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IMPEDANCE MEASURING APPARATUS FOR ELECTRONIC COMPONENT

BACKGROUND OF THE INVENTION

The priority document for this application, Japanese Patent Application No. 11-221995, is here incorporated by reference in its entirety.

1. Field of the Invention

The present invention relates to an impedance measuring apparatus for an electronic component using a four-terminal method (Kelvin method).

To simplify the description in this specification, an example has been chosen involving the measurement of a resistance to which DC signals are applied. Due to the natures of DC, the only parasitic parameters generated in a circuit are resistance components. When measurement is applied in the case of AC signals, though the parasitic parameters become impedances which are denoted using complex numbers, the concepts are akin to those for the measurement using DC signals.

2. Description of the Related Art

Hitherto, a two-terminal method, as shown in Fig. 1, is used to measure the impedance of an electronic component. In this case, a measured value of the impedance can be measured as $R_M = V/I$. R_M , which is measured using this method, includes contact resistances R_H and R_L occurring in measurement cables (or terminals), other than the impedance R_{dut} of the electronic component, which is a measurement object. This contact resistance includes lead-wire resistances of the measurement cables or the like. R_M may be expressed as:

$$R_M = V/I = R_{dut} + R_H + R_L$$

When R_H and R_L are very high relative to R_{dut} , making the value of R_{dut} negligible, a measurement error results. The contact resistances R_H and R_L vary whenever contact occurs between the measurement object and the measurement terminals. Accordingly, the influence of R_H and R_L cannot be removed by means of compensation or the like.

When the measurement error caused by the contact resistances R_H and R_L is not negligible, such as a case in which the measurement object has a low impedance, the measurement may be performed using a four-terminal method, as shown in Fig. 2.

In this method, the measured value $R_M = V/I = R_{dut}$ is obtained, and R_H and R_L are avoided as measurement error factors.

However, there are problems in the four-terminal method when contact failure occurs at voltage detection lines (H_P , L_P). For example, when many measurement objects are measured one after another, the H_P line is subject to contact failure, as shown in Fig. 3. If stray capacitance C_{HP} is generated on the H_P line at this time, the stray capacitance appears to have been charged by the voltage obtained on the measurement object before the present measurement of current was obtained. When a measurement object is measured in this state, the following expression is obtained.

$$R_M = V \text{ (previous voltage)} / I \text{ (present current)} = R_{dut}$$

(1)

The value obtained in this manner is not the resistance of the measurement object currently intended to be measured, as it is influenced by the most recent normal measurement of the measurement object. There is a possibility that measurement failure may occur on the L_P line as well as the H_P line, for similar reasons.

Therefore, when a contact failure occurs on a voltage detection line, the measured resistance value is not accurate when a "pure" four-terminal method is used.

Because such inaccuracies, there is a risk of delivering defective products instead of good products. In regard to current measurement, when a contact failure occurs at a current-carrying line H_C or L_C , measurement cannot be performed since the current I becomes zero.

It is desirable to use a voltage detection unit having a high input impedances R_{INH} and R_{INL} in the measuring apparatus, yet the input impedances are not infinite.

In addition, since the impedance of stray capacitance of the measurement cable is inserted so as to be in parallel, the input impedance is decreased. Accordingly, the voltage detected at the voltage detection unit is voltage-divided by the contact resistances R_{HP} and R_{LP} , and R_{INH} and R_{INL} . When R_{HP} and R_{LP} become too high

to be negligible, a measurement error occurs. Since R_{HP} and R_{LP} vary when contact occurs between the measurement object and the measurement cables, the measurement error due to this cannot be removed by means of a method such as compensation. Furthermore, when measurement using AC signals is performed, there is a possibility that measurement failure may occur because of electrostatic coupling or electromagnetically inductive coupling among the H_C and L_C lines, and the H_P and L_P lines.

SUMMARY OF THE INVENTION

Accordingly, it is an object of the present invention to provide an impedance measuring apparatus for an electronic component in which use of a simple circuit prevents a defective product from being inadvertently determined as a good product when contact failure occurs at a measurement terminal thereof.

