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LEAKAGE CURRENT DETECTION METHOD AND DEVICE
LECKSTROMDETEKTIONSVERFAHREN UND -VORRICHTUNG
PROCÉDÉ ET DISPOSITIF DE DÉTECTION DE COURANT DE FUITE

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The present invention relates to the field of leakage current detection technologies, and in particular, to a leakage current detection method and apparatus.

Leakage current refers to a very small current flowing through a semiconductor component when a PN junction is in cut-off state or when charging of a capacitor is complete, and is also referred to as an Ir leakage current. The leakage current is an inherent feature and an important performance indicator of a semiconductor component, a filter, a power supply, and a capacitor. Due to surface damages of a component, wafer cracks, and the like caused by problems such as vendor process exceptions, raw material contamination, and internal management, a leakage current of the component often exceeds a limit.

For example, JP H1172529A refers to an insulation resistance measurement instrument for a capacitor. Further, JP S58 129266A refers to a measuring device for micro current. Further, US 2009/0243636A1 refers to a programmable gain trans-impedance amplifier overload recovery circuit.

When a component is just delivered from the factory, latent problems such as stress, cracks, and contamination may not be directly presented as an abnormal leakage current. In an initial stage of the leakage current, generally functions of a product are not affected directly. Therefore, a leakage current exceeding a limit belongs to a latent defect of the component. After the component experiences power-on, reflow soldering, and thermal shock, air inside the cracks of the component expands or contamination ions rapidly diffuse. Therefore, abnormality of the component occurs, resulting in a leakage current exceeding a limit. As time goes by, under an effect of an environmental factor such as humidity, temperature, and voltage, the leakage current becomes severe gradually, which even shortens service life of the product substantially.

In prior art 1, a test pen is operated manually to probe a component under detection to perform a leakage current test. This manual testing manner is inefficient and consumes a lot of manpower and material resources.

In prior art 2, a leakage current test is performed by using a commercial semiconductor tester (for example, Agilent, 4339B, or the like). As shown in FIG. 1, a nominal voltage is applied between two ends of a component under detection, and an ammeter is used to measure a small current flowing through the component under detection. The leakage current is generally at a 10^E to -9 A level. Therefore, in a common electrical qualification test for a board-mounted component, it is difficult to stably test a leakage current. In addition, this manner is mainly applied to sample inspection and delivery detection in incoming quality control (Incoming Quality Control, IQC), batch detection cannot be implemented, and a detection ratio is limited.

Moreover, the foregoing test manners are only intended for testing an isolated component. When the component is surface mounted to a board, leakage current detection may not be performed any longer. When leakage current detection is required, the component needs to be removed from the board before being detected. Consequently, a large number of components subject to a leakage current problem flow into markets, causing a board function failure.

In view of the above, a technical problem to be resolved by the present invention is to provide a leakage current detection method and apparatus, so as to implement that a leakage current test is performed on a board-mounted component without a need of removing the component under detection from a board, thereby improving test efficiency and accuracy, and increasing an detection ratio.

In the present invention, the technical problem is resolved as follows:

To resolve the foregoing technical problem, an embodiment of the present invention provides a leakage detection method, which is applied to leakage current detection for a board-mounted component on a PCBA (Printed Circuit Board Assembly) board. The method includes:

- isolating the board-mounted component under detection from one or more other components to which the board-mounted component under detection is connected, wherein the isolating comprises:
- making one or more other components that are connected to a leakage current input end of the board-mounted component under detection equivalent to a first resistor, making one or more other components that are connected to a leakage current output end of the board-mounted component under detection equivalent to a second resistor.

Consequently, a large number of components subject to a leakage current problem flow into markets, causing a board function failure.
current output end of the board-mounted component under detection equivalent to a second resistor, and configuring
an isolation end between the first resistor and the second resistor to have a same potential as the leakage current output
end of the board-mounted component under detection;

providing a fixed voltage for the leakage current input end of the board-mounted component under detection, and
connecting the leakage current output end of the board-mounted component under detection to an inverting input
device of an operational amplifier of a resistance testing module, wherein the resistance testing module comprises the
operational amplifier and a reference resistor that is connected between the inverting input end of the operational
amplifier and the leakage current output end;
detecting an output voltage of the resistance testing module; and
calculating, based on Ohm’s law and according to the output voltage and the reference resistor, a leakage current
flowing through the board-mounted component under detection.

[0010] As regards the foregoing leakage current detection method, in a possible implementation manner, when the
board-mounted component under detection is a capacitor having a positive pole and a negative pole, the leakage current
input end is the positive pole of the capacitor, and the leakage current output end is the negative pole of the capacitor.

[0011] As regards the foregoing leakage current detection method, in a possible implementation manner, when the
board-mounted component under detection is a capacitor without a positive pole or a negative pole, the leakage current
input end is one end of the capacitor, and the leakage current output end is the other end of the capacitor.

[0012] As regards the foregoing leakage current detection method, in a possible implementation manner, the isolating
the board-mounted component under detection from the one or more other components to which the board-mounted
component under detection is connected further includes:
when the board-mounted component under detection is a board-mounted semiconductor component, configuring the
board-mounted semiconductor component to be in cut-off state.

[0013] As regards the foregoing leakage current detection method, in a possible implementation manner, the calculat-
ing, based on Ohm’s law and according to the output voltage and the reference resistor, the leakage current flowing
through the board-mounted component under detection includes: calculating the leakage current flowing through the
board-mounted component under detection according to Formula 7:

\[
I_X = \frac{V_i}{R_X} = \frac{V_O}{R\text{ref}} = I_{ref}
\]

Formula 7

where \(I_X\) is the leakage current of the board-mounted component under detection, \(V_i\) is the fixed voltage, \(R_X\) is an
equivalent direct current impedance of the board-mounted component under detection, \(V_O\) is the output voltage of the
resistance testing module, \(R\text{ref}\) is a resistance of the reference resistor of the resistance testing module, and \(I_{ref}\) is a
current flowing through the reference resistor.

