

**AN EARTH LEAKAGE DETECTOR CIRCUIT****1. Field of the invention:**

The present invention relates to an electrical earth leakage circuit breaker.

**2. Description of the related art:**

Earth leakage circuit breakers have been proposed in the prior art in numerous patents whereby a core balance (differential) current transformer is used for the detection of electrical earth faults and should any one of the two electrical supply wires leak to the electrical earth by the pre-determined level, the circuit breaker will trip thereby alerting the user of the excess of leakage current. Such a circuit comprises a core balance (differential) transformer having primary coils usually consisting of the "Live" and "Neutral" coils, and a secondary sensing coil and a trigger circuit to energise the solenoid of the circuit breaker. The circuitry is usually arranged in such a way that should the electrical leakage current exceeds the pre-determined level (usually 30 to 100 milli-amperes), the current induced in the secondary sensing coil will trigger the solenoid of the circuit breaker via the trigger circuit/mechanism to shut down the electrical supply.

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The safety level at which the leakage current can pass through the human body without severe shock or injury is estimated to be below 10 milli-amperes with a duration of less than 250 milli-seconds. However, most of the electrical appliances in use in the homes and offices today do have certain degree of electrical leakage current and when they are used together with the same circuit breaker, the total leakage current could easily exceed the pre-determined level of the circuit breaker.

This phenomenon poses a problem in selecting the pre-determined level of leakage current since if the electrical leakage current is set to a safe level of say, below 10 milli-amperes, to ensure the safety of the user, then the circuit breaker is rendered useless as it would trip frequently when several electrical appliances with normal leakage current are used simultaneously. Conversely, if the pre-determined level of leakage current is set at a higher level to enable the electrical appliances with normal leakage current to be used, then the electrical leakage current setting would have exceeded the safety limit the human body could endure.

With such a dilemma, it is difficult to design the circuit breaker to protect the user from severe electrical shock or injuries as well as to provide a safe limit for all the electrical appliances in use. Moreover, with the

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increasing number of electrical appliances in use in the homes and offices, the risk of the user receiving an electrical shock is higher. Such increase in the use of electrical appliances also mean a higher electrical leakage current is required in order to prevent frequent tripping of the circuit breaker even though there was no electrical earth fault in all of the appliances in use.

### Summary of the Invention

It is the object of the present invention to overcome these disadvantages of the prior art described above by providing an apparatus to differentiate between the electrical earth leakage current of electrical appliances and the electrical leakage current passing through the human body.

According to the invention in the first aspect there is provided an earth leakage detector circuit comprising means for sensing current flow in live, neutral and earth lines, and for sensing a difference between the current flowing in the live line and the sum of currents flowing in the neutral and earth lines, the sensitivity of the current sensing means for the earth line being arranged to differ from that of the live and neutral lines and means responsive to the sensing means for actuating a circuit breaker if said difference exceeds a pre-determined level.



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The preferred embodiment of the invention includes a differential current sensing transformer, 130 with its primary coils consisting of the "Live", "Neutral" and "Earth" coils and a secondary coil, 140 which is tuned to coincide with or around the local electrical mains supply frequency. The primary coils of the differential current sensing transformer, 130 are so arranged such that the live and neutral coils are identical to each other in all aspects but not the earth coil. The difference in the characteristic/sensitivity of the earth coil may be achieved magnetically or electrically or the combination of both. The degree of the difference in the characteristic/sensitivity of the primary coils is used to determine the ratio of sensitivity between the electrical shock current and the leakage current of all the electrical appliances connected to the circuit breaker. A voltage amplifying means to amplify the induced voltage of the tuned secondary coil, 140 in which the voltage amplifier is incorporated with a T-notch filter wired in the feedback loop of the voltage amplifier to serve as a band-pass amplifier which frequency is tuned to or around the local electrical mains supply frequency.

The described embodiment of the present invention provides a circuit to detect the difference between the aforementioned kinds of leakage current so that the circuit breaker can be made to respond by triggering a circuit with

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high sensitivity of say, below 5 milli-amperes when it senses that the electrical leakage current is flowing through a different earth/ground plane (ie a human body or any living thing) while allowing a normal pre-determined level of leakage current to flow through the electrical earth system (ie electrical appliances) without tripping the circuit breaker unless the pre-determined level designated for the electrical appliances have been exceeded.

According to the invention in a second aspect, there is provided an earth leakage detector circuit comprising a plurality of earth leakage detectors, each for sensing the level of earth leakage from a different source and means responsive to the detector for actuating a circuit breaker if any one of said plurality of detectors detects an earth leakage in excess of a pre-determined level.

The described embodiment of circuit breaker of the first aspect of the invention can be incorporated with multiple earth leakage detectors of the second aspect for separate groups of electrical appliances in use with the same circuit breaker, each of which with a trip leakage current of, for example, 10 to 30 milli-amperes. The total trip current of all the earth leakage current detectors can then be set to trip the circuit breaker at, say 200 milli-amperes by means of designing the sensitivity ratio of, for

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example 1 : 100 between the electrical shock current and the leakage current of all the appliances. In this case, the electrical shock trip current will be 2 milli-amperes (or thereabouts).

A preferred embodiment containing the first and second aspects of the invention may comprise a differential current sensing transformer which consists of three primary coils for the "Live", "Neutral", and "Earth" supply, and a tuned secondary coil to detect the electrical leakage when current is flowing through a human body to a different earth/ground plane, in which the sensitivity of the earth primary coil is arranged to differ from that of the live and neutral primary coils, a band-pass voltage amplifier to amplify this weak electrical current to a suitable level, a buffer amplifier and an offset transformer to neutralise the potential difference between the Neutral and Earth Lines, a plurality of earth leakage current detectors to detect the earth leakage current of the appliances in use, a trigger circuit to combine the amplified signal from the differential current sensing transformer with the leakage current from the earth leakage detectors to trigger the solenoid of the circuit breaker and a low voltage power supply for the apparatus.

According to the invention in the third aspect, there is provided a differential current transformer having a

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plurality primary coils and a secondary coil for sensing current imbalance between the primary coils and wherein the position of the coils relative to each other is/are adjustable.

The differential transformer of a third aspect of the invention may comprise a core upon which the primary and secondary coils are mounted, the coil or coils being slidable on the core.

The adjustability of the coil or coils allows them to be moved to a position to obtain a null between live and neutral coils and thus compensate for unequal physical dimensions/position of the primary coils.

According to the invention in a fourth aspect, there is provided an earth leakage detector circuit comprising means for sensing current flow in live, neutral and earth lines, and for sensing a difference between the current flowing in the live line and the sum of currents flowing in the neutral and earth lines, means responsive to the sensing means for actuating a circuit breaker if said difference exceeds a pre-determined level and wherein the current sensing means comprises a differential current sensing transformer having primary coils corresponding to the live and neutral lines and an earth leakage current detector transformer having a primary coil for sensing earth leakage



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current on the live line, a first secondary coil connected to the differential current sensing transformer and a second secondary coil connected to the earth leakage current detector transformer; and the difference sensing means comprises means for comparing the current signals from the secondary transformers.

### Brief Description of the Drawings

An embodiment of the invention will now be described, by way of example, with reference to the accompanying drawings, in which:

Figure 1 is a block diagram of an embodiment of the circuit breaker with expandable earth leakage current detector transformers for electrical appliances.

Figure 2 is an earth leakage current flow circuit showing the difference between the electrical earth of an appliance and the earth/ground plane of a human body or living things.

Figure 3 is a band-pass voltage amplifier with tunable band-pass frequency to suit the frequency of the local electrical mains supply.

Figure 4 shows a trigger circuit with light-emitting



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diode indicators and with individual Reset switches for the different earth faults detectors.

Figures 5A and 5B are a plan view and side view in the direction of arrow A of figure 5A respectively and show a construction of a differential current sensing transformer.

Figure 6 illustrates a second embodiment of the invention.

Figures 7A and 7B show alternative construction of the balance circuit of Figure 6.

Figure 7C shows a modification of the circuit of Figure 6 for multiple earth leakage detection.

#### Description of the preferred Embodiment

A preferred embodiment of the present invention will be described in reference to Figure 1 and Figure 2. This apparatus basically consists of an electro-mechanical switch, 100 which serves as a circuit breaker. The input terminals, L1/N1 of the circuit breaker, 100 are connected to the "Live" and "Neutral" of the incoming electrical supply. The "Live" and "Neutral" terminals are further connected to a conventional low-voltage power supply circuitry, 110 via a step-down transformer, 120 to provide

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the necessary low-voltage supply (Direct Current supply) to operate the electronic circuitry.

