User's Guide

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instrumentos de medida

Insulation Resistance Measurement Handbook

Contents

1　Introduction

　Insulation properties are evaluated in a variety of products and materials that make up products. If products or parts have conductive areas that are undesirable for electricity to flow through, their safety is evaluated based on their insulation properties; for example wires and cables, the enclosures of electric products, and separators between electrode materials in batteries. . Electrical insulation properties are represented by a numerical value called "Insulation resistance ".Some materials with high insulation resistance require measures to address static electricity, including clothing, fiber, paper, paint, IC packaging, and chip component reels. Typically, substances with high insulation resistance readily accumulate electric charges, which can result in static buildup, therefore resistance must be neither too high nor too low.

　Besides these materials, insulation resistance is one of the indicators that determines the properties of electronic devices such as capacitors. As described above, insulation properties are quantitatively evaluated in many fields.　[1]

　In order to quantitatively and accurately evaluate insulation properties, it is necessary to understand the appropriate measuring instrument and measuring method based on your objective and on the test environment. This Guide describes characteristic properties of devices under test as well as measurement principles and introduces associated measurement expertise and applications for products provided by HIOKI.

2　Resistance

-1　Resistance [2]

In this context, resistance refers to electrical resistance. Resistance is measured using the ohm (Ω) as the unit.

When the potential difference V occurs across a pair of terminals, charge (electrons or holes) moves toward the electrode with different polarity. Resistance interferes with this movement. According to Ohm's law, the current I can be expressed as follows:

$$I = \frac{V}{R} \tag{2-1}$$

This law indicates that the larger the potential difference V, and the smaller the resistance R, the more current I will flow. The resistance value can be expressed using Equation (2-2):

$$R = \rho \frac{l}{S} \tag{2-2}$$

(where ρ : indicates resistivity、l : the length of the resistor、S : the cross-sectional area of the resistor)

Resistance increases with the length and thinness of the conductor. The resistance value varies with physical size in this way, and resistance values generally fall within the range illustrated in Figure 2-3.
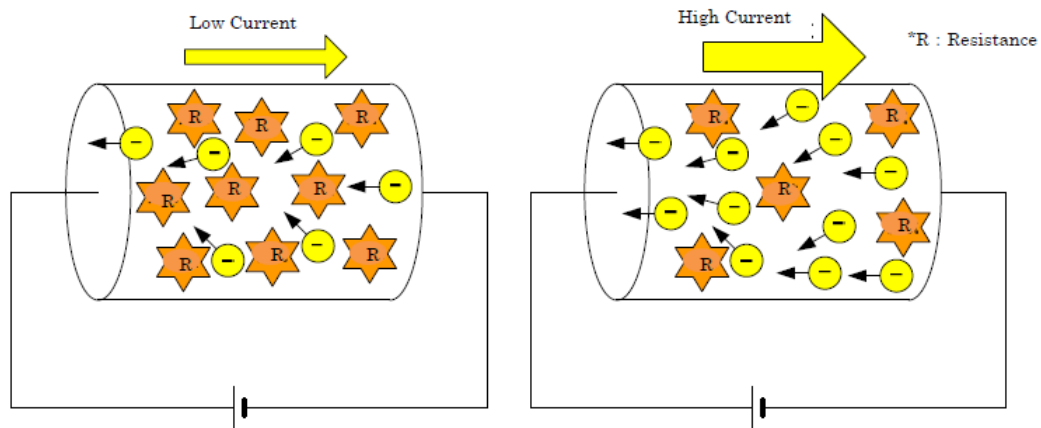
Figure 2-1. High resistance　　　　　　Figure 2-2. Low resistance

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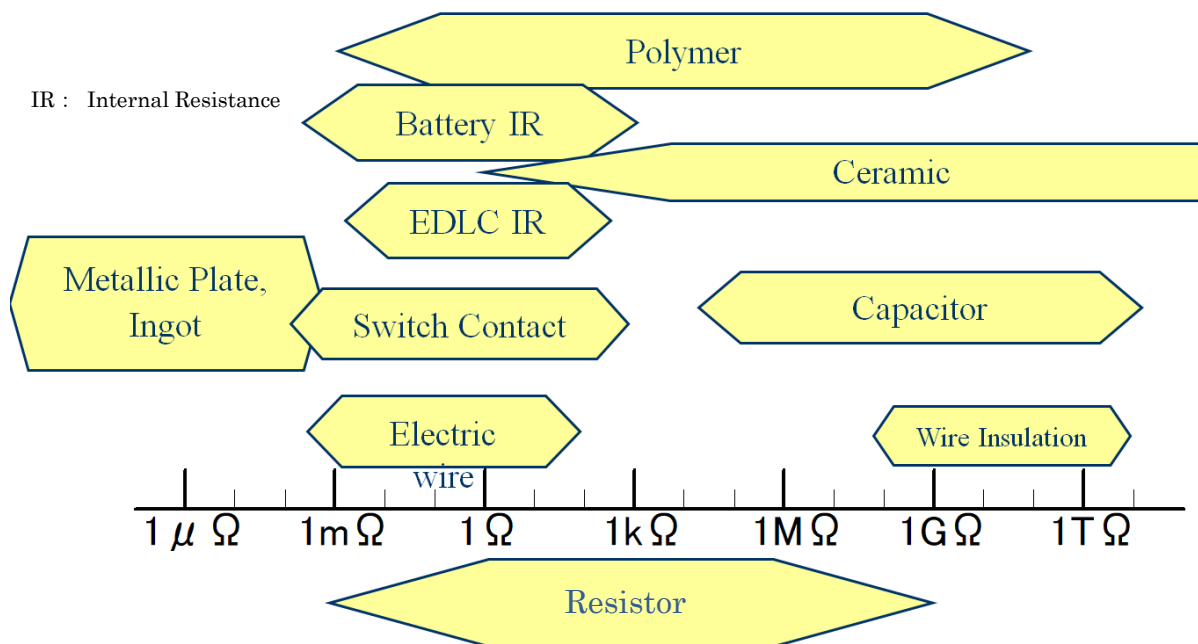
Figure 2-3. Various measurement targets and resistance

-2 Insulation resistance

(1) Insulators [3]

Insulation resistance measurement is a technique used to measure insulators, which generally impede the flow of electricity. Whereas conductors are conducive to the flow of electricity, such materials that impede the flow of electricity are electromagnetically classified as either **non-conductors** or **insulators**. Insulators lack free electrons, with the result that their electrons change potential only slightly when a high level of energy is applied. Insulators whose electrons' energy state changes when electrical energy is applied (for example, when a voltage is applied) are known as **dielectrics**.   This document describes measurement methods and technologies used to evaluate the properties of leakage currents and minuscule currents that flow when a voltage is applied in insulators and dielectrics.

(2) Insulation resistance [4]

Insulators are materials that impede the flow of electricity.   The higher resistance values they have, the more they impede the flow of electricity. Insulation resistance refers to the extremely high resistance that characterizes insulators.

Insulation resistance is generally evaluated by applying a DC voltage to an insulator and then measuring the current that flows through the insulator (Figure 2-4).
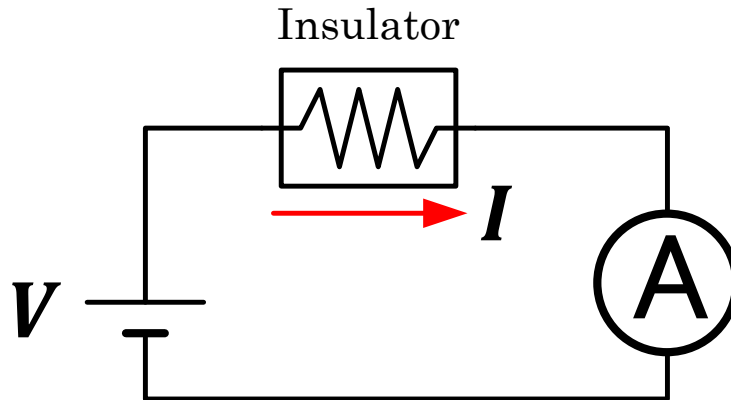
Figure 2-4. Insulator when a DC voltage is applied

An approximation of Ohm's Law applies between the DC voltage V and the minuscule current I in this circuit just as it does for a typical DC circuit.

$$R = V/I \qquad\qquad (2\text{-}3)$$

The insulation resistance value is calculated using the above equation. In an actual measurement, the generated voltage and the measured current value are substituted for V and I, respectively. For more information about current measurement methods and power supplies, see Chapter 4; for more information about resistance measurement methods used to assess insulation resistance, see Chapter 5.

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3　Characteristics of Devices under Test

　　Chapter 1 explained that insulation resistance is the ratio of the current that flows when a voltage is applied to an insulator and the applied voltage. Since the voltage applied to the device under test(DUT) is a constant voltage, the DUT can be treated as the insulator (dielectric) in a constant electric field. In other words, the insulation resistance value can be described as the quantity that expresses the electrical state of the insulator (dielectric) in a constant electric field. Additionally, the insulation resistance value at that time can be treated as an indicator of the change in the dielectric's properties. This chapter introduces the dielectric phenomena and electrical characteristics of typical DUTs while using actual measurement examples to describe how they are related to insulation resistance values. However, it does not address the underlying physical properties in a detailed manner, limiting itself to a phenomenological explanation.

-1　Properties of Dielectric Substances

(1)　Dielectric Constant　[5]

　　The dielectric constant expresses the material-specific electrical properties of a particular dielectric. In other words, the dielectric constant is the quantity that expresses the magnitude of the electrostatic energy stored in a unit volume in a unit electric field.

　　Imagine a parallel flat plate capacitor filled with a dielectric between two electrodes. When the voltage V is applied to a capacitor with the capacitance C, the charge Q that accumulates between the electrodes is known to exhibit the relationship expressed in Equation (3-1).

$$Q = CV \qquad (3\text{-}1)$$

Generally, the capacitance C is expressed by the electrode area S and the distance between electrodes d, as shown in Equation (3-2).

$$C = \varepsilon \frac{S}{d} \qquad (3\text{-}2)$$

In this equation, ε represents the dielectric constant. The capacitance C_0 when the dielectric is replaced by a vacuum is given by the following equation:

$$C_0 = \varepsilon_0 \frac{S}{d} \qquad (3\text{-}3)$$

C_0 is known as the **geometrical capacitance**. Here ε_0 is the dielectric constant in a vacuum, and the dielectric constant ε_r, defined by $C \equiv \varepsilon_r C_0$ (where $\varepsilon_r > 1$), can be described in terms of the following relationship:

$$\varepsilon = \varepsilon_0 \varepsilon_r \qquad (3\text{-}4)$$

Returning to our parallel flat plate capacitor filled with a dielectric between two electrodes, the energy $\boldsymbol{W}$ stored by this capacitor is described by Equation (3-5):

$$W = \frac{1}{2}CV^2 = \frac{1}{2}\varepsilon\frac{S}{d}V^2 \qquad (3\text{-}5)$$

The uniform electric field $\boldsymbol{E}$ occurs in the capacitor's dielectric when the voltage $\boldsymbol{V}$ is being applied. The electric field and the voltage between the capacitor's terminals can be described as $\boldsymbol{dE = V}$. The energy stored in the capacitor as shown in Equation (3-5) can be rewritten as shown in Equation (3-6):

$$W = \frac{1}{2}\varepsilon(Sd)E^2 \qquad (3\text{-}6)$$

Consequently, the dielectric constant $\boldsymbol{\varepsilon}$ can be expressed as shown in Equation (3-7):

$$\varepsilon = \frac{2W^2}{(Sd)E^2} \qquad (3\text{-}7)$$

-2   Insulation Resistance of Dielectric Constants [4] [6]

Quantitative phenomena can be reproduced by replacing an insulating material such as a dielectric to which a DC voltage is applied with a model consisting of a large number of elements, as illustrated in Figure 3-1 (a),. For purposes of simplification, the following explanation and figures describe parallel elements consisting of insulation resistance components and capacitance components such as the one shown in (b) as an insulation/dielectric model.
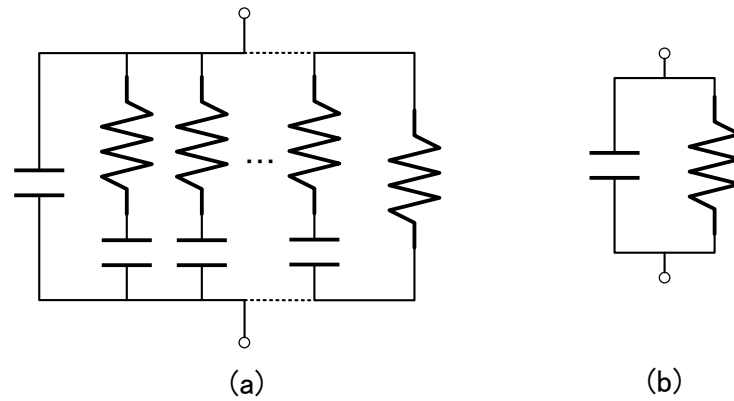
Figure 3-1. (a) Model to reproduce phenomena related to the insulation resistance of dielectrics and (b) simplified model

The previous section explained how an ideal parallel flat plate capacitor to which a constant voltage is applied from an external source stores energy that depends on the dielectric constant per unit volume. However, in fact, a parallel flat plate capacitor to which a DC voltage is applied has an extremely small leakage current in parallel resistor element, as in the model shown in Figure 3-1 (b). A similar model expresses the phenomenon resulting from an AC voltage (Figure 3-2) [6]。
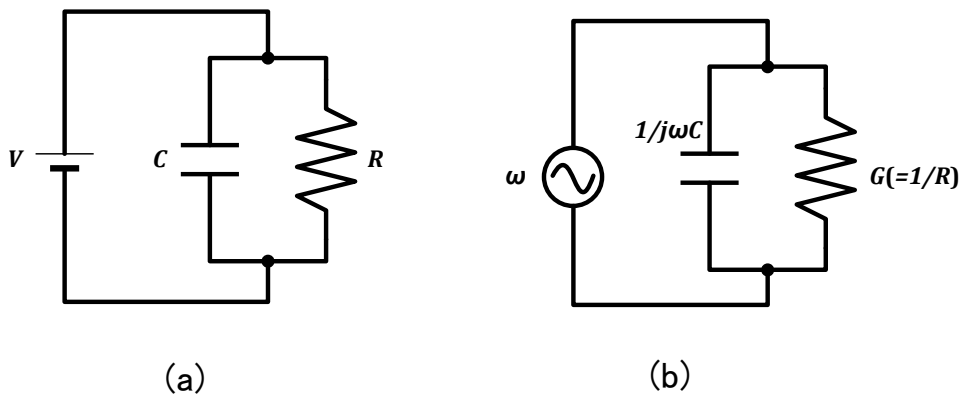
Figure 3-2. (a) An insulator exposed to a DC voltage and (b) an insulator exposed to an AC voltage

(1)   Dielectric Absorption

   A momentary charging current flows to a dielectric when a voltage is applied but then decreases gradually and converges on a certain value. The current that converges at a certain value is known as the **leakage current.** The transient current that flows until the momentary charging current converges on the leakage current is known as the **absorption current**. Figure 3-3 provides a diagram of this change in current.
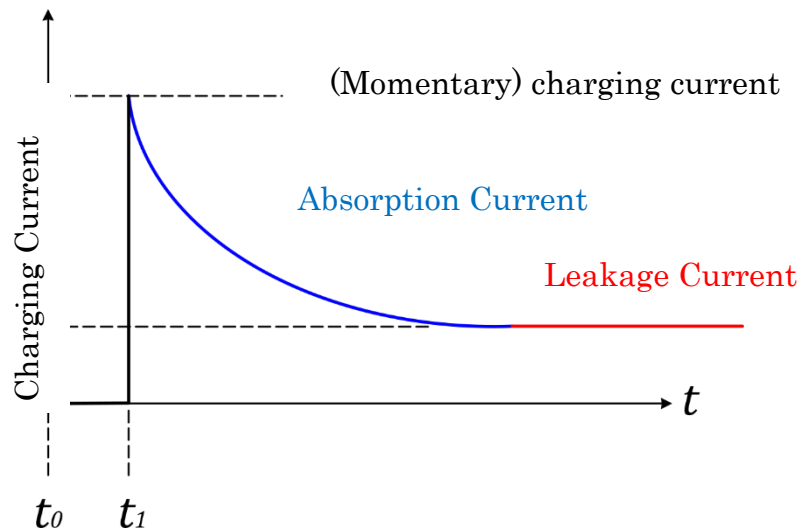
Figure 3-3. Dielectric absorption

The vertical axis in Figure 3-3 indicates the current flowing to the DUT, while the horizontal axis indicates time. A voltage is applied at time t_1 in the figure, and a charging current flows at that instant. An absorption current that varies with time as the charge is absorbed by the dielectric flows immediately afterwards and converges on the leakage current. This dielectric phenomenon, in which an absorbed charge causes changes in the current that flows, is known as **dielectric absorption**. Dielectric absorption occurs in reverse when a dielectric that has absorbed a charge is discharged. Figure 3-4 below illustrates that phenomenon.
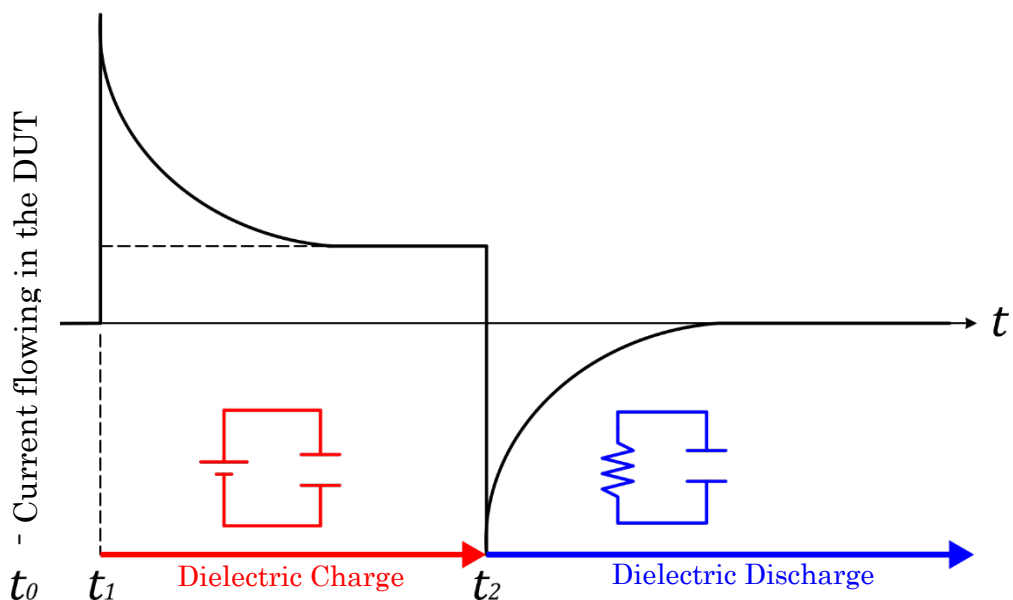
Figure 3-4. Dielectric absorption during the dielectric charging and discharging process

In the model shown in Figure 3-4, a constant voltage is applied to the capacitor at time t_1, and only the leakage current resulting from the stored charge flows. The capacitor is fully charged at

this time. At time t_2 it exhibits resistance discharge and the voltage applied at the instant t_2 is in the opposite direction of the voltage at t_1. The charge is discharged as the discharging current flows while exhibiting the same converging characteristics as during the charging process. The current which varies with time during the discharging process is also known as the absorption current. This type of change is observed in all insulating materials, and the charging and discharging times vary with the material, as does the characteristic curve describing dielectric absorption. Since dielectric absorption influences the current that flows to an insulator, it is important to ensure adequate charging (by applying an adequate voltage over an adequate period of time) and adequate discharging (by minimizing the residual charge in the DUT) in order to obtain the insulation resistance value as calculated from the leakage current.

(2)　1-minute values　[4]

　As described in the preceding paragraph, a voltage must be applied for a certain amount of time in order to obtain the ideal leakage current. However, it may take anywhere from several hours to several days to measure materials that are subject to longer charging times, for example high-capacity capacitors. Therefore a quantity known as **the 1-minute value** is used for reasons of expedience. As its name suggests, the 1-minute value is **the value at the 60th second after the start of voltage application**, and that value is used as an indicator of insulation resistance in standards such as JIS C2139 and JIS K6911. Incidentally, the 1-minute value has no theoretical basis. It is merely used to keep measurement conditions uniform. Consequently, the same substance may yield different values if the voltage across the DUT's terminals, the current flowing to the DUT, or the DUT's charge quantity changes.

　When measuring the same sample multiple times, dielectric absorption will occur if a charge remains because not enough time is allowed for the DUT to discharge. Conditions change each time a voltage is applied, and naturally those conditions affect insulation resistance values. As a result, adequate discharge before measurement is extremely important in ensuring the reproducibility of measured values.

4　Current Measurement Method

Methods used by insulation resistance testers to measure minuscule currents include the shunt method, feedback method, and integration method.　Each method has its own advantages and disadvantages. It is necessary to understand this information when configuring the instrument and connecting it to samples. This chapter introduces methods used to measure minuscule currents.

Table　1. Measurement methods and their characteristics

Method		Noise immunity	Response speed	HIOKI products
Resistance methods	Shunt method	Susceptible to the effects of Johnson noise High-frequency noise　med Low-frequency noise　good	Varies with DUT and shunt resistance.	SM-82xx series
	Feedback method	Susceptible to the effects of Johnson noise High-frequency noise　med Low-frequency noise　good	Does not vary with DUT. Faster than the shunt method.	ST5520
Integration method		Not susceptible to the effects of Johnson noise High-frequency noise　excellent Low-frequency noise　med	Does not vary with DUT. Faster than the shunt method.	SM71xx series SM7420 SM7810

-1　Shunt Method [7]

Figure 4-1 illustrates an insulation resistance measurement circuit that uses the shunt method. This method is the most fundamental current measurement circuit, and it is used to measure a wide range of currents, from miniscule currents to large currents.