[0014] To resolve the foregoing technical problem, another embodiment of the present invention provides a leakage
detection apparatus, which is applied to leakage current detection for a board-mounted component on a PCBA board,
and includes:
a voltage providing module, connected to a leakage current input end of a board-mounted component under detection,
and configured to provide a fixed voltage for the board-mounted component under detection;
a resistance testing module, including an operational amplifier and a reference resistor that is connected between
an inverting input end of the operational amplifier and a leakage current output end, and configured to provide the
reference resistor, where the inverting input end is connected to the leakage current output end of the board-mounted
component under detection; and
a control module, connected to the board-mounted component under detection, the resistance testing module, and
the voltage providing module, and configured to calculate, based on Ohm’s law and according to an output voltage
of the resistance testing module and the reference resistor, a leakage current flowing through the board-mounted
component under detection, wherein the control module further comprises:
an isolating unit, configured to make one or more other components that are connected to the leakage current input
end of the board-mounted component under detection equivalent to a first resistor, make one or more other com-
ponents that are connected to the leakage current output end of the board-mounted component under detection
equivalent to a second resistor, and configure an isolation end between the first resistor and the second resistor,
which is away from the board-mounted component under detection, to have a same potential as the leakage current
output end of the board-mounted component under detection.
As regards the foregoing leakage current detection apparatus, in a possible implementation manner, when the board-mounted component under detection is a capacitor having a positive pole and a negative pole, the leakage current input end is the positive pole of the capacitor, and the leakage current output end is the negative pole of the capacitor.

As regards the foregoing leakage current detection apparatus, in a possible implementation manner, when the board-mounted component under detection is a capacitor without a positive pole or a negative pole, the leakage current input end is one end of the capacitor, and the leakage current output end is the other end of the capacitor.

As regards the foregoing leakage current detection apparatus, in a possible implementation manner, the control module includes:

- a detecting unit, connected to the voltage providing module and the leakage current output end of the resistance testing module, and configured to detect the output voltage of the resistance testing module;
- a calculating unit, connected to the detecting unit, and configured to calculate the leakage current according to Formula 7:

\[
I_L = \frac{V_i}{R_X} = \frac{V_O}{R_{ref}} = I_{ref}
\]

where \( I_L \) is the leakage current of the board-mounted component under detection, \( V_i \) is the fixed voltage provided by the voltage providing module, \( R_X \) is an equivalent direct current impedance of the board-mounted component under detection, \( V_O \) is the output voltage of the resistance testing module, \( R_{ref} \) is a resistance of the reference resistor of the resistance testing module, and \( I_{ref} \) is a current flowing through the reference resistor.

As regards the foregoing leakage current detection apparatus, in a possible implementation manner, the isolating unit is further configured to: when the board-mounted component under detection is a board-mounted semiconductor component, configure the board-mounted semiconductor component to be in cut-off state.

Beneficial effects

According the leakage current detection method and apparatus provided in the embodiments of the present invention, a board-mounted component under detection is connected to a resistance testing module, and a specific voltage is applied. In this way, a leakage current of the board-mounted component on a PCBA board can be calculated according to a reference resistor of the resistance testing module and an output voltage. Batch detection can be implemented without a need of removing the board-mounted component from the board, and a detection ratio is high. In addition, as proven by experiments, detection accuracy and detection efficiency are high.

Exemplary embodiments are described in detail with reference to accompanying drawings to make other features and aspects of the present invention clearer.

BRIEF DESCRIPTION OF DRAWINGS

Accompanying drawings included in the specification and constituting a part of the specification and the specification illustrate exemplary embodiments, features, and aspects of the present invention, and are used for explaining principles of the present invention.

FIG. 1 shows a circuit diagram of leakage current detection in the prior art;
FIG. 2 shows a flowchart of a leakage current detection method according to an embodiment of the present invention;
FIG. 3 shows a circuit diagram corresponding to the method shown in FIG. 2;
FIG. 4 shows a flowchart of a leakage current detection method according to another embodiment of the present invention;
FIG. 5 shows a circuit diagram corresponding to the method shown in FIG. 4;
FIG. 6 shows a schematic structural diagram of a leakage current detection apparatus according to an embodiment of the present invention;
FIG. 7 shows a schematic structural diagram of a leakage current detection apparatus according to another embodiment of the present invention; and
FIG. 8 shows a accuracy effect diagram of a test that uses the leakage current detection method and apparatus according to the present invention.
DESCRIPTION OF EMBODIMENTS

[0022] Various exemplary embodiments, features, and aspects of the present invention are described in detail hereinafter with reference to accompanying drawings. In the drawings, identical reference numerals denote elements that have an identical or similar function. Although various aspects of the embodiments are shown in the drawings, unless otherwise specified, the drawings are not necessarily drawn to scale.

[0023] The special term "exemplary" herein refers to "can be used as an example, an embodiment, or an illustration". Any embodiment described as "exemplary" herein is not necessarily to be interpreted as optimal or better than other embodiments.

[0024] In addition, to better describe the present invention, many details are given in the following specific implementation manners. A person skilled in the art shall understand that the present invention may still be implemented even without such details. In other instances, well-known methods, means, elements, and circuits are not specifically described, so as to highlight the subject of the present invention.

Embodiment 1

[0025] FIG. 2 is a flowchart of a leakage current detection method according to an embodiment of the present invention. As shown in FIG. 2, the method is applied to leakage current detection for a board-mounted component on a printed circuit board assembly (Printed Circuit Board Assembly, PCBA) board. The method includes the following steps:

Step S110. Connect a leakage current input end of a board-mounted component under detection to a voltage providing module, and connect a leakage current output end of the board-mounted component under detection to a resistance testing module.

