electrical equipment and more particularly to such systems as used to monitor the ground connections of hospital equipment.

In some prior ground monitoring systems a direct current is circulated in a series circuit between the chassis of the equipment which is being monitored and an alarm system. When this series circuit is interrupted, as for example when the ground connection to the chassis is broken, the monitor sounds an alarm. Systems of this type are commonly used to monitor industrial equipment. One disadvantage in applying such systems to monitor hospital equipment is that the D.C. monitoring current poses a potential danger to the hospital patient who might be connected to the equipment. For example, extremely low D.C. currents on the order of 10 microamperes may cause fibrillation in the heart of an extremely ill heart patient in the event that the system fails and the heart patient becomes the ground connection from the test equipment to some natural ground terminal such as a water pipe or some properly grounded equipment.

Another disadvantage of such prior industrial monitoring ground systems is that they are relatively insensitive to a slight increase in the resistance of the ground connection to the equipment which, although not sufficient to impede the monitoring current, is nevertheless sufficient to allow a voltage potential to build up between the chassis of the hospital equipment and natural ground connections within the hospital room so as to present a hazard to the seriously ill patient who may come in contact with the chassis.

Still another disadvantage of some prior monitoring systems is that while providing an alarm to indicate that a ground failure has occurred, many such systems do not also provide a redundant ground connection to the chassis of the equipment to ensure that no danger is presented to the user of the equipment. Even such systems as do provide a redundant ground require bulky electro-mechanical switching equipment to make the ground connection.

The present invention overcomes these and other disadvantages by a novel design which requires a minimum of parts, construction and labor, and may be assembled in a relatively small container.

SUMMARY OF THE INVENTION

A preferred embodiment of the present invention comprises a series circuit including the output winding of a first transformer, the chassis of the equipment to be monitored, a ground connection such as the ground terminal in a conventional wall outlet, and the input winding of a second transformer. The primary winding of the first transformer is provided with a high frequency signal of a predetermined frequency from an oscillator, and the secondary winding of the second transformer is connected to an alarm circuit. The alarm circuit is activated when the high frequency signal circulating in the series circuit falls below a predetermined amplitude level. In one embodiment a switch is provided in the series circuit in order to test the operation of the ground safe system.

In the preferred embodiment the oscillator is a stabilized multi-vibrator which generates a high frequency signal between 10KHz and 100KHz in the primary winding of the first transformer. The secondary winding of the second transformer is connected through a diode to a base electrode of a first transistor. The first transistor is normally in the cut-off region of its operating characteristics due to the bias provided by the rectified high frequency signal generated by the oscillator and carried by the series circuit. The collector electrode of the first transistor is directly connected to the base electrode of a second transistor whose output circuit is connected in series with an alarm device such as an indicator lamp. The second transistor is biased in such a manner that when the first transistor is in the cut-off region the second transistor is also operated in the cut-off region. When the high frequency signal is interrupted, or decreases sufficiently in its amplitude, the first transistor is then biased into the conducting region of its operating characteristics which also causes the bias on the second transistor to operate it in the conducting region of its operating characteristics, thereby activating the indicator device. A single-pole, single-throw switch is provided between the base and emitter electrodes of the first transistor to turn the circuit off when it is not in use.

One advantage in the use of a high frequency 10KHz - 100KHz, low voltage (5 millivolt) continuity signal for detecting small changes in the resistance in the ground connection is that a larger current may be safely used than if the continuity signal were a direct current. This result is due to the fact that the human heart does not respond to high frequency signals as readily as it responds to low frequency, less than 1000Hz, signals. This is due to the excitability curve of the heart. Thus a 5 millivolt, 10KHz to 100KHz signal is the physiological equivalent of a direct current which is less than one microampere. This phenomenon allows the electronic circuitry to be greatly simplified since less amplification is needed to detect changes in the resistance of the ground connection path.

Another advantage of the present system is that a redundant ground connection is provided through the transformers between the chassis of the electrical equipment being monitored and the ground terminal in the wall outlet to eliminate possible leakage current which might harm the patient connected to the hospital equipment. Still another advantage is that the use of transformers between the monitoring equipment and the chassis of the equipment being monitored provides isolation from the common power line in order to protect the patient. A still further advantage is that the ground safe system is operated in a fail safe condition.

The ground safe system of the present invention has many applications, as will be explained in greater detail hereinafter, in all areas where class A equipment is prescribed for use in a hospital. Such equipment might be an electrocardiograph, an electroencephalograph, or a heart pacemaker. This system can be incorporated as an integral part of the equipment to monitor the ground system of that equipment or it can even be installed in the wall outlet itself.