DUT : Device under test
V_{DUT} : Voltage applied to DUT
I_X : Current flowing through the DUT
R_{in} : Input Resistance
R_X : Insulation resistance of the DUT
C_X : Capacitance of the DUT
E : Test voltage
e_n : Noise voltage
E_{in} : Potential Op amp input
R_S : Shunt resistance
V_S : Voltage drop caused
　　by shunt resistance
G_A : Gain of Op amp A
V_O : Output Voltage

Figure4-1. Insulation resistance measurement circuit using the shunt method

When the test voltage E is applied to the DUT, the current I_x flows. The current I_x flows to the shunt resistor R_s, causing the voltage drop V_s across the terminals of the shunt resistor R_s.

The voltage drop V_s is amplified by operational amplifier A and output as the output voltage V_o. The impedance is converted by operational amplifier A and transmitted to the downstream circuitry. The relationship between the output voltage V_o and the current I_x is expressed by Equation (4-1).

$$V_o = I_x R_s \left(1 + \frac{R_2}{R_1} \right) \qquad (4\text{-}1)$$

The test voltage E applied to the DUT is divided by the DUT's insulation resistance R_x and the shunt resistance R_s. Consequently, the operational amplifier's input potential E_{in} can be expressed by Equation (4-2).

$$E_{in} = E \frac{R_s}{R_x + R_s} \qquad (4\text{-}2)$$

Equation (4-2) indicates that the operational amplifier A's input potential E_{in} increases (approaching E) with the shunt resistance R_s. At this time, the voltage V_{DUT}, **which is applied to the DUT,** is expressed with Equation (4-3). It indicates that the gap between V_{DUT} and test voltage E increases with the shunt resistance R_s.

$$V_{DUT} = E - E_{in} \qquad (4\text{-}3)$$

An instrument can provide multiple measurement ranges by switching the value of the shunt resistance R_s. The input resistance R_{in} is expressed by Equation (4-4). As indicated in Equation (4-4), the input resistance varies with the shunt resistance R_s. An error component may be introduced due to variations in the input resistance R_{in} when switching ranges.

$$R_{in} = R_s \qquad (4\text{-}4)$$

Response speed is determined by the DUT's insulation resistance R_x, capacitance Cx, and shunt resistance R_s. The input circuit response is expressed by Equation (4-5). Equation (4-5) indicates that when measuring the same DUT, the input circuit's time constant decreases as the DUT's insulation resistance R_x, capacitance Cx, and shunt resistance R_s decrease, with the result that response speed increases.

$$\tau_s = C_x \frac{R_s R_x}{R_s + R_x} \qquad (4\text{-}5)$$

The AC noise component v_{on} of the output voltage V_o is expressed by Equation (4-6).

Additionally, the DUT's impedance Z_x is expressed by Equation (4-7).

$$v_{on} = (1 + \frac{R_2}{R_1}) \frac{R_s}{R_s + Z_x} e_n \qquad (4\text{-}6)$$

$$Z_x = \frac{R_x}{1 + j\omega C_x R_x} \qquad (4\text{-}7)$$

-2   Resistance Feedback Method [7] [8]

Figure 4-2 illustrates an insulation resistance measurement circuit that uses the resistance feedback method.

DUT : Device under test
V_{DUT} : Voltage applied to the DUT
I_X : Current flowing through the DUT
R_{in} : Input resistance
R_X : Insulation resistance of the DUT
C_X : Capacitance of the DUT
E : Test voltage
e_n : Noise voltage
E_{in} : Potential of the OP Amp inputs
R_f : Feedback resistance
V_f : Voltage drop due to
        feedback resistance
C_F : Capacitance limiting the AC gain
G_A : Gain of OP Amp A
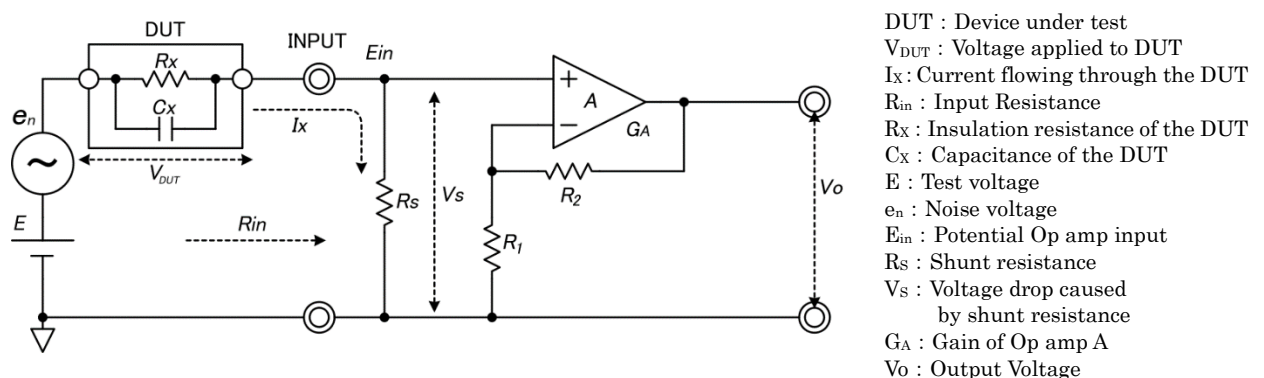V_o : Output Voltage
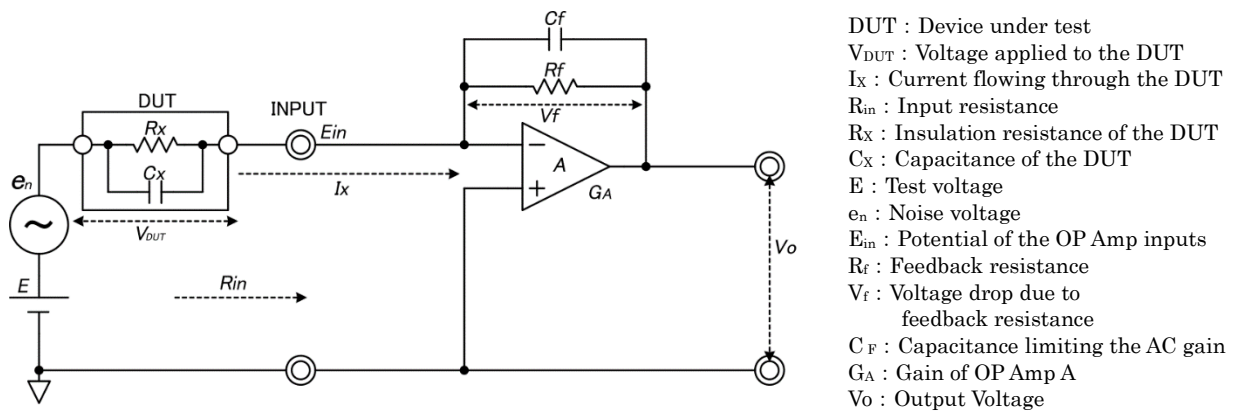
Figure 4-2. Insulation resistance measurement circuit using the resistance feedback method

When the test voltage E is applied to the DUT, the current I_x flows. The current I_x flows through the feedback resistance R_f connected between the inverting input terminals and output terminals of operational amplifier A, causing the voltage drop V_f across the terminals of feedback resistance R_f. At this time, the output voltage V_o is output to the output terminals so that the voltages at operational amplifier A's inverting input terminal and non-inverting input terminal are equal. The relationship between the output voltage V_o and the current I_x is expressed by Equation (4-8).

$$V_o = -I_x R_f \qquad (4\text{-}8)$$

The instrument can provide multiple measurement ranges by switching the value of the feedback resistance R_f. If the operational amplifier A's gain is G_A, the input resistance R_{in} is expressed by Equation (4-9). Since the gain G_A of an ideal operational amplifier A is extremely large, the input resistance R_{in} given by Equation (4-9) is extremely small.

$$R_{in} = \frac{R_f}{1 + G_A} \qquad (4\text{-}9)$$

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As the test voltage E is divided by the DUT's insulation resistance R_x and input resistance R_{in}, the potential E_{in} at an ideal operational amplifier's inputs is the circuit's ground potential, as shown in Equation (4-10) (i.e., a virtual short).

$$E_{in} = 0 \qquad (4\text{-}10)$$

Consequently, because the voltage V_{DUT} applied to the DUT is equal to the test voltage E as shown in Equation (4-11), this method allows measurement to be performed while eliminating one cause of applied voltage error from which the shunt method suffers.

$$V_{DUT} = E - E_{in} = E \qquad (4\text{-}11)$$

Response speed is determined by the magnitude of the feedback resistor R_f and the capacitor C_f. The capacitor C_f, which is connected in parallel with the feedback resistor R_f, serves to limit the response speed (AC gain) of operational amplifier A. The input circuit's response is expressed by Equation (4-12), which indicates that lower values for the feedback resistor R_f and the capacitor C_f give the circuit a smaller time constant, increasing response speed. Additionally, Equation (4-12) does not include the insulation resistance R_x or the capacitance C_x of the DUT. Consequently, the insulation resistance R_x and the capacitance C_x of the DUT do not affect the circuit's response speed. However, if the instrument provides multiple measurement ranges, response speed will vary with the value of the feedback resistor R_f.

$$\tau_f = C_f R_f \qquad (4\text{-}12)$$

The AC noise component v_{on} of the output voltage V_o is expressed by Equation (4-13). Additionally, the impedance Z_f of the circuit consisting of a parallel connection between the feedback resistor R_f and the capacitor C_f is expressed by Equation (4-14), while the impedance Z_x of the DUT is expressed by Equation (4-15).

$$v_{on} = -\frac{Z_f}{Z_x} e_n \qquad (4\text{-}13)$$

$$Z_f = \frac{R_f}{1 + j\omega C_f R_f} \qquad (4\text{-}14)$$

$$Zx = \frac{Rx}{1 + j\omega C_x R_x} \qquad (4\text{-}15)$$

-3 Integration Method [7] [9]

Figure 4-3 illustrates an insulation resistance measurement circuit that uses the integration method.
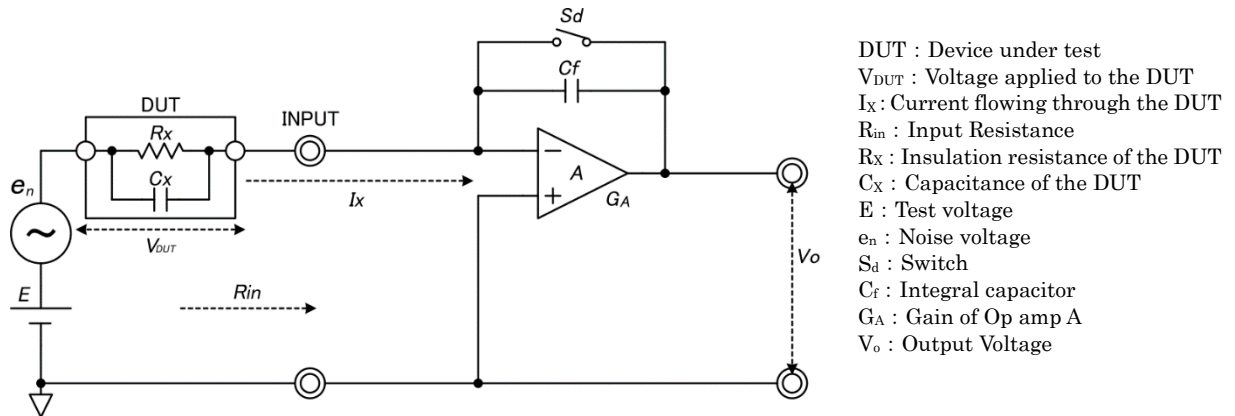
Figure 4-3. Insulation resistance measurement circuit using the integration method

DUT : Device under test
V_{DUT} : Voltage applied to the DUT
I_X : Current flowing through the DUT
R_{in} : Input Resistance
R_X : Insulation resistance of the DUT
C_X : Capacitance of the DUT
E : Test voltage
e_n : Noise voltage
S_d : Switch
C_f : Integral capacitor
G_A : Gain of Op amp A
V_o : Output Voltage

An insulation resistance measurement circuit that uses the integration method is implemented as follows. Figure 4-4 illustrates the relationship between the output voltage V_o and the integration time T_x.

- When switch S_d is switched off at the time $T1$ in Figure 4-4, the current I_x flows to integrating capacitor C_f for the duration of the integration time T_x. It causes the charging voltage V_f to be applied across the integrating capacitor C_f.

- The output voltage V_o is output to the output terminal so that the voltages at the operational amplifier A's inverting input terminal and non-inverting input terminal are equal. The switch S_d is switched on after a certain amount of time has elapsed so that the integrating capacitor C_f discharges.

Figure 4-4. Relationship between the output voltage V_o and the integration time T_x

- The relationship between the output voltage V_o and the current I_x is expressed by Equation (4-146).

$$V_o = -\frac{I_x T_x}{C_f} \qquad (4\text{-}146)$$

- When the switch S_d is switched on at $T2$ in Figure 4-4, the charge stored in the integrating capacitor C_f is discharged. Therefore, the output terminal of the operational

amplifier A becomes ground potential.

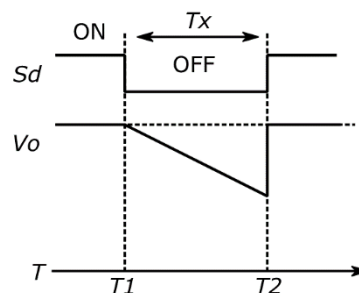The instrument can provide multiple measurement ranges by switching the value of the integrating capacitor C_f. As with ammeters used in the resistance feedback method, no error is caused by the voltage drop. Additionally, response speed does not vary depending on the DUT or the magnitude of the integrating capacitor C_f in use. However, error derives from factors such as the temperature variation, time variation, and dielectric absorption of integrating capacitor C_f. Since capacitors have relatively poor characteristics compared to resistors, precision suffers. To make measurements with a high degree of precision requires that the capacitor's temperature and time variability be corrected internally by the instrument.

The AC noise component v_{on} of the output voltage V_o is expressed by Equation (4-17). Additionally, the impedance Z_f of the integrating capacitor C_f and the impedance Z_x of the DUT are expressed by Equations (4-18) and (4-19), respectively.

$$v_{on} = -\frac{Z_f}{Z_x}e_n \tag{4-17}$$

$$Z_f = \frac{1}{j\omega C_f} \tag{4-18}$$

$$Zx = \frac{Rx}{1+j\omega C_x R_x} \tag{4-19}$$

-4 Effects of Noise [7]

(1)   Johnson noise

Johnson noise is noise caused by irregular movements of the electrons inside a resistor. Ammeters that use resistors as current detection elements suffer from the effects of Johnson noise. Ammeters that use the integration method do not suffer from those effects, since they use a capacitor as a current detection element. The Johnson noise e_{tn} is expressed by Equation (4-20), where k_B represents Boltzmann's constant; T, the temperature of the conductor [K]; and Δf, the bandwidth [Hz].

$$e_{tn} = \sqrt{4k_B T R \Delta f} \tag{4-20}$$

Figures 4-5 and 4-6 illustrate shunt method and resistance feedback method ammeters along with the Johnson noise e_{tn}. Equations (4-21) and (4-22) illustrate the output voltage V_o taking into account the Johnson noise e_{tn} for the shunt method and resistance feedback method,

respectively. As indicated by Equations (4-21) and (4-22), the Johnson noise e_{tn} is added to the output voltage V_o when measuring the current I_x. As indicated by Equation (4-~~18~~20), the Johnson noise e_{tn} increases in proportion to the resistor's resistance value. When measuring a minuscule current, the effects of the Johnson noise e_{tn} increase due to the typical practice of using current detection resistors with values ranging from several hundred kiloohms to several gigaohms.

$$V_o = (I_x R_s + e_{tn})\left(1 + \frac{R_2}{R_1}\right) \qquad (4\text{-}21)$$
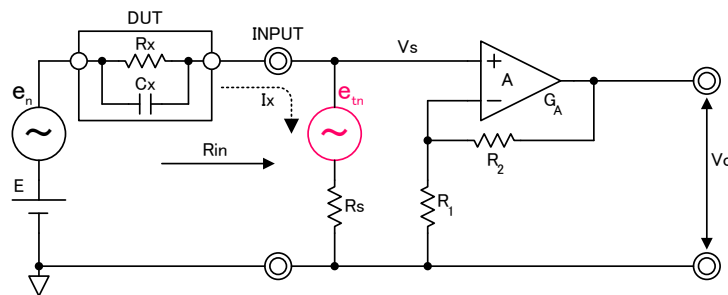

Figure 4-5. Shunt method ammeter circuit incorporating Johnson noise

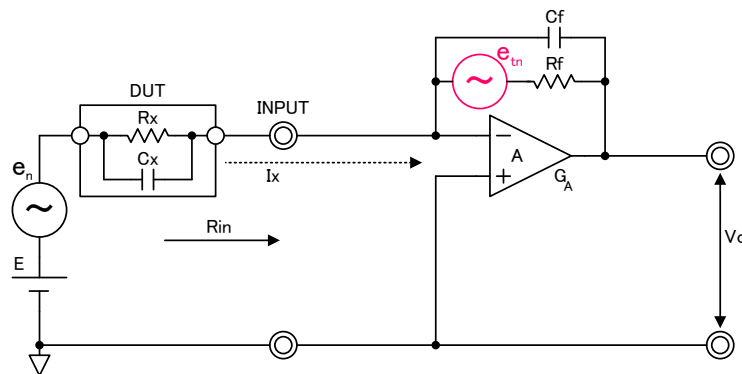$$V_o = -I_x R_f - e_{tn} \qquad (4\text{-}22)$$

Figure 4-6. Resistance feedback method ammeter circuit incorporating Johnson noise

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(2)　　Inductive Noise and Power Supply Noise(Conductive)

The characteristics of noise immunity that result from differences in the current measurement method are described in (a), (b), and (c) below. The level of noise amplification was simulated using the current measuring circuit models shown in Figures 4-1, 4-2, and 4-3 under design conditions that allowed them to measure the same range of current. The level of noise amplification in a current measuring circuit is known as AC gain. Figures 4-7, 4-8, and 4-9 illustrate how AC gain changes according to the noise frequency.

(a) Shunt method

Shunt method ammeters are susceptible to the effects of high-frequency AC noise. Equations (4-6) and (4-7) illustrate how this noise depends on the impedance Z_x of the DUT and on the resistance R_s, R_1 and R_2 of the ammeter measurement circuit. Figure 4-7 illustrates the AC gain frequency characteristics for a shunt method instrument. The circuit is more affected by noise as the high-frequency AC gain increases and as the frequency increases.
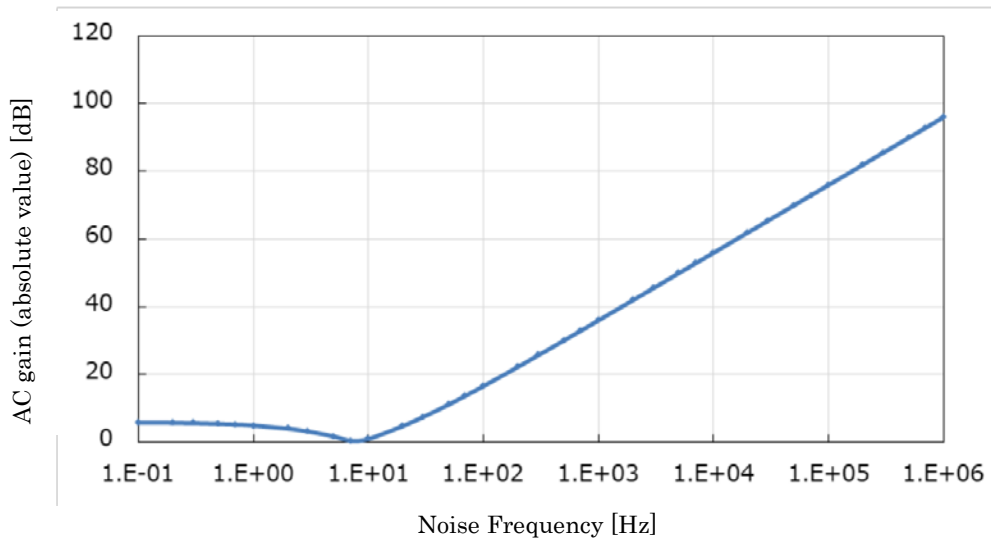
Figure 4-7. AC Gain-frequency characteristics for a shunt method circuit

(b) Resistance feedback method

Resistance feedback method ammeters are susceptible to the effects of high-frequency AC noise. Equation (4-11) illustrates that AC gain of operational amplifier A increases as the capacitance C_x of the DUT grows larger than the capacitor C_f. Figure 4-8 illustrates the AC gain frequency characteristics of a resistance feedback ammeter.
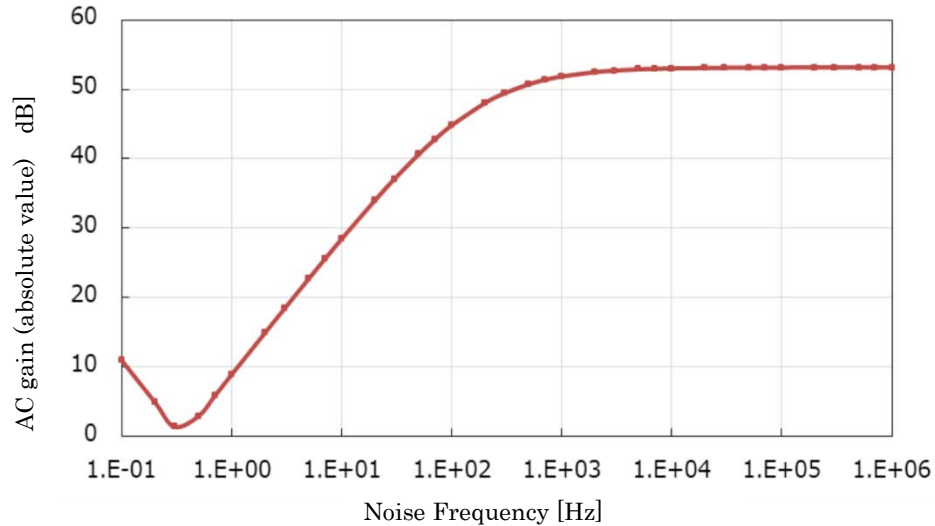
Figure 4-8. AC gain-frequency characteristics for a resistance feedback method circuit

Just as Figure 4-8 indicates a tendency for the AC gain to increase in the high-frequency band, the high-frequency AC noise component v_{on} included in the output voltage V_o will increase and become a source of measurement error because the amplifier A's AC gain is characterized by a tendency to increase as the frequency rises. Additionally, the circuit will exhibit AC gain relative to conductive noise entering the circuit from the input terminals. To address this noise, the amplifier A's AC gain could be reduced. As indicated by Equation (4-11), the amplifier A's AC gain can be reduced by increasing the capacitor C_f connected in parallel with the feedback resistor R_f. However, as Equation (4-10) indicates, increasing the capacitor C_f creates a problem in the form of slower response speeds.

