(12) UK Patent Application (19) GB (11) 2 109 163 A

(21) Application No **8133223**
(22) Date of filing **4 Nov 1981**
(43) Application published **25 May 1983**
(51) **INT CL³** **H01H 83/14**
(52) Domestic classification **H1N** 588 623 700 701 753 833 AX **U1S** 2083 2087 H1N
(56) Documents cited **GB A 2071915** **GB 1346802**
(58) Field of search **H1N**

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(54) Circuit breakers

(57) An earth leakage circuit breaker provides for manual circuit breaking under normal conditions and for automatic circuit breaking both in the event of earth leakage and electrical overload and comprises a detector transformer 12 to monitor the electrical throughput to an electrical load to be protected, a signal processing circuit 22 connected to a secondary winding 23 of the detector transformer 12 and responsive to an out-of-balance condition in the electrical conductors monitored by the transformer to generate an output signal. The signal processing circuit comprises a circuit board 40 formed of alumina, providing a substrate for the connector and resistor elements which are formed of electrically conductive film printed thereon. A trip coil 24 is connected to circuit 22 and is responsive to the output signal of the circuit to cause a pair of switch contacts 28,30 to break the circuit in the electrical conductors monitored by the detector transformer.

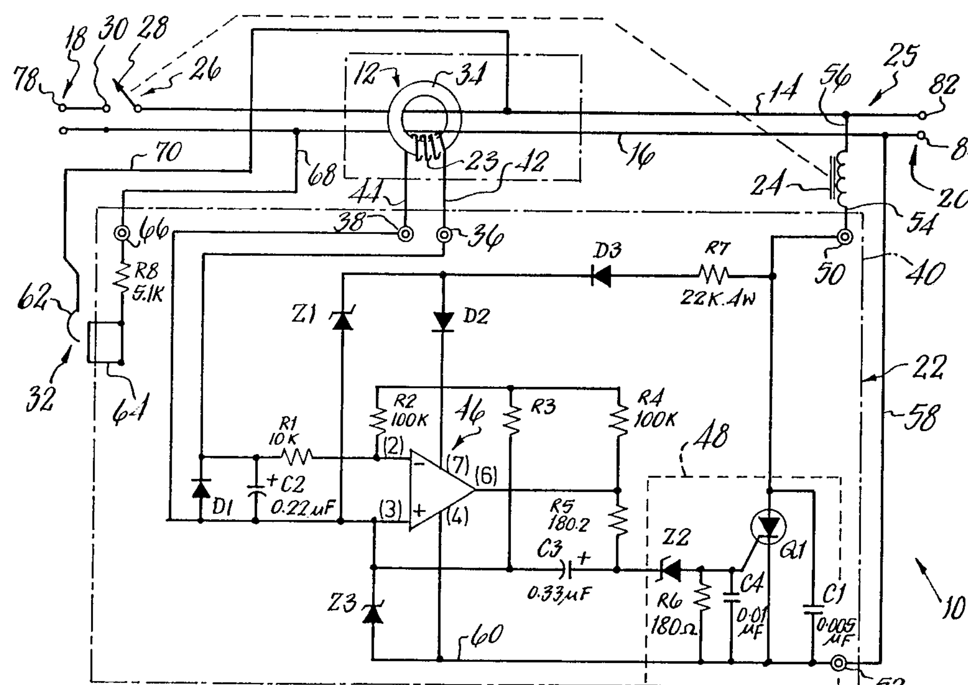

FIG.1

The drawing(s) originally filed was/were informal and the print here reproduced is taken from a later filed formal copy.

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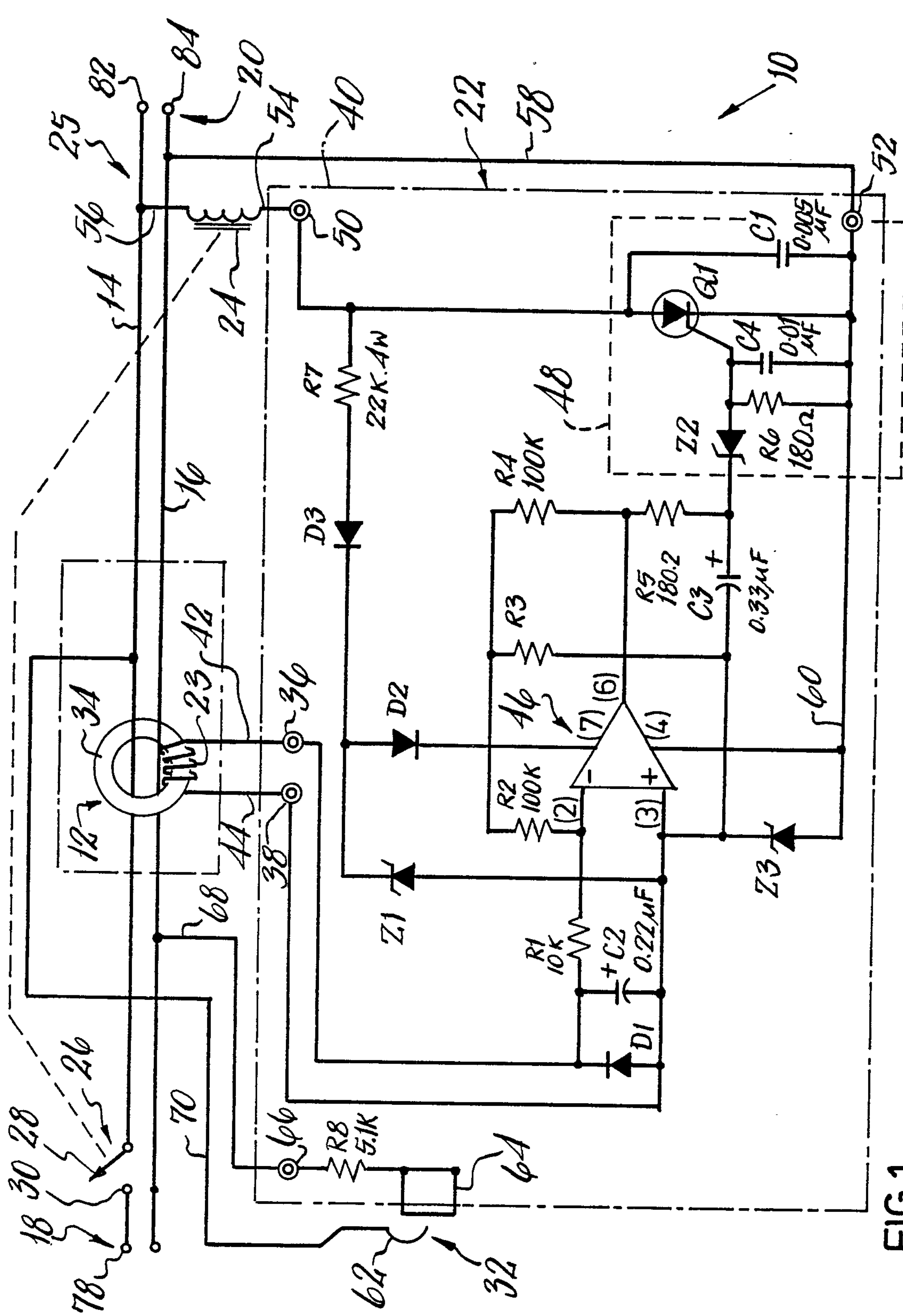