The incoming earth line is connected to one terminal of the secondary winding of an offset transformer 350, the primary winding of which is connected to the output of a buffer amplifier, 360. The input of the buffer amplifier 360 is connected to the Neutral line via capacitor 370, preset resistor 372 and resistor 374. This arrangement ensures that any "stray" voltage which appears between the neutral and earth lines is neutralised by adjusting the preset resistor, 372, thereby reducing the possibility of a false tripping. The "stray" voltage which appears between the neutral and earth lines is the result of the voltage dropped along the neutral line and/or earth resistance when electrical power is drawn between the live and neutral lines.

In a single-phase 2-conductor supply system (without the incoming earth conductor), the input of the earth terminal, E1 may be connected to the neutral terminal, N1. In this case, the offset transformer, 350 and the buffer amplifier, 360 may be omitted since there is no potential difference between the neutral and earth lines, the sensitivity of the current sensing means for the earth line being arranged to differ from that of the live and neutral lines.

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The other terminal of the secondary winding of the offset transformer 350, together with the output, L2/N2 of the circuit breaker, 100 are connected to L3/N3/E1 of a differential current sensing transformer, 130 whose primary coils 135, 137, 139, are so arranged such that the characteristic/sensitivity of the live and neutral coils are identical in all aspects but not the earth coil. The difference in the sensitivity of the earth primary coil may be achieved magnetically or electrically or the combination of both. The degree of difference in the sensitivities of the primary coils is used to determine the ratio of sensitivity between the electrical shock current and the leakage current of all the electrical appliances connected to the circuit breaker by means of the following examples:

- a) Magnetically - As shown in Figure 5, in which the coils are mounted on a toroidal core 500, if the ratio of the cross-sectional area between the differential current sensing transformer core 501 on to which the earth coil 139 is positioned and a magnetic flux linkage 502 that bridges across the two magnetic poles of the earth coil is 9 : 1, assuming the length of the core 501 and branch 502 are equal and the number of turns of all the primary coils 135, 137, 139 are equal, and if the sensitivity of the electrical shock current is designed to trip at 1 milli-ampere, then the trip leakage current for electrical appliances

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will be approximately 10 milli-amperes.

- b) Electrically - if the ratio of the number of turns between the live/neutral coil and the earth coil is 10 : 9 and the sensitivity of the electrical shock current is designed to trip at 1 milli-ampere, then the trip leakage current for electrical appliances will be 10 milli-amperes.

A fourth coil, 140 of the differential current sensing transformer, 130 serves as the secondary coil the resonant frequency of which is tuned to coincide with or around the local mains supply frequency by means of capacitor, 145. The secondary coil, 140 is connected to a band-pass voltage amplifier, 150 via resistor 155 and two clamp diodes, 157 and 159. The function of the resistor, 155 is to limit the high current surge and transient when the two clamp diodes, 157 and 159 are brought into action each time the electrical surge and transient are present in the electrical power lines.

The band-pass voltage amplifier, 150 is shown in more detail in figure 3 and comprises an integrated circuit amplifier, 400 biased by resistors 402, 404, having an input through broad band filter 406, 408, with a T-notch filter, 410 placed in the feed back path of the amplifier

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400. The filter 410 is of standard band-pass construction including capacitors 412, 414, 416 and resistors 418, 420. Variable resistor 422 connects ground to the connection between capacitors 412, 414 and is adjustable to provide maximum amplification at the band-pass frequency corresponding to the electrical main frequency (generally 50/60 Hz) or thereabouts.

The "Earth" coil terminal, E2 of the differential current sensing transformer, 130 is connected to terminals E3 (... to Ex) of an earth leakage current detector transformer, 170(1) the output terminals of which E4(... to Ey) together with terminals L4 and N4 of the differential current sensing transformer, 130 are terminated as the electrical supply outputs Live 1, Neutral 1, Earth 1 ... Earth n ready to be connected to all the electrical appliances in the conventional and well-known manner.

Under normal working conditions, there is no signal output from the secondary coil, 140 of the differential current sensing transformer, 130 when an electrical appliance is connected to the output terminals, Live 1, Neutral 1 and Earth 1 (or Live 1, Neutral 1 and Earth n) of the apparatus because the current flowing through the "Live" coil, 135, is equal and of the opposing phase to that flowing through the "Neutral" coil, 137 and "Earth" coil, 139. However, when the load current of the electrical appliance is high,

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slight electrical current imbalance between the "Live" and "Neutral" coils of the differential current sensing transformer, 130 would result in a small voltage being induced in the secondary coil, 140 because of the unequal physical dimensions/position of the "Live", "Neutral" and "Earth" coils.

This problem is solved by a specially constructed differential current sensing transformer, 130 as shown in figure 5 in which the coils are allowed to slide along/around its core 500 to obtain a "null" between the "Live" and "Neutral" coils, 135, 139. The current imbalance between the "Live" and "Earth" coils is insignificant because the current flowing (leakage current of the appliance) from the "Live" to the "Earth" is usually small. In fact, when the electrical leakage current of the appliance exceeds the pre-determined level (usually below 100 milli-amperes), the circuit breaker would have tripped by then. In the preferred embodiment shown in Figure 5, only the secondary coil 140 is movable, as indicated by arrows 510.

The earth leakage current of the electrical appliance(s) will appear across the terminals EL1 and EL2 of the earth leakage current detector transformer, 170(1). A plurality of earth leakage current detectors can be incorporated to provide separate groupings of electrical appliances

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connected to the same output terminals Live 1 and Neutral 1 but having the earth wiring connected to a different earth terminal, such as Earth n of the earth leakage current detector transformer, 170(n). This arrangement enhances the reliability of the apparatus in such a way that the electrical earth leakage of each group of appliances within the same earth leakage current detector transformer are not compounded with the other groups of electrical appliances and the total electrical leakage current of all the electrical appliances in use, thereby preventing unwarranted tripping of the circuit breaker even though none of the electrical appliances in use are faulty of excessive earth leakage. The total trip current along the earth conductor from which all the earth leakage current detectors are connected is determined by the ratio of sensitivity between the live/neutral primary coils and the earth coils. Moreover, the grouping of separate earth leakage current detectors also facilitates easy identification of the faulty group of appliances in question. A trigger circuit 200, for actuating circuit breaker 100 in response to earth leakage current detector transformers 170, will now be described with reference to figure 4.

The output signal VO from the band-pass voltage amplifier, 150 is connected to input Es of the trigger circuit 200 of figure 4, via a variable preset resistor, 210 (Figure 1)

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which can be used to set the electrical shock leakage current in the range of 1 to 5 milli-amperes. Similarly, the output signals from the plurality of earth leakage detector transformers, 170(1) to 170(n), are connected to the inputs PS1, PS2, ... PSn of the trigger circuit 200, via individual appliance earth leakage current variable resistor presets, 220(1) - 220(n) (Figure 1) which have the earth leakage current limit set in the range of 10 to 30 milli-amperes or any other leakage current of practical limits. The total earth leakage current of all the leakage current detectors, 170(1) to 170(n) will appear at the secondary coil, 140 of the differential current sensing transformer, 130 as if electrical shock current has been detected but at a lower sensitivity. The degree of sensitivity between the electrical shock current and the total leakage current of electrical appliances is determined by the ratio of the difference in its primary coils as described earlier.

The trigger circuit basically consists of a SN74LS14 Schmitt trigger circuit 230 to toggle a SN74LS00 wired as RS Flip-flop circuit 240. The earth leakage current signals from the voltage amplifier, 150 and the plurality of the earth leakage current detector transformers, 170(1) - 170(n) are connected to the inputs of respective Schmitt triggers 230 via respective transistor emitter-follower circuits 250. The outputs Q from all the RS Flip-flop

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circuits, 240 are connected to a two-stage transistor driver 270 to energise the solenoid of the circuit breaker 100 via respective diodes 280. The other output Q1 from each RS Flip-flop circuit, 240 is used to drive a respective light-emitting diode indicator, 290 to facilitate easy identification of the faulty appliance. Once the fault has been identified and rectified it is then reset by activating respective Reset switch 295 (Figure 4) before switching on the circuit breaker 100 again.