(c) Integration method

Since the integrating capacitor C_f in an integration method ammeter does not exert any causal effects on response time, amplifier A's AC gain can be decreased by increasing the integrating capacitor C_f. When the integrating capacitor C_f increases, the impedance Z_f decreases, as shown in Equation (4-16). Consequently, the amplifier A's AC gain will decrease, and the AC noise component v_{on} included in the output voltage V_o will decrease, as indicated by Equation (4-15). However, since the amplifier A's AC gain will increase relative to low-frequency AC noise, the low-frequency AC noise component v_{on} included in the output voltage V_o will increase, becoming a source of measurement error. Figure 4-9 illustrates the AC gain frequency characteristics of an integration method circuit. AC gain has a tendency to increase in the low-frequency band.

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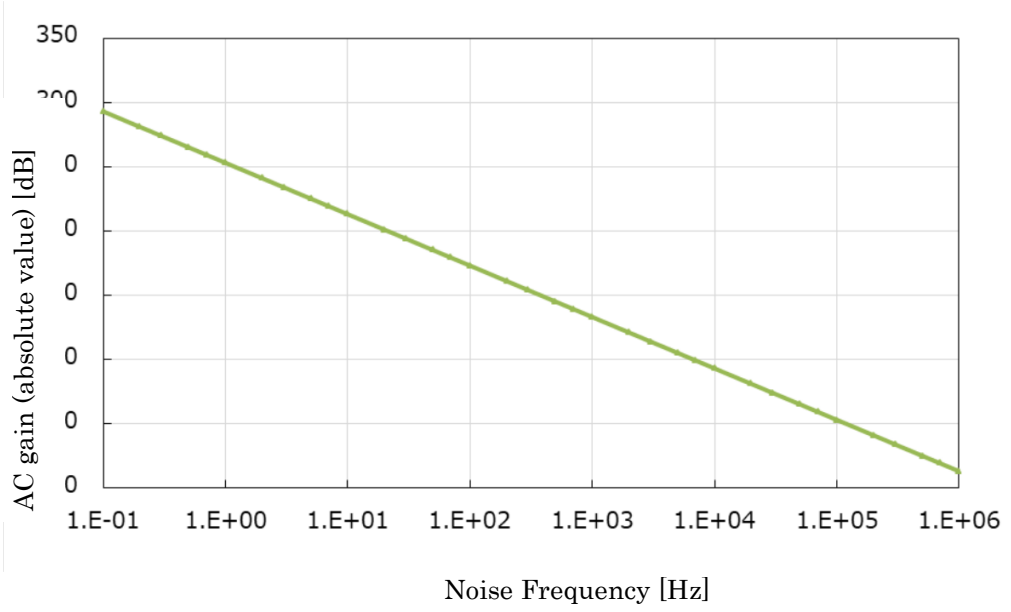
Figure 4-9. AC gain-frequency characteristics for an integration method circuit

5 Methods for Measuring Insulation Resistance Values and Insulation Resistivity

-1 Fundamentals of Insulation Resistance Measurement

This section describes resistance measurement methods.

(1) Voltage Drop Method (Constant Voltage Method) [2]

The voltage drop method is the most commonly used method for measuring insulation resistance. The current I and the voltage V are measured by a high-precision ammeter and a voltmeter, respectively, and then the resistance R is calculated according to Ohm's Law ($R = V/I$). Insulation resistance meters and super megohmmeters, which measure particularly high resistance values, are wired as shown in Figure 5-1 using **the constant voltage method**.
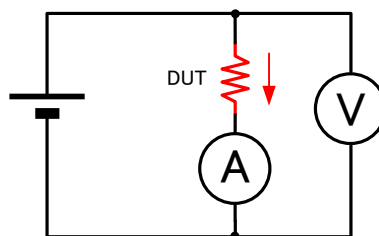
Figure 5-1. Voltage drop method (constant voltage method)

The constant voltage method resistance measurement circuit shown in Figure 5-1 allows an ammeter to measure the minuscule leakage current that flows to the DUT (resistance shown in red in the figure) due to the DC voltage applied from a constant voltage source. At this time, the ammeter is connected in series with the DUT so that just the leakage current flowing through the DUT can be measured, while the voltmeter measures the voltage drop including the DUT and the ammeter. When measuring high resistance with a circuit setup such as this one, an error may be introduced if the voltage drop at the ammeter is large.

(2) Reasons for Using the Constant Voltage Method

Figure 5-2 illustrates constant current method wiring, which is not actually used to measure insulation resistance for the reason described below.

Leakage current of DUT + Leakage current to voltmeter
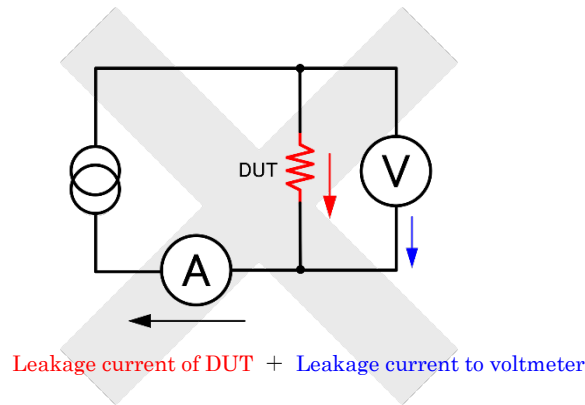
Figure 5-2. Constant current method

In the constant current method, the voltage across the DUT is measured while a constant current flows through the device. In the case of insulation resistance measurement, the need to measure a minuscule current means that the leakage current flowing to the ammeter, indicated by the blue arrows in the figure, affects measured values. Thus, it is desirable to measure the voltage drop that includes the DUT and the ammeter with the voltmeter, as shown in Figure 5-1.

When using a constant current source, it takes a remarkably long time to charge stray capacitance in the circuit that includes the DUT. Consequently, it is necessary to use a constant voltage source such as that shown in Figure 5-1 when measuring insulation resistance.

(3)   Reasons for Applying a DC Voltage during Insulation Resistance Measurement [6]

As described in "3.-2 Insulation Resistance of Dielectric Constants" (p.10), DUT in insulation resistance measurement can be assumed in an equivalent circuit model in which a resistance component and a capacitance component are connected in parallel, as illustrated in Figure 5-3.
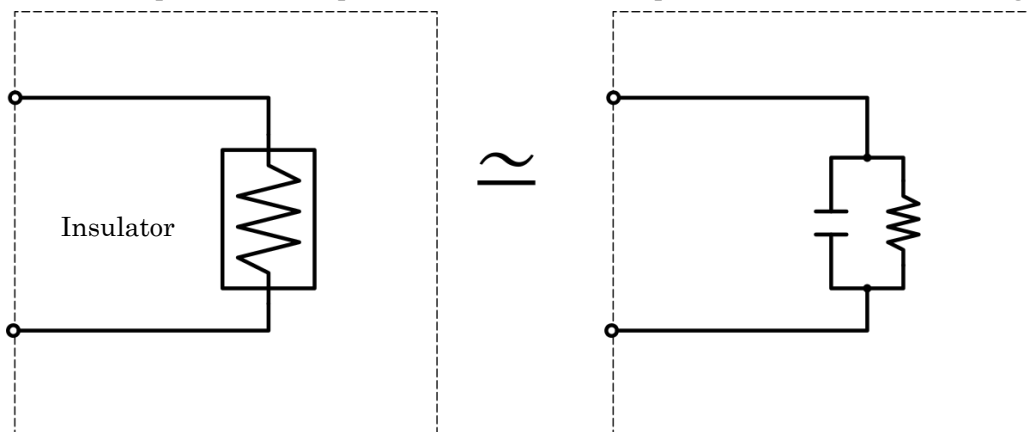
Figure 5-3. Equivalent model for a DUT to which a DC voltage is applied during insulation resistance measurement

The purpose of measuring leakage current in the DUT is to ascertain how much leakage current the device (dielectric) produces. If a constant AC voltage were applied, there would always be a voltage drop in proportion to the AC voltage impedance, and as a result, it would not be possible to directly observe only the resistance component of the DUT.

By contrast, consider what happens when a DC voltage is used. When the DC voltage is applied, the DUT's capacitance component is charged transiently in proportion to the applied voltage and the capacitance. Once charging is complete, the polarized capacitance component exhibits no net flow of DC current. DC current flows only to the DUT's resistance component. That current represents the leakage current that flows through the DUT (dielectric). For this reason, a DC voltage is applied to the DUT when measuring insulation resistance.

(4)   Guarding [2]

Sections (1) and (2) above explained the need for a circuit that generates a constant voltage and circuits that measure current and voltage in order to measure insulation resistance. The important thing here is that the measured currents are minuscule in magnitude. Since voltages are applied to high resistance in excess of $10^6 \sim 10^{15}\,\Omega$ (several M$\Omega\sim$several PΩ) in order to measure insulation resistance, the measured current values become smaller as the resistance values become larger. An ammeter with a resolution on the order of 10^{-12}A (several fA) is required. Since extremely small currents are measured, exposure of the measurement circuit to noise in the form of currents other than the current you wish to measure will prevent accurate measurement. Consequently, guarding serves as a technique for blocking undesirable currents. The following sections describe how guarding can be used to block (i.e., guard against) undesirable currents that become sources of error.

[1] Leakage to the stand in contact with the DUT

If the DUT is not floating in the air (for example, if it is sitting on a test pedestal or otherwise supported), a voltage will be applied to the DUT and the support insulator as parallel resistors as shown in Figure 5-4 (1). At this time, leakage current will flow to the support insulator and be input to the current measurement circuit in addition to current that flows through the DUT.

[2] Leakage from measurement cables

There is also leakage current that flows via the insulation of cables used in measurement. This current is input to the current measurement circuit via the insulation resistance shown in Figure 5-4 (2).

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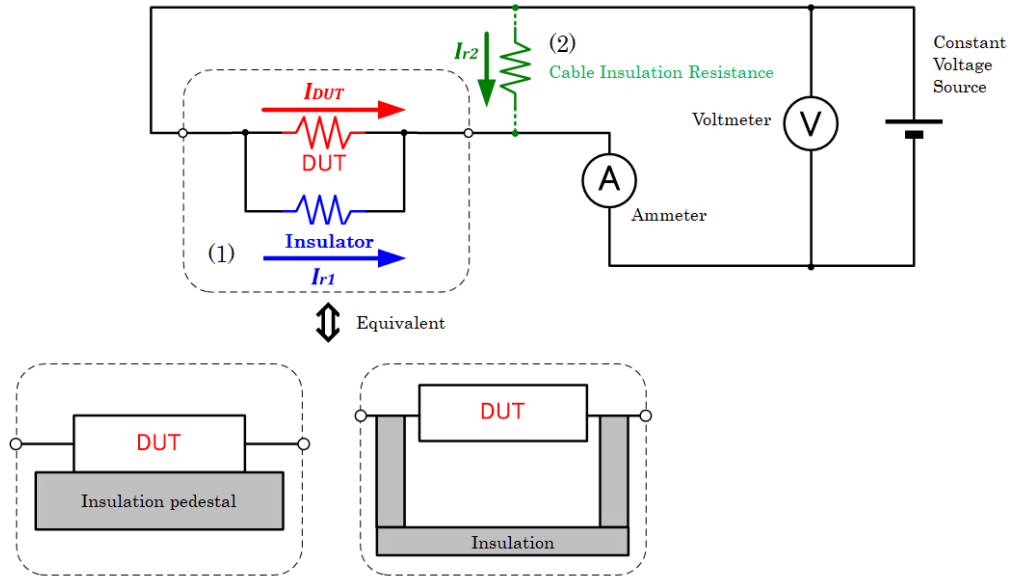
Figure 5-4. (1) Leakage from objects in contact with the DUT and (2) leakage from the cable's insulation resistance

By adopting a setup shown in Figure 5-5 below, it is possible to prevent currents that would become sources of error from being input to the ammeter.
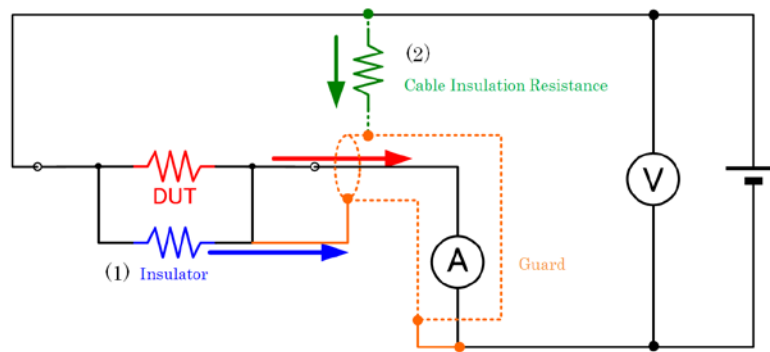
Current from (1) and (2) is guarded so that it does not enter the ammeter.

Figure 5-5. Guarding against current leaking from pedestal insulation and cables

The purpose of guarding is to prevent error current from entering the ammeter. Figure 5-5 illustrates example circuit connections for implementing such protection. Leakage current from (1) the insulated pedestal and (2) cables would become a source of error. By routing this current to the ground potential side of the measurement circuit, it can be kept from entering the ammeter. Such guarding can be implemented by adding an electrical contact or terminal to the input side of the measuring instrument, thereby providing an alternative route for such current. HIOKI's Super Megohm Meter SM7110/SM7120/SM7420 augment such guarding with shielding to reduce sources of error. Shielding refers to the kind of electrical contact or terminal shown with the dotted purple line in Figure 5-6. It creates a potential for routing current to the measurement circuit's ground via a route that differs from guarding in order to keep conductive

noise and other disturbances from being input to the ammeter.
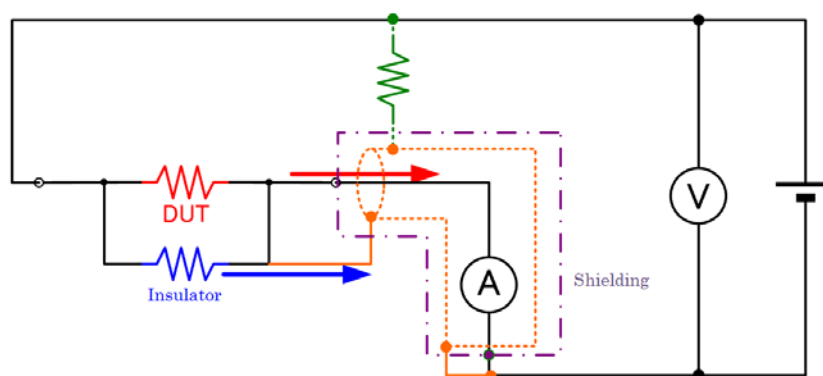
Figure 5-6. Shielding

[3] Leakage current flowing internally in the DUT

Leakage current in the context of insulation resistance measurement can be thought of as a combination of current flowing through the inside of the DUT and current flowing over the surface of the DUT. Since these two currents have different properties depending on how the insulating material in question is being used, they sometimes need to be evaluated separately. In such cases, guarding is used to isolate the surface resistance and volume resistance. The following sections describe these processes.

-2 Volume Resistance of Insulating Materials [4]

（1） Volume Resistance Measurement Principle

Volume resistance is a coefficient indicating the difficulty with which current flows through the inside of an insulating material. In the previous section's explanation of guarding, a guard terminal/electrical contact was added to the measurement circuit. In measurement of volume resistance, the addition of an electrical contact for guarding purposes on the electrode side prevents current from flowing through the surface of the insulating material. Figure 5-7 illustrates a fundamental setup of measuring volume resistance.
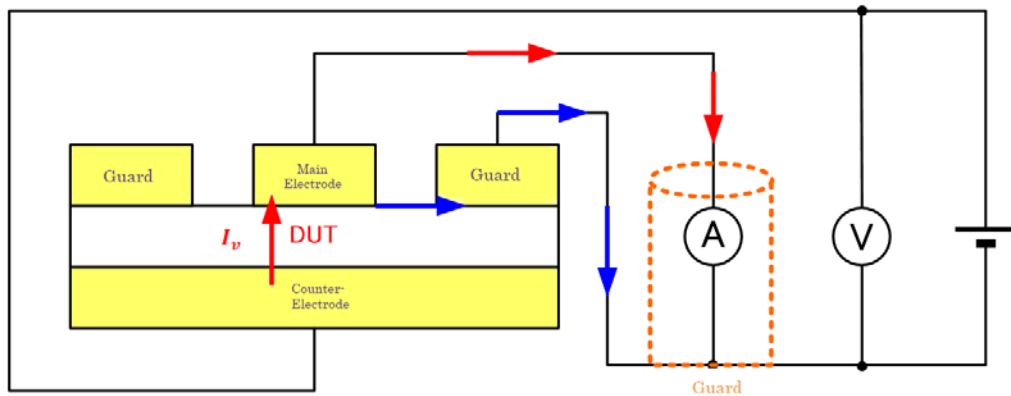
Figure 5-7. Volume resistance measurement principles

The electrode through which the current you wish to measure flows is known as the main electrode, while the electrode on the opposite side is known as the counter-electrode. Current flowing through the inside of the DUT is input to the ammeter, while current flowing through the surface of the DUT is blocked by the guard electrode. When the voltage V is applied, the current I_v flowing through the inside of the DUT can be expressed by the relationship shown in Equation (5-1) below:

$$R_v = {V}/{I_v} \tag{5-1}$$

The value R_v is known as the volume resistance. However, volume resistance is affected by electrode shape, dimensions, and spacing (as is surface resistance; see below).

(2)　Method for Calculating Volume Resistivity

Because volume resistance depends on electrode shape, dimensions, and position, it is typical to treat resistivity as a coefficient that is specific to the DUT. For volume resistance, this coefficient is known as **the volume resistivity**. When the distance between the main electrode and guard electrode is sufficiently small relative to the radius of the main electrode, as in Figure 5-8 (a), the law $= \rho(l/S)$, which defines the electrical resistance R for a conductor of length l and cross-sectional area S, can be applied to calculate volume resistivity.

(a) Model that is good for considering the underlying principle   (b) Standard model that is affected by electrode position
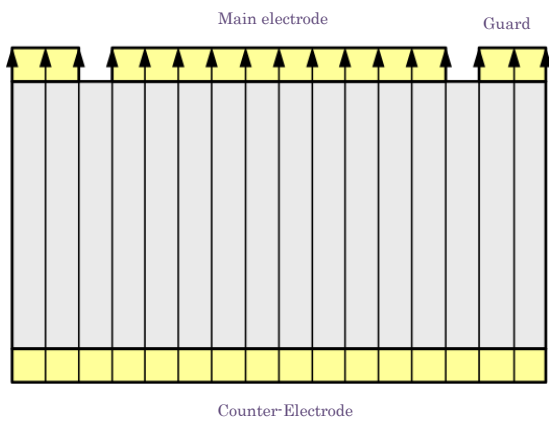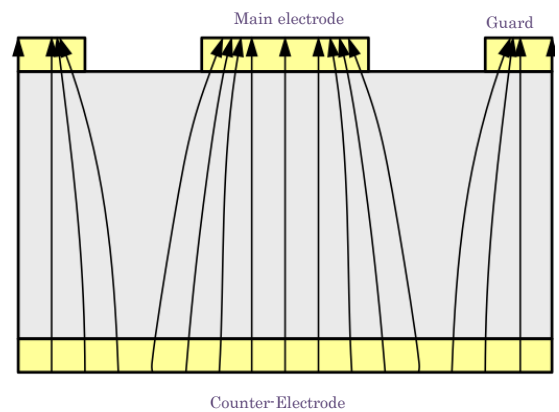
Figure 5-8. Electrode position when measuring volume resistance

Current flows from the counter-electrode to the main and guard electrodes when measuring volume resistance. The arrows in the figure illustrate the electric flux in the DUT. When the distance between the main electrode and the guard electrode is sufficiently small, as in (a), the density of the current flowing into the main electrode is uniform. By contrast, when the main and guard electrodes are placed too far apart, as in (b), the current density on the outside edges of the main electrode increases. From the standpoint of the ideal model (a), **the volume resistivity** ρ_v for a main electrode with an area of S and a DUT with a thickness of t is given by Equation (5-2) below:

$$\rho_v = R_v \, \frac{S}{t} \quad [\Omega \cdot \mathbf{cm}] \tag{5-2}$$

Typically, electrodes with a round shape when seen longitudinally relative to the DUT, as shown in Figure 5-9, are used.