[0026] To be specific, the board-mounted component under detection is an isolated board-mounted component, that is, a board-mounted component not connected to any other component. With respect to the isolated board-mounted component, in a PCB design stage of the board, a test point is separately arranged at the leakage current input end and the leakage current output end of the isolated board-mounted component. With respect to a component with a plurality of pins, two pins may be selected as the leakage current input end and the leakage current output end according to actual needs. For example, when the board-mounted component under detection is a semiconductor component, the leakage current input end is a start end of the semiconductor component in cut-off state, and the leakage current output end is an end terminal of the semiconductor component in cut-off state; when the board-mounted component under detection is a capacitor having a positive pole and a negative pole, the leakage current input end is the positive pole of the capacitor, and the leakage current output end is the negative pole of the capacitor; and when the board-mounted component under detection is a capacitor without a positive pole or a negative pole, the leakage current input end is one end of the capacitor, and the leakage current output end is the other end of the capacitor.

[0027] In this step, the leakage current input end is connected to the voltage providing module, and the leakage current output end is connected to the resistance testing module.

[0028] For example, as shown in FIG. 3, a board-mounted component Rx under detection is an isolated board-mounted component, in a PCB design stage of the board, a test point is separately arranged at the leakage current input end and the leakage current output end of the isolated board-mounted component. With respect to a component with a plurality of pins, two pins may be selected as the leakage current input end and the leakage current output end according to actual needs. For example, when the board-mounted component under detection is a semiconductor component, the leakage current input end is a start end of the semiconductor component in cut-off state, and the leakage current output end is an end terminal of the semiconductor component in cut-off state; when the board-mounted component under detection is a capacitor having a positive pole and a negative pole, the leakage current input end is the positive pole of the capacitor, and the leakage current output end is the negative pole of the capacitor; and when the board-mounted component under detection is a capacitor without a positive pole or a negative pole, the leakage current input end is one end of the capacitor, and the leakage current output end is the other end of the capacitor.

[0029] Step S120. Detect an output voltage of the resistance testing module.

[0030] In this embodiment, detection steps are performed in an in-circuit test (In-Circuit Test, ICT) stage of manufacturing. As shown in FIG. 3, the resistance testing module includes: an operational amplifier OP, where an inverting input end of the operational amplifier OP is connected to the F end of the board-mounted component Rx under detection, a reference resistor Rref is connected between the inverting input end of the OP and the leakage current output end, and a non-inverting input end of the OP is connected to the reference ground. In this step, an output voltage $V_O$ relative to the reference ground, and the resistance testing module is connected to the test point at the F end.

[0031] In another possible implementation manner, the resistance testing module may be a multimeter or an ohmmeter.

[0032] Step S130. Calculate, based on Ohm’s law and according to the output voltage of the resistance testing module and the reference resistor of the resistance testing module, a leakage current flowing through the board-mounted component under detection.

[0033] Specifically, it may be learnt from FIG. 3 that the following Formula 1, Formula 2, and Formula 3 are valid:

$$V_O = -A \cdot V_{in}$$  Formula 1
$V_O$ is the output voltage of the resistance testing module relative to the reference ground, $A$ is an open-loop gain of the operational amplifier OP, and is a voltage of the F end.

\[ I_{ref} = \frac{V_{in} - V_O}{R_{ref}} \]  
\[ \text{Formula 2} \]

$R_{ref}$ is a resistance of the reference resistor Rref of the resistance testing module, and $I_{ref}$ is a current flowing through the reference resistor Rref.

\[ I_X = \frac{V_i - V_{in}}{R_X} \]  
\[ \text{Formula 3} \]

$R_X$ is an equivalent direct current impedance of the board-mounted component Rx under detection.

[0034] According to a principle of a virtual open loop at the input end of the operational amplifier OP, Formula 4 is valid:

\[ I_X \approx I_{ref} \]  
\[ \text{Formula 4} \]

[0035] In combination with the foregoing Formulas 1 to 4, Formula 5 is obtained:

\[ R_X = -(\frac{A}{A + 1} \cdot \frac{V_i}{V_O} + \frac{1}{A + 1}) \cdot R_{ref} \]  
\[ \text{Formula 5} \]

[0036] Because the open loop gain $A$ of the operational amplifier OP in the ICT device is far greater than 1, Formula 5 may be transformed into Formula 6:

\[ R_X \approx \frac{V_i}{V_O} \cdot R_{ref} \]  
\[ \text{Formula 6} \]

[0037] In the foregoing formula, voltage $V_i$ is a known value, impedance $R_X$ can be measured by using the control module, and $V_{in} \approx 0$ is obtained by using Ohm’s law and the principle of the virtual open loop at the input end of the operational amplifier OP. Therefore, Formula 7 may be deduced. In this step, leakage current $I_X$ is calculated according to Formula 7:

\[ I_X = \frac{V_i}{R_X} \cdot \frac{V_O}{R_{ref}} = I_{ref} \]  
\[ \text{Formula 7} \]

[0038] It should be noted that, the board-mounted component in this embodiment mainly include: a semiconductor, an oscillator, or a capacitor on the PCBA board, where the semiconductor may be a diode (including a light-emitting diode LED), a triode, a MOS transistor, or an IC component.

**Embodiment 2**

[0039] FIG. 4 is a flowchart of a leakage current detection method according to another embodiment of the present invention. As shown in FIG. 4, a major difference between the embodiment shown in FIG. 4 and the embodiment shown in FIG. 2 lies in that the embodiment shown in FIG. 4 is used to detect a leakage current of a board-mounted component connected to one or more other components. The method mainly includes the following steps:

[0040] Step 210. Isolate a board-mounted component under detection from one or more other components to which the board-mounted component under detection is connected.