It is therefore an object of the present invention to provide a ground monitoring system of small size and simple construction.

It is another object of the invention to provide a ground monitoring system utilizing a high frequency

current which is the physiological equivalent of a very low magnitude direct current.

It is still another object of the invention to provide a ground monitoring system wherein a redundant ground connection is provided to eliminate possible leakage current from the chassis of the equipment being monitored.

The foregoing and other objectives, features, and advantages of the invention will be more readily understood upon consideration of the following detailed description of certain preferred embodiments of the invention, taken in conjunction with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a simplified schematic diagram of one preferred embodiment of the invention;

FIG. 2 is a schematic diagram of a modification of the preferred embodiment of FIG. 1.

DESCRIPTION OF CERTAIN PREFERRED EMBODIMENTS

Referring now more particularly to FIG. 1, the ground safe system is generally designated as 10 and it includes a first transformer 12 having a primary winding 14 and a secondary winding 16 and a second transformer 18 which has a primary winding 20 and a secondary winding 22. The primary winding 14 of the transformer 12 is connected to the output of an oscillator 24 which generates a high frequency signal having a predetermined frequency in the range of from 10KHz to 100KHz. The secondary winding 16 of the transformer 12 and the primary winding 20 of the transformer 18 are connected together in series with a test switch 26, the chassis 28 of the equipment to be monitored, and the ground connection 40 of the equipment. This series circuit is also connected to one or more ground terminals 30 of the type normally installed in three prong power wall outlets 32. The series connected circuit is also connected by a lead 34 to a natural ground terminal.

A resistance 36, which is of a relatively low value such as 5 ohms, is connected in parallel with the normally closed switch 26. The switch 26 provides a test of the operation of the ground safe system. In normal operation the alternating signal generated by the oscillator 24 is caused to flow in the series circuit and, through the transformer 18, is supplied to a detector circuit 38 connected to the secondary winding 22. As long as the alternating signal flows with a predetermined amplitude within the series circuit the detector 38 indicates that the equipment 28 is properly grounded. If the flow of this alternating signal is interrupted or impeded, such as by depressing the test switch 26 to cause the current to flow through the resistance 36, the detector 38 will operate an alarm to indicate that the resistance in the ground lead connection of the equipment has increased. It should be noted that the chassis of the equipment under test 28 is redundantly grounded through the lead 34 and the transformers 12 and 18. The chassis 28 of the equipment under test is normally grounded through its own ground connection 40 which is typically the ground wire of the power cord connected to the equipment. The lead 40 is grounded in the ground terminal of the wall socket 32.

Referring now more particularly to FIG. 2 the circuit details of a modified embodiment of the ground safe system are illustrated. Power is supplied to the system through a standard three prong plug 42, the ground terminal 44 of which is connected to the chassis of the ground safe system 10. The contacts of the plug 42 are connected to the primary winding 46 of a transformer 48. An indicator light 50 is connected in series with a resistance 52 across the leads of the primary winding 46. The indicator light 50 indicates that the monitoring system is in operation.

The secondary winding 50 of the power transformer 48 is connected across a diode bridge 52. The positive terminal of the diode bridge is connected to a voltage regulator 54. The negative terminal of the diode bridge 52 is connected to the chassis ground of the monitoring system 10. A filtering capacitor 56 is connected between the positive and negative terminals of the bridge 52. The output from the voltage regulator 54 is a DC voltage, such as 8 volts for the embodiment depicted in FIG. 2, and this voltage is supplied to the oscillator 24 and the detector 38. It should be apparent that the voltage supply system discussed above could be replaced in other embodiments by batteries or could be used in parallel with batteries which would allow the system to continue operation in the event of a power failure. This latter feature is most advantageous when the system is used to monitor equipment having its own auxiliary power source.

The output of the voltage regulator 54 is connected to the oscillator 24 at a junction 56. The oscillator 24 is basically a multivibrator circuit and includes a first transistor 58 and a second transistor 60. The junction 56 is connected to the base electrode of the NPN transistor 58 by a bias resistance 62 and to the collector electrode of the transistor 58 by a bias resistance 64. The junction 56 is also connected to the base electrode of the NPN transistor 60 by a bias resistor 66 and to its collector electrode through the primary winding 14' of the transformer 12' which correspond, respectively, to the winding 14 and the transformer 12 of the embodiment depicted in FIG. 1. A capacitor 68 is connected in parallel with the winding 14'. The capacitor 68 and the transformer winding 14' together constitute a LC circuit which determines the frequency of oscillation of the oscillator 24.