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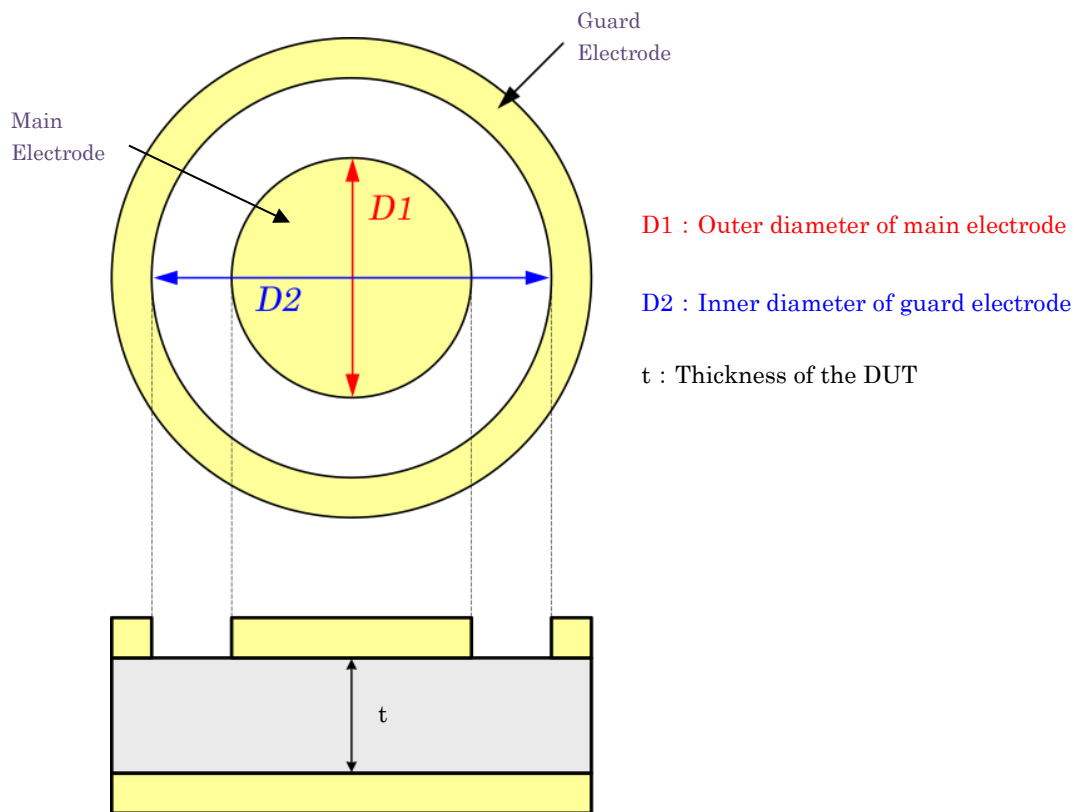
Figure 5-9. Electrode position when calculating volume resistivity

Since volume resistivity can be considered in terms of the model described in Equation (5-2) only when the gap between the two electrodes is sufficiently smaller than the radius of the main electrode, the volume resistivity is given by Equation (5-3).

$$\rho_v = R_v \left(\pi\, D1^2 / 4t \right) \tag{5-3}$$

(When $\frac{D2-D1}{2} \ll \frac{D1}{2}$, the area S of a main electrode where the current density will be uniform is given by $= \pi(D1/2)^2$)

However, in actual usage, the current density at the outside edges of the main electrode increases as shown in Figure 5-8 (b) because the distance between the main and guard electrodes and the radius of the main electrode are not ideal. To simplify the calculation, a model in which the apparent size of the main electrode has changed, as shown on the right side of Figure 5-10, can be used if the electrode's outer diameter is corrected so that the density of the current flowing to the main electrode remains uniform.
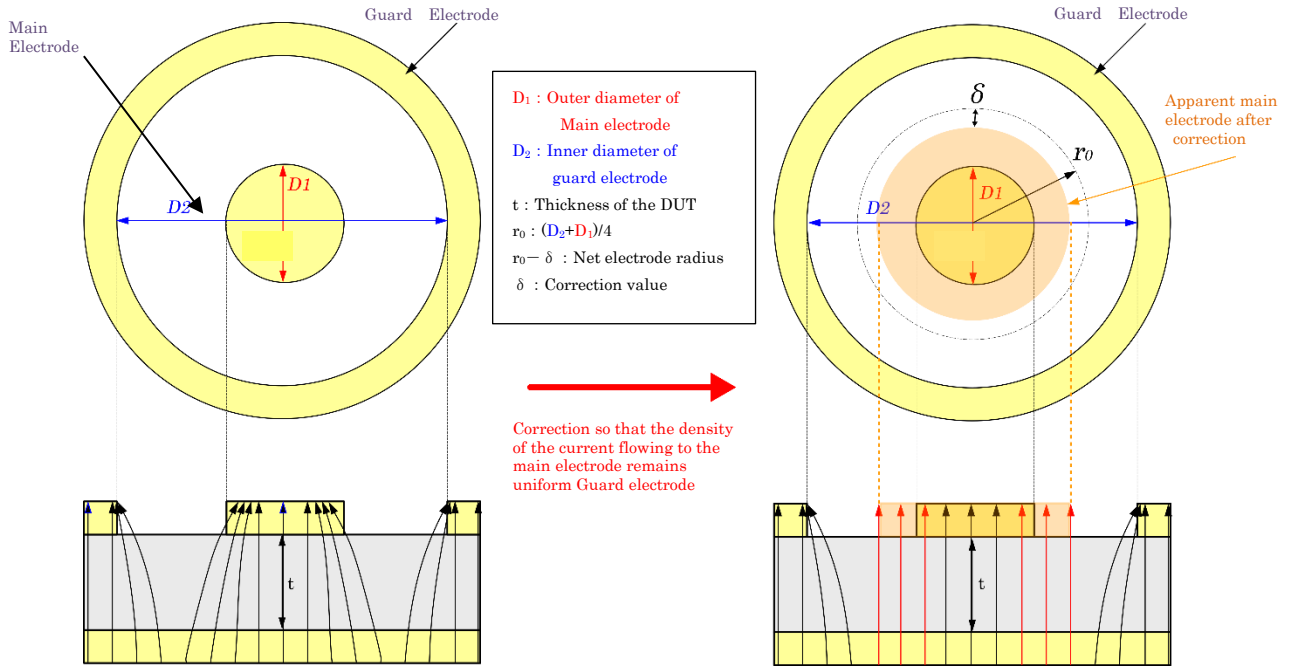
Figure 5-10 Correction of the electrode during actual calculation of volume resistivity

When corrected so that the conditions shown on the left are replaced by the conditions shown on the right, as in Figure 5-10, the apparent main electrode radius for which the density of the current flowing to the electrode remains uniform can be expressed as $(r_0 - \delta)$. In other words, when using a typical electrode, volume resistivity can be expressed using Equation (5-4), where $r_0 = (D2 + D1)/4$.

$$\rho_v = R_v \left(\pi \left(r_0 - \delta\right)^2 / t\right) \tag{5-4}$$

The correction value δ applied here is derived theoretically based on a complex equation, yielding Equation (5-5).

$$\delta = \frac{2t}{\pi} \log_e \left(\cosh \left(\frac{\pi}{4} \cdot \frac{g}{t} \right) \right)$$

$$= \frac{2t}{\pi} \log_e \left(\frac{\exp\left(\frac{\pi}{4}\frac{g}{t}\right) + \exp\left(-\frac{\pi}{4}\frac{g}{t}\right)}{2} \right)$$

(However, $g = (D2 - D1)/2$: distance between the main and guard electrodes)

$$(5\text{-}5)$$

This correction value is determined by the ratio of the electrode position and the thickness of the DUT. If the gap between the main and guard electrodes is extremely close to the thickness, the following equation applies:

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$$\lim_{g/t \to 0} \delta = 0$$

<div align="right">(5-6)</div>

Since the value r_0 at this time is close to $D1/2$, the volume resistivity is the same as Equation (5-3). Conversely, if the gap g between the main and guard electrodes is sufficiently larger than the thickness of the DUT, Equation (5-7) below applies:

$$\lim_{g/t \to \infty} \delta = g/2$$

<div align="right">(5-7)</div>

Consequently, the volume resistivity expressed in Equation (5-4) can be treated as Equation (5-8) below, which is ultimately the same as the volume resistivity calculated from the principle expressed in Equation (5-3):

$$\rho_v = R_v \left(\pi \, (r_0 - \delta)^2 / t \right)$$

$$= R_v \left(\pi \, (r_0 - g/2)^2 / t \right)$$

$$= R_v \left(\pi \, \left(\frac{D2+D1}{4} - \frac{D2-D1}{4} \right)^2 / t \right)$$

$$= R_v \left(\pi \, \left(\frac{D1}{2} \right)^2 / t \right)$$

$$\therefore \ \rho_v = R_v \left(\pi \, D1^2 / 4t \right) \qquad [\Omega \cdot \text{cm}] \qquad (5\text{-}8)$$

However, this derivation assumes that the radius $D1/2$ of the main electrode is sufficiently large compared to the thickness t of the DUT.

Equation (5-8) is the volume resistivity equation defined by standards (JIS C2170:2004/IEC 61340-2-3:2000), and it is also used by the resistivity calculation function provided by the HIOKI SM7110 series.

-3   Surface Resistance of Insulating Materials   [4]

(1)   Surface Resistance Measurement Principle

The coefficient indicating the difficulty with which current flows through the surface of an insulating material is known as **the surface resistance**. Like volume resistance, when measuring surface resistance the addition of electrical contacts for guarding on the sides of the electrode is used to prevent the flow of current to the inside of the insulating material. Figure 5-11 illustrates a theoretical setup used to measure surface resistance.
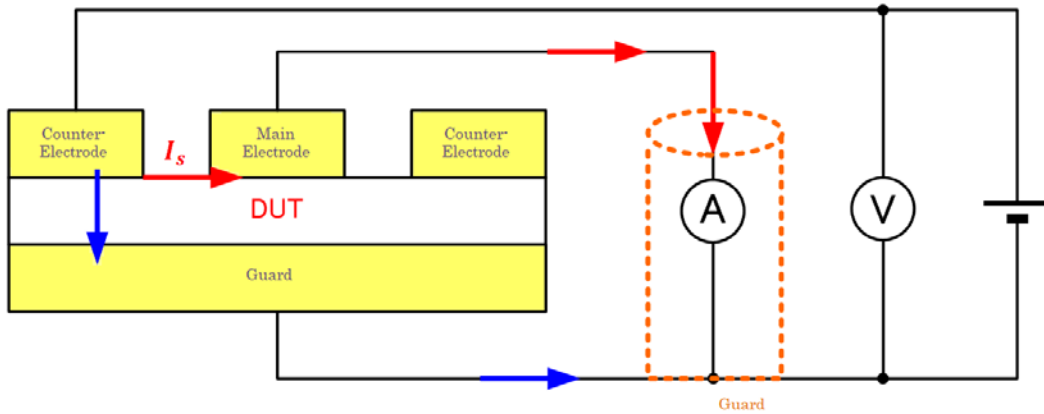
Figure 5-11. Surface resistance measurement principles

The electrode through which the current you wish to measure flows is known as the main electrode, while the electrode on the opposite side is known as the counter-electrode. Current flowing through the surface of the DUT is input to the ammeter, while current flowing through the inside of the DUT is blocked by the guard electrode. When the voltage V is applied, the value R_s, which is known as **the surface resistance,** is related to the current I_s that flows across the surface of the DUT as follows.

$$R_s = {V}/{I_s} \tag{5-9}$$

. Surface resistance is affected by electrode shape, dimensions, and spacing.

(2)　Method for Calculation Surface Resistivity

Because surface resistance depends on electrode shape, dimensions, and position, it is typical to treat resistivity as a coefficient that is specific to the DUT. For surface resistance, this coefficient is known as **the surface resistivity**. As with volume resistivity, we will consider the process using round electrodes.

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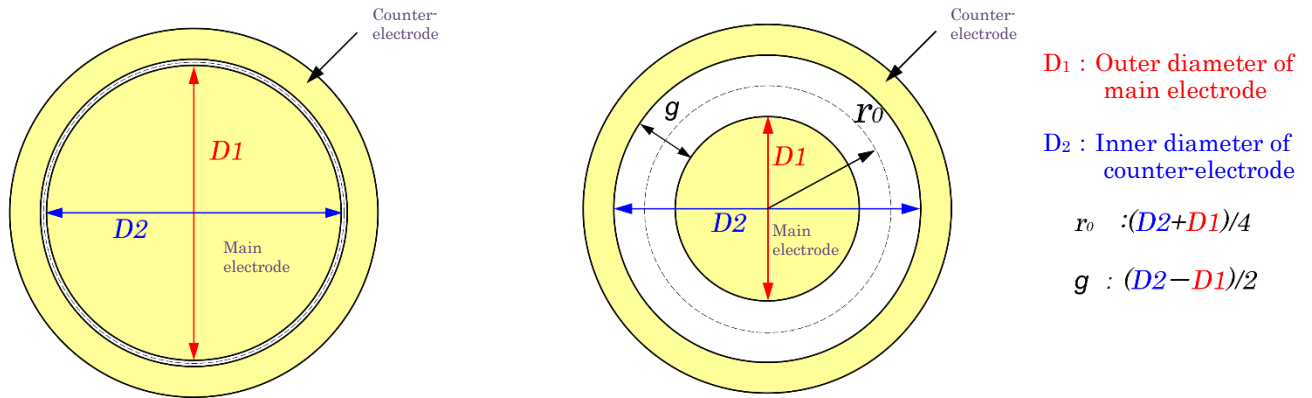
Figure 5-12.   Measurement principle model of surface resistivity

In Figure 5-12 (a), consider a favorable model in which the distance between the main electrode and the counter-electrode is extremely short. In this case, we need only consider the resistivity in the round, extremely narrow band that comprises the gap between the electrodes, which means we can use Equation (5-9).

$$\rho_s = R_s(2\pi r_0/g)$$

$$= R_s\left(\frac{\pi(D2+D1)}{D2-D1}\right) \qquad [\Omega] \qquad\qquad (5\text{-}9)$$

This approach is not typical, and it cannot be used when there is a large gap between the electrodes. Consider Figure 5-13.
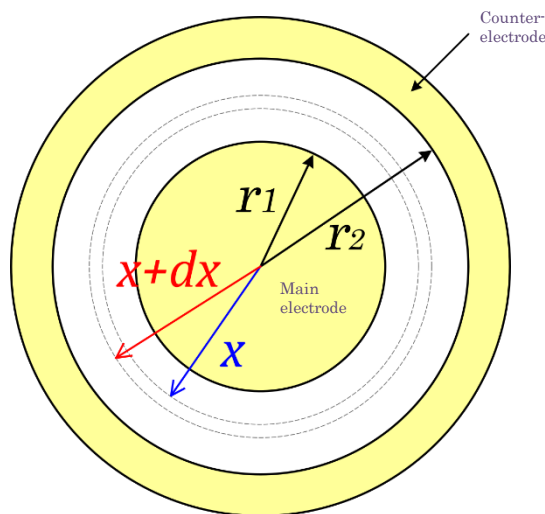
Figure5-13. Standard model for considering surface resistivity measurement principles

The surface resistance in the region between the two electrodes can be thought of as the

resistance of a ring with a minuscule width extending from x to $x + dx$. If values are integrated over the interval from r_1 to r_2, the surface resistance to surface current flowing from the main electrode to the counter-electrode can be calculated. In other words, the surface resistance when using round electrodes such as these can be expressed by Equation (5-10) below:

$$R_s = \int_{r_1}^{r_2} \rho_s \frac{dx}{2\pi x}$$

$$= \frac{\rho_s}{2\pi} \log_e(r_2/r_1) \tag{5-10}$$

Consequently, surface resistivity is expressed by Equation (5-11).

$$\rho_s = \frac{2\pi R_s}{\log_e(r_2/r_1)} \tag{5-11}$$

When a $\log_e(1 + x)$ Taylor expansion is applied to the denominator of Equation (3-11), the equation can be expanded into Equation (5-12):

$$\log_e y = 2\left[\frac{y-1}{y+1} + \frac{1}{3}\left(\frac{y-1}{y+1}\right)^3 + \frac{1}{5}\left(\frac{y-1}{y+1}\right)^5 + \cdots + \frac{1}{2n+1}\left(\frac{y-1}{y+1}\right)^{2n+1} + \cdots\right]$$

$$\tag{5-12}$$

If we take just the first term of this expansion, we end up with Equation (5-13):

$$\rho_s = R_s \frac{\pi(r_2 + r_1)}{r_2 - r_1}$$

$$= R_s \frac{2\pi r_0}{g}$$

$$\therefore \ \rho_s = R_s \frac{\pi(D2+D1)}{D2-D1} \tag{5-13}$$

This is the same as the principle equation provided by Equation (5-9), indicating that for approximation purposes, the same equation can also be used without issue in the standard model.

Equation (5-13) is defined for the purpose of calculating surface resistivity by standards (JIS C2170:2004/IEC 61340-2-3:2000), and it is also used by the resistivity calculation function

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provided by the HIOKI SM7110 series.

-4　Liquid Volume Resistance Measurement Principles [4]

　　When DUT takes the form of a liquid, designated electrodes are used. The equations used to calculate measured values must be changed to accommodate the electrodes. The following describes the principles underlying methods used to measure volume resistance of liquids and to calculate the volume resistivity of liquids, using typical electrodes shaped to serve as a container as an example (product provided by HIOKI: SME-8330).

　　Figure 5-14 illustrates the structure of the electrodes used for liquid samples. The outer electrode that serves as the container function as the counter-electrode, while the electrode inserted into the container makes up the main electrode and guard. The gap between the electrodes is supported by a strong insulator, and the guard electrode serves to block leakage current flowing to the support insulator. Additionally, HIOKI's Liquid Sample Electrode SME-8330 uses polytetrafluoroethylene (PTFE, Teflon) and polychloro-trifluoroethylene (PCTFE) for the support insulators and nickel-plated brass for the electrodes.
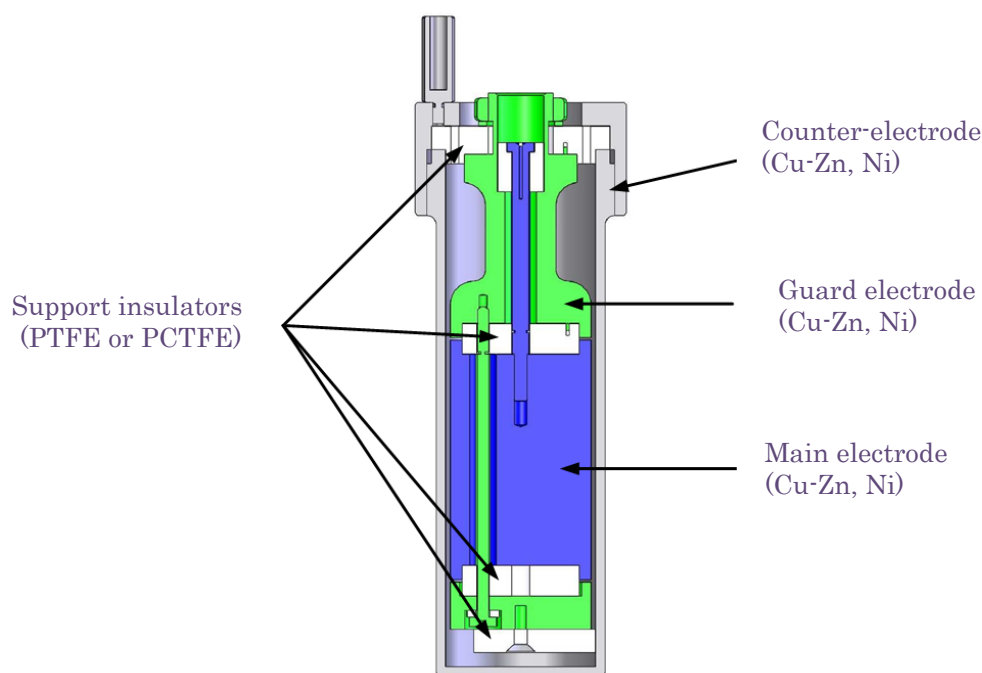
Figure 5-14. Structure of an electrode for liquid samples

Volume resistivity is ordinarily calculated based on a consideration of the shape of the electrodes. However, because that approach is difficult to apply to electrodes used for liquid samples, volume resistivity can be calculated based on Equation (5-14) using the geometric capacitance C_0 [F] between the main electrode and the counter-electrode as well as the **dielectric constant** ε_0 [F·cm] in a vacuum.

$$\rho = \frac{1}{\varepsilon_0}\, C_0 R_v = K R_v \quad [\Omega \cdot \mathbf{cm}] \tag{5-14}$$

K is known as **the electrode constant**, and the resistivity is calculated by multiplying it by the measured resistance value. Additionally, the electrode constant is part of the component arising from the dimensions of the electrode when calculating volume resistivity and surface resistivity for round electrodes. In this context, geometric capacitance is defined as follows:

$$C_0 = \varepsilon_0 \frac{S}{t} \quad [\mathbf{F}] \tag{5-15}$$

$$\rho_v = R_v \frac{S}{t} \quad [\Omega \cdot \mathbf{cm}] \tag{5-2}$$

If the above equation is compared to Equation (5-2), it becomes clear that the volume resistivity of a liquid can be calculated using Equation (5-14).

-5 Various Electrodes for Insulation Resistance and Resistivity Measurement Applications

To measure the resistivity of an insulator as described above, it is necessary to obtain electrodes that have been specifically designed for the purpose. HIOKI provides a range of electrodes. For more information about how to choose electrode products, see 7-1(4) in "Chapter 7. Introduction to HIOKI Products."

(1)　SM7110 Series Equation for Calculating Resistivity

With HIOKI's Super Megohm Meter SM7110 series, volume resistivity is calculated using the equations described below (Figure 5-15: Excerpted from the SM7110 User's Manual).

(1) Example of electrodes

	Volume resistivity	Surface resistivity
A	Main electrode	Main electrode
B	Guard electrode	Counter electrode
C	Counter electrode	Guard electrode

(2) Access point

Main electrode:　　INPUT terminal
Guard electrode:　　GUARD terminal
Counter electrode:　OUTPUT terminal

The product of the measured volume resistance and the electrode constant is called volume resistivity (ρv), while the product of the surface resistance and the electrode constant is called surface resistivity (ρs).