In figure 2, the earth wire connected to the electrical appliance 300 is shown to have been disconnected accidentally (marked X) so that the chassis of the electrical appliance has become LIVE. The live chassis of the unearthed electrical appliance will cause an unequal current flow between the three coils 135, 137, 139 when the chassis of the unearthed electrical appliance 300 is touched by the unaware user because the electric current has leaked through the user to a different earth/ground plane (the floor/ground) thereby causing the current flowing through coil 135 to be greater than the current flowing through coil 137 and coil 139. Such unequal flow of electric current in the three coils causes a voltage to be induced in the secondary coil, 140 of the differential current sensing transformer, 130. The same applies when the 'live wire is accidentally touched by the user.

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The induced voltage from the secondary coil, 140 of the differential current sensing transformer, 130 is amplified by the band-pass voltage amplifier, 150 in the manner as described earlier. The amplified signal is made adjustable and calibration can be made to correspond the triggering voltage with the desired limits of the electrical leakage current flowing through a human body.

The test switches, 300 (Appliances) and 310 (Electrical Shock) are also incorporated to facilitate periodical testing of its circuitry as shown in Figure 1, these operating by providing a short from live to earth via respective resistors connected to the output earth 1 terminal and E1 on either side of transformer, 130.

As can be understood from the above, the earth leakage circuit breaker according to the present invention can be of a simple configuration, ie - single earth leakage current detection with a differential current sensing transformer as described in the above invention with a fixed secondary coil, for low current operation or a more elaborate configuration with multiple earth leakage current detection terminals for multiple groups of appliances connected to the same circuit breaker and a sliding primaries and/or secondary coils of the differential current sensing transformer as shown in figure 5 for higher current operation.

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Figure 6 shows an alternative method of differentiating between the electrical earth leakage of appliances and the electrical leakage current flowing through a human body by means of a conventional differential current sensing transformer, 130 having its primary coils corresponding to the live and neutral coils but without an earth coil.

The sensing coil, 140 of the differential current sensing transformer, 130 and the secondary coil, EL1/EL2 of the earth leakage current detector transformer, 170 are mixed together in the balance circuit network, 151 so that the induced currents of both the sensing coil, 140 and the secondary coil, EL1/EL2 cancel or oppose each other when the electrical earth leakage occurs between the power lines and the electrical earth of the appliances. The balance circuit network, 151 may consists of a parallel-connected or a series-connected circuits as shown in Figure 7A and 7B respectively. The polarity of the sensing coil, 140 and the secondary coil, EL1/EL2 are connected "out-of-phase" in a parallel-connected circuit and "phase-to-phase" in a series-connected circuit. The polarity of the coils and its connections are indicated by a dot marking next to one terminal of each coil as illustrated in Figure 7A and 7B. The variable resistor, VR is included in the circuit to set/adjust the induced currents of both the sensing coil, 140 and the secondary coil, EL1/EL2 so as to obtain an output corresponding to the ratio of the two earth currents

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at terminal D of the balance circuit network, 151. The output terminal D of the balance circuit network, 151 may be offset by adjusting the variable resistor VR so as to obtain a "null output" if separate detection of the two earth currents is desired. The output terminal D of the balance network, 151 is connected to the voltage amplifier, 150 in the same manner as previously described. The capacitor, 146 is connected to the terminals, EL1 and EL2 of the earth leakage current detector transformer, 170 to form an LC tuned circuit whose frequency is tuned to or around the mains supply frequency.

Under normal working condition, there is no signal output from the terminal D of the balance circuit network, 151 when an electrical appliance is connected to the apparatus since the currents flowing in both the live and neutral coils of the differential current sensing transformer, 130 are equal and are of the opposing phase. However, when an electrical earth leakage occurs between the power lines and the electrical earth of the appliance(s) it causes an unequal flow of currents in the live and neutral coils, thereby inducing a signal corresponding to the magnitude of the leakage current of the appliance(s) in the sensing coil, 140 of the differential current sensing transformer, 130. Since, an earth leakage current detector transformer, 170 is connected in between the electrical earth supply and the appliance, a signal corresponding to the magnitude of

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the leakage current of the appliance(s) will also be induced in the secondary coil, EL1/EL2 of the earth leakage current detector transformer, 170. These two signals from the sensing coil, 140 and the secondary coil, EL1/EL2, which may or may not be of equal amplitude, are mixed together in the balance circuit network, 151 in such a way that the two signals cancel or oppose each other so as to maintain a desired ratio of sensitivity at the output output terminal D of the balance circuit network, 151. Any unequal amplitude between the sensing coil, 140 and the secondary coil, EL1/EL2 will cause a signal to appear at terminal D of the balance circuit network, 151 and this is compensated by means of adjusting the variable resistor, VR to obtain the desired ratio of sensitivity at the output terminal D of the balance circuit network, 151. The output at terminal D may also be adjusted to "null" if separate detection of the two earth currents is desired.

The balance circuit network, 151 will cause a signal to appear at its terminal D when an earth leakage current flow through a different path, which could be a human being or any living things because of the fact that the current induced in the sensing coil, of the sum of the earth leakage current of the appliance(s) ( $I_L$ ) and the electrical shock current ( $I_{ES}$ ) flowing through a human body, such that:

$$\text{Sensing Coil, 140(SC)} = I_L + I_{ES}$$

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Whereas the current induced in the earth leakage current detector transformer, 170 consists of only the earth leakage current of all the appliances( $I_L$ ) connected to it, such that:

$$\text{Earth leakage detector, 170(ELD)} = I_L$$

Therefore, the signal at the output terminal D of the balance circuit network, 151 may be expressed as follows:

(a) Combined detection determined by the ratio of sensitivity between the two earth currents:

$$\begin{aligned} \text{SC-ELD} &= I_L + I_{ES} - 0.9(I_L) \\ &= I_{ES} + 0.1(I_L) \\ (\text{Sensitivity ratio} &= 10:1) \end{aligned}$$

(b) Separate Detection of the two earth currents)

$$\begin{aligned} \text{SC} - \text{ELD} &= I_L + I_{ES} - I_L \\ &= I_{ES} \end{aligned}$$

The electrical shock current( $I_{ES}$ ) and the leakage current of appliances at the pre-determined level will trigger the circuit breaker via the trigger circuit, 200.

In the case of a simple configuration where separate detection of the two earth currents is desired, the

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apparatus may consist of a conventional differential current sensing transformer, 130 and a single earth leakage current detector transformer, 170 for detecting the earth leakage current of all the electrical appliances connected to the apparatus, the triggering signal for all the electrical appliances is taken from the terminal EL1 of the earth leakage current detector transformer, 170 (shown in broken line in Figure 6) via preset resistor, 220, whereas the triggering signal for the electric shock current is taken from terminal D of the balance network, 151 via voltage amplifier 150 (in this case, the output terminal D of the balance network, 151 is set by VR to obtain a "null" output). For multiple earth leakage detection, the circuit may comprise a plurality of earth leakage current detector transformers, 170(1-n) arranged as shown in Figure 7C. The common earth line to which one terminal of the primary coil of all the earth leakage current detector transformers, 170(1-n) are connected together is connected to E4 of the earth leakage current detector transformer, 170 of Figure 6. A capacitor, C may be connected across each secondary coil of all the earth leakage current detector transformers, 170(1-n) as shown in Figure 7C which function is similar to capacitor, 146 of Figure 6.

It must be noted that the details of the design and construction of the invention may be varied and therefore it does not limit the patent hereon granted other than as

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indicated by the scope of the appended claims.

For example, the described embodiment combines means for sensing a leakage current on the earth lead so that any difference between live and the sum of neutral and earth currents will indicate a current leakage through another path which could be the human body, means of determining the sensitivity ratio between the electrical shock current and the earth leakage current of electrical appliances and, also, the provision of multiple earth leakage current detectors for different groups of appliances to facilitate (1) easy identification of faulty appliances or groups of appliances, (2) separate and adjustable leakage current setting (sensitivity) for different loads and (3) higher reliability by ensuring that the "trace" leakage currents from one application or a group of appliances do not sum up together with other groups of appliances. However, as will be apparent to one skilled in the art, these features are independent and may be used separately one from the other. Also, the arrangement shown in the drawings relate to a single-phase power supply circuit but the invention is also applicable to multi-phase power supply circuits, including three-phase power supply circuits.