It is another object of the present invention to provide an impedance measuring apparatus for an electronic component which decreases the measurement error due to contact resistance.

To this end, according to a first aspect of the present invention, there is provided an impedance measuring apparatus for an electronic component that measures the impedance of the electronic component using a four-terminal method.

The impedance measuring apparatus for the electronic component includes a first current-carrying line and a first voltage detection line connected to one electrode of

the electronic component; a first resistor establishing a connection between the first current-carrying line and the first voltage detection line; a second current-carrying line and a second voltage detection line connected to the other electrode of the electronic component; and a second resistor establishing a connection between the second current-carrying line and the second voltage detection line. In the impedance measuring apparatus, the first resistor and the second resistor have sufficiently high resistances compared to contact resistances occurring among the electrodes of the electronic component, the current-carrying lines, and the voltage detection lines.

According to a second aspect of the present invention, there is provided an impedance measuring apparatus for an electronic component for measuring the impedance of the electronic component using a four-terminal method. The impedance measuring apparatus for the electronic component includes a first current-carrying line connected to one electrode of the electronic component and a first voltage detection line connected to the other electrode thereof; a first resistor establishing a connection between the first current-carrying line and the first voltage detection line; a second current-carrying line connected to the other electrode of the electronic component and a second voltage detection line connected to the one electrode thereof; and a second resistor establishing the second current-carrying line and the second voltage detection line. In the impedance measuring apparatus, the first resistor and the second resistor have sufficiently high resistances compared to contact resistances occurring among the electrodes of the electronic component, the

current-carrying lines, and the voltage detection lines.

The impedance measuring apparatus according to the first aspect of the present invention may be used to effectively determine whether a product is defective or not when the impedance thereof is higher than a standard value. That is, in a measuring apparatus according to the first aspect of the present invention, when the measuring terminals and the electronic component are in good contact with each other, the result is a measurement equivalent to the four-terminal method, and the measured value is the impedance of the electronic component. If any of the measuring terminals fails to be in contact with the electronic component, the result is that the measurement method is converted from the equivalent of a four-terminal method to a two-terminal method at an electrode unit in which contact failure occurs.

When contact failure occurs, the measured value is increased by the corresponding amount of the contact resistances. By pulling-up the voltage detection lines, contact failure may be estimated, to reduce or eliminate the risk of delivering defective products as good products.

When contact failure occurs, it is desired to estimate the location of the contact failure. In accordance with a further embodiment of the present invention, a third resistor may be connected to the current-carrying line provided between the one electrode of the electronic component and the first resistor; and a fourth resistor may be connected to the current-carrying line provided between the other electrode of the electronic component and the second resistor. Preferably, the resistances of the third and fourth resistors are sufficiently lower than the first and second resistors, and

are sufficiently higher than the contact resistances, with the resistors each having a different resistance value. In this case, by changing the resistances of the third resistor and the fourth resistor, it is possible to estimate at which voltage terminal contact failure occurs.

In addition to connecting resistors to the current-carrying lines, a fifth resistor and a sixth resistor may be connected to the voltage detection lines. By setting the resistances of the third to the sixth resistors so as to be different from one another, it is possible to estimate every location of the occurrence of contact failure.

The impedance measuring apparatus according to the second aspect of the present invention may be used to effectively determine whether a product is defective or not when the impedance thereof is lower than a standard value. That is, in a measuring apparatus according to the second aspect of the present invention, when contact failure occurs on any of the measuring terminals, the measured value is decreased by an amount corresponding to the contact resistances. By pulling-down the voltage detection lines, contact failure may be estimated, to reduce or eliminate the risk of delivering defective products as good products.

In the impedance measuring apparatus according to the first or the second aspect of the present invention, it is desirable to have a sufficiently high input impedance of a voltage detection unit of the measuring apparatus. When measurement is performed using AC signals by means of the four-terminal method, there is a case in which a measuring apparatus has a high input impedance using a DC signal, yet has low input impedance for an AC signal due to input capacitance. In

addition, even though the input impedance of the measuring apparatus is high, the input impedance thereof is lowered due to stray capacitance of a measurement cable.