FIG.1

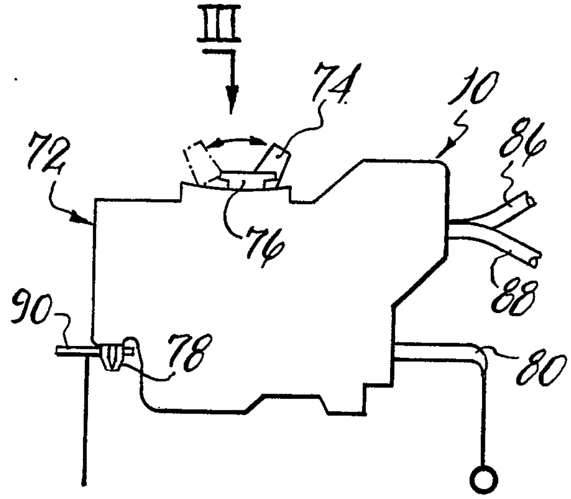


FIG. 2

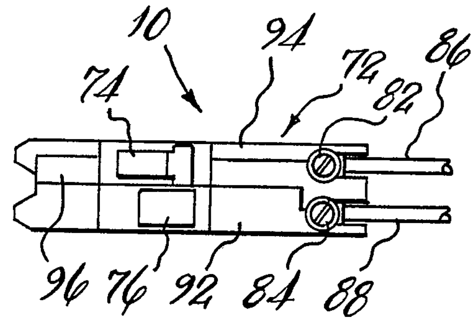


FIG.3