[0041] The isolation is intended to eliminate bypass impact of the one or more other components to which the board-mounted component under detection is connected on the board-mounted component under detection, and ensure that a current flowing through a second resistor R2 is 0, that is, $I_2 = 0$ (as shown in FIG. 5), and $I_X = I_{ref}$. 
In this embodiment, the isolation is performed in the following manner.

As shown in FIG. 5, one or more other components connected to a leakage current input end of a board-mounted component Rx under detection are made equivalent to a first resistor R1, one or more other components connected to a leakage current output end of the board-mounted component Rx under detection are made equivalent to the second resistor R2, and an isolation end (a G end) of the first resistor R1 and the second resistor R2, that is, an end away from the board-mounted component Rx under detection, is set to have a same potential as an F end of the board-mounted component Rx under detection. Because an inverting input end and a non-inverting input end of an operational amplifier OP both have a same potential as a reference ground, the G end of the first resistor R1 and the second resistor R2 has a same potential as the reference ground.

In addition, with respect to a board-mounted semiconductor component, the board-mounted semiconductor component further needs to be configured to be in cut-off state.

Greater resistances of the first resistor R1 and the second resistor R2 indicate a higher test accuracy of a leakage current. Therefore, preferably the resistances of the first resistor R1 and the second resistor R2 are not less than 1K ohms. When the resistances of the first resistor R1 and the second resistor R2 increase to be infinite, the board-mounted component under detection is equated with the isolated board-mounted component illustrated in Embodiment 1.

Steps 220 to 240 are the same as steps 110 to 130.

The isolation measure in step 210 eliminates bypass impact of the first resistor R1 and the second resistor R2. Therefore, with respect to a board-mounted component connected to one or more other components, a leakage current can be calculated by using the same method in Embodiment 1.

Preferably, this embodiment further includes:

Step 250. Determine whether the calculated leakage current is not less than a preset threshold, and send notification information according to a determination result.

The preset threshold may be an empirical value. If it is determined that the leakage current is not less than the preset threshold, it is considered that the leakage current exceeds a limit, and a warning notification or another sound notification is sent so that work personnel timely examine and repair the component whose leakage current exceeds the limit. If it is determined that the leakage current is less than the preset threshold, it is considered that the leakage current does not exceed the limit and the component is qualified. In this case, the system may send a notification indicating that the product is qualified, or may also be set not to make a notification.

Under special circumstances, with respect to a board-mounted component connected to one or more other components, where the resistances of the first resistor R1 and the second resistor R2 are relatively small, a leakage current cannot be detected effectively by using the method illustrated in Embodiment 2. In this case, a component the same as the component under detection may be surface mounted to a redundant location on a board, and then leakage current detection may be performed by using the method illustrated in Embodiment 1. In this case, although the component used on the board is not directly detected, in a case in which leakage currents of batch components from a vendor exceed the limit, this method can detect components that have a leakage current exception, may have a specific coverage, and plays a role in intercepting the batch components on a board whose leakage currents exceed the limit.

In addition, the leakage current detection method provided in the present application is not limited to being applied to an ICT stage, for example, it may further be applied to a functional test (Functional Test, FT) stage. However, an ICT device itself has a resistance testing module and can also detect an output voltage of a resistance testing module, and therefore, applying the method to the ICT stage is more convenient and efficient, without a need of additionally arranging apparatuses such as the resistance testing module and a control module.

**Embodiment 3**

FIG. 6 is a schematic structural diagram of a leakage current detection apparatus according to an embodiment of the present invention. As shown in FIG. 6, the apparatus 100 includes: a voltage providing module 11, a resistance testing module 12, and a control module 13.

The voltage providing module 11 is connected to a leakage current input end of a board-mounted component 14 under detection, and is configured to provide, for the board-mounted component 14 under detection, a fixed voltage relative to a reference ground; the resistance testing module 12 is connected to a leakage current output end of the board-mounted component 14 under detection, and is configured to provide a reference resistor; and the control module 13 is connected to the resistance testing module 12 and the voltage providing module 11, and is configured to calculate, according to an output voltage of the resistance testing module 12 and the reference resistor, a leakage current flowing through the board-mounted component 14 under detection.

In this embodiment, the board-mounted component 14 under detection is an isolated board-mounted component. To be specific, in this embodiment, the control module 13 includes a detecting unit 131 and a calculating unit 132.
the calculating unit 132 is connected to the detecting unit 131, and is configured to calculate the leakage current of the board-mounted component 14 under detection according to Formula 7:

\[
I_X = \frac{V_i}{R_X} = \frac{\Delta V}{R_{ref}} = I_{ref}
\]  

Formula 7

where \( I_X \) is the leakage current of the board-mounted component 14 under detection, \( V_i \) is the fixed voltage relative to the reference ground provided by the voltage providing module 11, \( R_X \) is an equivalent direct current impedance of the board-mounted component 14 under detection, \( V_\Delta \) is the output voltage of the resistance testing module 12 relative to the reference ground, \( R_{ref} \) is a resistance of the reference resistor of the resistance testing module 12, and \( I_{ref} \) is a current flowing through the reference resistor.

In addition, in this embodiment, a structure of the resistance testing module 12 may be the structure shown in FIG. 3 and FIG. 5, and may also be a multimeter or an ohmmeter. Any specific structure may be equivalent to the structure shown in FIG. 3 and FIG. 5.