In these cases, preferably, by inserting a voltage follower having a high input impedance ahead of an input unit of the measuring apparatus, the influence due to contact failure is lessened, which can decrease the measurement error.

The voltage follower is preferably provided on at least the higher-voltage detection side of the voltage detection lines. It may be provided on the lower-voltage detection side of the voltage detection lines when necessary.

In addition, the impedance measurement can be performed by inserting resistors in the measuring circuit. Since no particular contact detection circuit is required, the measuring apparatus in accordance with the present invention may advantageously be realized with low cost.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a circuit diagram of an impedance measuring apparatus using a conventional two-terminal method;

Fig. 2 is a circuit diagram of an impedance measuring apparatus using a conventional four-terminal method;

Fig. 3 is a circuit diagram in a case in which contact failure occurs on a voltage detection line using the conventional four-terminal method;

Fig. 4 is a circuit diagram of a first embodiment of the impedance measuring apparatus according to the present invention;

Fig. 5 is a circuit diagram of a second embodiment of the impedance measuring apparatus according to the present invention;

Fig. 6 is a circuit diagram of a third embodiment of the impedance measuring apparatus according to the present invention;

Fig. 7 is a circuit diagram of a fourth embodiment of the impedance measuring apparatus according to the present invention; and

Fig. 8 is a circuit diagram of a fifth embodiment of the impedance measuring apparatus according to the present invention.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Fig. 4 shows a first embodiment of an impedance measuring apparatus using a four-terminal method according to the present invention. This measuring apparatus is used for estimating whether a product is defective in a case in which, for example, an inductor is defective when the impedance thereof is higher than a standard value.

In the figure, R_{dut} is an electronic component, which is a measurement object, and T_H and T_L are electrodes of the measurement object R_{dut} . An impedance measuring apparatus 1 includes a current source 2 (here, it is represented as a direct-current source, yet it may be an alternating-current source), an internal resistor 3, an ammeter 4, and a voltmeter 5. The current source 2 is connected to current terminals 6 and 7 via current-carrying lines H_c and L_c , respectively, and the voltmeter 5 is connected to voltage terminals 8 and 9 via voltage detection lines H_p and L_p ,

respectively. The current terminal 6 and the voltage terminal 8 are constructed so as to be in contact with one electrode T_H , while the current terminal 7 and the voltage terminal 9 are constructed so as to be in contact with the other electrode T_L .

R_{HC} and R_{LC} are contact resistances generated between the current terminal 6 and the electrode T_H , and between the current terminal 7 and the electrode T_L , respectively, each of which includes a lead-wire resistor of a measurement cable or the like forming the corresponding current-carrying line H_C or L_C . A first resistor R_{H1} is connected between the current-carrying line H_C and the voltage detection line H_P , which are connected to one electrode T_H , and a second resistor R_{L1} is connected between the current-carrying line L_C and the voltage detection line L_P , which are connected to the other electrode T_L . The resistances (for example, 100 k Ω) of the first and second resistors R_{H1} and R_{L1} are preferably set to be sufficiently higher than resistances (normally, equal to or below 10 Ω) which are normal for the contact resistances R_{HC} , R_{LC} , R_{HP} , and R_{LP} . That is, it is preferred that the resistances are related as follows.

$$R_{H1} \gg R_{HC}, R_{HP}$$

$$R_{L1} \gg R_{LC}, R_{LP}$$

Here, input impedances R_{INH} and R_{INL} of the voltmeter 5 of the measuring

apparatus 1 are assumed to be sufficiently high.

The measured value R_M of the above-described measuring apparatus 1 is given by the following expression.

$$R_M = V/I = R_{dut} + R_{HC}R_{HP}/(R_{HC} + R_{HP} + R_{H1}) + R_{LC}R_{LP}/(R_{LC} + R_{LP} + R_{L1}) \quad (2)$$

When the above-described measurement terminals 6 to 9 are in good contact with the measurement object R_{dut} (R_{HC} , R_{LC} , R_{HP} , and R_{LP} are, for example, below 10 Ω), the measurement is equivalent to the one using a normal four-terminal method. Since the second and third terms of the above-described expression become approximately zero, $R_M = V/I = R_{dut}$ is obtained.