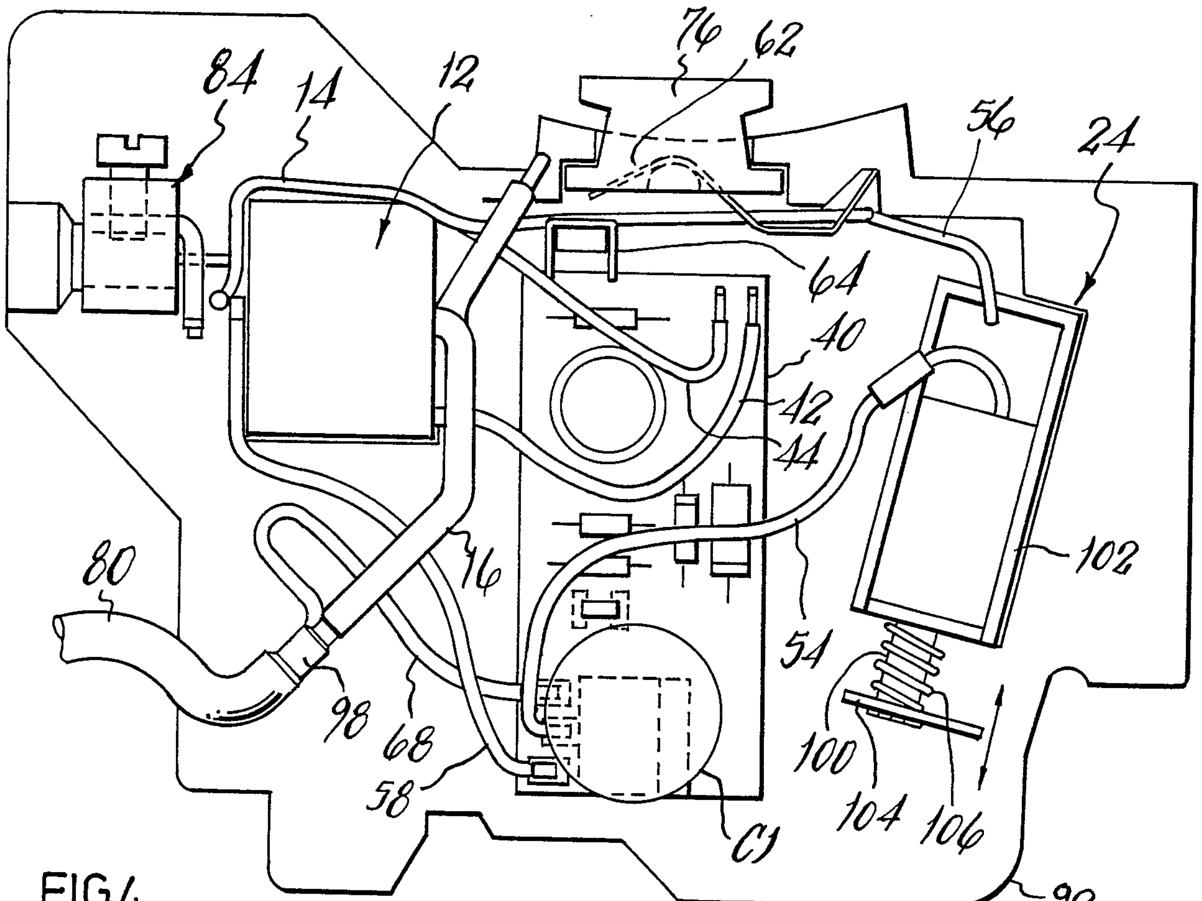


FIG.4

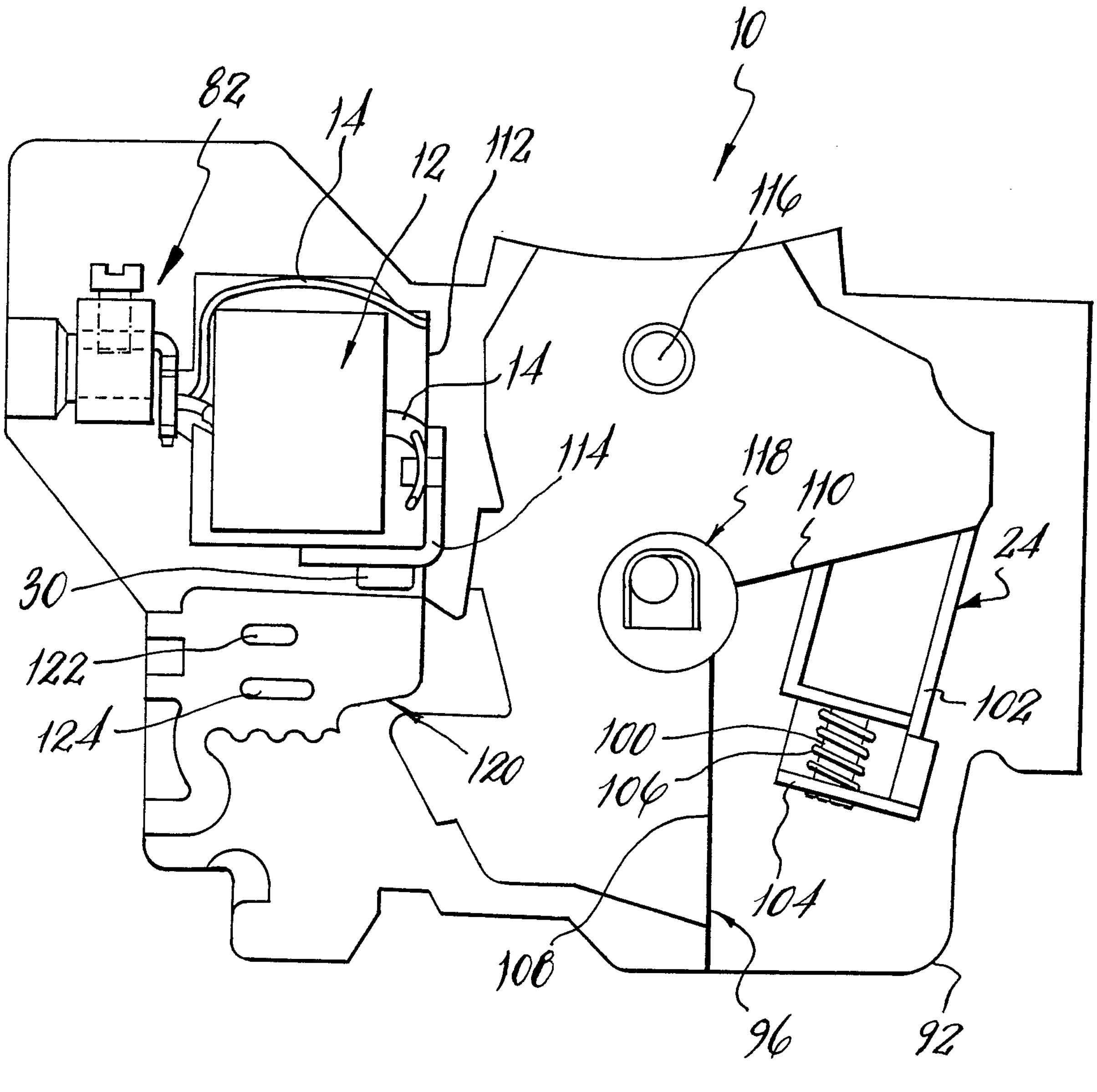
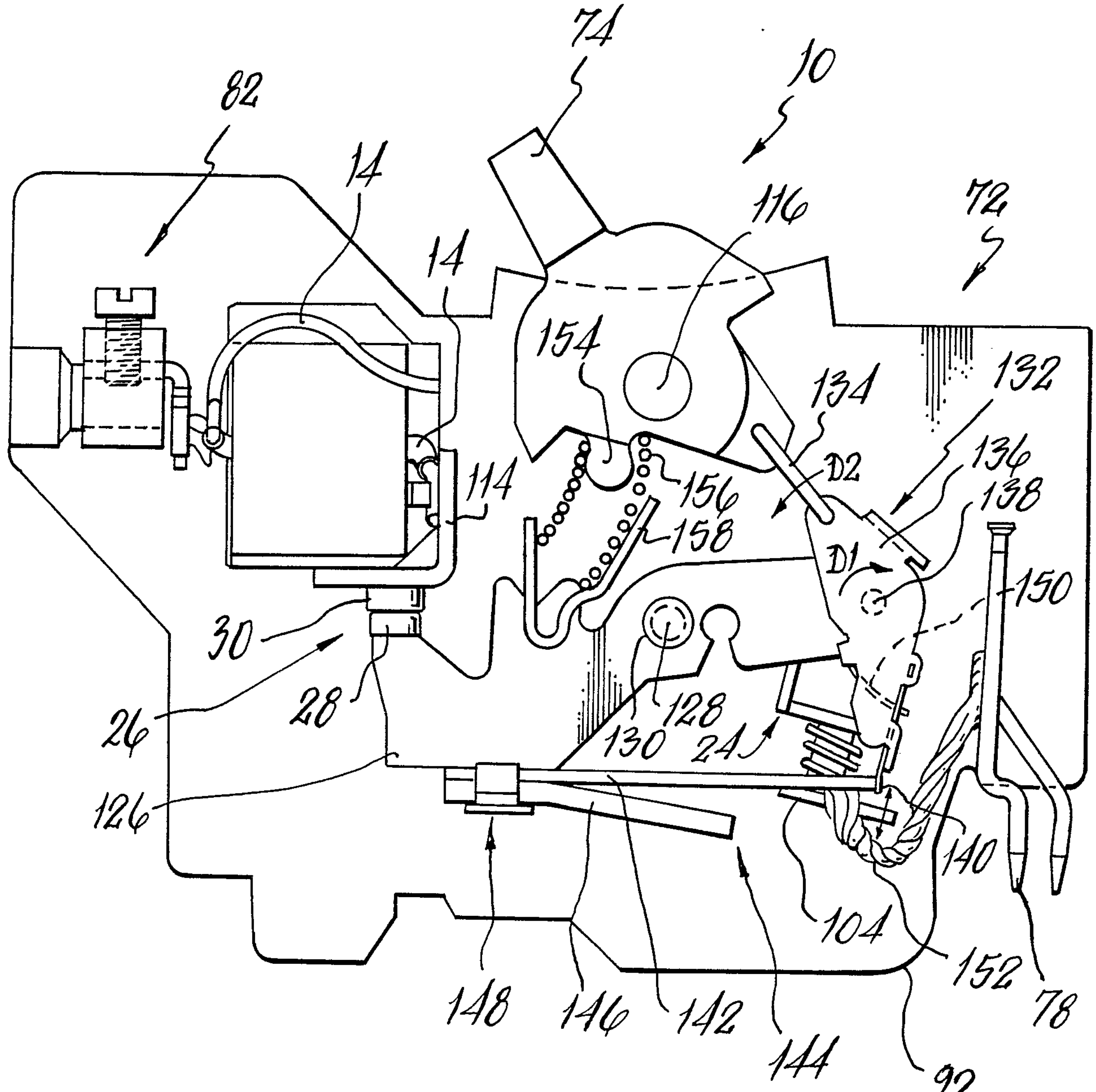