**Embodiment 4**

As shown in FIG. 7, a major difference between a detection apparatus 200 shown in FIG. 7 and the detection apparatus 100 shown in FIG. 6 lies in that: a board-mounted component 15 under detection in this embodiment is a board-mounted component connected to one or more other components; to eliminate bypass impact of the one or more other components to which the board-mounted component 15 under detection is connected on the board-mounted component under detection, the board-mounted component 15 under detection needs to be isolated from the one or more other components to which the board-mounted component 15 under detection is connected. Accordingly, the control module 16 in this embodiment further includes: an isolating unit 164. The isolating unit 164 is configured to isolate the board-mounted component 15 under detection from the one or more other components to which the board-mounted component 15 under detection is connected. Specifically, the isolating unit 164 makes one or more other components that are connected to a leakage current input end of the board-mounted component 15 under detection equivalent to a first resistor, and makes one or more other components that are connected to a leakage current output end of the board-mounted component 15 under detection equivalent to a second resistor, and configures an isolation end between the first resistor and the second resistor, which is away from the board-mounted component 15 under detection, to have a same potential as the leakage current output end of the board-mounted component 15 under detection.

Further, to enable a work personnel to timely learn a situation of an abnormal leakage current, the controller 16 in this embodiment further includes a determining unit 165 and a notifying unit 166. The determining unit 165 is configured to determine whether a calculated leakage current is not less than a preset threshold, and the notifying unit 166 is configured to send a notification according to a determination result of the determining unit 165, for example, report an alarm if the leakage current is not less than the preset threshold.

The control module 16 in this embodiment further includes a determining unit 165 and a calculating unit 162 that are the same as the detecting unit 131 and the calculating unit 132 of the control module 13 in Embodiment 3.

FIG. 8 is a schematic diagram of a test effect of leakage current detection performed by using the leakage current detection method and apparatus according to the embodiments of the present invention. The transverse axis indicates time spent in testing a leakage current, and the longitudinal axis indicates a value of the leakage current. It may be seen from FIG. 8 that accuracy of a leakage current test performed by using the method and apparatus reaches 0.02 µA. As regards test efficiency, the present invention can achieve a microsecond level, which is higher than the minute-level test efficiency in the prior art by a plurality of magnitude levels. In addition, the test can be stable and is substantially not affected by a component fluctuation.

According to the leakage current detection method and apparatus provided in the embodiments of the present invention, test points are arranged on the board-mounted component in a PCB design stage of the board, and in an ICT stage, a specified voltage and a reference resistor are provided on the board-mounted component to perform the leakage current test. In this way, 100% full detection can be implemented for the board-mounted component, a detection ratio is high, test accuracy is high, and a specific detection ratio may be flexibly adjusted according to an input-output ratio.

A person of ordinary skill in the art may be aware that exemplary units and algorithm steps in the embodiments described in the specification may be implemented by electronic hardware or a combination of computer software and electronic hardware. Implementing the functions in a form of hardware or software depends on specific applications and design restriction conditions of the technical solutions. Those skilled in the art may select different methods according
to the specific applications to implement the described functions. However, such implementation shall not be construed as going beyond the scope of the present invention.

If the functions are implemented in the form of computer software and are for sale or use as separate products, to some extent, it may be considered that all or a part (for example, the part contributing to the prior art) of the technical solutions of the present invention are embodied in the form of a computer software product. The computer software product is generally stored in a computer-readable storage medium, and includes several instructions for instructing a computer device (which may be a personal computer, a server, a network device, or the like) to perform all or a part of the steps of the methods described in the embodiments of the present invention. The foregoing storage medium includes any medium that can store program code, such as a USB flash drive, a removable hard disk, a read-only memory (ROM, Read-Only Memory), a random access memory (RAM, Random Access Memory), a magnetic disk, or an optical disc.

The foregoing descriptions are merely specific embodiments of the present invention, but are not intended to limit the protection scope of the present invention. Any variation or replacement readily figured out by a person skilled in the art within the technical scope disclosed in the present invention should fall within the protection scope of the present invention. Therefore, the protection scope of the present invention is subjected to the appended claims.

Claims

1. A leakage current detection method, applied to leakage current detection for a board-mounted component on a PCBA board, wherein the method comprises:
   isolating the board-mounted component under detection from one or more other components to which the board-mounted component under detection is connected, wherein the isolating comprises:
   making one or more other components that are connected to a leakage current input end of the board-mounted component under detection equivalent to a first resistor, making one or more other components that are connected to a leakage current output end of the board-mounted component under detection equivalent to a second resistor, and configuring an isolation end between the first resistor and the second resistor to have a same potential as the leakage current output end of the board-mounted component under detection (step 210);
   providing a fixed voltage for the leakage current input end of the board-mounted component under detection, and connecting the leakage current output end of the board-mounted component under detection to an inverting input end of an operational amplifier of a resistance testing module, wherein the resistance testing module comprises the operational amplifier and a reference resistor that is connected between the inverting input end and the leakage current output end of the operational amplifier and the leakage current output end (step 220);
   detecting an output voltage of the resistance testing module (step 230); and
   calculating, based on Ohm’s law and according to the output voltage and the reference resistor, a leakage current flowing through the board-mounted component under detection (step 240).

2. The leakage current detection method according to claim 1, wherein:
   the board-mounted component under detection is a capacitor having a positive pole and a negative pole, the leakage current input end is the positive pole of the capacitor, and the leakage current output end is the negative pole of the capacitor.

3. The leakage current detection method according to claim 1, wherein:
   the board-mounted component under detection is a capacitor without a positive pole or a negative pole, the leakage current input end is one end of the capacitor, and the leakage current output end is the other end of the capacitor.

4. The leakage current detection method according to any of the preceding claims, wherein the isolating the board-mounted component under detection from the one or more other components to which the board-mounted component under detection is connected further comprises:
   when the board-mounted component under detection is a board-mounted semiconductor component, configuring the board-mounted semiconductor component to be in cut-off state.

5. The leakage current detection method according to any of the preceding claims, wherein the calculating, based on Ohm’s law and according to the output voltage and the reference resistor, the leakage current flowing through the board-mounted component under detection comprises: calculating the leakage current flowing through the board-mounted component under detection according to Formula 7:
wherein $I_X$ is the leakage current of the board-mounted component under detection, $V_i$ is the fixed voltage, $R_X$ is an equivalent direct current impedance of the board-mounted component under detection, $V_O$ is the output voltage of the resistance testing module, $R_{ref}$ is a resistance of the reference resistor of the resistance testing module, and $I_{ref}$ is a current flowing through the reference resistor.