When the voltage terminals 8 and 9 are not in contact with the measurement object, in other words, when contact failure occurs on the voltage detection line H_P and/or L_P , the measured value is as follows. When the voltage terminal 8 (the H_P line) is not in contact with the measurement object, $R_M = V/I = R_{dut} + R_{HC}$. When the voltage terminal 9 (the L_P line) is not in contact with the measurement object, $R_M = V/I = R_{dut} + R_{LC}$. When neither of the voltage terminals 8 and 9 (the H_P and L_P lines) are contact with the measurement object, $R_M = V/I = R_{dut} + R_{HC} + R_{LC}$.

In accordance with the present invention, when contact failure occurs, the

measured value may be increased by the corresponding amount of the contact resistances by pulling-up the voltage detection lines. In this way, the present invention is able to more accurately determine whether a product is defective or not, when the resistance thereof is higher than a standard value. Hence, the risk of inadvertently selecting a defective product as being a good product may be reduced or avoided. On the other hand, when the resistance is less than the standard value (in spite of the inclusion of the contact resistances) the present invention naturally determines the product as being a good product.

Likewise, the present invention may also be used to detect the case in which the current terminal 6 or 7 is not in contact with the measurement object. When the current terminal 6 (the H_C line) is not in contact with the measurement object, $R_M = V/I = R_{dut} + R_{HP}$. When the current terminal 7 (the L_C line) is not in contact with the measurement object, $R_M = V/I = R_{dut} + R_{LP}$. Accordingly, the result is that the measurement may be considered to be effectively performed by means of a two-terminal method using the H_P and L_P lines.

Fig. 5 shows a second embodiment of the measuring apparatus according to the present invention, which is an example in which a part of the measuring apparatus shown in Fig. 4 is modified. In accordance with this embodiment, the voltage detection lines or the current detection lines on which a contact failure occurs may be detected when the resistance of the measurement object is relatively low, based on the measured value.

A third resistor R_{H3} is connected to the current-carrying line H_C provided between one electrode T_H of the measurement object R_{dut} and the first resistor R_{H1} , and a fourth resistor R_{L3} is connected to the current-carrying line L_C provided between the other electrode T_L thereof and the second resistor R_{L1} . A fifth resistor R_{H4} is connected to the voltage detection line H_P provided between one electrode T_H thereof and the first resistor R_{H1} , and a sixth resistor R_{L4} is connected to the voltage detection line L_P provided between the other electrode T_L thereof and the second resistor R_{L1} . The resistances of the third to the sixth resistors R_{H3} , R_{L3} , R_{H4} , and R_{L4} are preferably each sufficiently lower than the resistances of the first and the second resistors R_{H1} and R_{L1} , and are sufficiently higher than the resistances which are normal for the contact resistances R_{HC} , R_{LC} , R_{HP} , and R_{LP} . In addition, each of them is different from one another. That is, it is preferred that the resistances are related as follows.

$$R_{H1} \gg R_{H3}, R_{H4} \gg R_{HC}, R_{HP}$$

$$R_{L1} \gg R_{L3}, R_{L4} \gg R_{LC}, R_{LP}$$

For example, when R_{dut} is about 100 m Ω , when values which R_{HC} , R_{LC} , R_{HP} , and R_{LP} can normally take are below 1 Ω , and when $R_{H3} = 20 \Omega$, $R_{L3} = 10 \Omega$, $R_{H4} =$

40 Ω , and $R_{L4} = 80 \Omega$, the measured value varies in accordance with the location of the occurrence of contact failure, and may be determined as follows. When contact failure occurs on the H_P line, the measured value is in the 20 Ω region. When contact failure occurs on the L_P line, the measured value is in the 10 Ω region. When contact failures occur on both of the H_P line and the L_P line, the measure value is in the 30 Ω region. When contact failure occurs on the H_C line, the measured value is in the 40 Ω region. When contact failure occurs on the L_C line, the measured value is in the 80 Ω region. When contact failure occurs on both of the H_C line and the L_C line, the measured value is in the 120 Ω region. As described above, the location of the occurrence of contact failure may be determined based on the measured value.