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CLAIMS

1. An earth leakage detector circuit comprising means for sensing current flow in live, neutral and earth lines; and means for sensing a difference between the current flowing in the live line, and the sum of currents flowing in the neutral and earth lines; the sensitivity of the current sensing means for the earth line being arranged to differ from that of the live and neutral lines; and means responsive to the sensing means for actuating a circuit breaker if said difference exceeds a pre-determined level.
2. A circuit is claimed in claim 1 wherein the sensing means comprises a differential current sensing transformer having a plurality of primary coils corresponding to the live, neutral and earth lines and a secondary coil for sensing said difference.
3. A circuit is claimed in claim 2 wherein the transformer includes a core upon which the primary and secondary coils are mounted and the core includes a magnetic flux linkage bridging the earth coil.
4. A circuit is claimed in claim 2 wherein the number of turns of the earth coil differs from the number of turns of the line and neutral coils.

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5. A circuit is claimed in any one of claims 1 to 4 wherein the secondary coil and the primary coils are adjustable in position relative to each other.
6. A circuit is claimed in claim 5 wherein the primary and secondary coils are mounted on a yoke and the secondary coil is slidable on the yoke.
7. A circuit is claimed in any one of the preceding claims further comprising a plurality of earth leakage detectors, each for sensing the level of earth leakage from a different source, the detectors being connected to said responsive means for actuating the circuit breaker when a said earth leakage exceeds a pre-determined level.
8. A circuit as claimed in any one of the preceding claims further comprising voltage compensation means for compensating for voltage difference between the neutral and earth lines.
9. A circuit as claimed in claim 8 wherein said voltage compensation means comprises voltage sensing means, amplifying means for producing a compensation voltage and means for applying said compensation voltage to the earth line.

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10. A circuit as claimed in claim 9 wherein said applying means comprises a transformer.
11. A circuit is claimed in claim 1 wherein the current sensing means comprises a differential current sensing transformer having primary coils corresponding to the live and neutral lines and an earth leakage current detector transformer having a primary coil for sensing earth leakage current on the live line, a first secondary coil connected to the differential current sensing transformer and a second secondary coil connected to the earth leakage current detector transformer; and the difference sensing means comprises means for comparing the current signals from the secondary transformers.
12. The circuit is claimed in claim 11 wherein the secondary coils are connected in parallel and out-of-phase to each other or are connected in series and phase-to-phase.
13. A circuit is claimed in claim 11 or claim 12 further comprising an adjustment means for adjusting the relative magnitudes of the current signals.

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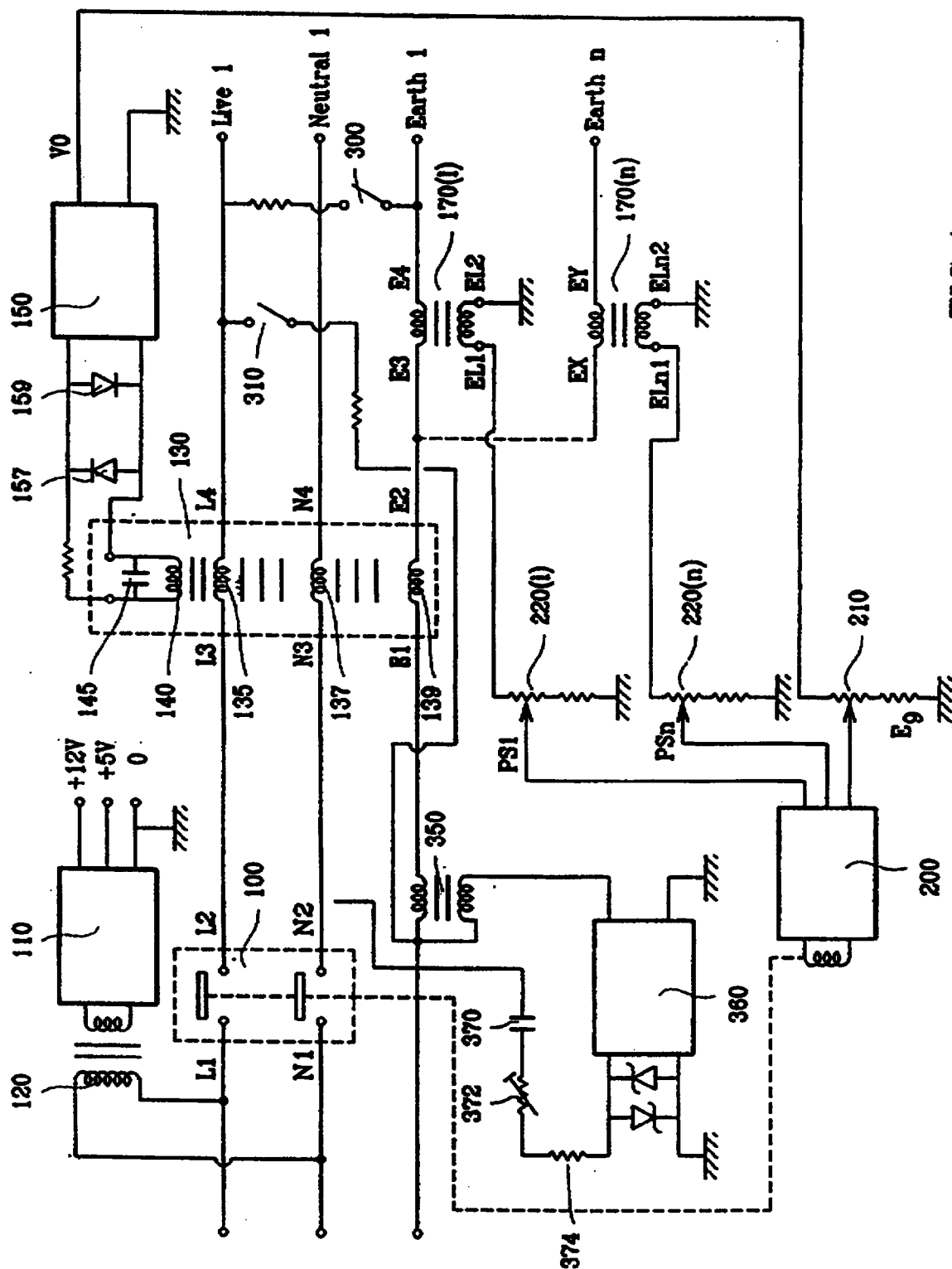


FIG.1

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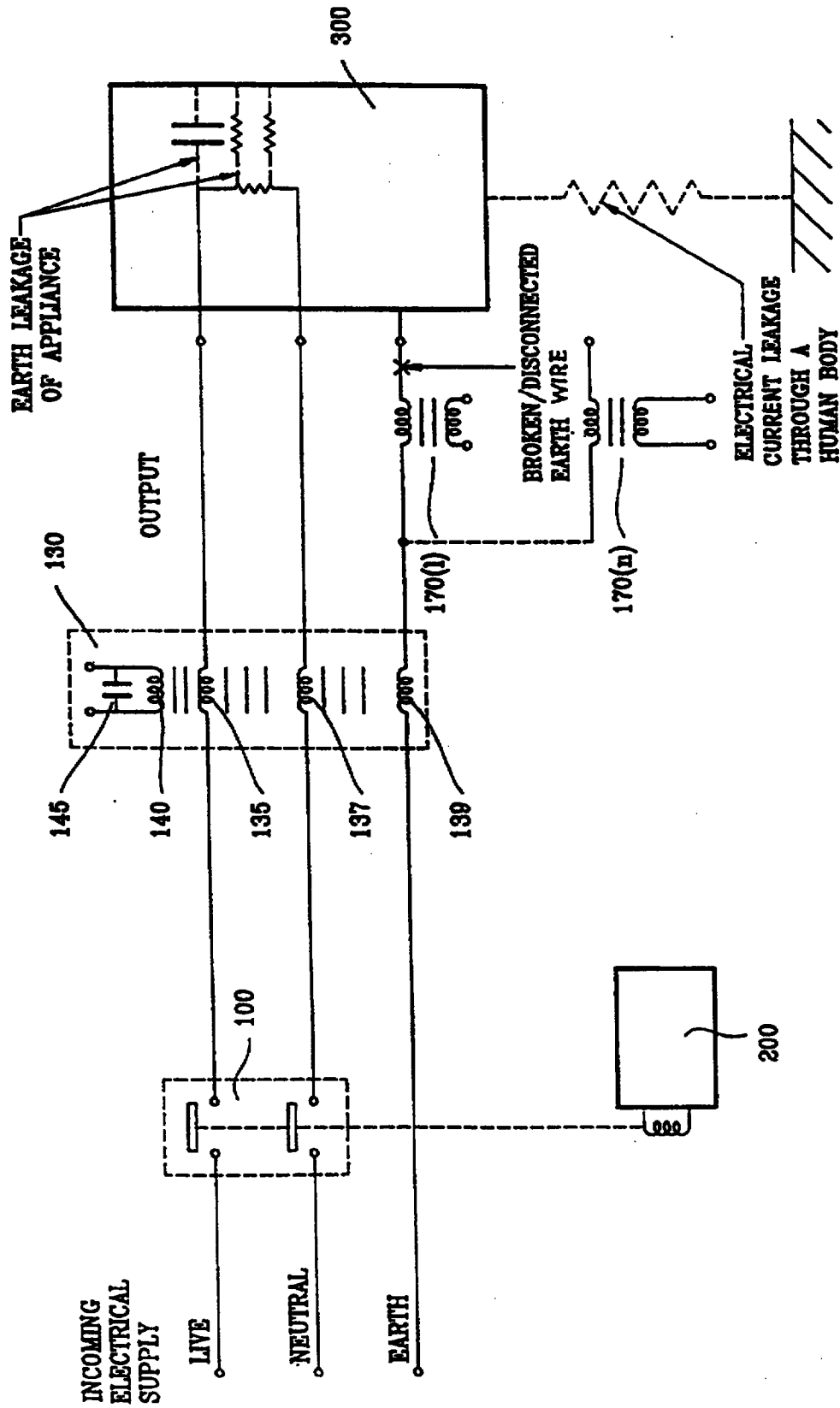