6. A leakage current detection apparatus (200), applied to leakage current detection for a board-mounted component on a PCBA board, wherein the leakage current detection apparatus (200) comprises:

- a voltage providing module (11), connected to a leakage current input end of a board-mounted component under detection, and configured to provide a fixed voltage for the board-mounted component under detection;
- a resistance testing module (12), comprising an operational amplifier and a reference resistor that is connected between an inverting input end of the operational amplifier and a leakage current output end, and configured to provide the reference resistor, wherein the inverting input end is connected to the leakage current output end of the board-mounted component under detection; and
- a control module (16), connected to the board-mounted component under detection, the resistance testing module, and the voltage providing module, and configured to calculate, based on Ohm’s law and according to an output voltage of the resistance testing module and the reference resistor, a leakage current flowing through the board-mounted component under detection,

wherein the control module (16) further comprises:

- an isolating unit (164), configured to make one or more other components that are connected to the leakage current input end of the board-mounted component under detection equivalent to a first resistor, make one or more other components that are connected to the leakage current output end of the board-mounted component under detection equivalent to a second resistor, and configure an isolation end between the first resistor and the second resistor, which is away from the board-mounted component under detection, to have a same potential as the leakage current output end of the board-mounted component under detection.

7. The leakage current detection apparatus (200) according to claim 6, wherein:

the board-mounted component under detection is a capacitor having a positive pole and a negative pole, the leakage current input end is the positive pole of the capacitor, and the leakage current output end is the negative pole of the capacitor.

8. The leakage current detection apparatus (200) according to claim 6, wherein:

the board-mounted component under detection is a capacitor without a positive pole or a negative pole, the leakage current input end is one end of the capacitor, and the leakage current output end is the other end of the capacitor.

9. The leakage current detection apparatus (200) according to any one of claims 6 to 8, wherein the control module comprises:

- a detecting unit, connected to the voltage providing module and the leakage current output end of the resistance testing module, and configured to detect the output voltage of the resistance testing module;
- a calculating unit, connected to the detecting unit, and configured to calculate the leakage current according to Formula 7:

$$I_X = \frac{V_i}{R_X} = \frac{V_O}{R_{ref}} = I_{ref} \quad \text{Formula 7}$$

wherein $I_X$ is the leakage current of the board-mounted component under detection, $V_i$ is the fixed voltage provided by the voltage providing module, $R_X$ is an equivalent direct current impedance of the board-mounted component under detection, $V_O$ is the output voltage of the resistance testing module, $R_{ref}$ is a resistance of the reference resistor of the resistance testing module, and $I_{ref}$ is a current flowing through the reference resistor.

10. The leakage current detection apparatus (200) according to claim 6, wherein the isolating unit is further configured to: when the board-mounted component under detection is a board-mounted semiconductor component, configure
the board-mounted semiconductor component to be in cut-off state.

**Patentansprüche**

1. Leckstrom-Nachweisverfahren, angewandt auf Leckstromnachweis für eine platiniertmontierte Komponente auf einer PCBA-Platine, wobei das Verfahren Folgendes umfasst: Isolieren der unter Nachweis stehenden platiniertmontierten Komponente von einer oder mehreren Komponenten, mit denen die unter Nachweis stehende platiniertmontierte Komponente verbunden ist, wobei das Isolieren Folgendes umfasst:

   Angleichen von einer oder mehreren anderen Komponenten, die mit einem Leckstrom-Eingangsende der unter Nachweis stehenden platiniertmontierten Komponente verbunden sind, an einen ersten Widerstand, Angleichen von einer oder mehreren anderen Komponenten, die mit einem Leckstrom-Ausgangsende der unter Nachweis stehenden platiniertmontierten Komponente verbunden sind, an einen zweiten Widerstand, und Konfigurieren eines Isolationsendes zwischen dem ersten Widerstand und dem zweiten Widerstand, dass es ein gleiches Potenzial wie das Leckstrom-Ausgangsende der unter Nachweis stehenden platiniertmontierten Komponente hat (Schritt 210);

   Bereitstellen einer festen Spannung für das Leckstrom-Eingangsende der unter Nachweis stehenden platiniertmontierten Komponente, und Verbinden des Leckstrom-Ausgangsendes der unter Nachweis stehenden platiniertmontierten Komponente mit einem invertierenden Eingangsende eines Operationsverstärkers eines Widerstandsprüfmoduls, wobei das Widerstandsprüfmodul den Operationsverstärker und einen Referenzwiderstand umfasst, der zwischen dem invertierenden Eingangsende des Operationsverstärkers und dem Leckstrom-Ausgangsende geschaltet ist (Schritt 220);

   Nachweisen einer Ausgangsspannung des Widerstandsprüfmodule (Schritt 230); und

   Berechnen, auf der Basis des Ohmschen Gesetzes und gemäß der Ausgangsspannung und dem Referenzwiderstand, eines Leckstroms, der durch die unter Nachweis stehende platiniertmontierte Komponente fließt (Schritt 240).