In a variation of the embodiment shown in Fig. 5, the resistors R_{H4} and R_{L4} need not be included. That is, although the current-carrying lines H_C and L_C and the voltage detection lines H_P and L_P are connected to the resistors R_{H3} , R_{L3} , R_{H4} , and R_{L4} , respectively, the resistors R_{H4} and R_{L4} provided on the current-carrying lines H_C and L_C respectively, can be omitted. This is due to the fact that the resistors R_{H4} and R_{L4} , which serve to detect contact failure on the current-carrying lines H_C and/or L_C , bring about no measurement error as long as no contact failure occurs on either of the voltage detection lines H_P and L_P .

Fig. 6 shows a third embodiment of the impedance measuring apparatus

according to the present invention. This measuring apparatus is used for estimation in a case in which a product is defective when the impedance thereof is lower than a standard value.

A first resistor R_{H2} is connected among the current-carrying line H_C connected to one electrode T_H of the measurement object R_{dut} , the voltage detection line L_P connected to the other electrode T_L . A second resistor R_{L2} is connected between the current-carrying line L_C connected to the other electrode T_L and the voltage detection line H_P connected to the electrode T_H . The resistances (for example, 50 k Ω) of these first and second resistors R_{H2} and R_{L2} are preferably set so as to be sufficiently higher than values (normally, equal to or below 10 Ω) which are normal for the contact resistances R_{HC} , R_{LC} , R_{HP} , and R_{LP} . That is, it is preferred that the resistances are related as follows.

$$R_{H2} \gg R_{HC}, R_{HP}$$

$$R_{L2} \gg R_{LC}, R_{LP}$$

In the measuring apparatus in Fig. 6, when contact failure occurs on the voltage detection lines H_P and/or L_P , the measured value R_M is typically related as follows.

$$R_M = - R_{LC} \text{ (when the } H_P \text{ line is not in contact)}$$

$$R_M = - R_{HC} \text{ (when the } L_P \text{ line is not in contact)}$$

$$R_M = -R_{dut} - R_{LC} - R_{HC} \text{ (when neither } H_P \text{ nor } L_P \text{ is in contact)}$$

Accordingly, when contact failure occurs on the voltage detection lines H_P and L_P in this manner, by pulling-down the voltage detection lines, the measured value decreases. Hence, in a manner of selection in which a product is judged to be defective when the resistance of the product is less than a standard value, the risk of inadvertently selecting a defective product as being a good product may be reduced or avoided.

Fig. 7 shows a fourth embodiment of the impedance measuring apparatus according to the present invention, wherein the fourth embodiment is a variation of the embodiment in Fig. 6. In Fig. 6, when contact failure occurs, a measured value may be negative in some cases. In those instances that it is desired for the measured value to be positive, or in the case in which the measured value is desired to be in the proximity of a predetermined resistance even though contact failure occurs, as shown in Fig. 7, the resistors R_{H1} and R_{L1} are each preferably connected between the corresponding current-carrying lines and the corresponding voltage detection lines that are in contact with the same electrodes in addition to the resistors R_{H2} and R_{L2} .

The resistances (for example, 100 k Ω) of these resistors R_{H1} and R_{L1} are preferably set so as to be sufficiently higher than values (normally, equal to or below 10 Ω) which are normal for the contact resistances R_{HC} , R_{LC} , R_{HP} , and R_{LP} .

In the above-described measuring apparatus, when contact failure occurs on the voltage detection lines H_P and/or L_P , the measured value can be seemingly offset

to some extent by causing the voltmeter 5 to detect what is obtained by voltage-dividing the applied voltage using these resistors R_{H1} , R_{L1} , R_{H2} , and R_{L2} . These resistances and the voltage-divided ratio are selected in accordance with the measurement object R_{dut} .