10
82
14
12
112
116
14
114
118
110
24
30
122
124
120
102
100
106
104
108
96
92

FIG.5



74
10
82
14
14
116
72
154
134
132
136
138
D2
156
114
158
D1
150
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26
28
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78
148
146
142
144
92

FIG.6

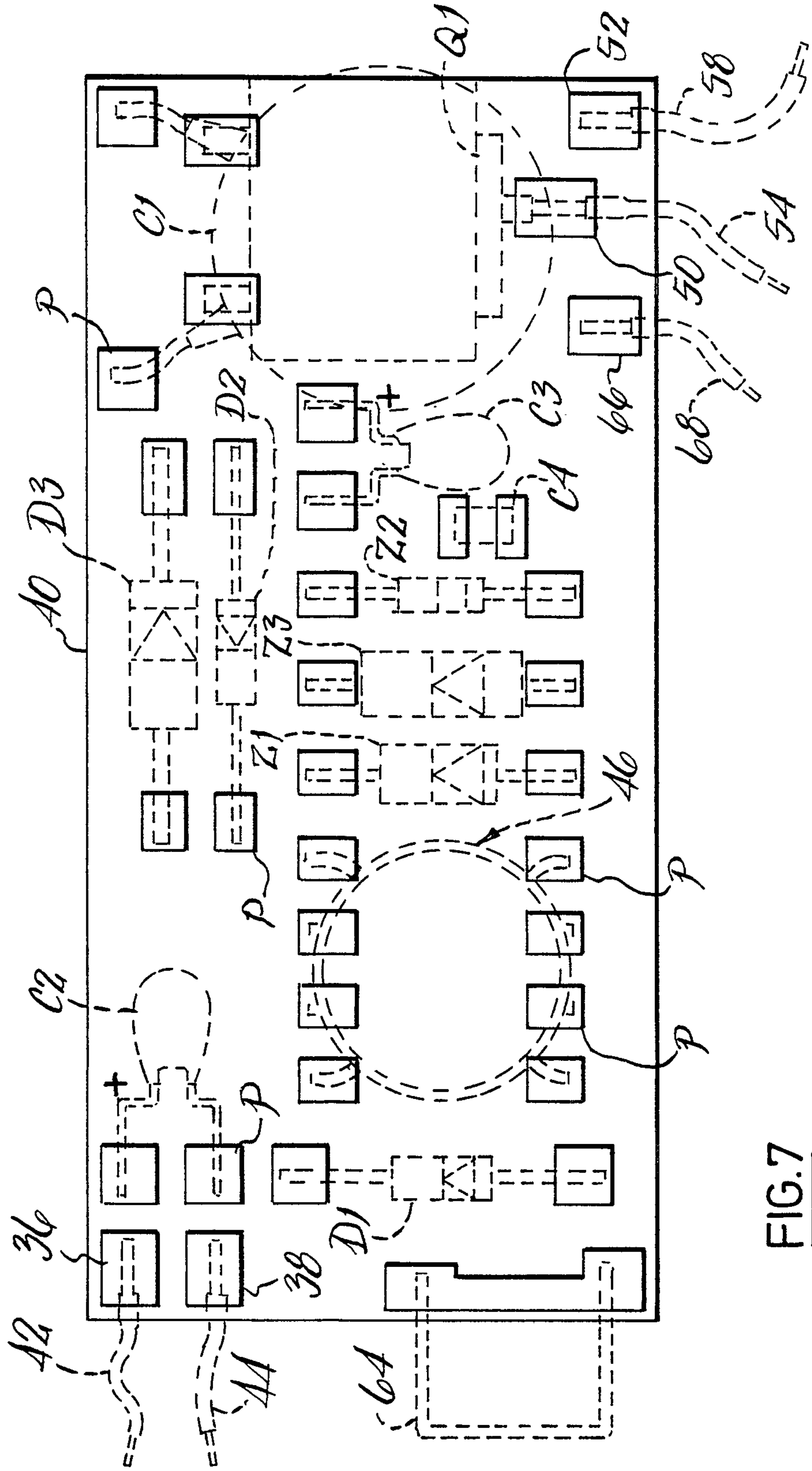

FIG.7

SPECIFICATION

Circuit breakers

This invention relates to circuit breakers, and in particular to earth leakage circuit breakers. An example of a type of earth leakage circuit breaker to which the invention particularly (but not exclusively) relates is a so-called miniature earth leakage and overload circuit breaker of the moulded case type, which provides for manual circuit breaking under normal conditions and for automatic breaking of the circuit both in the event of earth leakage and electrical overload. This device is intended primarily for the protection of industrial, commerical and domestic electrical installations. The circuit breaker components are mounted in a sealed moulded casing of plastics or similar material which is adapted to be mounted on a distribution panel alongside other circuit breakers, and the mechanism has non-adjustable operating characteristics for use on voltages up to 415 volts, currents to 100 amps, with short circuit capacity of 9000 amps.

One of the problems which arises in the design and manufacture of miniature circuit breakers of the kind mentioned in the last preceding paragraph is that of space available for the necessary components. The maximum size of the whole circuit breaker assembly including the moulded case is dictated by accepted standards in the country concerned and for a circuit breaker to be commercially acceptable it must be of a size so as to be interchangeable with existing equipment. Therefore the space available for the circuit breaker components is strictly limited.

A further factor in the design of earth leakage circuit breakers is the requirement for heat resistance. This requirement arises particularly under overload conditions. The circuit breaker must operate reliably under a wide range of ambient temperatures while maintaining an acceptably constant sensitivity to detected earth leakages.

Yet another design criterion for each leakage circuit breakers is the requirement for adequate sensitivity to the relatively small earth leakage currents which represent danger levels for operators of electrical equipment and the associated requirement for a relatively large power output whereby the circuit breaker contacts can be rapidly disengaged when a predetermined earth leakage has been detected.

In addition, there are of course the usual requirements, particularly for the domestic market, for a minimum manufacturing cost and a long working life with a high degree of reliability.

Existing and previously proposed earth leakage circuit breakers utilizing detector transformers and associated relays are in some cases very large and cumbersome, and in other cases though of a generally acceptable size nevertheless do not meet present day requirements so far as overload and short circuit capacity are concerned. Moreover, there has hitherto been insufficient space available within the body of moulded case circuit breakers for the provision of improved circuit breaker contact assemblies.