5. Leckstrom-Nachweisverfahren gemäß einem der vorhergehenden Ansprüche, wobei das Berechnen, auf der Basis des Ohmschen Gesetzes und gemäß der Ausgangsspannung und dem Referenzwiderstand, des Leckstroms, der durch die unter Nachweis stehende platiniertmontierte Komponente fließt, Folgendes umfasst: Berechnen des Leckstroms, der durch die unter Nachweis stehende platiniertmontierte Komponente fließt, gemäß der Formel 7:

   \[ I_x = \frac{V_i}{R_X} = \frac{V_O}{R_{ref}} = I_{ref} \]  

   Formel 7

wobei \( I_x \) der Leckstrom der unter Nachweis stehenden platiniertmontierten Komponente ist, \( V_i \) die feste Spannung ist, \( R_X \) eine entsprechende Gleichstromimpedanz der unter Nachweis stehenden platiniertmontierten Komponente ist, \( V_O \) die Ausgangsspannung des Widerstandsprüfmoduls ist, \( R_{ref} \) ein Widerstand des Referenzwiderstands des
Widerstandsprüfmoduls ist, und \( I_{\text{ref}} \) ein durch den Referenzwiderstand fließender Strom ist.

6. Leckstrom-Nachweisvorrichtung (200), angewandt auf Leckstromnachweis für eine platinenmontierte Komponente auf einer PCBA-Platine, wobei die Leckstrom-Nachweisvorrichtung (200) Folgendes umfasst:

- ein Spannungsbereitstellungsmodul (11), das mit einem Leckstrom-Eingangsende einer unter Nachweis stehenden platinenmontierten Komponente verbunden und dazu ausgelegt ist, eine feste Spannung für die unter Nachweis stehende platinenmontierte Komponente bereitzustellen;
- ein Widerstandsprüfmodul (12), das einen Operationsverstärker und einen Referenzwiderstand umfasst, der zwischen einem invertierenden Eingangsende des Operationsverstärkers und einem Leckstrom-Ausgangsende geschaltet und dazu ausgelegt ist, den Referenzwiderstand bereitzustellen, wobei das invertierende Eingangsende mit dem Leckstrom-Ausgangsende der unter Nachweis stehenden platinenmontierten Komponente verbunden ist; und
- ein Steuermodul (16), das mit der unter Nachweis stehenden platinenmontierten Komponente, dem Widerstandsprüfmodul und dem Spannungsbereitstellungsmodul verbunden und dazu ausgelegt ist, auf der Basis des Ohmschen Gesetzes und gemäß einer Ausgangsspannung des Widerstandsprüfmoduls und des Referenzwiderstands einen Leckstrom zu berechnen, der durch die unter Nachweis stehende platinenmontierte Komponente fließt,

wobei das Steuermodul (16) ferner Folgendes umfasst:
- eine Trenneinheit (164), die dazu ausgelegt ist, eine oder mehrere andere Komponenten, die mit dem Leckstrom-Eingangsende der unter Nachweis stehenden platinenmontierten Komponente verbunden sind, an einen ersten Widerstand anzugleichen, eine oder mehrere andere Komponenten, die mit einem Leckstrom-Ausgangsende der unter Nachweis stehenden platinenmontierten Komponente verbunden sind, an einen zweiten Widerstand anzugleichen, und ein Isolationsende zwischen dem ersten Widerstand und dem zweiten Widerstand, das von der unter Nachweis stehenden platinenmontierten Komponente entfernt ist, zu konfigurieren, dass es ein gleiches Potential wie das Leckstrom-Ausgangsende der unter Nachweis stehenden platinenmontierten Komponente hat.

7. Leckstrom-Nachweisvorrichtung (200) gemäß Anspruch 6, wobei:
- die unter Nachweis stehende platinenmontierte Komponente ein Kondensator mit einem positiven und einem negativen Pol ist, das Leckstrom-Eingangsende der positive Pol des Kondensators ist, und das Leckstrom-Ausgangsende der negative Pol des Kondensators ist.

8. Leckstrom-Nachweisvorrichtung (200) gemäß Anspruch 6, wobei:
- die unter Nachweis stehende platinenmontierte Komponente ein Kondensator ohne einen positiven oder negativen Pol ist, das Leckstrom-Eingangsende ein Ende des Kondensators ist, und das Leckstrom-Ausgangsende das andere Ende des Kondensators ist.

9. Leckstrom-Nachweisvorrichtung (200) gemäß einem der Ansprüche 6 bis 8, wobei das Steuermodul Folgendes umfasst:
- eine Nachweiseinheit, die mit dem Spannungsbereitstellungsmodul und dem Leckstrom-Ausgangsende des Widerstandsprüfmoduls verbunden und dazu ausgelegt ist, die Ausgangsspannung des Widerstandsprüfmoduls zu erfassen;
- eine Berechnungseinheit, die mit der Nachweiseinheit verbunden und dazu ausgelegt ist, den Leckstrom gemäß der Formel 7 zu berechnen:

\[
I_x = \frac{V_i}{R_X} = \frac{V_O}{R_{\text{ref}}} = I_{\text{ref}} \quad \text{Formel 7}
\]

wobei \( I_x \) der Leckstrom der unter Nachweis stehenden platinenmontierten Komponente ist, \( V_i \) die von dem Spannungsbereitstellungsmodul bereitgestellte feste Spannung ist, \( R_X \) eine entsprechende Gleichstromimpedanz der unter Nachweis stehenden platinenmontierten Komponente ist, \( V_O \) die Ausgangsspannung des Widerstandsprüfmoduls ist, \( R_{\text{ref}} \) ein Widerstand des Referenzwiderstands des Widerstandsprüfmoduls ist, und \( I_{\text{ref}} \) ein durch den Referenzwiderstand fließender Strom ist.