Fig. 8 shows a fifth embodiment of the impedance measuring apparatus according to the present invention.

As shown in the first to the fourth embodiments, in order to actually use a method in which the voltage detection lines are pulled-up or pulled-down, it is preferred that the input impedances R_{INH} and R_{INL} of the voltage detection unit of the measuring apparatus 1 be sufficiently high. For example, there is a case in which a measuring apparatus has a high input impedance for a DC signal, yet has a low input impedance for an AC signal due to input capacitance. In addition, there is a case in which the input impedance of the measuring apparatus is lowered due to stray capacitance of a measurement cable. In these cases, when, as shown in the first to the fourth embodiments, contact resistances are added to be in series with the corresponding voltage detection lines H_p and L_p , the measurement error increases.

Accordingly, in this embodiment, voltage followers VF_H and VF_L having high input impedances are inserted ahead of the voltage detection unit (H_p , L_p) of the measuring apparatus 1, whereby the measurement error due to contact resistances decreases. The voltage followers VF_H and VF_L serve to greatly enhance the input impedance of the measurement system observed from the measurement object side

as well as to greatly reduce output impedance of the measurement object observed from the measuring-apparatus side (impedance conversion). In order to avoid the occurrence of unnecessary noise, a low-noise type operational amplifier or the like is desired to be used to form the voltage followers VF_H and VH_L .

Fig. 8 shows an embodiment in which the voltage followers VF_H and VF_L are applied to the embodiment shown in Fig. 4. In the same manner, the voltage followers can be applied to the embodiments in Figs. 5, 6 and 7.

In addition, it is effective that the voltage followers VF_H and VF_L are provided on the higher-voltage detection side of the voltage detection lines H_P and L_P .

It should be understood that the present disclosure of preferred forms of the present invention are exemplary and not limited in every respect. The scope of the invention is defined by the appended claims rather than by the description preceding them, and all changes that fall within the scope of the claims, or equivalence of such scope of the claims, are intended to be included by the claims.



WHAT IS CLAIMED IS:

1. An impedance measuring apparatus for an electronic component for measuring impedance of an electronic component using a four-terminal method, the impedance measuring apparatus for the electronic component comprising:

a first current-carrying line and a first voltage detection line connected to one electrode of said electronic component;

a first resistor establishing a connection between said first current-carrying line and said first voltage detection line;

a second current-carrying line and a second voltage detection line connected to the other electrode of said electronic component; and

a second resistor establishing a connection between said second current-carrying line and said second voltage detection line,

wherein said first resistor and said second resistor have sufficiently high resistances compared to contact resistances occurring among the electrodes of said electronic component, the current-carrying lines, and the voltage detection lines.

2. The impedance measuring apparatus for an electronic component according to Claim 1, further comprising:

a third resistor connected to said first current-carrying line provided between the one electrode of said electronic component and said first resistor; and

a fourth resistor connected to said second current-carrying line provided between the other electrode of said electronic component and said second resistor,

wherein resistances of said third resistor and said fourth resistor are sufficiently low compared to the resistances of said first resistor and said second resistor, are sufficiently high compared to the contact resistances occurring among the electrodes of said electronic component, the current-carrying lines, and the voltage detection lines, and are different from each other.



3. The impedance measuring apparatus for an electronic component according to Claim 1, further comprising:

a voltage follower having a high input impedance and inserted on at least the higher-voltage detection side of the voltage detection lines provided among said first resistor, said second resistor, and the measuring apparatus.

4. An impedance measuring apparatus for an electronic component for measuring impedance of the electronic component using a four-terminal method, the impedance measuring apparatus for the electronic component comprising:

a first current-carrying line connected to one electrode of said electronic component and a first voltage detection line connected to the other electrode thereof;

a first resistor establishing a connection between said first current-carrying line and said first voltage detection line;

a second current-carrying line connected to the other electrode of said electronic component and a second voltage detection line connected to the one electrode thereof; and



a second resistor establishing a connection between said second current-carrying line and said second voltage detection line,

wherein said first resistor and said second resistor have sufficiently high resistances compared to contact resistances occurring among the electrodes of said electronic component, the current-carrying lines, and the voltage detection lines.