An object of the present invention is to provide an improved earth leakage circuit breaker, and a method of manufacturing the same, offering improvements in relation to some at least of the factors discussed above. According to one aspect of the present invention there is provided an earth leakage circuit breaker comprising a detector transformer to monitor the current throughput to an electrical load to be protected, a signal processing circuit connected to a secondary winding of said detector transformer and responsive to an out-of balance condition in the electrical conductors monitored by said transformer to generate an output signal, said signal processing circuit comprising an insulating substrate carrying an electrically conductive film providing both electrical connectors and resistors of the signal processing circuit, and a solenoid connected to said signal processing circuit and responsive to the output signal of said signal processing circuit to cause a pair of switch contacts to break the circuit in the electrical conductors monitored by said detector transformer.

According to a particular aspect of the invention there is provided an earth leakage circuit breaker as defined in the last preceding paragraph and mounted in a casing which is adapted to be mounted on a distribution panel with other circuit breakers. Preferably the casing is divided into two compartments by a divider, the switch contacts and associated mechanical components being on one side of the divider and at least the major components of said signal processing circuit being located on the other side of the divider.

Arc plates may be provided in the casing in association with said switch to increase the short circuit breaking capacity of the circuit breaker. Modification of the form of the casing may be required to accommodate the arc plates.

Preferably the signal processing circuit is formed by printing said connectors and resistors on said insulating substrate using an ink producing an electrically conductive surface film on the substrate. Said substrate may comprise alumina or other ceramic material. The resistors are preferably trimmed to predetermined electrical resistance values during manufacture and the insulating substrate and printed conductor and resistor elements is coated with a protective film. Other components of the signal processing circuit, such as capacitors, diodes and integrated circuit amplifiers, may be secured to said conductors by soldering printed conductor pads on said insulating substrate.

The signal processing circuit may comprise a voltage dropping resistor for current supply purposes and which may require to dissipate heat at a significant rate, and preferably such voltage dropping resistor is printed on said substrate in at least two spaced portions.

Preferably said solenoid is arranged to trip a switch release mechanism to disengage said switch contacts. Said switch release mechanism preferably also includes means responsive to electrical overload to trip the switch release mechanism. Said means may comprise a heat responsive bi-metallic element and/or an electro-magnetic member. Manually operable means such as a switch lever may be provided to trip said switch release mechanism.

According to another aspect of the invention there is provided a method of manufacturing an earth leakage circuit breaker as defined in the last preceding paragraphs including the step of depositing a film on said insulating substrate to form said conductors and resistors, and the step of trimming said resistors to predetermined values.