FIG.2

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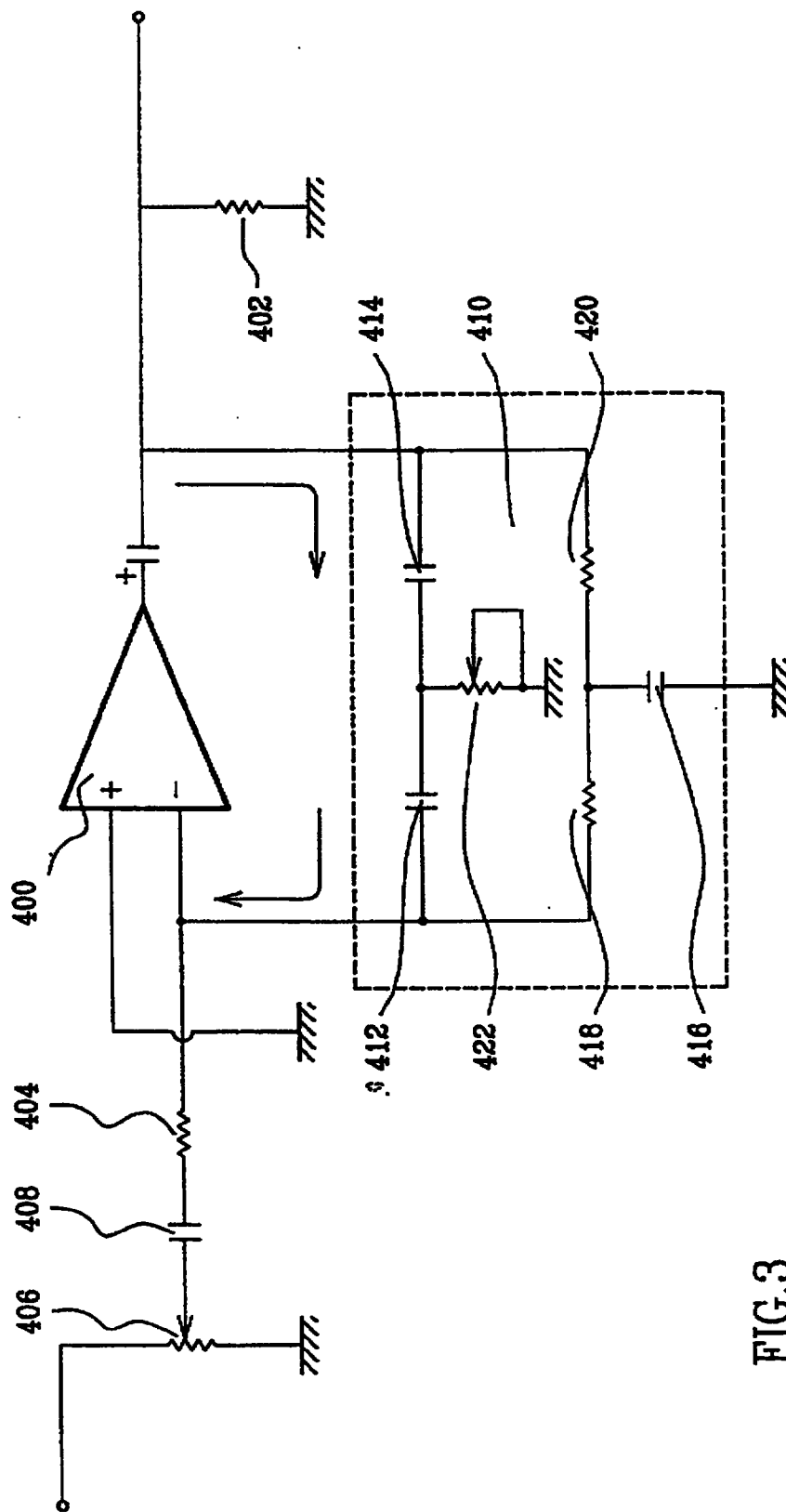
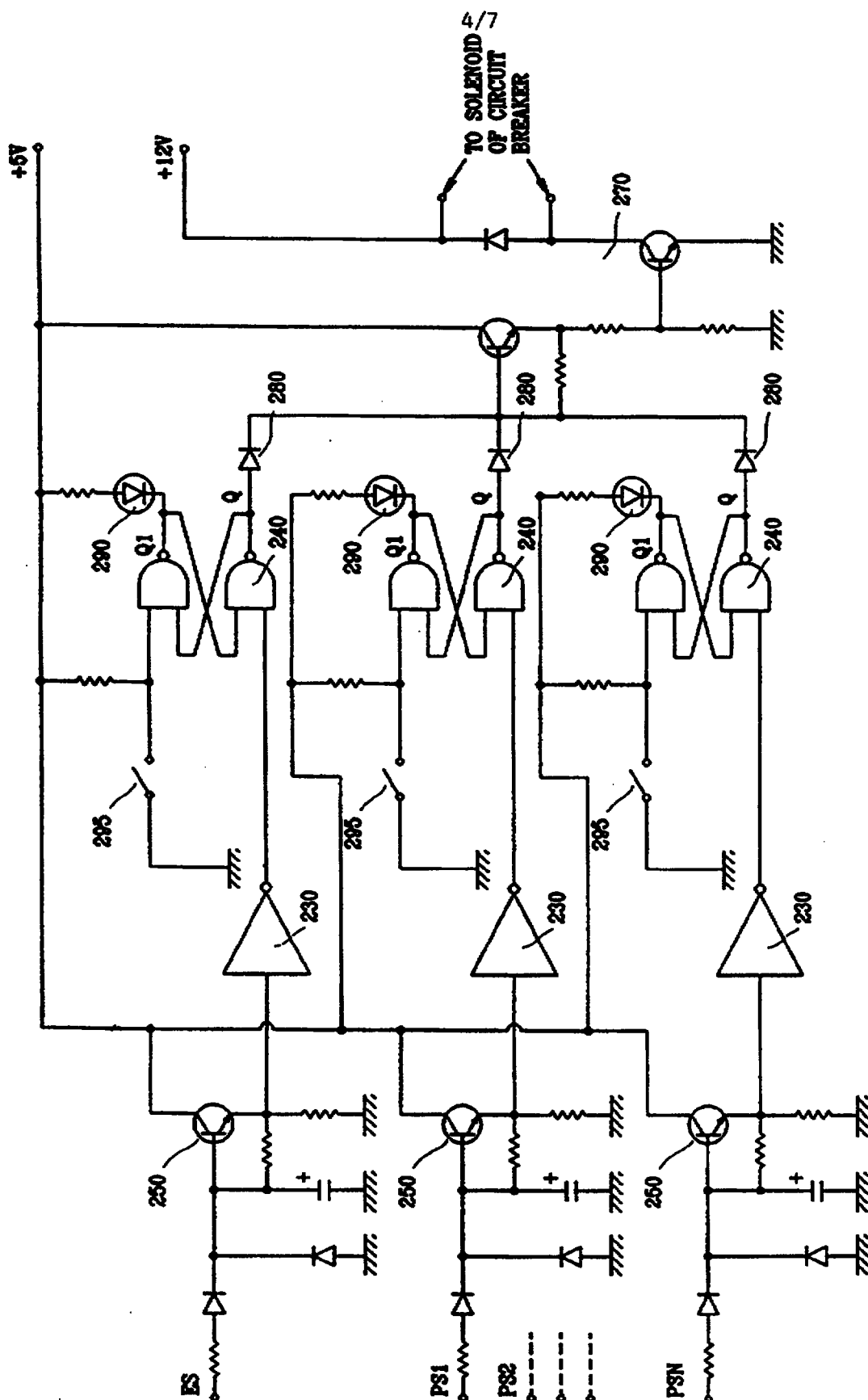