5. The impedance measuring apparatus for an electronic component according to Claim 4, further comprising:

a voltage follower having a high input impedance and inserted on at least the higher-voltage detection side of the voltage detection lines provided among said first resistor, said second resistor, and the measuring apparatus.

6. A four-terminal type impedance measuring apparatus for measuring impedance of a device under test, said impedance measuring apparatus comprising:

a voltage detection path electrically connected between first and second terminals which are in communication with the device under test, the voltage detection path characterized by a voltage detection path resistance which comprises a first contact resistance R_{HP} associated with said first terminal and a second contact resistance R_{LP} associated with said second terminal; and

a voltage meter electrically connected in between the first and the second terminals as part of said voltage detection path, a voltage reading across said voltage meter being represented as V ;

a current detection path electrically connected between third and fourth terminals which are in communication with the device under test, the current detection path characterized by a current detection path resistance which comprises a third contact resistance R_{HC} associated with said third terminal and a fourth contact resistance R_{LC} associated with said fourth terminal;

a current meter electrically connected in series with a current source between the third and the fourth terminals as part of said current detection path, said current source providing a current represented as I through said current meter;

a first resistor R_{H1} having one end connected to the current detection path between said current meter and said third terminal and having an other end connected to the voltage detection path between said voltage meter and said first terminal;

a second resistor R_{L1} having one end connected to the current detection path between said current meter and said fourth terminal and having an other end connected to the voltage detection path between said voltage meter and said second terminal;

whereby said first resistor R_{H1} and second resistor R_{L1} are larger than said contact resistances R_{HP} , R_{LP} , R_{HC} , R_{LC} such that a resistance R_M calculated by V/I is substantially the same as a voltage across said device under test V_{dut} due to the current from said current source.



7. The impedance measuring apparatus for an electronic component

according to Claim 6, wherein the said first resistor R_{HI} and second resistor R_{LI} are at least ten times larger than larger than said contact resistances R_{HP} , R_{LP} , R_{HC} , R_{LC} .

8. The impedance measuring apparatus for an electronic component according to Claim 6, wherein a resistance measurement of said device under test R_M is characterized by the relationship:

$$R_M = V / I = R_{dut} + R_{HC}R_{HP} / (R_{HC} + R_{HP} + R_{HI}) + R_{LC}R_{LP} / (R_{LC} + R_{LP} + R_{LI}).$$



9. An impedance measuring apparatus comprising:
a voltmeter connected between a first terminal and a second terminal;
an ammeter connected in series with a current source between a third terminal and a fourth terminal;
a first resistor connected between the first terminal and the third terminal; and
a second resistor connected between the second terminal and the fourth terminal;
wherein a current passing through said third terminal is greater than a current passing through said first resistor; and
wherein a current passing through said fourth terminal is greater than a current passing through said second resistor.

10. The impedance measuring apparatus for an electronic component according to Claim 9, wherein the first terminal is connected to the third terminal,

and the second terminal is connected to the fourth terminal.

11. The impedance measuring apparatus for an electronic component according to Claim 10, wherein said first terminal is characterized by a first contact resistance, said second terminal is characterized by a second contact resistance, said third terminal is characterized by a third contact resistance, and said fourth terminal characterized by a fourth contact resistance.



12. The impedance measuring apparatus for an electronic component according to Claim 11, wherein a resistance of the first resistor is higher than the first contact resistance or the third contact resistance, and a resistance of the second resistor is higher than the second contact resistance or the fourth contact resistance

13. The impedance measuring apparatus for an electronic component according to Claim 12, wherein the resistance of the first resistor is at least ten times higher than the first contact resistance or the third contact resistance, and the resistance of the second resistor is higher than the second contact resistance or the fourth contact resistance.

14. The impedance measuring apparatus for an electronic component according to Claim 9, wherein the first terminal is connected to the fourth terminal, and the second terminal is connected to the third terminal.