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

Figure 1 shows the circuit diagram of an earth leakage circuit breaker assembly;

Figure 2 shows a side elevation view of the assembly of the earth leakage circuit breaker in a moulded plastics case;

Figure 3 shows a plan view of the circuit breaker of Figure 2, the direction of viewing being indicated by arrow III in Figure 2;

Figure 4 shows, on a larger scale, the earth leakage circuit breaker of Figure 2, in side elevation and viewed from the opposite side, with one side and the central dividing panel removed so as to show the general arrangement of a detector transformer, a hybrid circuit board for a signal processing circuit, a solenoid switch and associated components;

Figure 5 shows, in a view similar to that of Figure 4, the earth leakage circuit breaker of Figure 4 after having superimposed on it a central panel or partition of the plastics case;

Figure 6 shows, in a view similar to that of Figures 4 and 5, the assembly of Figure 5 with the addition of a manually operable switch, and its associated movable switch contact assembly and associated components; and

Figure 7 shows, on a larger scale the hybrid circuit board of the signal processing circuit of Figure 4, including the capacitors and diodes, an integrated circuit amplifier and other components.

As shown in Figure 1, an earth leakage circuit breaker 10 comprises a detector transformer 12 to monitor the electrical current throughput of conductors 14 and 16 which transmit electrical power from an electrical power supply 18 to an electrical load 20 to be protected.

A signal processing circuit 22 is connected to a secondary winding 23 of transformer 12 and is responsive to the voltage generated in secondary winding 23 by an out-of-balance condition of the electrical current carried by conductors 14 and 16 (due to earth leakage) to generate an output signal for operation of a solenoid switch.

The solenoid switch comprises a solenoid 24 connected between the output of signal processing circuit 22 and the line voltage conductor 14 of the power transmission line 25 formed by conductors 14 and 16. The solenoid switch further comprises a switch assembly 26 comprising a moving contact 28 and a fixed contact 30 provided in line voltage conductor 14 to break and re-make the power transmission line 25. Contacts 26 and 28 are also manually operable by means of a switch lever, and the switch assembly also includes electrical overload sensing means which can likewise open the contacts.

In operation, earth leakage from power transmission line 25 results in the generation of a voltage in transformer 12 which is monitored by signal processing circuit 22 and amplified. When the output voltage of transformer 12 reaches a predetermined value, a triggering circuit energises solenoid 24 and causes switch assembly 26 to break the circuit. A test switch assembly 32 is provided to enable the operator to periodically manually check that the earth leakage circuit breaker is in proper working condition. The circuit is likewise broken automatically when an electrical overload is sensed, and can be manually broken at any time by means of the switch lever.

Circuit breaker 10 has a voltage rating of up to 415 volts, a current rating of 30 amps, and a short circuit capacity of 2000 amps.

The structure and circuit of earth leakage circuit breaker 10 will now be described in more detail with reference to Figure 1.

Detector transformer 12 comprises an annular core 34 of mu metal through which conductors 14 and 16 of power transmission line 25 pass. Secondary winding 23 of the transformer comprises approximately eighteen hundred turns and is directly connected to connector pads 36, 38 on a circuit board 40 formed of a ceramic material such as alumina. The connector wires from secondary winding 23 to connector pads 36, 38 are designated 42 and 44.

Signal processing circuit 22 comprises an amplifier 46 of the monolithic integrated circuit kind which amplifies the output of secondary winding 23 of detector transformer 10 and applies this voltage to a triggering circuit designated as a whole by reference numeral 48. Circuit 48 is triggered by a predetermind voltage from amplifier 46 to energise solenoid 24 and open switch contacts 28, 30.

The voltage generated across secondary winding 23 is applied through input resistor R1 (10K ohms) to the input connections (2) and (3) of amplifier 46. The gain of the amplifier is controlled by resistors R2 and R4 (both one hundred K ohms). The amplifier has a gain of twenty times and is of the closed loop kind and provided with feedback.

A sensitivity control resistor R3 is connected across the amplifier input connections (2) and (3). The value of R3 may be between 4.87 K ohms for the maximum sensitivity normally required in such circuits to 15.8 K ohms for a reduced sensitivity.

The power supply for processing circuit 22 is derived from power transmission line 25 through connector pads 50, 52 on circuit board 40. Pad 50 is connected by a connector wire 54 to solenoid 24 and hence through connector wire 56 to line voltage conductor 14. Connector pad 52 is connected by a connector wire 58 to conductor 16 of the power transmission line.

Biasing connection (7) of amplifier 46 is connected to connector pad 50 through diodes D2 and D3 and dropper resistor R7 (22K ohms). The latter resistor is required to dissipate heat at a rate approaching 4 watts, and the form and layout of the resistor as printed on circuit board 40 is discussed below.

Biasing connection (4) of amplifier 46 is directly connected to the positive line 60 of circuit 22.

The output of amplifier 46 passes from output connection (6) via a limiting resistor R5 (180 ohms) to triggering circuit 48. The triggering circuit comprises zener diode Z2, thyristor Q1 and associated components R6 (180 ohms), C4 (0.01 microfarads) and C1 (0.005 microfarads). Components R6 and C4 limit the current supplied to thyristor Q1.

In use, when no earth leakage occurs in load 20, no potential difference is generated across winding 23 of transformer 12. When earth leakage occurs, an unbalance condition exists in conductors 14 and 16 which causes the application of an e.m.f. to amplifier 46 through the input network comprising R1, diode D1 and capacitor C2 (0.22 microfarads). Zener diode Z1 protects amplifier 46 against input overload.

The output of the amplifier passes via resistor R5 and zener diode Z2, and when it reaches a predetermined e.m.f., triggers thyristor Q1 to cause switch assembly 26 to break the circuit in power transmission line 25.