10. Leckstrom-Nachweisvorrichtung (200) gemäß Anspruch 6, wobei die Trenneinheit ferner für Folgendes ausgelegt ist:
Procédé de détection de courant de fuite, appliqué à une détection de courant de fuite pour un composant monté sur carte sur une carte PCBA, le procédé comprenant :
la mise en équivalence à une première résistance d’un ou de plusieurs autres composants connectés à une extrémité d’entrée de courant de fuite du composant monté sur carte soumis à détection, et la configuration d’une extrémité d’isolement entre la première résistance et la deuxième résistance de façon à ce qu’elle présente un même potentiel que celui de l’extrémité de sortie de courant de fuite du composant monté sur carte soumis à détection (étape 210) :
la fourniture d’une tension fixe pour l’extrémité d’entrée de courant de fuite du composant monté sur carte soumis à détection, et la connexion de l’extrémité de sortie de courant de fuite du composant monté sur carte soumis à détection à une extrémité d’entrée inverseuse d’un amplificateur opérationnel d’un module de mesure de valeur de résistance, le module de mesure de valeur de résistance comprenant l’amplificateur opérationnel et une résistance de référence connectée entre l’extrémité d’entrée inverseuse de l’amplificateur opérationnel et l’extrémité de sortie de courant de fuite (étape 220) :
le calcul, sur la base de la loi d’Ohm et selon la tension de sortie et la résistance de référence, d’un courant de fuite circulant dans le composant monté sur carte soumis à détection (étape 240).
6. Appareil de détection de courant de fuite (200), appliqué à une détection de courant de fuite pour un composant monté sur carte sur une carte PCBA, l’appareil de détection de courant de fuite (200) comprenant :

un module de fourniture de tension (11), connecté à une extrémité d’entrée de courant de fuite d’un composant monté sur carte soumis à détection, et configuré pour fournir une tension fixe pour le composant monté sur carte soumis à détection ;

un module de mesure de valeur de résistance (12), comprenant un amplificateur opérationnel et une résistance de référence connectée entre une extrémité d’entrée inverseuse de l’amplificateur opérationnel et une extrémité de sortie de courant de fuite, et configuré pour fournir la résistance de référence, l’extrémité d’entrée inverseuse étant connectée à l’extrémité de sortie de courant de fuite du composant monté sur carte soumis à détection ; et

un module de commande (16), connecté au composant monté sur carte soumis à détection, au module de mesure de valeur de résistance et au module de fourniture de tension, et configuré pour calculer, sur la base de la loi d’Ohm et selon une tension de sortie du module de mesure de valeur de résistance et la résistance de référence, un courant de fuite circulant dans le composant monté sur carte soumis à détection,

le module de commande (16) comprenant en outre :

une unité d’isolement (164), configurée pour mettre en équivalence à une première résistance un ou plusieurs autres composants connectés à l’extrémité d’entrée de courant de fuite du composant monté sur carte soumis à détection, mettre en équivalence à une deuxième résistance un ou plusieurs autres composants connectés à l’extrémité de sortie de courant de fuite du composant monté sur carte soumis à détection, et configurer une extrémité d’isolement entre la première résistance et la deuxième résistance, à l’écart du composant monté sur carte soumis à détection, de façon à ce qu’elle présente un même potentiel que celui de l’extrémité de sortie de courant de fuite du composant monté sur carte soumis à détection.

7. Appareil de détection de courant de fuite (200) selon la revendication 6, dans lequel :

le composant monté sur carte soumis à détection est un condensateur possédant un pôle positif et un pôle négatif, l’extrémité d’entrée de courant de fuite constituant le pôle positif du condensateur et l’extrémité de sortie de courant de fuite constituant le pôle négatif du condensateur.

8. Appareil de détection de courant de fuite (200) selon la revendication 6, dans lequel :

le composant monté sur carte soumis à détection est un condensateur sans pôle positif ni pôle négatif, l’extrémité d’entrée de courant de fuite constitue une extrémité du condensateur et l’extrémité de sortie de courant de fuite constitue l’autre extrémité du condensateur.

9. Appareil de détection de courant de fuite (200) selon l’une quelconque des revendications 6 à 8, dans lequel le module de commande comprend :

une unité de détection, connectée au module de fourniture de tension et à l’extrémité de sortie de courant de fuite du module de mesure de valeur de résistance, et configurée pour détecter la tension de sortie du module de mesure de valeur de résistance ;

une unité de calcul, connectée à l’unité de détection, et configurée pour calculer le courant de fuite selon la Formule 7 :

\[ I_x = \frac{V_i}{R_x} = \frac{V_O}{R_{ref}} = I_{ref} \]  

Formule 7

\( I_x \) représentant le courant de fuite du composant monté sur carte soumis à détection, \( V_i \) représentant la tension fixe fournie par le module de fourniture de tension, \( R_x \) représentant une impédance équivalente en courant continu du composant monté sur carte soumis à détection, \( V_O \) représentant la tension de sortie du module de mesure de valeur de résistance, \( R_{ref} \) représentant une valeur de résistance de la résistance de référence du module de mesure de valeur de résistance et \( I_{ref} \) représentant un courant circulant dans la résistance de référence.

10. Appareil de détection de courant de fuite (200) selon la revendication 6, dans lequel l’unité d’isolement est configurée en outre pour : lorsque le composant monté sur carte soumis à détection est un composant à semi-conducteur monté sur carte, configurer le composant à semi-conducteur monté sur carte pour qu’il occupe un état bloqué.
FIG. 1

Connect a first test end of a board-mounted component under detection to a voltage providing module, and connect a second test end to a resistance testing module

Detect an output voltage of the resistance testing module

Calculate a leakage current of the board-mounted component under detection according to the output voltage and a reference resistor of the resistance testing module

FIG. 2
FIG. 3

Isolate a board-mounted component under detection from a component to which the board-mounted component under detection is connected

Connect a first test end of the board-mounted component under detection to a voltage providing module, and connect a second test end to a resistance testing module

Detect an output voltage of the resistance testing module

Calculate a leakage current of the board-mounted component under detection according to the output voltage and a reference resistor of the resistance testing module

Determine whether the leakage current is not less than a preset threshold, and send notification information according to a determination result

FIG. 4
FIG. 5

FIG. 6
FIG. 7

FIG. 8
REFERENCES CITED IN THE DESCRIPTION

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