Surface resistivity: $\rho s = \dfrac{\pi \cdot (D2 + D1)}{D2 - D1} \times (\text{Measured value})$

Flat sample volume resistivity: $\rho v = \dfrac{\pi \cdot D1^2}{4t} \times \dfrac{(\text{Measured value})}{10}$

Liquid sample volume resistivity: $\rho l = K \times (\text{Measured value})$

ρs:	Surface resistivity	Unit [Ω]
$\rho v, \rho l$:	Volume resistivity	Unit [$\Omega \cdot$cm]
π:	Circular constant = 3.14	
$D1$:	Diameter of the main electrode	Unit [mm]
$D2$:	Internal diameter of the counter electrode	Unit [mm]
t:	Thickness of sample	Unit [mm]
K:	Electrode constant	Unit [cm]

Figure 5-15 SM7110 resistivity equations

Volume resistivity is expressed in [$\Omega \cdot$ cm]. In other words, volume resistivity as defined above is a quantity with resistance and geometric distance dimensions. Since HIOKI products use [mm] as the dimension for electrodes in equation variables, it is necessary to multiply the results of calculations by 1/10 relative to the defining equations.

Additionally, although HIOKI uses [mm] as the dimension for electrodes in equations used to calculate surface resistivity, the distance terms ultimately cancel each other out when plugged

back into the defining equations, so the same equation as the definition can be used for that quantity.

Please note that the unit used in the calculation results ([cm]) and the units used by the product for variables ([mm]) differ. Because the definition of resistivity derived from research conducted using cgs units, the unit defined for resistivity is $[\Omega \cdot cm]$, while electrode length dimensions are expressed in [mm] after multiplying the actual scale used (10^{-3}) based on the unit [m] in accordance with international units.

-6　Standard and HIOKI Insulation Resistance Measurement Electrodes

JIS standards defined several methods for measuring insulation, and some specially designed electrodes supplied by HIOKI comply with those standards (Table 5-1). The following table introduces electrodes that can be used to measure surface resistance, volume resistance, and liquid volume resistance, along with some standard-compliant options.

Table 5-1. Electrodes, options, and standard compliance

type	Electrode	Main Electrode	Ring Electrode		Conforming standard		Remarks
			Inner diameter	Outer diameter			
For surface / volume resistance	SM9001	φ30.5mm	φ57mm	φ63mm	JIS C2170	IEC61340-2-3	Resistance and resistivity measurement method
For surface resistance	SME-8301	φ30mm	φ34mm				
For flat plate samples	SME-8310	φ50mm	φ70mm	φ80mm	JIS K6911	JIS K6271	Thermosetting plastic general test method
	SME-8311	φ19.6mm	φ24.1mm	φ28.8mm			
Weight electrode	SME-8320	φ50mm	φ70mm	φ80mm	JIS K6911※		Thermosetting plastic general test method ※Combination with SME-8350
For liquid sample	SME-8330				JIS C2101		Electrical insulating oil test method
Shielded box	SME-8350				JIS K6911※		Thermosetting plastic general test method ※Combination with SME-8350

HIOKI offers other electrodes and options not included in the above table (see p.63). In some cases, a specific type of electrode may not be defined depending on the conditions characterizing the object being measured and the method of measurement, and measurement methods may not be defined by applicable standards.

-7　Power Supplies [1]

In this context, the term "power supply" refers to the device that generates the voltage that is applied to the DUT. Broadly speaking, power supplies used in insulation resistance measurement are required to offer three types of performance: low power supply noise, high current capacity, and current absorption functionality. This section explains why these three types of performance are necessary and introduces how they affect measurement.

(1)　Power Supply Noise

For more information, see "Effects of 1/f Noise (Conductive Noise) from the Power Supply (Measurement Constant-voltage Source)" (p. 48).

(2)　Current Capacity

When a capacitor is charged with a constant current, the terminal voltage is proportional to the charging time, as illustrated in Figure 5-16 (b).
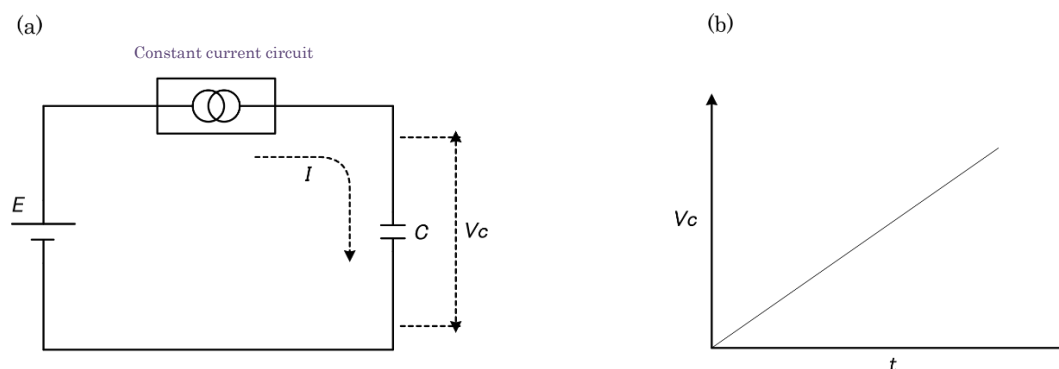
Figure 5-16. Charging a capacitive DUT in insulation resistance measurement (a) and associated charging time (b)

Here, the capacitor charging time t can be expressed by:

$$t = \frac{C \cdot V_c}{I} \qquad \text{(5-16)}$$

Adequate charging is necessary in order to measure insulation resistance (for more information, see the description of dielectric absorption on p. 11). Equation (5-16) shows how charging time decreases as current capacity increases. In other words, the amount of time that must elapse before measurement can be reduced. In applications where takt time is important, for example automated insulation resistance testing equipment, the power supply must have a high current capacity.

(3)　Current Absorption Functionality

Current absorption functionality provides functionality for absorbing and discharging electric charge from the charged DUT. If the DUT remains charged instead of being discharged, the following can occur:

・Capacitors and other components may short each other out, causing damage.

・In case of a capacitive DUT, the residual charge may cause electric shock.

・If conducting multiple measurements, measured values may be affected. (For more information, see the description of 1-minute values on p. 13.)

(1) Calibration

Calibration is the process of calculating the relationship between the value indicated by a measuring instrument and the true value while using a standard, standard sample, or other reference (JIS Z 8103).

The quantities and values indicated by instruments change over time. Consequently, for appropriate measurement, it is desirable to assess the nature of these changes over time on a regular basis according to the conditions under which the instrument is being used. When performing calibration, verify that that value of the standard input into the instrument falls within the instrument's allowable range (accuracy).

(2) Calibration of Insulation Resistance Meters (Super Megohm Meters)

As was described in Chapter 5, "Methods for Measuring Insulation Resistance Values and Insulation Resistivity," insulation resistance meters apply a constant voltage to the DUT and measure the current value flows to the device. Consequently, it is necessary to calibrate the generated voltage value as well as the measured current value.

HIOKI's Super Megohm Meters have defined accuracy figures for reference values or current values. Calibration is performed using current input or resistance input depending whether the instrument lists current values or resistance values, respectively.

Specifications

Model		SM-8213
Measurement voltage and measurement range	5 V	2.5×10^4 to $1 \times 10^{11}\,\Omega$
	10 V	5×10^4 to $2 \times 10^{11}\,\Omega$
	15 V	7.5×10^4 to $3 \times 10^{11}\,\Omega$
	25 V	1.25×10^5 to $5 \times 10^{11}\,\Omega$
	50 V	2.5×10^5 to $1 \times 10^{12}\,\Omega$
	100 V	5×10^5 to $2 \times 10^{12}\,\Omega$
	250 V	
	500 V	
	1000 V	

Accuracy Specifications
Current measurement accuracy

Range	Max. display	Resolution	FAST / FAST2
20 pA	19.9999 pA	0.1 fA	–
200 pA	199.999 pA	1 fA	–
2 nA	1.99999 nA	10 fA	0.5+600
20 nA	19.9999 nA	100 fA	0.5+30
200 nA	199.999 nA	1 pA	0.5+30
2 µA	1.99999 µA	10 pA	0.5+30
20 µA	19.9999 µA	100 pA	0.5+30
200 µA	199.999 µA	1 nA	0.5+30
2 mA	1.99999 mA	10 nA	0.5+30

Left: Resistance values listed for the SM-8213

Right: Current values listed for the SM7110

(Excerpted from the product pamphlet)

(3)　Calibration Examples

　　　・SM-8220

　　　Calibration targets: Voltage output, current measurement

　　　HIOKI provides the Standard Resistor SR-2 for use as a standard resistance in calibration.

DMM

Resistance input　　　　　　　　　　　　　　Voltage output

Figure 5-17. Example of SM-8220 calibration

　　　・SM7110

　　　Calibration targets: Voltage output, current measurement

Current generator

DMM

Current input　　　　　　　　　　　　　　Voltage output

Figure 5-18. Example of SM7110 calibration

6 Causes of Measurement Error and Expertise in Addressing Them

In order to measure insulation resistance in a stable manner, it is necessary to take steps to address sources of error, for example noise and leakage. The following provides representative examples of some causes of error that demand caution when measuring insulation resistance along with associated countermeasures. Please note that this content is not conceived to offer comprehensive coverage of the fundamentals of general noise countermeasure technologies, but rather to offer a selection of measures and expertise with particular relevance to our topic of insulation resistance measurement.[1]

-1 Effects of Dielectric Absorption

The dielectric absorption phenomenon causes variations in the current that flows due to the absorption and discharge of electric charges during the polarization process as caused by the dielectric characteristics of the DUT during insulation resistance measurement (Figure 6-1). As a result, the insulation resistance value may vary when the same DUT is measured continuously after applying a voltage. Consequently, a value known as the 1-minute value is used to compare readings for the same material.

(See the detailed explanation of this phenomenon for more information: p. 11)
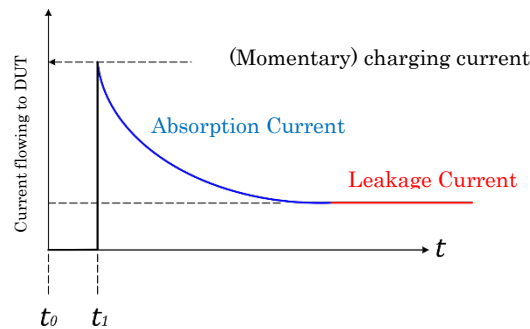
Figure 6-1. Change in current flowing to the DUT due to the dielectric absorption phenomenon

If measurement cables whose insulation is made of a material with a high dielectric constant, the issue can be resolved by using cables with a small absorption current (for example, cables made of Teflon or polyethylene). Triple coaxial cables that are guarded are also effective for dealing with the problem.

If the DUT itself has a high dielectric constant, it may be necessary to eliminate the polarized state by means of adequate discharging or heat treatment prior to measurement.

-2 Effects of External Noise (Inductive Noise)

Current may be induced due to capacitive coupling from the high-voltage circuitry used in

---

[1] Depending on the usage environment, other factors may affect results. The sources of error described here should be considered requirements for insulation resistance measurement.

power cords, fluorescent lamps, solenoid valves, computer displays, and other devices. When an induced current is combined with the measurement current, measured values can be affected in insulation measurement, which must measure minuscule currents. To prevent this issue, shielding (electrostatic shielding) can be used to prevent fluctuations in measured values caused by inductive noise. Ideally, all lines from the DUT to the ammeter would be shielded.
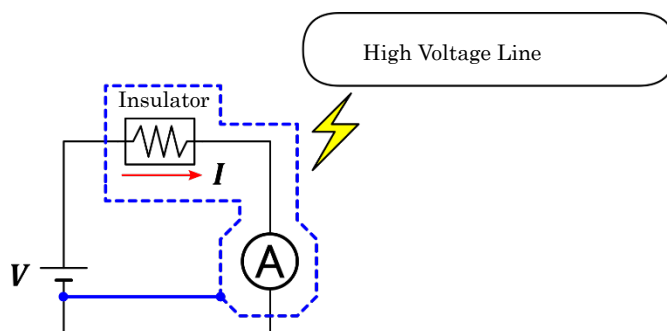
Figure 6-2. Shielding against inductive noise from high-voltage lines

By dropping the potential with which the DUT is shielded to the insulation resistance meter's guard potential, you can implement a measure shown in Figure 6-2.

-3   Effects of Leakage Current from Devices Other Than the DUT

Guarding serves to protect the measurement process from the effects of leakage current reaching the measurement circuit from devices other than the DUT (for example, insulators supporting the DUT, the measurement stage used to load the DUT into an automatic testing system or other hardware, etc.). The approach is the same as that used for shielding, and it consists of wiring so that unnecessary currents do not pass through the ammeter (Figure 6-3). (For more information, see the following: p.26)

Figure 6-3. Example of guarding

-4   Effects of Measurement Cables

(1)   Cable Fabricating Methods

When fabricating the ends of cables to accommodate the DUT, an improper fabrication can cause

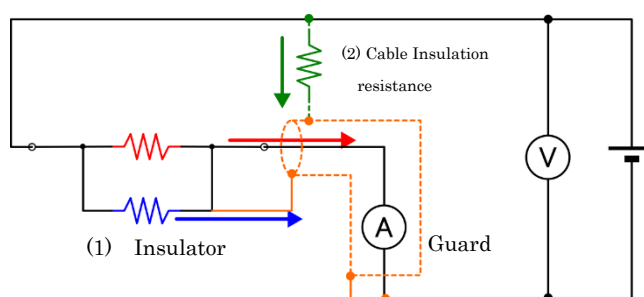the cables to pick up a large amount of noise, which will become a source of error. To prevent problems with noise, cables connected to an instrument that is subject to guarding and shielding must be terminated in an appropriate manner (Figure 6-4).
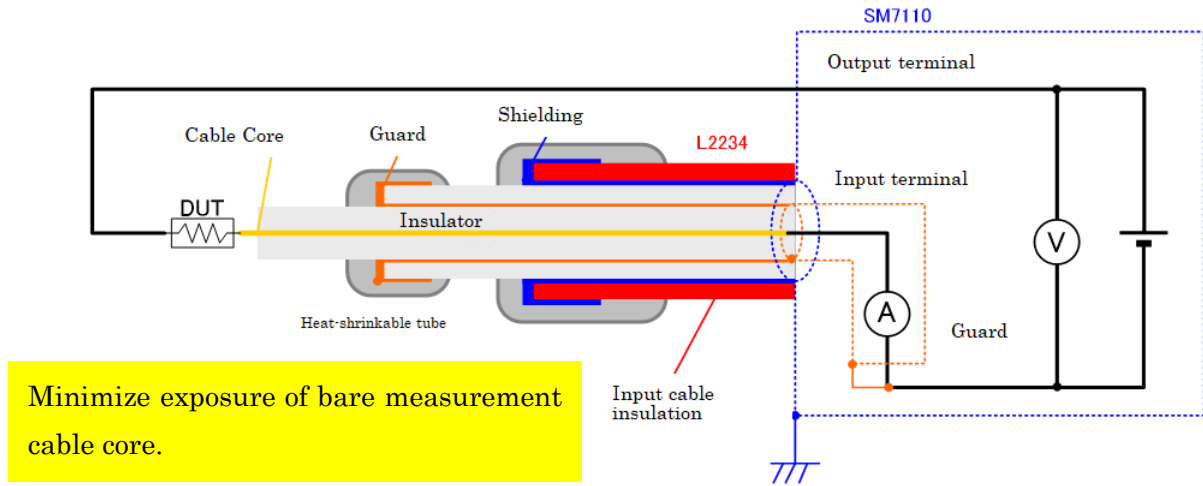

Figure 6-4. Cable fabrication methods

Imagine that the DUT is floating, as shown in Figure 6-4. In this case, it is necessary to cover the shield wires and guard wires with heat-shrinkable tubes and connect them such that the wire cores do not extend beyond the insulating layer. Too much exposure of the wire cores will cause the setup to be susceptible to the effects of leakage and inductive noise.

(2)   Cable Friction Noise [2]

When friction between a cable's core and its shielding, or between conductors used as guards and wire insulation, causes static electricity, the result can be a potential difference between the wire core and the shielding (guard), causing a current that is dependent on the potential difference and cable insulator to flow to the wire core. Since the current flows to the wire core, it will be conspicuous when measuring a high resistance. Figure 6-5 (b) illustrates one method for preventing friction between cable insulation, insulators, and conductors. In the typical shielding wire shown in Figure 6-5 (a), the core is surrounded by an insulator, and the shielding wire is placed around that. By contrast, cables that are designed to prevent static electricity caused by friction add a semi-conductive coating between the insulator and the shielding conductor.

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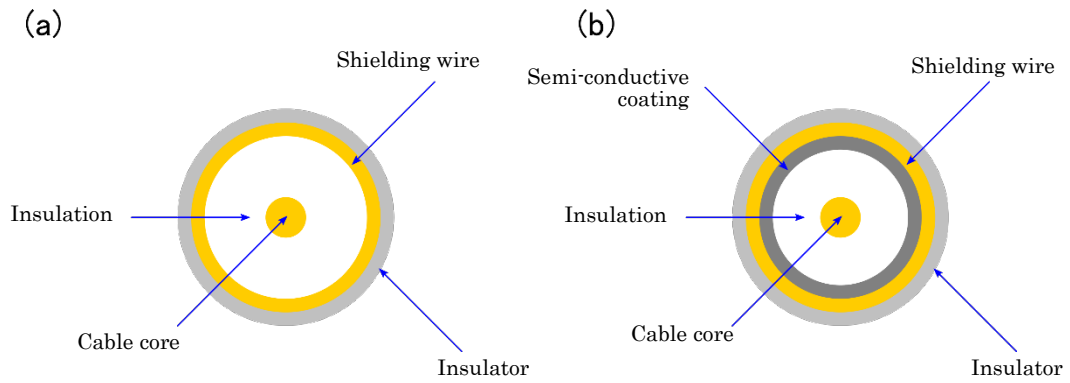
Figure 6-5 (a) Typical shielding wire, (b) Low-noise cable

Figure 6-6 illustrates the voltage generated when a cable with polyethylene insulation and a low-noise cable are flexed at a constant time interval while connected to a terminal resistor $R_x = 100$ [MΩ] as shown in Figure 6-7. The terminal resistor simulates the comparatively low-impedance part of the cable. In this case, the current generated from friction from flexing of the cables is given by ((Voltage generated between the wire core and shielding)/R_x), which means that a current of 200 pA to 300 pA will result for a typical polyethylene cable. Such currents represent a fatal error for Super Megohm Meters, which have a resolution on the order of femtoamperes. When using the instrument in an automated test system or similar application, caution is necessary since vibrations at a regular interval could result in a friction noise current that would affect measured values. By contrast, almost no noise is observed when using low-noise cables, as shown by Figure 6-6.
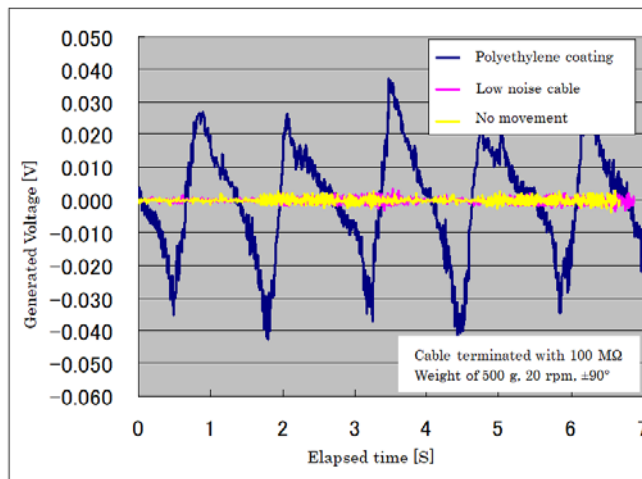
Figure 6-6. Friction noise when cables are flexed
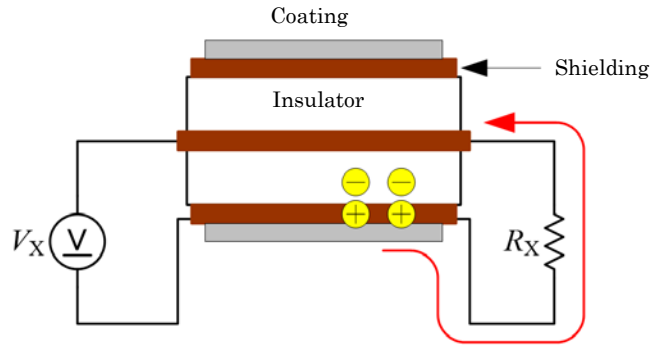
Figure 6-7. Diagram showing static electricity caused by friction between wires during a flexing test

Although low-noise cables are resistant to noise, some of them are physically less resistant to flexing than typical cables.

-5 Effects of 1/f Noise (Conductive Noise) from the Power Supply (Measurement Constant-voltage Source)

Noise contained in constant-voltage power supplies exerts an effect on measured values as conductive noise. One cause of such noise is 1/f noise, which results from variations in electrical resistance caused by incomplete contact between electronic components. Since the noise voltage is inversely proportional to the frequency, this noise is known as 1/f noise. Figure 6-8 explains the effects caused when this type of noise occurs inside a measuring instrument. In the figure, a test voltage of 100 V is applied to a DUT that consists of the equivalent of 10μF and 100MΩ in parallel, here, let us assume that 1/f noise has entered the measurement lines.

Figure 6-8. Conductive noise from a power supply

In (a), the noise source is a 1 mV, 0.1 Hz AC signal, and the current I_n passing through the capacitance component is given by Equation (6-1).