Test switch assembly 32 comprises a manually-operable springy moving contact 62 and an associated fixed contact 64. The latter contact is connected through resistor R8 (5.1K ohms), connector pad 66 and connector wire 68 to conductor 16 of power transmission line 25. Moving contact 62 is connected by a connector wire 70 to conductor 14 of power transmission line 25. Wires 68 and 70 are connected to their respective conductors on opposite sides of transformer 12. In consequence, manual engagement of contacts 62 and 64 causes a current to flow through R8 setting up an unbalanced condition in transformer 12 and hence generating an e.m.f. in secondary winding 23 whereby thyristor Q1 is triggered in the same manner as described above, whereby switch assembly 26 is opened. Thus test switch assembly 32 enables manual verification of the correct operation of the whole earth leakage circuit breaker 10.

Figures 2 to 6 show the physical embodiment of earth leakage circuit breaker 10 corresponding to the circuit diagram of Figure 1.

As shown in Figures 2 and 3, circuit breaker 10 comprises a moulded case 72 of plastics material with a manually operable switch lever 74, a test switch button 76, a line input voltage connector 78, a neutral input voltage connector wire 80, and power output connectors 82 and 84 which are connected by wires 86 and 88 to load 20. Connector 78 is a push fit into a line bus bar 90 on the distribution panel on which circuit breaker 10 is mounted, and neutral wire 80 is secured by a connector (not shown) on the same panel.

As can be seen in Figure 3, moulded case 72 is formed in three parts: first and second side panels 92 and 94 respectively, and a central dividing panel 96.

Figures 4, 5 and 6 show the progressive assembly of panels 92, 94 and 96 one on to the other, and their associated components.

As shown in Figure 4, first side panel 92 has mounted thereon connector 84, detector transformer 12, circuit board 40 and its associated components forming signal processing circuit 22, test switch button 76, and solenoid 24. These components are mounted on side panel 92 in recesses moulded therein. The conductors interconnecting the components are shown in Figure 4 and identified by the same reference numerals as in Figure 1. Neutral input voltage wire 80 is soldered at 98 to neutral conductor 16 of power transmission line 25, which passes through the centre of core 34 of transformer 12.

Solenoid 24 has an output rod 100 movably mounted in the casing 102 of the solenoid for in and out movement under the control of the solenoid coil. An actuator plate 104 is provided at the end of rod 100 to trip switch assembly 26 in a manner to be described. A coiled return spring 106 acts between the lower end of casing 102 and plate 104.

Figure 5 shows the next stage in the assembly of earth leakage circuit breaker 10. Dividing panel 96 is mounted over the assembly seen in Figure 4. The dividing panel has a cut out region defined by edges 108 and 110 which leave solenoid 24 exposed for switch actuation purposes.

Likewise, a cut out 112 is provided in panel 96 to receive transformer 12. Alongside the transformer, output connector 82 is mounted in a recess moulded in the panel therefor.

Fixed contact 30 of switch assembly 26 is mounted on an L-shaped bracket 114 bonded to dividing panel 96 and electrically connected to conductor 14.

Panel 96 provides a boss 116 to form a pivot for switch lever 74. Directly below boss 116 there is provided a recess 118 to receive a pivot spring (see Figure 6) about which the movable contact 28 of switch assembly 26 is pivotable.

Dividing panel 96 has a recessed switch contact zone 120 in which there are moulded raised portions 122 and 124.

Figure 6 shows the next stage in the assembly of the earth leakage contact breaker 10, in which the further components to be mounted on dividing panel 96 have been mounted in position.

In Figure 6, the details of the mouldings of panels 92 and 96 have mostly been omitted for reasons of clarity, so as to show the structure and arrangement of the switch gear and associated components.

Moving contact 28 of switch assembly 26 is mounted at one end of an arm 126 which is mounted for pivotal movement about an axis 128 by means of a pivot spring 130 which extends through arm 126 and enters recess 118.

A toggle assembly 132 is provided at the other end of switch arm 126 and pivotally connected to switch lever arm 74 by a U-shaped link member 134 for switch actuation purposes.

Toggle assembly 132 comprises a switch release member 136 mounted on switch arm 126 for pivotal movement about an axis 138. The switch release member has a sliding keeper 140 mounted on it for engagement with a bi-metallic arm 142 of an electrical overload release assembly 144 having a second arm 146 of carbon steel which forms an electromagnetic member or rigid armature, to facilitate release under electrical overload. Arms 142, 146 are rigidly secured by a fastening 148 to switch arm 126.

Keeper 140 is slidable lengthwise of switch release member 136 and biased outwards by a spring 150 to a position in which it engages the end of arm 142.

In the region of the same end of arm 142, a heavy copper conductor 152 connects arm 142 to line input voltage connector 78. The latter connector is located in position in a recess (not shown) moulded into plastic case 72.

Switch lever arm 74 is itself a plastic moulding and thus insulates the operator from the line voltage carried by arm 126 and associated metallic components. A boss 154 moulded in the lever arm receives one end of a spring 156 which acts between the lever arm 74 and the switch arm 126 carrying moving contact 28. The lower end of spring 156 is received in a generally V-shaped mounting member 158 which itself lodges in a complementary-shaped recess in arm 126.

In use, the switch assembly has the configuration shown in Figure 6 in its "on" position. Manual movement of switch lever 74 in a clockwise direction (as seen in Figure 6) to its "off" position causes the switch lever to move toggle assembly 132 to its released position, the directions of angular movement of switch release member 136 and link member 134 being indicated in Figure 6 by arrows D1 and D2 respectively. At the same time as the toggle mechanism is released, spring 156 rapidly moves arm 126 anticlockwise about axis 128, thereby moving switch contact 28 away from contact 30 and breaking the circuit.

In the case of automatic operation of the switch assembly to break the circuit when an earth leakage is detected, the switch lever 74 is in the "on" position seen in Figure 6 and contacts 28 and 30 are initially in the closed position as shown, and toggle mechanism 132 is likewise in the position shown in Figure 6.