The base of the transistor 60 is connected to the collector electrode of the transistor 58 through a capacitor 70. The emitter of the transistor 58 and the emitter of the transistor 60 are connected to the chassis ground through the resistors 72 and 74, respectively. The collector electrode of the transistor 60 is connected to the base electrode of the transistor 58 through a capacitor 76. In the preferred embodiment illustrated in FIG. 2, the oscillator 24 produces an alternating signal of a predetermined frequency within the range of from 10KHz to 100KHz in the primary winding 14'. However, in other embodiments other oscillator circuits may be utilized.

In the embodiment depicted in FIG. 2 the transformer 12' has a plurality of secondary windings 16a, 16b, 16c and 16d which correspond to the single winding 16 in the embodiment depicted in FIG. 1. Each of these windings is connected through a separate series circuit for checking the ground connection of a separate piece of hospital equipment. In the following description only the circuit including the secondary wind-

ing 16a will be described in detail as it will be understood that the remaining circuits operate in a substantially identical manner.

One lead of the secondary winding 16a is connected in series with a test switch 26a to the chassis of the equipment under test (not shown) such as the device 28 in FIG. 1. A resistor 36a is connected in parallel with the switch 26a. The switch 26a and the resistor 36a correspond to the switch 26 and resistor 36, respectively, previously described in reference to FIG. 1. In a similar fashion one lead of each of the windings 16b, 16c and 16d is connected to parallel switch-resistor combinations 26b-36b, 26c-36c and 26d-36d, respectively.

The other leads of the windings 16a, 16b, 16c and 16d are each connected to one lead of the primary windings 20a, 20b, 20c and 20d, respectively, of the transformers 18a, 18b, 18c and 18d. The transformers 18a, 18b, 18c and 18d each correspond to the transformer 18 described in reference to FIG. 1. Each of the transformers 18a, 18b, 18c and 18d has a secondary winding 22a, 22b, 22c and 22d, respectively, and one lead of each secondary winding is separately connected to the input to a detector circuit 38a, 38b, 38c and 38d, respectively. The remaining leads of the windings 20a, 22a, 20b, 22b, 20c, 22c, 20d and 22d are connected to the circuit ground. A detailed description will only be given of the detector circuit 38a since it will be understood that the circuits 38b, 38c and 38d operate in a substantially identical manner. Corresponding reference designations have been given to corresponding circuit elements.

The ungrounded lead of the winding 22a of the transformer 18a is connected to the cathode terminal of a diode 78a. The anode terminal of the diode 78a is connected to the base of an NPN transistor 80a through a resistor 82a. The anode terminal of the diode 78a is also connected to the circuit ground through a capacitor 84a.

The output from the voltage regulator 54 is connected to a junction 86 common to all of the detector circuits. The base of the transistor 80a is connected through a resistor 88a to the junction 86. The collector electrode of the transistor 80a is connected through a resistor 90a to the junction 86. The emitter electrode of the transistor 80a is connected to the circuit ground. The base electrode of the transistor 80a is connected through a normally open switch 92a to the circuit ground.

The collector electrode of the transistor 80a is also connected to the base electrode of a PNP transistor 94a. The emitter electrode of the transistor 94a is connected directly to the junction 86. The collector electrode of the transistor 94a is connected through an indicating device 96a, such as an alarm, to the circuit ground.

In operation, the oscillator 24 generates an alternating signal which flows through the series circuits including the windings 16a, 20a, the chassis of the equipment under test and its ground connection. The alternating signal appears at the leads of the winding 22a and is rectified by the diode 78a. The resistors 88a and 82a, together with the diode 78a, constitute a voltage divider biasing network which normally biases the base electrode of the transistor 80a such that the transistor is in the conducting region of its operating characteristics. However, the alternating signal rectified by the

diode 78a produces an opposing bias which forces the transistor 80a into its cut-off region. As long as the alternating signal is present with a sufficient amplitude at the output lead of the winding 22a, the transistor 80a is biased to be essentially non-conducting and its collector electrode has a relatively high positive voltage potential. Since this voltage potential is applied directly to the base of the transistor 94a, transistor 94a is also operated in the cut-off or non-conducting region of its operating characteristics and no power is supplied to the indicating device 96a.

When the series circuit which includes the windings 16a or 20a is interrupted by a break in the ground lead of the monitored equipment or when its resistance is increased sufficiently, the output signal from the winding 22a is diminished in amplitude and the bias supplied by the resistors 82a and 88a causes the transistor 80a to become conducting. The bias supplied to the base of the transistor 94a is thereby substantially reduced in potential which causes the transistor 94a to become conducting and to activate the alarm device 96, thereby indicating that the ground connection of the equipment under test is faulty.