FIG. 3



**FIG. 4**

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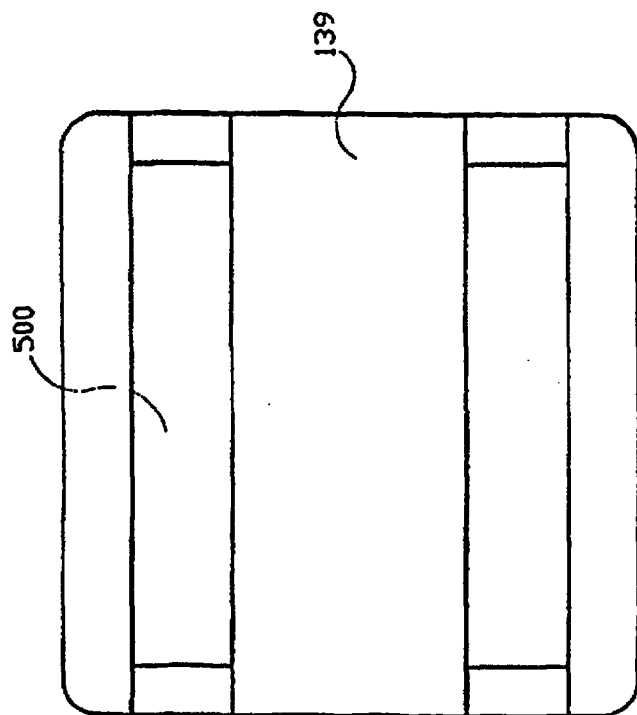