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$$I_n = V_n \cdot 2\pi f_n C_x$$
$$= 1 \times 10^{-3} \times 2\pi \times 0.1 \times 10 \times 10^{-6}$$
$$= 6.28 \,[\text{nA}] \qquad\qquad (6\text{-}1)$$

In the above equation, V_n: represents the voltage of the noise signal ； f_n: its frequency ； and C_x: the DUT's capacitance. If the noise signal frequency is increased to 1 Hz for the same DUT, as shown in (b), a similar calculation yields the results shown in Equation (6-2):
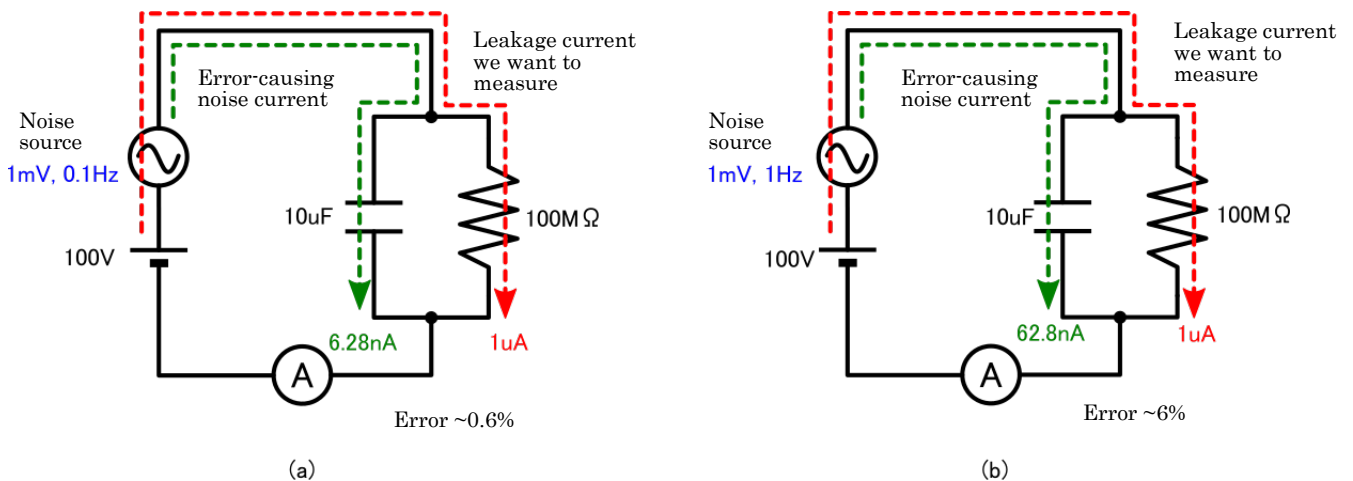
$$I_n = V_n \cdot 2\pi f_n C_x$$
$$= 62.8 \,[\text{nA}] \qquad\qquad (6\text{-}2)$$

As this result and the equation indicate, the current value that becomes the source of error increases as the noise signal's frequency increases. Additionally, a DUT with a large capacitance value will cause the error current resulting from the noise to increase. Since the capacitance of the DUT cannot be changed in order to reduce the source of error, it is important to limit this type of conductive noise on the instrument side.

Let us consider the AC gain-frequency characteristics for each current measurement method described in Chapter 4. AC gain is low in the low-frequency band but high in the high-frequency band for the shunt and resistance feedback methods. Since the voltage of 1/f noise decreases as the frequency rises, the effects of this type of noise are not particularly pronounced for those two measurement methods. By contrast, since the integration method is characterized by high gain in the low-frequency band, that approach is more susceptible to the effects of 1/f noise. Consequently, it is important to implement a sufficient amount of band limitation in the constant-voltage source being used for integration-method testing.

-6 Effects of Temperature and Humidity (Devices Used：SM7120, SME-8310, Z5010)

Generally speaking, insulation resistance falls as temperature rises. Figure 6-9 below provides an example by illustrating how the insulation resistance of a chip ceramic capacitor with X5R temperature characteristics at 10μF change with temperature. The temperature dependency data shown here was obtained by measuring the DUT in a 40% RH humidistat bath.

The vertical axis in the figure shows insulation resistance 1-minute values obtained when 100 V was applied to the ceramic capacitor, and its horizontal axis shows the temperature of the ceramic capacitor. The results indicate that the insulation resistance value decreases with the temperature rise.
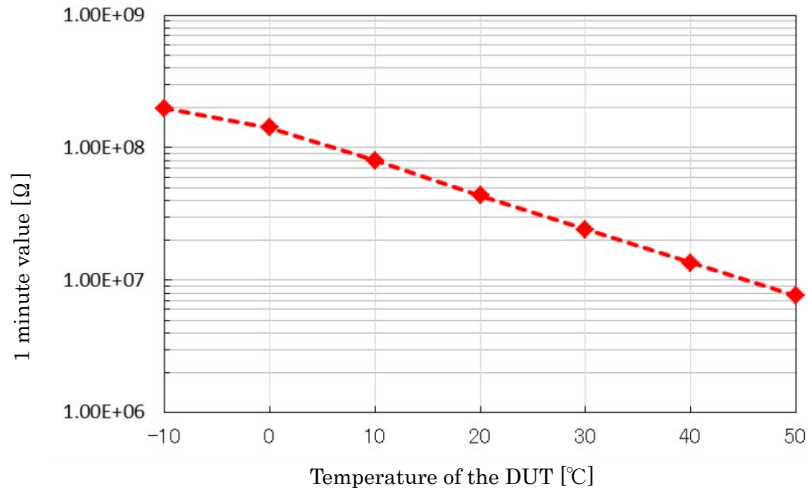
Figure 6-9. Insulation resistance value-temperature dependence of a ceramic capacitor

Figure 6-10 provides another example by illustrating how the insulation resistance of a chip ceramic capacitor (the same DUT used in the measurements shown in Figure 6-9) vary with relative humidity, indicating how the results change based on the relative humidity. This relative humidity dependency data was obtained by measuring the component in a thermostatic chamber at 27°C. The vertical axis in the figure shows 1-minute insulation resistance values when 100 V is applied to the component, while the horizontal axis shows the relative humidity in the thermostatic chamber. For this ceramic capacitor, little variation in insulation resistance due to relative humidity was observed. However, relative humidity may affect measured values depending on the material, shape, and fabrication state of the DUT in question.
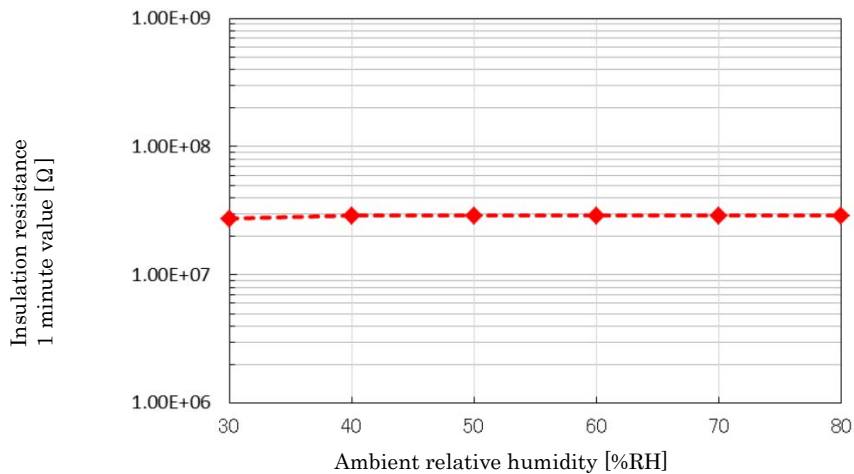
Figure 6-10. Insulation resistance value-ambient relative humidity dependence of a ceramic capacitor

Moving on, Figures 6-11 and 6-12 illustrate the temperature variations and relative humidity variations in the volume resistivity and surface resistivity of a flat sheet of $LiTaO_3$ (lithium tantalite), respectively.

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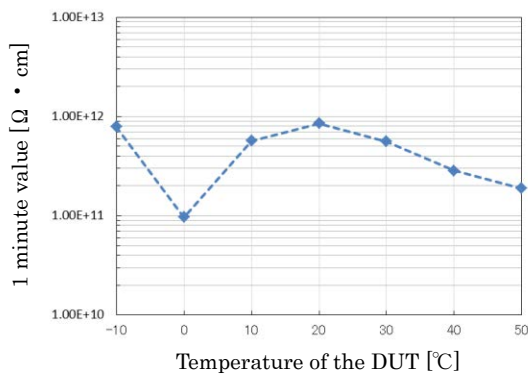
(a) Volume resistivity [Ω・cm]
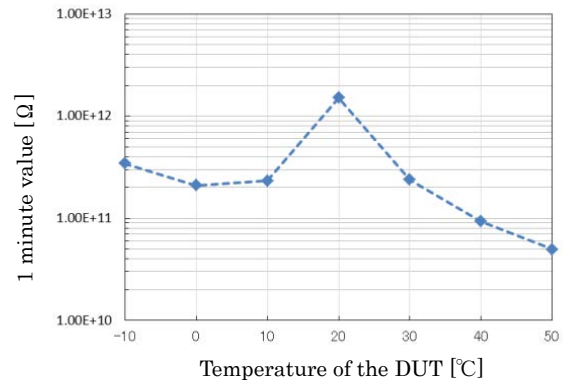
(b) Surface resistivity [Ω]

Figure 6-11. (a) Volume resistivity-temperature dependence and (b) surface resistivity-temperature dependence of an $LiTaO_3$ sheet

The results of the temperature dependency of the $LiTaO_3$ sheet shown in Figure 6-11 do not suggest any significant change caused by temperature. However, the results for humidity dependence shown in Figure 6-12 do show a tendency for resistivity to decrease as humidity rises. These results indicate that the flat DUT used in these tests is comparatively susceptible to the effects of ambient relative humidity.
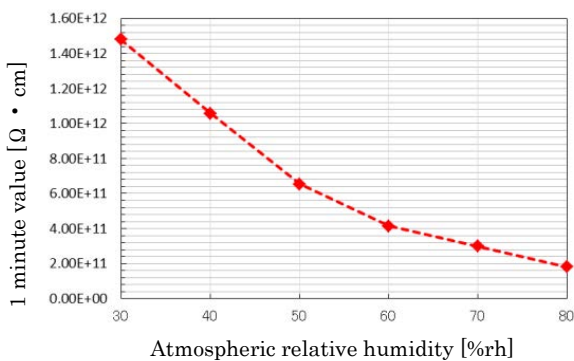
(a) Volume resistivity [Ω・cm]
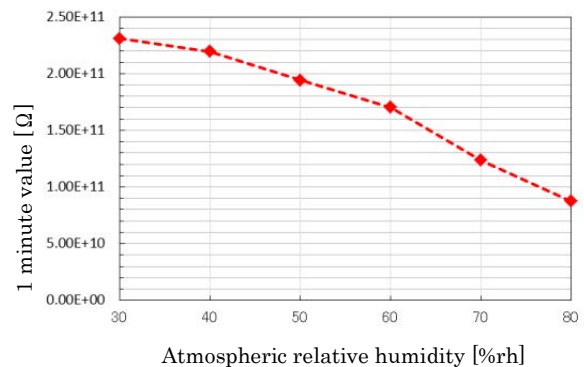
(b) Surface resistivity [Ω]

Figure 6-12. (a) Volume resistivity-ambient relative humidity dependency and (b) surface resistivity-ambient relative humidity dependency of an $LiTaO_3$ sheet

As shown above, the temperature of the substance of the measurement target as well as the ambient relative humidity can affect insulation resistance values. However, the results for temperature and humidity dependence presented in this section are only examples. Some substances are more susceptible to these effects. In order to obtain stable measurement values and conduct reproducible tests, it is ideal to maintain a constant testing environment.

-7　Effects of Dirt on the DUT

Dirt contaminating the DUT will introduce an error component into minuscule current

readings. In most cases, the dirt will have a different resistance value and dielectric constant than the DUT, raising the risk that the measurement will include leakage current flowing to the dirt. Figure 6-13 illustrates the results of measuring insulation resistance while changing multiple conditions.
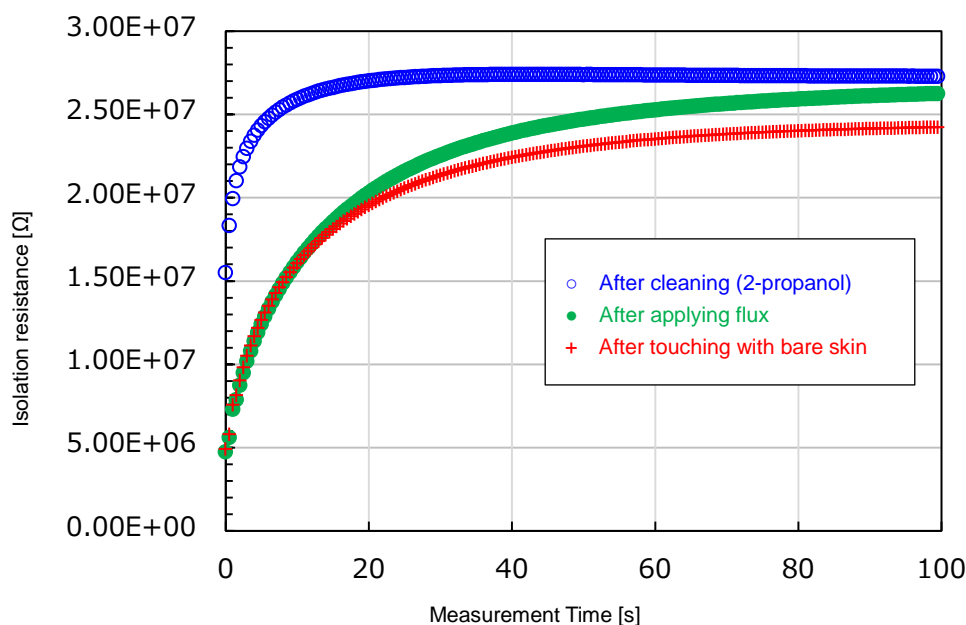
Figure 6-13. Effects of dirt on the DUT

Figure 6-13 illustrates the results of measuring the insulation resistance of a chip ceramic capacitor with X5R temperature characteristics at 10μF under a variety of states of cleanliness while applying 100 V for 100 sec. at a room temperature of 27°C and a relative humidity of 40%. Values were sampled every 0.5 sec., and measurement continued for 200 samples. The blue line indicates insulation resistance values for the capacitor after subjecting it to ultrasonic cleaning for 1 hour in 2-propanol; the green line, after applying flux; and the red line, after touching the capacitor with bare skin. As these results indicate, the dielectric absorption characteristics change depending on the condition (in terms of cleanliness) of the DUT. You can see how charging slows when the component is dirty compared to when it is clean. Since the 1-minute value will change when the dielectric absorption characteristics change, even for the same sample, it is necessary to exercise caution when comparing or judging multiple samples of the same material.

-8   Effects of Contact Resistance When Using Specially Designed Electrodes

When using specially designed electrodes such as those introduced on page 63, the contact resistance between the electrode and material may affect measured values.

For example, electrodes designed to comply with standards for measuring the insulation resistance of an anti-static mat are made of conductive rubber to ensure a uniform degree of

adhesion. When the same electrodes are used with a material that has surface roughness that is nearly uniform at the molecular level, for example a multilayer semiconductor board, contact resistance will become a source of measurement error if the conductive rubber surface is rough. If this causes variability in measured values, it will be necessary to take steps so that the materials approach uniform adhesion by changing the hardness of the material used for the electrodes.

Figure 6-14 provides an example involving differences in contact resistance with the DUT caused by electrode hardness. An enlarged view of the electrode and DUT reveals that if the DUT has smooth surface, a large adhesion area and uniform contact will result as long as the hardness of the electrode is lower than that of the DUT; however, if the hardness of the electrode is higher than that of the DUT, contact will only occur in a limited area. Figure 6-15 illustrates how such partial contact affects electrical characteristics.
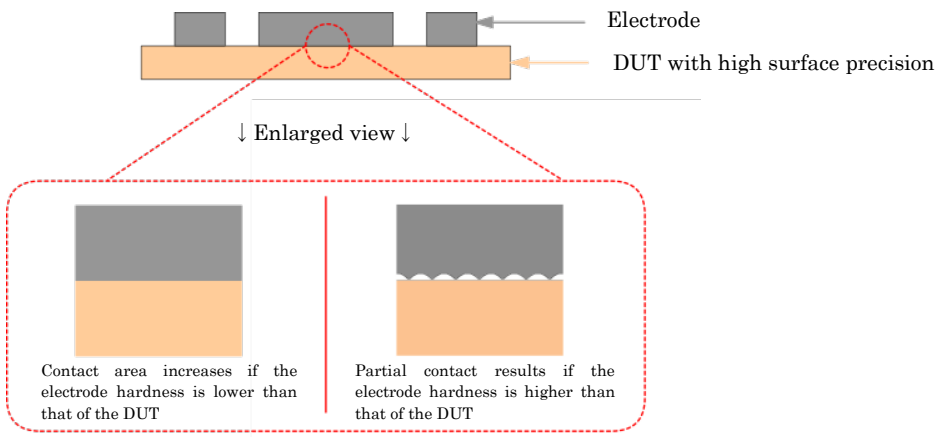
Figure 6-14. Differences in the state of contact with the DUT caused by electrode hardness

(a)　Volume resistivity measurement

(b)　Volume resistivity measurement
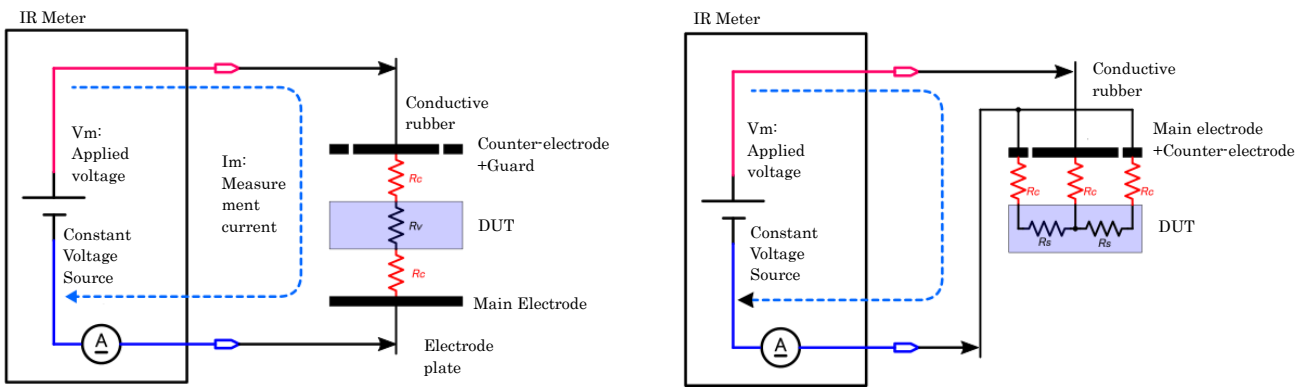
Figure 6-15. Effects of electrode contact resistance

Figure 6-15 illustrates equivalent circuits for (a) volume resistivity measurement and (b) surface

resistivity measurement under conditions of partial contact between the electrodes and the DUT. When adhesion with the surface of the DUT is poor, the measurement results will include the contact resistance R_C shown in red in the figure along with the resistance component of the DUT.

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7 Introduction to HIOKI Products

-1 Positioning Map

(1) R&D Use

Highly stable, noise-resistant measurement
Ideal for evaluating the insulation resistance of components with high breakdown voltages since it can apply up to 2000 V

SM7110

1 kΩ~20EΩ

Large, easy-to-read LCD digital/analog display
Easy enough for anyone to operate
Ideal for evaluation and testing of materials (film, etc.) and liquids (insulating oil)

25 kΩ~2TΩ   SM-8213
250 kΩ~20TΩ   SM-8215
50 kΩ~20PΩ   SM-8220

Freely configurable test voltage
Clear judgments based on upper and lower threshold comparator

2 kΩ~10GΩ   ST5520

Measured resistance range

100Ω 1kΩ 10kΩ 100kΩ 1MΩ 10MΩ 100MΩ 1GΩ 10GΩ 100GΩ 1TΩ 10TΩ 100TΩ 1PΩ 10PΩ 100PΩ 1EΩ 10EΩ 100EΩ

(2) Product Line Use

Unique MLCC 8-channel Super Megohm Meter
Simultaneous measurement of 8 channels at up to 6.8 ms for improved productivity
Helps lower MLCC cost

1 kΩ~1PΩ   SM7810

Produce 1600 components per minute with speeds of up to 6.4 ms (including contact check) *SM7420
Ideal for capacitor testing lines

SM7110   SM7420

1 kΩ~20EΩ

Lightning-fast judgment and built-in contact check functionality
Ideal for measuring battery insulation resistance

2 kΩ~10GΩ   ST5520

Measured resistance range

100Ω 1kΩ 10kΩ 100kΩ 1MΩ 10MΩ 100MΩ 1GΩ 10GΩ 100GΩ 1TΩ 10TΩ 100TΩ 1PΩ 10PΩ 100PΩ 1EΩ 10EΩ 100EΩ

(3) Power Supply

The SM7810 and SM7420 do not have voltage generation functionality. Consequently, when used on a production line, they must be paired with a power supply.

● **SM7860-xx**

　　Up to 32 channels of output

　　Fast charging times thanks to maximum

　　current output of 50 mA/channel

　*Maximum current output is limited to 10 mA/channel in the 1 kV output voltage model.

● **Power supply selection criteria**

Figure 7-1 provides an example of the roles of each stage in an automated testing system used on a production line. MLCCs enter the turntable and move around it from stage to stage. The fundamental measurement stage measures capacitance, insulation resistance, and capacitance, in that order. MLCCs must be charged in preparation for insulation resistance measurement to ensure accurate results and then discharged following insulation resistance measurement to keep from affecting testing in downstream processes. Additionally, a power supply a voltage source for each polarity is necessary if switching the polarity of the voltages applied during measurements (1) and (2).