When solenoid 24 is energised by detection of an earth leakage, actuator plate 104 is moved upwards against the action of spring 106 and engages a projection (not shown) on keeper 140 thereby sliding the keeper upwards and disengaging it from the end of arm 142 and allowing the switch release member 136 to move anticlockwise about axis 138 to its released position. Such disengagement of keeper 140 from arm 142 causes the assembly of arm 126, release member 136 and arm 142 no longer to be rigid, and spring 156 is able freely to pivot arm 126 anticlockwise about axis 128, thereby moving contact 28 away from contact 30.

In the case of automatic circuit breaking under electrical overload, the end of bi-metallic arm 142 is likewise disengaged from keeper 140 by virtue of heating of the arm (at 135% of normal current rating) and supplemented (at 10 times normal current rating) by electro-magnetic attraction to arm 146, thereby breaking the circuit.

Figure 7 shows the layout of circuit board 40 and its associated components and connectors. The circuit board is formed of a ceramic meterail, such as alumina, providing a substrate for the connector and resistor elements of signal processing circuit 22 which are printed thereon in an ink which, in a subsequent firing process, becomes electrically conductive.

The resistors are initially printed to approximately the values indicated above for resistors R1 to R8 and are then trimmed by a computer-controlled laser to the exact values required. The values of resistors R1, R2 and R4 determine the gain of amplifier 46 and are critical to the correct operation of circuit 22. For this purpose, likewise, resistors R2 and R4 are exactly matched during manufacture. The hybrid circuit board is then coated with a protective film and the capacitors, diodes, integrated circuit and thyristor are then soldered to printed conductor pads formed on the circuit board.

Figure 7, is of course, a greatly enlarged representation of hybrid circuit board 40 and the actual size of the latter is 43mm by 20mm (excluding fixed contact 64).

Despite the small size of hybrid circuit board 40 there is still adequate room for the resistor and conductor elements to be printed between the connector pads P on which the circuit capacitors, diodes etc. are mounted. In the case of dropper resistor R7, in view of the relatively large rate of heat dissipation required (about 4 watts) this resistor is printed in three spaced portions whereby the heat generated therein is more readily dissipated.

The principal advantages of the embodiment of the invention described above include the significantly improved performance of the earth leakage circuit breaker at high ambient temperatures and overload conditions. The hybrid circuit board 40 provided for signal processing circuit 22 gives greater circuit integrity and reliability. Even if, under high temperature conditions, the circuit board bends the resistive value of the resistors printed thereon remains substantially unchanged and the operation of the whole circuit is not significantly affected. Moreover, the presence of a minimum of soldered joints itself makes for greater circuit integrity and reliability. The provision of the resistors of the circuit at accurately matched values leads to much lower tolerances in the required performance of the whole circuit - and this is of great value in the operation of equipment having a life saving function.

Moreover, the greatly reduced space required by the signal processing circuit 22 allows the provision of modified contact arrangements for the main switch contacts 28, 30, including the provision of arc plates (not shown in the drawings). A consequential advantage is the reduced manufacturing cost and time required in respect of circuit 22.

CLAIMS (filed on 3.11.82.)

1. An earth leakage circuit breaker comprising a detector transformer to monitor the current throughput to an electrical load to be protected, a signal processing circuit connected to a secondary winding of said detector transformer and responsive to an out-of-balance condition in the electrical conductors monitored by said transformer to generate an output signal, said signal processing circuit comprising an insulating substrate carrying an electrically conductive film providing both electrical connectors and

resistors of the signal processing circuit, and a solenoid connected to said signal processing circuit and responsive to the output signal of said signal processing circuit to cause a pair of switch contacts to break the circuit in the electrical conductors monitored by said detector transformer.

2. A circuit breaker according to claim 1 mounted in a casing which is adapted to be mounted on a distribution panel with other circuit breakers.

3. A circuit breaker according to clim 2 wherein the casing is divided into two compartments by a divider, the switch contacts and associated mechanical components being on one side of the divider and at least the major components of said signal processing circuits being located on the other side of the divider.

4. A circuit breaker according to claim 2 or claim 3 wherein arc plates are provided in the casing in association with said switch to increase the short-circuit breaking capacity of the circuit breaker.

5. A circuit breaker according to any one of the preceding claims wherein the signal processing circuit is formed by printing said connectors and resistors on said insulating substrate using an ink producing an electrically conductive surface film on the substrate.

6. A circuit breaker according to any one of the preceding claims wherein said substrate comprises alumina or other ceramic material.

7. A circuit breaker according to any one of the preceding claims wherein the resistors of said signal processing circuit are trimmed to predetermined electrical resistance values during manufacture and the insulating substrate and printed conductor and resistor elements are then coated with a protective film.

8. A circuit breaker according to any one of the preceding claims wherein said insulating substrate is formed with conductor pads to which circuit components such as capacitors diodes and integrated circuit amplifiers may be secured by soldering.

9. A circuit breaker according to any one of the preceding claims wherein the signal processing circuit comprises a voltage dropping resistor for current supply purposes, the resistor being printed on the substrate in at least two spaced portions.

10. A circuit breaker according to any one of the preceding claims wherein said solenoid is arranged to trip a switch release mechanism to disengage said switch contacts.

11. A circuit breaker according to claim 10 wherein said switch release mechanism comprises means responsive to electrical overload to trip the switch release mechanism.

12. A circuit breaker according to claim 11 wherein said means responsive to electrical overload comprises a heat responsive bi-metallic element and/or an electro-magnetic member-

13. A circuit breaker according to claim 11 or claim 12 wherein manually operable means such as a switch lever is provided to trip said switch release mechanism.

14. An earth leakage circuit breaker substantially as described herein with reference to the accompanying drawings.

15. A method of manufacturing an earth leakage circuit breaker according to any one of claims 1 to 14 including the step of depositing a film on said insulating substrate to form said conductors and resistors, and the step of trimming said resistors to predetermined values.

Printed for Her Majesty's Stationery Office, by Croydon Printing Company Limited, Croydon, Surrey, 1983.
Published by The Patent Office, 25 Southampton Buildings, London, WC2A 1AY, from which copies may be obtained.