Fig. 5b

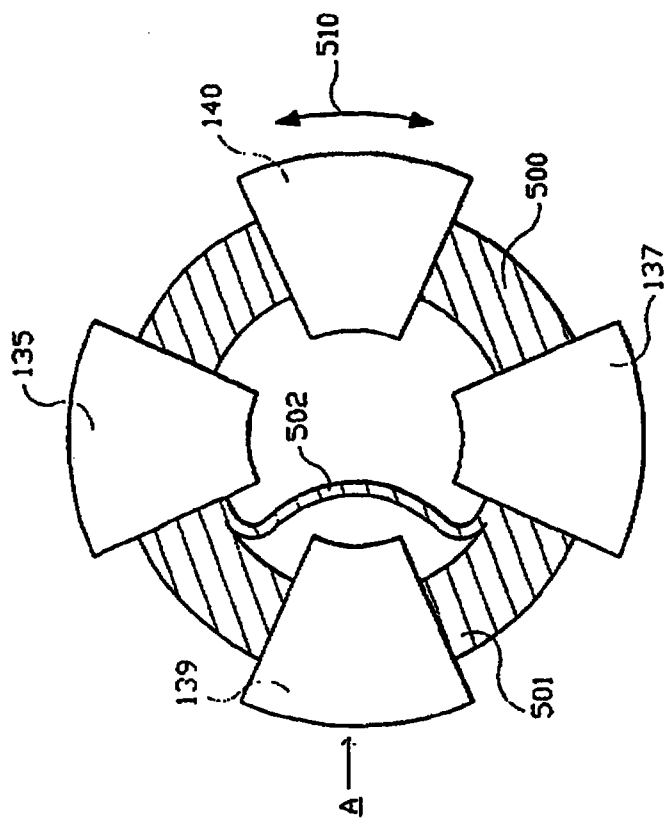


Fig. 5a

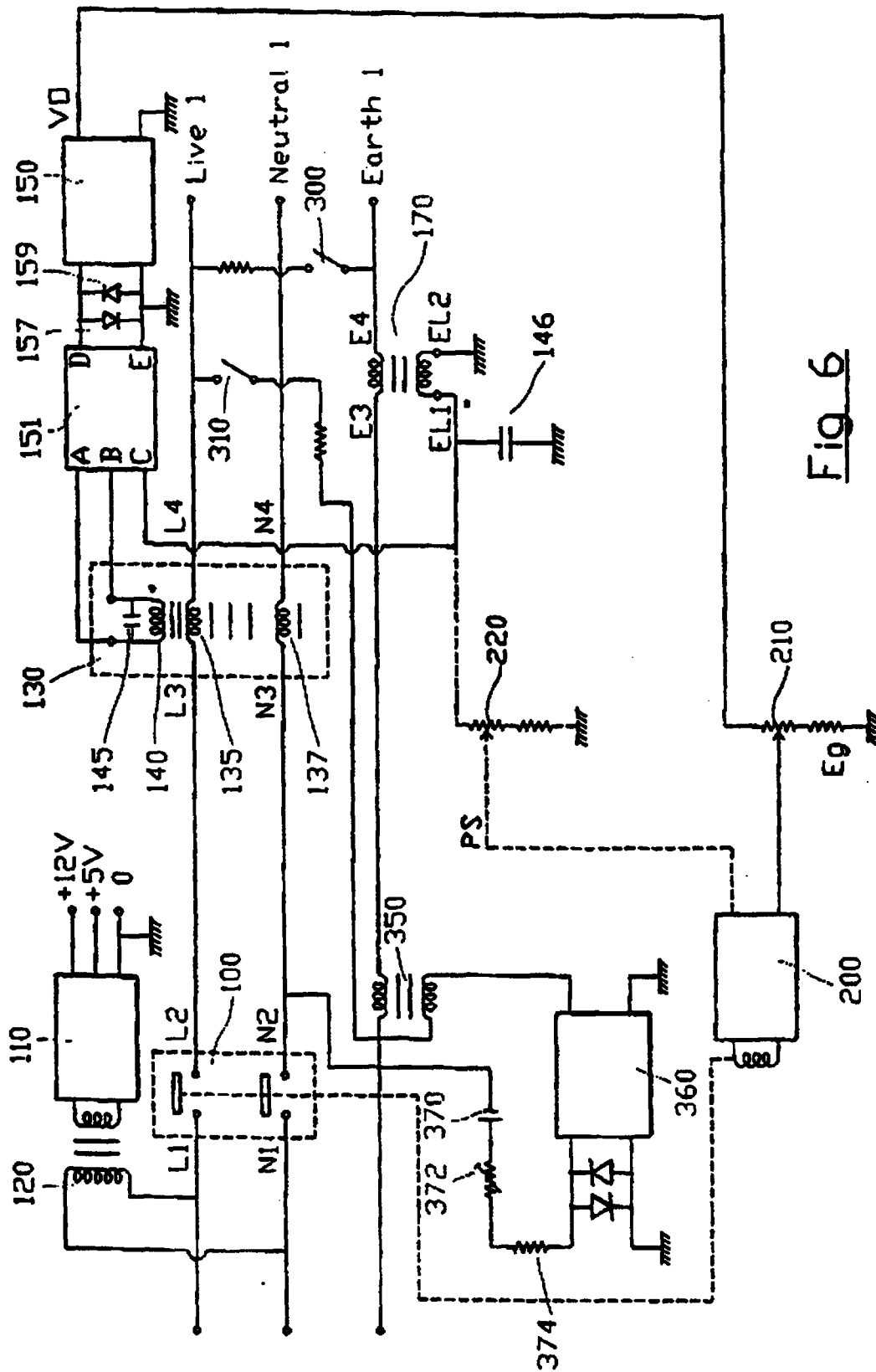


Fig. 6

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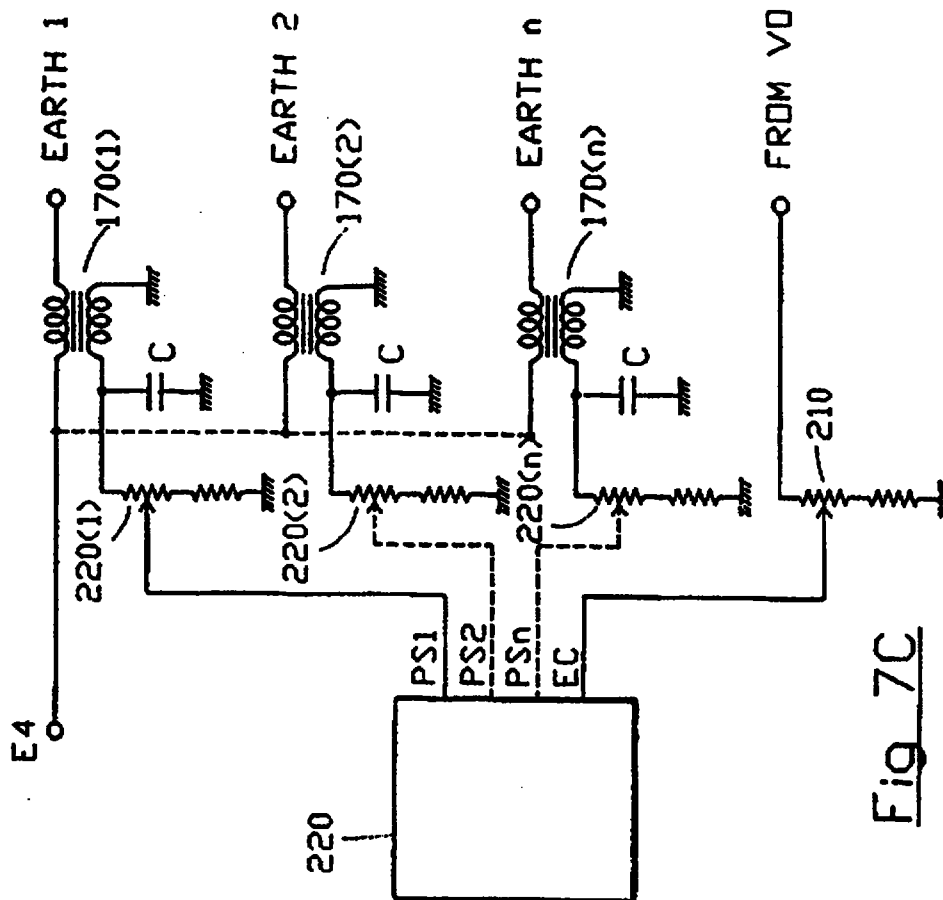


Fig 7C

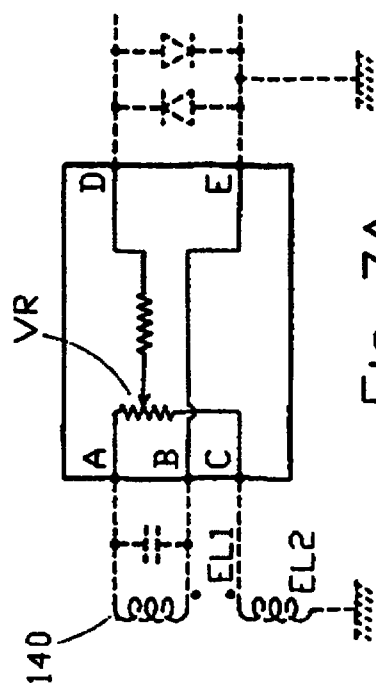


Fig 7A

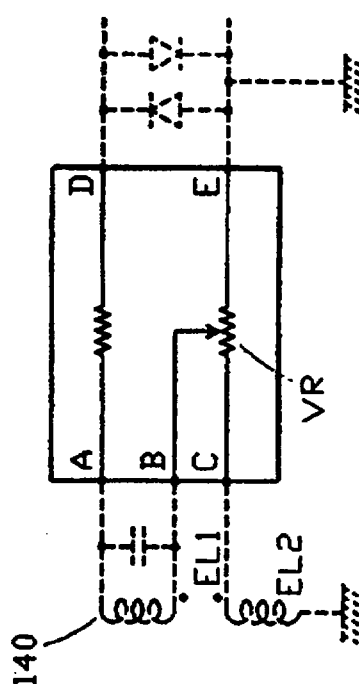


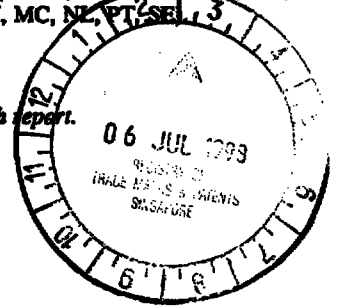
Fig 7B

PCT

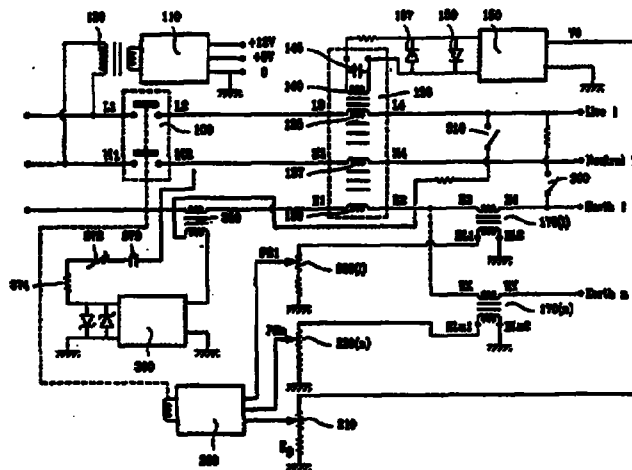
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## INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

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(54) Title: AN EARTH LEAKAGE DETECTOR CIRCUIT



## (57) Abstract

An earth leakage detection circuit is disclosed which includes a differential transformer (130) with primary coils (135/7/9) for sensing current flow in live, neutral and earth lines and a secondary coil (140) for sensing a difference between the current flowing in the live line and the sum of currents flowing in the neutral and earth lines and a trigger circuit (200) responsive to a difference signal from the secondary coil (140) for actuating a circuit breaker (100) if the difference exceeds a pre-determined level. Also disclosed is an earth leakage detection circuit comprising a plurality of earth leakage detectors (170) each for sensing for the level of earth leakage from a different source, the trigger circuit (200) being responsive to the detectors (170) for actuating the circuit breaker (100) if any one of the plurality of detectors (170) detects an earth leakage in excess of a pre-determined level. The secondary coil (140) of the differential transformer is also adjustable in position to obtain a null between primary coils and thus compensate for unequal physical dimensions/position of the primary coils.

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increasing number of electrical appliances in use in the homes and offices, the risk of the user receiving an electrical shock is higher. Such increase in the use of electrical appliances also mean a higher electrical leakage current is required in order to prevent frequent tripping of the circuit breaker even though there was no electrical earth fault in all of the appliances in use.

#### Summary of the Invention

It is the object of the present invention to overcome these disadvantages of the prior art described above by providing an apparatus to differentiate between the electrical earth leakage current of electrical appliances and the electrical leakage current passing through the human body.

According to the invention in the first aspect there is provided an earth leakage detector circuit comprising a differential current sensing transformer having a core, a plurality of primary coils connectable to live, neutral and earth lines and a secondary coil for sensing a difference between the current flowing in the live coil, and the sum of currents flowing in the neutral and earth coils, the core including a magnetic flux linkage bridging the earth coil; and means responsive to the transformer for actuating a circuit breaker if said difference exceeds a pre-determined level.

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plurality of primary coils and a secondary coil for sensing current imbalance between the primary coils and wherein the position of the coils relative to each other is/are adjustable.

The differential transformer of a third aspect of the invention may comprise a core upon which the primary and secondary coils are mounted, the coil or coils being slidable on the core.

The adjustability of the coil or coils allows them to be moved to a position to obtain a null between live and neutral coils and thus compensate for unequal physical dimensions/position of the primary coils.

According to the invention in a fourth aspect, there is provided an earth leakage detector circuit comprising a differential current sensing transformer having primary coils for sensing current flow in the live and neutral lines and a secondary coil; an earth leakage current detector transformer having a primary coil for sensing earth leakage current on the earth line and a secondary coil; means for comparing the current signals from the secondary coils and means responsive to the comparing means for activating a circuit breaker if said difference exceeds a predetermined level.

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Brief Description of the Drawings

An embodiment of the invention will now be described, by way of example, with reference to the accompanying drawings, in which:

Figure 1 is a block diagram of an embodiment of the circuit breaker with expandable earth leakage current detector transformers for electrical appliances.

Figure 2 is an earth leakage current flow circuit showing the difference between the electrical earth of an appliance and the earth/ground plane of a human body or living things.

Figure 3 is a band-pass voltage amplifier with tunable band-pass frequency to suit the frequency of the local electrical mains supply.