Figure 7-1. Example of an automated testing system

● **Product line**

Figure 7-2 summarizes HIOKI's line of power supplies. An extensive range of SM7860 models are available so that customers can choose the power supply that best suits their measurement needs.

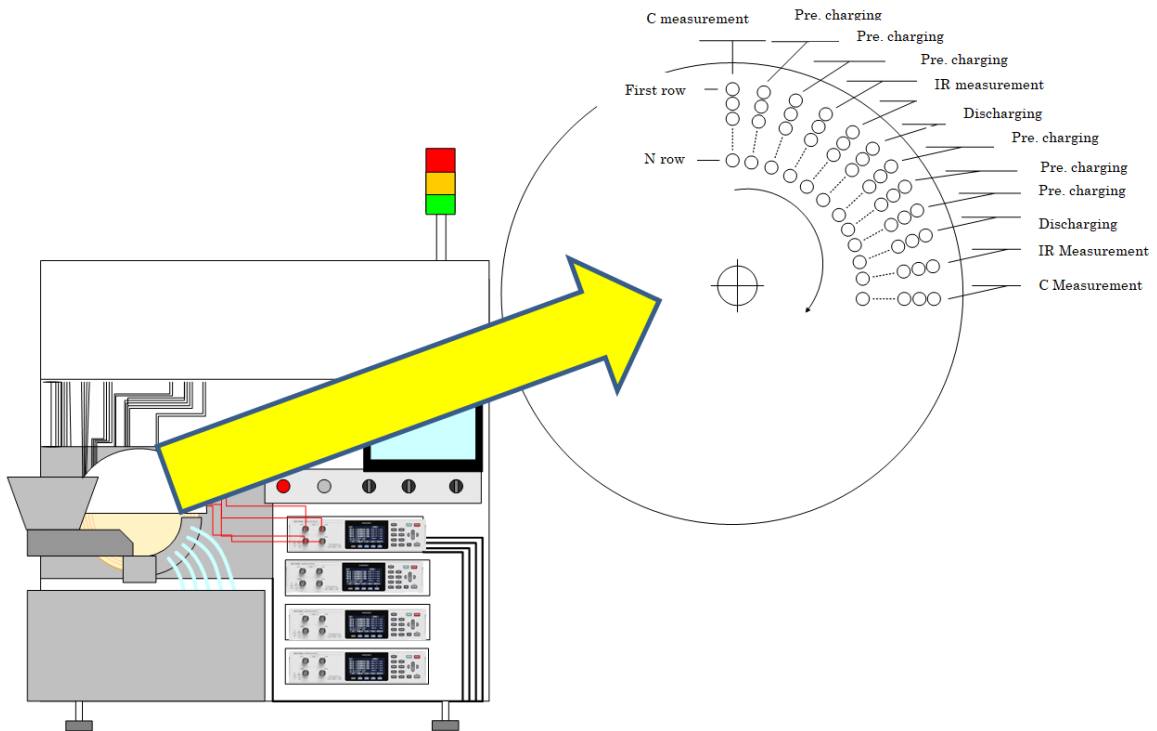| SM7860 output channel configuration		-01 / -21	-02 / -22	-03 / -23	-04 / -24	-05 / -25	-06 / -26	-07 / -27
OUT1 to 4 output content	OUT1 OUT2	+500V	+1kV	+500V +500V	+1kV +1kV	+500V discharge	+1kV discharge	+10V +10V
	OUT3 OUT4	-500V	-1kV	-500V -500V	-1kV -1kV	-500V discharge	-1kV discharge	+10V discharge
Overview (Total number of channels and output voltage)		16 ch ±500 V	16 ch ±1000 V	32 ch ±500 V	32 ch ±1000 V	32 ch ±500 V, discharge	32 ch ±1000 V, discharge	32 ch 10 V, discharge
Line A	Number of OUT1 channels	8 ch	8 ch	8 ch	8 ch	8 ch	8 ch	8 ch
	OUT1 output voltage range[3]	1.0 V to 500.0 V	250.0 V to 1000.0 V	1.0 V to 500.0 V	250.0 V to 1000.0 V	1.0 V to 500.0 V	250.0 V to 1000.0 V	1.0 V to 10.0 V
	Number of OUT2 channels	--	--	8 ch	8 ch	8 ch	8 ch	8 ch
	OUT2 output voltage range[3]			1.0 V to 500.0 V	250.0 V to 1000.0 V	discharge	discharge	1.0 V to 10.0 V
	Current limitation	±50 mA/ch	±10 mA/ch	±50 mA/ch	±10 mA/ch	±50 mA/ch	±10 mA/ch	±50 mA/ch
	Maximum output current[4]	430 mA (200 VA)	100 mA (100 VA)	430 mA (200 VA)	100 mA (100 VA)	430 mA (200 VA)	100 mA (100 VA)	430 mA (200 VA)
Line B	Number of OUT3 channels	8 ch	8 ch	8 ch	8 ch	8 ch	8 ch	8 ch
	OUT3 output voltage range[3]	-1.0 V to -500.0 V	-250.0 V to -1000.0 V	-1.0 V to -500.0 V	-250.0 V to -1000.0 V	-1.0 V to -500.0 V	-250.0 V to -1000.0 V	1.0 V to 10.0 V
	Number of OUT4 channels	--	--	8 ch	8 ch	8 ch	8 ch	8 ch
	OUT4 output voltage range[3]			-1.0 V to -500.0 V	-250.0 V to -1000.0 V	discharge	discharge	discharge
	Current limitation	±50 mA/ch	±10 mA/ch	±50 mA/ch	±10 mA/ch	±50 mA/ch	±10 mA/ch	±50 mA/ch
	Maximum output current[4]	430 mA (200 VA)	100 mA (100 VA)	430 mA (200 VA)	100 mA (100 VA)	430 mA (200 VA)	100 mA (100 VA)	430 mA (200 VA)

*2 The power supply voltage for the SM7860-01 to -07 is 100 VAC, and that for the SM7860-21 to -27 is 220 VAC.   *3 The resolution of the output voltage range is 0.1 V.
*4 Only when the operating conditions as stated in the restriction warnings of the specifications are met.

Figure 7-2. Line of power supply products

(4)   Electrodes

Electrodes are necessary for measuring the surface and volume resistance of materials as well as the insulation resistance of liquids. HIOKI offers an extensive range of electrodes for a range of applications as shown in Figure 7-3.
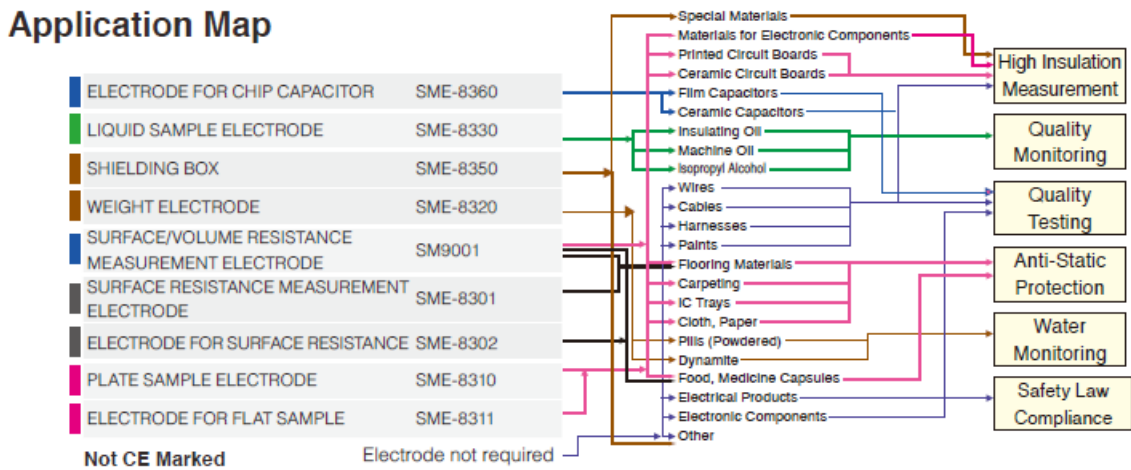
Figure 7-3. Electrode line (as of 2020)

-2   Super Megohm Meter and Power Supply Connection Methods

(1)   SM7810 and SM7860

The SM7860 has four voltage output terminals on its rear. Each terminal has 10 pins,

each of which can be assigned as a output channel or COM terminal. Output voltages are generated based on the COM terminals.

When using the SM7810 and SM7860 in combination, the voltage output terminals on the SM7860 are connected to the voltage input terminals on the rear of the SM7810 with cables. In this case, the same pin numbers on both devices should be connected.

The voltage input terminals on the rear of the SM7810 and the voltage output terminals on the front of the SM7810 have the same potentials. The DUT is connected between the voltage output terminal and the current input terminal.

Preparatory charging of the DUT can be performed using the SM7860 alone, without the SM7810. Connect the terminals on the SM7860 used for charging and discharging directly to the DUT. In this case, the COM terminals can be set to common.

The SM7810 and SM7860 can use GP-IB and RS-232C communications. Since they cannot be synchronized together, individual control is required..
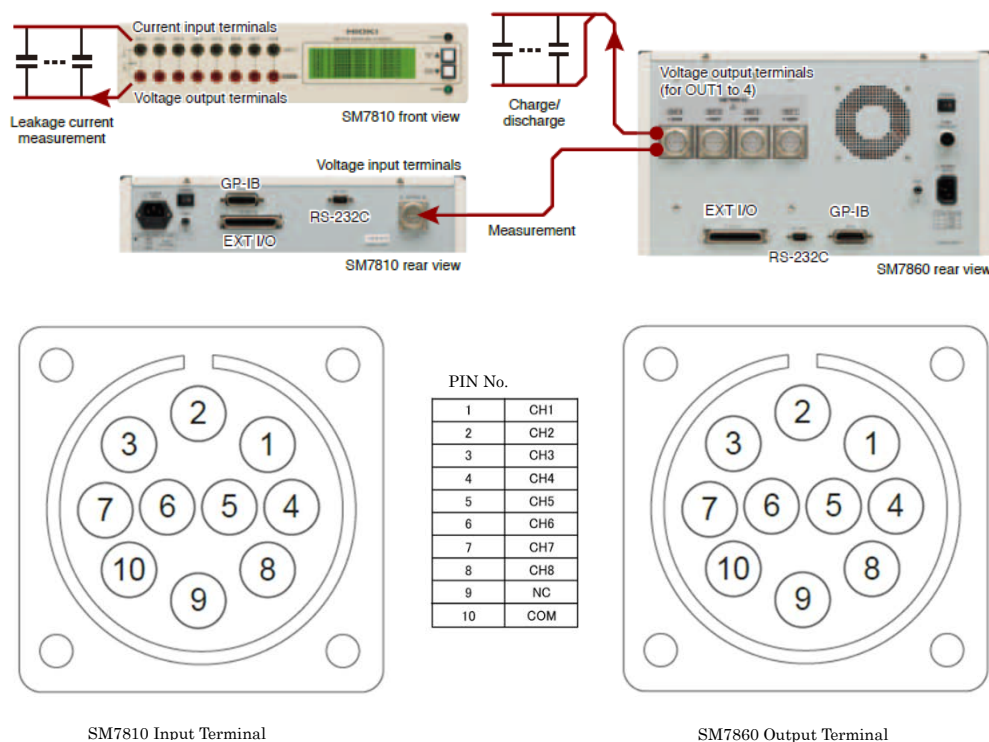
Figure 7-4. SM7810 and SM7860 used in combination

(2)   SM7420 and SM7860

Connect the DUT between the SM7860's voltage output terminals and the SM7420's input terminals. Connect the SM7860's COM terminal to the COM terminal on the rear of the SM7420 terminal. In this case, the SM7860's voltage output terminals have only one COM line, so it will need to be branched to each channel being used (Figure 7-5).

If performing preparatory charging of the DUT, that task can be performed using the

SM7860 alone, as described in the section about the SM7810 and SM7860 above.

The SM7420 can be controlled using GP-IB, RS-232C, or USB. Since synchronization is not possible for this combination, either, the devices must be controlled individually.
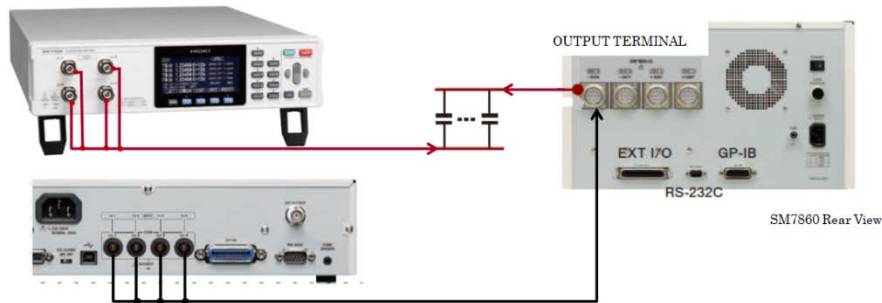
Figure 7-5. SM7420 and SM7860 used in combination

-3 Super Megohm Meter and Electrode Connection Methods

The SM7110, SM7120, and SM7420's input terminals use HIOKI's proprietary triple coaxial design, while the SM-8200 series, SM7810, and electrodes use dedicated coaxial terminals. Figure 7-6 illustrates these different terminal profiles. The Conversion Adapter Z5010 is required in order to connect terminals with different profiles. When connected as shown in Figure 7-7, surface and volume resistivity can be measured with proper guarding.

Figure 7-6. Differences in measurement lead terminals for different products

Figure 7-7. How to connect electrodes to the SM7110

(1)　Super Megohm Meter and Measurement Power Supplies

Test System Ideal for MLCC Leakage Current Measurement

SUPER MΩ HiTESTER　SM7810

GP-IB
RS-232C
Not CE Marked
3 year Warranty

- Test the leakage current of MLCCs at the fastest speed of 6.8ms simultaneously over 8 channels
- Conduct high-speed leakage current testing of large-capacity MLCCs in the high current range (1mA)
- Improve testing reliability using the contact check function
- Build a flexible system by making best use of the individual settings of each channel

Model No. (Order Code)　**SM7810**　　(100/110V AC power supply)
　　　　　　　　　　　　SM7810-20　(220V AC power supply)

The Super MΩ HiTESTER SM7810 is produced to order. An input/output terminal connection cable*1 is required separately. Please contact your local HIOKI representative.
*1 Input/output terminal connector/plug and connection cable
・Current input terminal connector and voltage output terminal plug are not included. Voltage input terminal connector is included.
・Input/output terminal connection cables are available in various lengths to suit HIOKI measurement systems. Please consult with your HIOKI representative.

Input/Output Cables

| MEASURING LEAD (RED) 0GA00007 1 m (3.28 ft) length | MEASURING LEAD (BLACK) 0GA00008 1 m (3.28 ft) length | MEASURING LEAD (BLACK) 0GA00016 5 m (16.41 ft) length | MEASURING LEAD (RED) 0GA00019 1 m (3.28 ft) length |
| MEASURING LEAD (RED) 0GA00021 2 m (6.56 ft) length | MEASURING LEAD (RED) 0GA00027 5 m (16.41 ft) length | | |

PC communication

RS-232C CABLE 9637 For the PC, 9pin - 9pin, cross, 1.8m (5.91 ft) length

Discontinued
RS-232C CABLE 9638 For the PC, 9pin - 25pin, cross, 1.8m (5.91 ft) length

GP-IB CONNECTOR CABLE 9151-02 2 m (6.56 ft) length

Bundled Accessories

CONNECTOR L2220 Voltage input connector for SM7810

■ Basic specifications (Accuracy guaranteed for 1 year, Post-adjustment accuracy guaranteed for 1 year)

|	
Number of channels	8 channels (parallel and simultaneous measurement)
Applied voltage	Supply voltage from external power source (voltage input terminal on the rear panel)
Measurement range	Current: 1 pA to 1 mA, Ranges: 100 pA/ 1 nA/ 10 nA/ 100 nA/ 1 µA/ 10 µA/ 100 µA/ 1 mA Resistance: $1 \times 10^2\ \Omega$ to $1 \times 10^{15}\ \Omega$
Measurement speed INDEX typical time	FAST: 6.8 ms, MED: 26.0 ms, SLOW: 100.0 ms, SLOW2: 320.0 ms
Basic measurement accuracy (1µA range, FAST)	Current accuracy: ±(2.0+ (0.5 µA / (Measured current value))) % Resistance accuracy: Current accuracy + Voltage generation accuracy of external power supply
Testing voltage setting	0.1 V to 1000.0 V (Resolution: 0.1 V)
Contact check	Judges the contact state by comparing the measured capacitance to a reference value
Other functions	Trigger delay, averaging, contact check, jig capacity open correction, Measured value comparison and judgment, jig resistance open correction functions
Interfaces	GP-IB, RS-232C, EXT I/O
Power supply	SM7810: AC 100 V/110 V, 50/60 Hz, 30 VA SM7810-20: AC 220 V, 50/60 Hz, 30 VA
Dimensions and mass	425 mm (16.73 in) W × 99 mm (3.90 in) H × 488 mm (19.21 in) D, 10.5 kg (370.4 oz)
Accessories	Power cord ×1, Instruction manual ×1, Voltage input connector L2220 ×1, Spare fuse (built into inlet) ×1, Rubber feet ×4
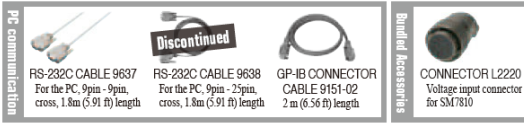
The Power Source Unit Ideal for MLCC Leakage Current Measurement

POWER SOURCE UNIT　SM7860 series

New
GP-IB
RS-232C
Not CE Marked
3 year Warranty

- Support for multi-channel systems up to 32-channel output
- 8-channels or 16-channels dual-line output voltage setting
- Positive and negative polarities required for the MLCC test line included in a single unit
- Output ON/OFF and current limitation can be performed for each channel
- Support for the discharge of the charge capacitor
- Output voltage of 1 kV is available
- Large current output of 50 mA */channel allows for reducing the number of backup charges

* Output voltage of 1 kV is limited to 10 mA/channel

Combination example of the SM7610

Model No. (Order Code)　**SM7860-51 /-52 /-53 /-54 /-55 /-56 /-57 /-58**　(100V AC power supply)
　　　　　　　　　　　　SM7860-61 /-62 /-63 /-64 /-65 /-66 /-67 /-68　(220V AC power supply)

The Power Source Unit SM7860 is produced to order. An output terminal connection cable*2 is required separately. Please contact your local HIOKI representative, or if you need to use a power supply voltage other than 100VAC or 220VAC.
*2 Output terminal cable
・Voltage output terminal connection cables are available in various lengths to suit HIOKI measurement systems. Please consult with your HIOKI representative.

Other

CONNECTOR L2221 Voltage output connector for SM7860

■ Basic specifications (Accuracy guaranteed for 1 year, Post-adjustment accuracy guaranteed for 1 year)

Supported device	Super MΩ HiTester SM7810 Object to which voltage is applied: MLCC (the Multilayer Ceramic Capacitor)
Generation accuracy	Output voltage accuracy: ±2% of set value ± 0.5 V (with no load) Inter-channel error: ± 0.01 V or less (between outputs on the same line with no load)
Interfaces	GP-IB, RS-232C, EXT I/O
Power supply	SM7860-51 to -58: 100 V AC, SM7860-61 to -68: 220 V AC, 50/60 Hz, 860 VA
Dimensions and mass	425 mm (16.73 in) W × 249 mm (9.80 in) H × 581 mm (22.87 in) D, 47 kg (1657.9 oz) [SM7860-57 / -67] : 34 kg (1199.3 oz)
Accessories	Power cable ×1, Instruction manual ×1, Operating precautions ×1

SM7860 Functions & output channel configuration

SM7860-XX[1]		-51 / -61	-52 / -62	-53 / -63	-54 / -64	-55 / -65	-56 / -66	-57 / -67	-58 / -68
OUT1 to 4 output content	OUT1 OUT2	+500V +500V	+1kV +1kV	+500V +500V	+1kV +1kV	+500V discharge	+1kV discharge	+10V +10V	+500V +500V
	OUT3 OUT4	+500V +500V	+1kV +1kV	-500V -500V	-1kV -1kV	-500V discharge	-1kV discharge	+10V discharge	+500V discharge
Overview (Total number of channels and output voltage)		32ch + 500V	32ch + 1000V	32ch ±500V	32ch ±1000V	32ch ±500V, discharge	32ch ±1000V, discharge	32ch + 10V, discharge	32ch + 500V, discharge
Line A	Number of OUT1 channels	8 ch	8 ch	8 ch	8 ch	8 ch	8 ch	8 ch	8 ch
	OUT1 output voltage range [2]	+1.0 V to +500.0 V	+250.0 V to +1000.0 V	+1.0 V to +500.0 V	+250.0 V to +1000.0 V	+1.0 V to +500.0 V	+250.0 V to +1000.0 V	+1.0 V to +10.0 V	+1.0 V to +500.0 V
	Number of OUT2 channels	8 ch	8 ch	8 ch	8 ch	8 ch	8 ch	8 ch	8 ch
	OUT2 output voltage range [2]	+1.0 V to +500.0 V	+250.0 V to +1000.0 V	+1.0 V to +500.0 V	+250.0 V to +1000.0 V	discharge	discharge	+1.0 V to +10.0 V	+1.0 V to +500.0 V
	Current limitation	±50 mA/ch	±10 mA/ch	±50 mA/ch	±10 mA/ch	±50 mA/ch	±10 mA/ch	±50 mA/ch	±50 mA/ch
	Maximum output current [2]	430 mA (200 VA)	100 mA (100 VA)	430 mA (200 VA)	100 mA (100 VA)	430 mA (200 VA)	100 mA (100 VA)	430 mA (4 VA)	430 mA (200 VA)
Line B	Number of OUT3 channels	8 ch	8 ch	8 ch	8 ch	8 ch	8 ch	8 ch	8 ch
	OUT3 output voltage range [2]	+1.0 V to +500.0 V	+250.0 V to +1000.0 V	-1.0 V to -500.0 V	-250.0 V to -1000.0 V	-1.0 V to -500.0 V	-250.0 V to -1000.0 V	+1.0 V to +10.0 V	+1.0 V to +500.0 V
	Number of OUT4 channels	8 ch	8 ch	8 ch	8 ch	8 ch	8 ch	8 ch	8 ch
	OUT4 output voltage range [2]	+1.0 V to +500.0 V	+250.0 V to +1000.0 V	-1.0 V to -500.0 V	-250.0 V to -1000.0 V	discharge	discharge	discharge	discharge
	Current limitation	±50 mA/ch	±10 mA/ch	±50 mA/ch	±10 mA/ch	±50 mA/ch	±10 mA/ch	±50 mA/ch	±50 mA/ch
	Maximum output current [3]	430 mA (200 VA)	100 mA (100 VA)	430 mA (200 VA)	100 mA (100 VA)	430 mA (200 VA)	100 mA (100 VA)	430 mA (4 VA)	430 mA (200 VA)

[1] SM7860-51 to -58: Power supply 100 V AC, SM7860-61 to -68: Power supply 220 V AC　[2] The resolution of the output voltage range is 0.1 V.
[3] Only when the operating conditions as stated in the restriction warnings of the specifications are met.