Although the embodiments of FIGS. 1 and 2 have been described as utilizing transistors, in other embodiments integrated circuits can be utilized so that the ground safe system according to the invention can be in a sub-miniature form. It should also be apparent that while it is preferable to provide a separate detector circuit for each piece of equipment which is to be grounded in some embodiments it is also possible to connect the chassis of several pieces of equipment in series with a single ground connection. Furthermore although only four detector circuits are depicted in FIG. 2, in other embodiments a larger number of detector circuits can be provided for each piece of equipment which is to be monitored.

The ground safe system of the present invention may be used to monitor all electrically conductive objects around the patient's room as well as hospital electrical equipment. By grounding every metal object in the patient's room to a common point, the patient is given a greater measure of safety. Certain devices, such as electric beds, electric heaters, and fluorescent lights can be fatal if ungrounded (i.e., not connected in common with all the metal objects in the room.)

Such precautions are especially necessary in situations where the patient is internally connected to the equipment, such as by a catheter applied directly to his heart. Typical devices which might be monitored by a system according to the invention are E.C.G. monitors, electric beds, bed lamps, call buzzers, electric heaters, telephone housings, metal furniture, suction equipment and infusion pumps.

The terms and expressions which have been employed here are used as terms of description and not of limitation, and there is no intention, in the use of such terms and expressions, of excluding equivalents of the features shown and described, or portions thereof, it being recognized that various modifications are possible within the scope of the invention claimed.

What is claimed is:

1. A system for monitoring the ground lead connection of an electrically conducting piece of equipment to a ground terminal comprising a first transformer having a primary winding and at least one secondary winding, an oscillator connected to the primary winding of the

first transformer for generating an alternating electrical signal in the primary and secondary windings of the first transformer at a predetermined, relatively high frequency, a second transformer having primary and secondary windings, means for providing an additional connection between the electrically conducting piece of equipment and the ground terminal in parallel with the ground lead connection, the additional ground connection means including means for directly connecting the secondary winding of the first transformer, the primary winding of the second transformer, the electrically conducting piece of equipment and the ground connection in a series circuit, and means connected to the secondary winding of the second transformer and responsive to the high frequency signal for providing an indication when the high frequency signal circulating in the series circuit falls below a predetermined magnitude.

2. A system for monitoring the conductivity of a grounding connection from an electrically conductive chassis of a piece of medical equipment to a ground terminal, the electrically conductive equipment being of the type which is connected by leads to a power source, the monitoring system comprising a first transformer having a primary winding and at least a secondary winding, means connected to the primary winding of the first transformer for generating an alternating electrical signal having a high frequency in the range between 10 KHz and 100 KHz, a second transformer having a primary winding and a secondary winding, means separate from the power leads for providing an additional connection between the equipment chassis and the ground terminal, the additional ground terminal connection means including means for connecting the secondary winding of the first transformer and the primary winding of the second transformer in series between the ground terminal and the chassis of the equipment to be monitored, detector means connected to the secondary winding of the second transformer and responsive to the high frequency signal appearing at the secondary winding of the second transformer for providing an indication of the decrease in the conductivity

of the grounding connection upon the decrease by a predetermined amount in the intensity of the high frequency signal.

3. A monitoring system as recited in claim 2 wherein the means for connecting the secondary winding of the first transformer and the primary winding of the second transformer in series with the equipment to be monitored includes means for selectively increasing the resistance in the series circuit in order to provide a test of the monitoring system.

4. A system for separately and simultaneously monitoring the conductivity of the grounding connections of a plurality of electrically conductive pieces of medical equipment to a ground terminal, the equipment being of the type which is connected by leads to a power source, the system comprising a first transformer having a primary winding and a plurality of secondary windings, means for generating an alternating electrical signal having a high frequency in the range of 10 KHz to 100 KHz in the primary winding of the first transformer, a plurality of detector circuits responsive to the high frequency signals appearing at the secondary windings of the first transformer, each detector circuit including a transformer having a primary and a secondary winding, means separate from the power leads for providing separate additional connections between the chassis of the pieces of equipment and the ground terminal, the additional ground terminal connection means including means for separately connecting each of the primary windings of the detector transformers and a separate one of the secondary windings of the first transformer in series between the ground terminal and the chassis of a separate piece of electrical equipment to be monitored.

5. A monitoring system as recited in claim 4 wherein the means for generating an alternating signal causes an alternating signal having a voltage substantially equal to 5 millivolts to flow in the means for separately connecting the primary windings of the detector transformers.

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