Figure 4 shows a trigger circuit with light-emitting

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indicated by the scope of the appended claims.

For example, the described embodiment combines means for sensing a leakage current on the earth ;lead so that any difference between live and the sum of neutral and earth currents will indicate a current leakage through another path which could be the human body, means of determining the sensitivity ratio between the electrical shock current and the earth leakage current of electrical appliances and, also, the provision of multiple earth leakage current detectors for different groups of appliances to facilitate (1) easy identification of faulty appliances or groups of appliances, (2) separate and adjustable leakage current setting (sensitivity) for different loads and (3) higher reliability by ensuring that the "trace" leakage currents from one appliance or a group of appliances do not sum up together with other groups of appliances. However, as will be apparent to one skilled in the art, these features are independent and may be used separately one from the other. Also, the arrangement shown in the drawings relate to a single-phase power supply circuit but the invention is also applicable to multi-phase power supply circuits, including three-phase power supply circuits.

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1. An earth leakage detector circuit comprising a differential current sensing transformer having a core, a plurality of primary coils connectable to live, neutral and earth lines and a secondary coil for sensing a difference between the current flowing in the live coil, and the sum of currents flowing in the neutral and earth coils, the core including a magnetic flux linkage bridging the earth coil; and means responsive to the transformer for actuating a circuit breaker if said difference exceeds a pre-determined level.

2. A circuit as claimed in claims 1 wherein the secondary coil and the primary coils are adjustable in position relative to each other..

3. A circuit as claimed in claim 2 wherein the primary and secondary coils are mounted on a yoke and the secondary coil is slidable on the yoke.

4. A circuit as claimed in any one of the preceding claims further comprising a plurality of earth leakage detectors, each for sensing the level of earth leakage from a different source, the detectors being connected to said responsive means for actuating the circuit breaker when a said earth leakage exceeds a pre-determined level.

5. A circuit as claimed in any one of the preceding claims further comprising voltage compensation means for compensating for voltage difference between the neutral and earth lines.

6. A circuit as claimed in claim 8 wherein said voltage compensation means comprises voltage sensing means, amplifying means for producing a compensation voltage and means for applying said compensation voltage to the earth line.

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7. A circuit as claimed in claim 6 wherein said applying means comprises a transformer.

8. An earth leakage detector circuit comprising a differential current sensing transformer having primary coils for sensing current flow in the live and neutral lines and a secondary coil; an earth leakage current detector transformer having a primary coil for sensing earth leakage current on the earth line, and a secondary coil; means for comparing the current signals from the secondary coils and means responsive to the comparing means for activating a circuit breaker if said difference exceeds a predetermined level.

9. The circuit is claimed in claim 8 wherein the secondary coils are connected in parallel and out-of-phase to each other or are connected in series and phase-to-phase.

10. A circuit is claimed in claim 8 or claim 9 further comprising an adjustment means for adjusting the relative magnitudes of the current signals.

11. An earth leakage detector circuit comprising a plurality of earth leakage detectors, each for sensing the level of earth leakage from a different source and means responsive to the detectors for actuating a circuit breaker if any one of said detectors detects an earth leakage in excess of a predetermined level.

12. A differential current transformer having a plurality of primary coils and a secondary coil for sensing current imbalance between the primary coils and wherein the position of the coils relative to each other is adjustable.

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increasing number of electrical appliances in use in the homes and offices, the risk of the user receiving an electrical shock is higher. Such increase in the use of electrical appliances also mean a higher electrical leakage current is required in order to prevent frequent tripping of the circuit breaker even though there was no electrical earth fault in all of the appliances in use.

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DATE : 30 JUN 1998

Plurality of primary coils and a secondary coil for sensing current imbalance between the primary coils and wherein the position of the coils relative to each other is/are adjustable.

The differential transformer of a third aspect of the invention may comprise a core upon which the primary and secondary coils are mounted, the coil or coils being slidable on the core.

The adjustability of the coil or coils allows them to be moved to a position to obtain a null between live and neutral coils and thus compensate for unequal physical dimensions/position of the primary coils.

According to the invention in a fourth aspect, there is provided an earth leakage detector circuit comprising a differential current sensing transformer having primary coils for sensing current flow in the live and neutral lines and an earth leakage current detector transformer having a primary coil for sensing earth leakage current on the earth line, a first secondary coil connected to the differential current sensing transformer and a second secondary coil connected to the earth leakage current detector transformer; means for comparing the current signals from the secondary coils and means responsive to the comparing means for activating a circuit breaker if said difference exceeds a predetermined level.

REPLACEMENT SHEET

DATE : 30 JUN 1956

Brief Description of the Drawings

An embodiment of the invention will now be described, by way of example, with reference to the accompanying drawings, in which:

Figure 1 is a block diagram of an embodiment of the circuit breaker with expandable earth leakage current detector transformers for electrical appliances.

Figure 2 is an earth leakage current flow circuit showing the difference between the electrical earth of an appliance and the earth/ground plane of a human body or living things.

Figure 3 is a band-pass voltage amplifier with tunable band-pass frequency to suit the frequency of the local electrical mains supply.

Figure 4 shows a trigger circuit with light-emitting

indicated by the scope of the appended claims.

For example, the described embodiment combines means for sensing a leakage current on the earth ;lead so that any difference between live and the sum of neutral and earth currents will indicate a current leakage through another path which could be the human body, means of determining the sensitivity ratio between the electrical shock current and the earth leakage current of electrical appliances and, also, the provision of multiple earth leakage current detectors for different groups of appliances to facilitate (1) easy identification of faulty appliances or groups of appliances, (2) separate and adjustable leakage current setting (sensitivity) for different loads and (3) higher reliability by ensuring that the "trace" leakage currents from one appliance or a group of appliances do not sum up together with other groups of appliances. However, as will be apparent to one skilled in the art, these features are independent and may be used separately one from the other. Also, the arrangement shown in the drawings relate to a single-phase power supply circuit but the invention is also applicable to multi-phase power supply circuits, including three-phase power supply circuits.



CLAIMS

1. An earth leakage detector circuit comprising a differential current sensing transformer having a core, a plurality of primary coils connectable to live, neutral and earth lines and a secondary coil for sensing a difference between the current flowing in the live coil, and the sum of currents flowing in the neutral and earth coils, the core including a magnetic flux linkage bridging the earth coil; and means responsive to the transformer for actuating a circuit breaker if said difference exceeds a pre-determined level.
2. A circuit as claimed in claims 1 wherein the secondary coil and the primary coils are adjustable in position relative to each other.
3. A circuit as claimed in claim 2 wherein the primary and secondary coils are mounted on a yoke and the secondary coil is slidable on the yoke.
4. A circuit as claimed in any one of the preceding claims further comprising a plurality of earth leakage detectors, each for sensing the level of earth leakage from a different source, the detectors being connected to said responsive means for actuating the circuit breaker when a said earth leakage exceeds a pre-determined level.
5. A circuit as claimed in any one of the preceding claims further comprising voltage compensation means for compensating for voltage difference between the neutral and earth lines.
6. A circuit as claimed in claim 8 wherein said voltage compensation means comprises voltage sensing means, amplifying means for producing a compensation voltage and means for applying said compensation voltage to the earth line.



7. A circuit as claimed in claim 6 wherein said applying means comprises a transformer.

8. An earth leakage detector circuit comprising a differential current sensing transformer having primary coils for sensing current flow in the live and neutral lines and an earth leakage current detector transformer having a primary coil for sensing earth leakage current on the earth line, a first secondary coil connected to the differential current sensing transformer and a second secondary coil connected to the earth leakage current detector transformer; means for comparing the current signals from the secondary coils and means responsive to the comparing means for activating a circuit breaker if said difference exceeds a predetermined level.

9. The circuit is claimed in claim 8 wherein the secondary coils are connected in parallel and out-of-phase to each other or are connected in series and phase-to-phase.

10. A circuit is claimed in claim 8 or claim 9 further comprising an adjustment means for adjusting the relative magnitudes of the current signals.

11. An earth leakage detector circuit comprising a plurality of earth leakage detectors, each for sensing the level of earth leakage from a different source and means responsive to the detectors for actuating a circuit breaker if any one of said detectors detects an earth leakage in excess of a pre-determined level.

12. A differential current transformer having a plurality of primary coils and a second coil for sensing current imbalance between the primary coils and wherein the position of the coils relative to each other is/are adjustable.

REPLACEMENT SHEET

DATE: 30 JUN 1998