　　　　　　　　　　　HIOKI E.E. CORPORATION

Min. 6.4 ms Measurement of Super Megohm or Very Small Current

SUPER MEGOHM METER SM7110, SM7120

USB2.0
GP-IB
RS-232C
CE
3 year Warranty

- 300 times better noise resistance
- Max. 2000 V output : SM7120
- Max. 1000 V output : SM7110
- Max. 2×10^{19} Ω display
- Min. 0.1 fA resolution
- Built-in EXT I/O, RS-232C, GP-IB and USB
- Flexible, Multipurpose Design, High Resistance Meter/Electrometer/Picoammeter/IR Meter
- Measure resistance of materials by combining with optional electrode

| Model No. (Order Code) | SM7110 | (1 ch, 1000 V) |
| | SM7120 | (1 ch, 2000 V) |

Note: Measurement leads are not included. Purchase the appropriate lead option for your application separately.

■ Basic specifications (Accuracy guaranteed for 1 year, Post-adjustment accuracy guaranteed for 1 year)

Number of channels	1 ch
DC current measurement	20 pA range (0.1 fA resolution), Accuracy: ±(2.0 % of rdg. +30 dgt.) 200 pA range (1.0 fA resolution), Accuracy: ±(1.0 % of rdg. +30 dgt.) 2 nA range (10 fA resolution), Accuracy: ±(0.5 % of rdg. +20 dgt.) 20 nA range (100 fA resolution), Accuracy: ±(0.5 % of rdg. +10 dgt.) 200 nA range (1 pA resolution), Accuracy: ±(0.5 % of rdg. +10 dgt.) 2 μA range (10 pA resolution), Accuracy: ±(0.5 % of rdg. +10 dgt.) 20 μA range (100 pA resolution), Accuracy: ±(0.5 % of rdg. +10 dgt.) 200 μA range (1 nA resolution), Accuracy: ±(0.5 % of rdg. +10 dgt.) *2 mA range (1 nA resolution), Accuracy: ±(0.5 % of rdg. +30 dgt.) (1) Measurement speed SLOW2 (internal integration time 13PLC) (2) At a temperature of 23 °C ±5 °C with humidity of 85% rh (3) 2 mA range (Measurement speed FAST only)
Resistance measurement capabilities	50 Ω to 2×10^{19} Ω *Note: Resistance measurement accuracy is defined by the current range accuracy and voltage setting accuracy.*
Setting voltage range (Accuracy)	0.1 to 100.0 V, 100 mV resolution, Accuracy: ±0.1 % of setting ±0.05% f.s. 100.1 to 1000 V, 1 V resolution, Accuracy: ±0.1 % of setting ±0.05% f.s. [SM7120 only] 1000 to 2000 V,1 V resolution, Accuracy: ±0.2 % of setting ±0.10% f.s.
Current Limiter	0.1 to 250.0 V: 5/ 10/ 50 mA, 251 to 1000 V: 5/ 10 mA, to 2000 V:1.8 mA
Measurement time setting	Delay: 0 to 9,999 ms
Functions	Comparator, averaging, self-calibration, jig Capacity open correction, cable length correction, surface resistivity, volume resistivity, voltage monitor, contact check
Program function	10 types of discharge, charge, measure and measurement sequence discharge patterns can be programmed.
Display	LCD (8 lines of 30 characters), with backlight, High voltage warning indicator
Interfaces	USB, RS-232C, GP-IB (NPN/PNP can be switched)
Power supply	100 to 240V AC , 50/60 Hz, 45 VA
Dimensions and mass	330 mm (12.99 in)W × 80 mm (3.15 in)H × 450 mm (17.72 in)D, 5.9 kg (208.1 oz)
Accessories	Power cord ×1, Instruction manual ×1, CD-R (Communications command instruction manual, USB driver) ×1, EXT I/O male connector ×1, Short plug ×1

4ch Micro Current Model /Perfect for Automated-Systems Integration

SUPER MEGOHM METER SM7420

USB2.0
GP-IB
RS-232C
CE
3 year Warranty

- 300 times better noise resistance
- 6000 ps/minute - ideal for mass production
- Channel-independent low capacity contact check
- Perfect for equipping on automated machines
- Max. 2×10^{19} Ω display
- Min. 0.1 fA resolution
- Built-in EXT I/O, RS-232C, GP-IB and USB
- Ideal for mounting in automated lines, easy to construct MLCC leakage current inspection lines

| Model No. (Order Code) | SM7420 | (4ch, Dedicated micro current measurement) |

Note: Measurement leads are not included. Purchase the appropriate lead option for your application separately.

■ Basic specifications (Accuracy guaranteed for 1 year, Post-adjustment accuracy guaranteed for 1 year)

Number of channels	4ch
DC current measurement	20 pA range (0.1 fA resolution), Accuracy: ±(2.0 % of rdg. +30 dgt.) 200 pA range (1.0 fA resolution), Accuracy: ±(1.0 % of rdg. +30 dgt.) 2 nA range (10 fA resolution), Accuracy: ±(0.5 % of rdg. +20 dgt.) 20 nA range (100 fA resolution), Accuracy: ±(0.5 % of rdg. +10 dgt.) 200 nA range (1 pA resolution), Accuracy: ±(0.5 % of rdg. +10 dgt.) 2 μA range (10 pA resolution), Accuracy: ±(0.5 % of rdg. +10 dgt.) 20 μA range (100 pA resolution), Accuracy: ±(0.5 % of rdg. +10 dgt.) 200 μA range (1 nA resolution), Accuracy: ±(0.5 % of rdg. +10 dgt.) *2 mA range (1 nA resolution), Accuracy: ±(0.5 % of rdg. +30 dgt.) (1) Measurement speed SLOW2 (internal integration time 13PLC) (2) At a temperature of 23 °C ±5 °C with humidity of 85% rh (3) 2 mA range (Measurement speed FAST only)
Resistance measurement capabilities	50 Ω to 2×10^{19} Ω *Note: Resistance measurement accuracy is defined by the current range accuracy and voltage setting accuracy.*
Measurement time setting	Delay: 0 to 9,999 msec
Functions	CH independent low capacity contact checks, CH independent cable length correction, CH independent jig capacity open compensation, comparator
Display	LCD (8 lines of 30 characters), with backlight, high voltage warning indicator
Interfaces	USB, RS-232C, GP-IB, EXT I/O (NPN/PNP can be switched)
Power supply	100 to 240V AC , 50/60 Hz, 45 VA
Dimensions and mass	330 mm (12.99 in)W × 80 mm (3.15 in)H × 450 mm (17.72 in)D, 6.5 kg (229.3 oz)
Accessories	Power cord ×1, Instruction manual ×1, CD-R (Communications command instruction manual, USB driver) ×1, EXT I/O male connector ×1

Shared options with the SUPER MEGOHM METER SM7110, SM7120 and SM7420

Measurement Leads

PIN TYPE LEAD (RED) L2230
1 m (3.28 ft) length

CLIP TYPE LEAD (RED) L2232
1 m (3.28 ft) length

OPEN LEAD (RED) L2234
3 m (9.84 ft) length

PIN TYPE LEAD (BLACK) L2231
1 m (3.28 ft) length

CLIP TYPE LEAD (BLACK) L2233
1 m (3.28 ft) length

OPEN LEAD (BLACK) L2235
3 m (9.84 ft) length

Humidity sensor

HUMIDITY SENSOR Z2011
1.5 m (4.92 ft) cord length

PC communication

RS-232C CABLE 9637
For the PC, 9pin - 9pin, cross, 1.8m (5.91 ft) length

Discontinued
RS-232C CABLE 9638
For the PC, 9pin - 25pin, cross, 1.8m (5.91 ft) length

GP-IB CONNECTOR CABLE 9151-02
2 m (6.56 ft) length

Other — For the SM7110, SM7120

Interlock Connection Cable DSM8104F
0.1 m (0.33 ft) length
Note: Other measurement electrodes are available

Super Megohm Measurement in Any Field

SUPER MEGOHMMETER SM-8213/8215/8220

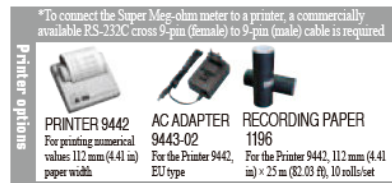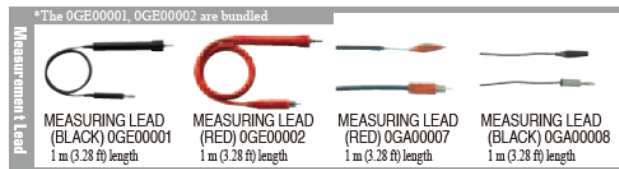

RS-232C

Not CE Marked

SM-8220

- Ultra megohm measurement
- Digital/analog display on LCD
- Compatible for measurement of several sample types with electrodes & other devices

Model No. (Order Code)		
SM-8213	(Max. 2×10^{12} Ω)
SM-8215	(Max. 2×10^{13} Ω)
SM-8220	(Max. 2×10^{16} Ω)

Note: RS-232C connection cable: The optional RS-232C Cable 9637 cannot be used with this product. Use a commercially available straight 9-pin/9-pin cable.

■ Basic specifications (Accuracy guaranteed for 1 year, Post-adjustment accuracy guaranteed for 1 year)

		SM-8213	SM-8215	SM-8220
Measuring resistance range	5 V	2.5×10^4 - 1×10^{11} Ω		
	10 V	5×10^4 - 2×10^{11} Ω		5×10^4 - 2×10^{14} Ω
	15 V	7.5×10^4 - 3×10^{11} Ω		
	25 V	1.25×10^5 - 5×10^{11} Ω		1.25×10^5 - 5×10^{14} Ω
	50 V	2.5×10^5 - 1×10^{12} Ω	2.5×10^5 - 1×10^{12} Ω	2.5×10^5 - 1×10^{15} Ω
	100 V	5×10^5 - 2×10^{12} Ω	5×10^5 - 2×10^{12} Ω	5×10^5 - 2×10^{15} Ω
	250 V		1.25×10^6 - 5×10^{12} Ω	1.25×10^6 - 5×10^{15} Ω
	500 V		2.5×10^6 - 1×10^{13} Ω	2.5×10^6 - 1×10^{16} Ω
	1000 V		5×10^6 - 2×10^{13} Ω	5×10^6 - 2×10^{16} Ω
Measuring accuracy		±10 % (within 10 times range of min. value on each range at 20°C), but ± 20 % at 10^8 range of the SM-8220		
Output current		Max. 50 mA	Max. 2 mA	
Display		LCD (digital & analog display)		
Standard function		Timer (1 to 999s), Comparator, Remote start, HV-EN (interlock)		
Interfaces		RS-232C, Comparator output (open-collector)		
Power supply		Selectable 100, 120, 220 or 240 V AC ±10%, 50/60 Hz, 25 VA		
Dimensions and mass		284 mm (11.18 in)W × 139 mm (5.47 in)H × 215 mm (8.46 in)D, 4.3 kg (151.7 oz)		
Accessories		Instruction manual ×1, Power cord ×1, Measuring lead (black) 0GE00001 ×1, Measuring lead (red) 0GE00002 ×1, Short plug (internal) ×1		

Measurement Lead

*The 0GE00001, 0GE00002 are bundled

MEASURING LEAD (BLACK) 0GE00001
1 m (3.28 ft) length

MEASURING LEAD (RED) 0GE00002
1 m (3.28 ft) length

MEASURING LEAD (RED) 0GA00007
1 m (3.28 ft) length

MEASURING LEAD (BLACK) 0GA00008
1 m (3.28 ft) length

Other measurement electrodes are available

Printer options

*To connect the Super Meg-ohm meter to a printer, a commercially available RS-232C cross 9-pin (female) to 9-pin (male) cable is required

PRINTER 9442
For printing numerical values 112 mm (4.41 in) paper width

AC ADAPTER 9443-02
For the Printer 9442, EU type

RECORDING PAPER 1196
For the Printer 9442, 112 mm (4.41 in) × 25 m (82.03 ft), 10 rolls/set

HIOKI E.E. CORPORATION

(2)   Super Megohm Meter Options and Electrodes

When connecting electrodes and shield boxes to SM7110/SM7120, note that CONVERSION ADAPTER Z5010 (special order) or a change of connectors is required. Please contact your local Hioki distributor for assistance.

Options for Super megohm meters (for surface resistance or volume resistance measurement)
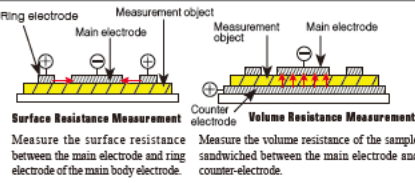
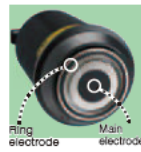#### SURFACE/VOLUME RESISTANCE MEASUREMENT ELECTRODE SM9001

Not CE Marked
- Electrodes compliant with the JIS C 2170 and IEC 61340-2-3 standards
- Measurement voltage up to 1000 V, and measurement resistance up to 10^{13} Ω
- Surface and volume resistance of sheets and films can be measured just as they are without the need to cut samples
- Measure the surface resistance of anti-static flooring and molded products

*When used with the SM-8200 series, measurement can take full advantage of the instrument's voltage and resistance ranges.

Surface Resistance Measurement — Measure the surface resistance between the main electrode and ring electrode of the main body electrode.

Volume Resistance Measurement — Measure the volume resistance of the sample sandwiched between the main electrode and counter-electrode.

Dimensions: φ 100mm (3.94in) × 223mm (8.78in), Mass: 2.5 kg (88.2oz)
Cable length: 1 m (3.28 ft)

Model No. (Order Code) **SM9001**
SM9002

VERIFICATION FIXTURE FOR SURFACE RESISTANCE MEASUREMENT SM9002
The SM9002 Verification Fixture for Surface Resistance Measurement (option) allows you to check the operation of the electrode to increase the reliability of measurement results.

Electrode for surface resistance SME-8301

Not CE Marked

Surface resistance can be easily measured by simply pushing the electrode against the specimen. It measures surface resistance of anti-static related goods in combination of mainly Model SM-8213. Measure resistance up to 10^{11} Ω.

Dimensions: φ 60mm (2.36in) × 50mm (1.97in)
Lead length 1m (3.28ft)

Model No. (Order Code) **SME-8301**

Electrode for plate samples SME-8310

Not CE Marked

Sample of 100mm square by up to 8mm in thickness is measurable. The main electrode dia. is 50mm and inner & outer dia. of ring electrode are 70mm & 80mm respectively. Measurement voltage becomes "OFF" while the lid is open to ensure safety. A selector switch allows selection of voltage or surface resistivity.
*A separately purchased interlock cable (DSM8104F) is required in order to use the product with the SM7110/SM7120, and DSM-8104.

Dimensions: 215mm (8.46in) W × 78mm (3.07in)H × 165mm (6.50in)D
Lead length 75cm (2.46ft)

Model No. (Order Code) **SME-8310**

Weight electrode SME-8320

Not CE Marked

This is an electrode for plate sample for use together with SME-8350 shield box. This electrode enables extremely easy measurement of surface resistivity and volume of sample with coarse surface such as carpets, etc. The main electrode dia. is 50mm, and the ring electrode inner-dia. and outer-dia. are 70mm and 80mm respectively.

Photo is Combination with Shield box SME-8350

Model No. (Order Code) **SME-8320**

Note: Included: Banana clips ×2

Shield box SME-8350

Not CE Marked

This is used as a sample accommodation box during measurement of a high-insulation resistance samples, or inductive or capacitive samples to perform electromagnetic shielding. When used in combination with mass electrode SME-8320, the electrode can be used as a counter electrode or a guard electrode. When measuring electronic components such as capacitors and transducers, external noise and leakage currents are prevented to ensure stable measurement.
*A separately purchased interlock cable (DSM8104F) is required in order to use the product with the SM7110/SM7120, and DSM-8104.

Dimensions: 250mm (9.84in) W × 100mm (3.94in)H × 200mm (7.87in)D
Lead length 80cm (2.62ft)

Model No. (Order Code) **SME-8350**

Note: Includes rubber sheet

Standard resistor box SR-2

Not CE Marked

This is a resistor box for calibration of the super megohmmeters.
Max. voltage is 1000 V DC and resistor value covers from 10 MΩ to 10000 MΩ in 24 points.

Dimensions: 270mm (10.63in) W × 90mm (3.54in)H × 195mm (7.68in)D

Model No. (Order Code) **SR-2**

Note: Includes inspection data sheet

Electrode for surface resistance SME-8302

Not CE Marked

Electrode for surface resistance of curved samples such as resin and rubber processed goods, TV cathode tubes or small samples. Surface resistance can be measured by pressing the rubber tips at the tip onto the sample. Measure electrodes up to 10^{11} Ω at 10mm intervals or greater.

An electrode distance: 4mm (0.16in)
Dimensions: φ 40mm (1.57in) × 115mm (4.53in),
Lead length 1m (3.28ft)

Model No. (Order Code) **SME-8302**

Electrode for plates SME-8311

Not CE Marked

Sample of 40 to 100mm square by up to 8mm in thickness is measurable. The main electrode dia. is 19.6mm and inner & outer dia. of ring electrode are 24.1mm & 28.8mm respectively. Measurement voltage becomes "OFF" while the lid is open to ensure safety.
The fundamental specifications are the same as SME-8310.
*A separately purchased interlock cable (DSM8104F) is required in order to use the product with the SM7110/SM7120, and DSM-8104.

Dimensions: 215mm (8.46in) W × 78mm (3.07in)H × 165mm (6.50in)D
Lead length 75cm (2.46ft)

Model No. (Order Code) **SME-8311**

Electrode for liquid samples SME-8330

Not CE Marked

Electrode for liquid samples which is electrically guarded. Total volume is 25ml. Capacitance between main and counter electrode is approx. 45pF. Electrode constant is approx. 500cm. Distance between both electrodes is 1mm. Outer dia. is 36mm, height is approx. 140mm. Measure resistance up to 10^{19} Ω (at 1000V) when used together with Model SM-8220.
Electrodes compliant with the JIS C 2101 standard.

Included: Connection cable 60cm (1.97ft) length (Red) 0GA00029 ×1
(Black) 0GA00030 ×1
Dimensions: φ 36mm (1.42in) × 140mm (5.51in)

Model No. (Order Code) **SME-8330**

Note: Includes inspection data sheet

Electrode for chip capacitor SME-8360

Not CE Marked

For measuring the resistance of tip capacitors, with adjustable jig from 0mm to 11mm. When connected to the meter by an interlock cable, measurement voltage becomes "OFF" while the lid is open to ensure safety.
The interlock cable must be modified in order to use the product with the SM-8220 series.

Dimensions: 200mm (7.87in) W × 52 mm (2.05in)H × 150mm (5.91in)D
Lead length 85cm (2.79ft)

Model No. (Order Code) **SME-8360**

8　FAQ

-1　Links to HIOKI's Website

　　HIOKI offers answers to frequently asked questions and videos about how to use its measuring instruments online. Please make use of the following links.

(If you're accessing this document on a computer, you can click each QR code to jump to the corresponding page.)

・**FAQ**　https://www.hioki.com/en/support/faq/

・Video about using the SM9001　・Video about using the Plate Sample Electrode SME-8310

・Video about using the Liquid Sample Electrode SME-8330, SME-8330 cleaning

-2　Controlling Instruments with Communications Commands

(1)　Overview

　　You can control, and download data from, instruments by connecting them to a computer via their communications interface. Communications commands are used to control and download data. You can download a sample program for sending and receiving commands from HIOKI's website. Please refer to that application when creating communications programs for instruments.

(Interfaces: LAN, USB, RS-232C, GP-IB; languages: C++, C#, VB, VBA, LabVIEW)

(2)　Sample Application

　　HIOKI offers sample applications for various instruments on its website. You can download some application software from HIOKI's website and use them to collect data on a computer. (Windows only)

(a)　SM Sample Application

　　This application supports functionality including interval measurement (measurement at a user-specified time interval) and voltage sweep measurement (measurement in which the voltage is varied). It also supports saving measurement data as an Excel or CSV file.

・Supported models: SM7110, SM7120, SM7420

(b) Data collection software for the Super Megohm Meter SM-8200 series

This application supports functionality including interval measurement and timer measurement (measurement after a set time has elapsed following application of the test voltage). It also supports saving measurement data as a CSV file.

・Supported models:　SM-8213、SM-8215、SM-8220

(c) Sample application for the Insulation Tester ST5520

This application supports interval measurement. It also supports saving measurement data as a CSV file.

・Supported models:　ST5520、ST5520-01

9　References

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Revision History

Edition	Date of publication	Revision history
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