Technical Notes

Super Megohm Meter SM7110/SM7120/SM7420

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***Abstract*—**The Super Megohm Meter SM7110/SM7120/SM7420 is an insulation resistance measuring instrument with a built-in high-precision ammeter and low-noise voltage source (the SM7420 includes the high-precision ammeter only). The instrument delivers highly stable, noise-resistant measurement and can measure the resistance of objects such as insulators with comparatively high resistance values. This paper describes the product's functionality, features, architecture, and other characteristics.

Appearance of the SM7120.

I. Introduction

As computerization continues to progress, large numbers of components such as multi-layer ceramic capacitors (MLCCs) and common-mode filters are being used in handheld devices such as smartphones and tablets as well as in-vehicle devices and electronic devices, pushing up production volumes of those parts. While measurement speed traditionally has been the key driver of the specifications of instruments used by manufacturers to measure the insulation resistance of capacitors and other electronic components in order to detect defective parts, there has been a recent trend toward an approach that captures and manages all data so as to provide feedback to production processes. Consequently, the reproducibility of the data yielded by instruments has joined measurement speed as a key criteria in purchase decisions.

In addition, the rated voltage of in-vehicle components is increasing due to the higher voltages of vehicle hardware. Consequently, insulation resistance testing carried out as part of the component inspection process at a conventional applied voltage of 1000 V is no longer adequate for testing a growing number of components, fueling demand for new solutions. Hioki developed the Super Megohm Meter SM7110 series to meet such demand.

II. Features

This section describes the features and functionality of the Super Megohm Meter SM7110 series.

A. Measurement of Minuscule Currents

The SM7110 series can make measurements across a broad range of currents, from a 20 pA range to a 2 mA range (with a 6-digit display resolution), allowing its use in a variety of applications.

B. Generation of a 2000 V Applied Voltage (SM7120 Only)

Adoption of components such as varistors and in-vehicle capacitors with high dielectric withstand voltages is driving up demand for inspections at voltages in excess of 1000 V. The SM7120 can apply a voltage of up to 2000 V.

C. High-Speed Measurement

The SM7110 series delivers a measurement time, including contact check, of 6.7 ms, approximately half that of legacy products. Furthermore, the SM7420 facilitates significantly higher productivity thanks to its ability to measure four channels simultaneously.

D. Highly Stable Measurement

Hioki has combined a floating circuit with a triaxial connector to significantly improve stability in the face of power supply noise and external noise. Thanks to these innovations, variability in measured values has been reduced to 1/60 that of legacy products in a typical operating environment and to 1/300 that of legacy products in noisy environments.

E. Contact Check Function

Poor contact between the measurement terminals and the device under test (DUT) during insulation measurement causes the instrument to display excessively high measured values, creating the potential for defective products to be erroneously classified as non-defective. Consequently, functionality for verifying proper contact is extremely important, and the SM7110 series delivers more enhanced contact check functionality than legacy products.

1) Ability to measure minuscule capacitance levels: In order to allow insulation measurement of components such as common-mode filters that have minuscule capacitance,

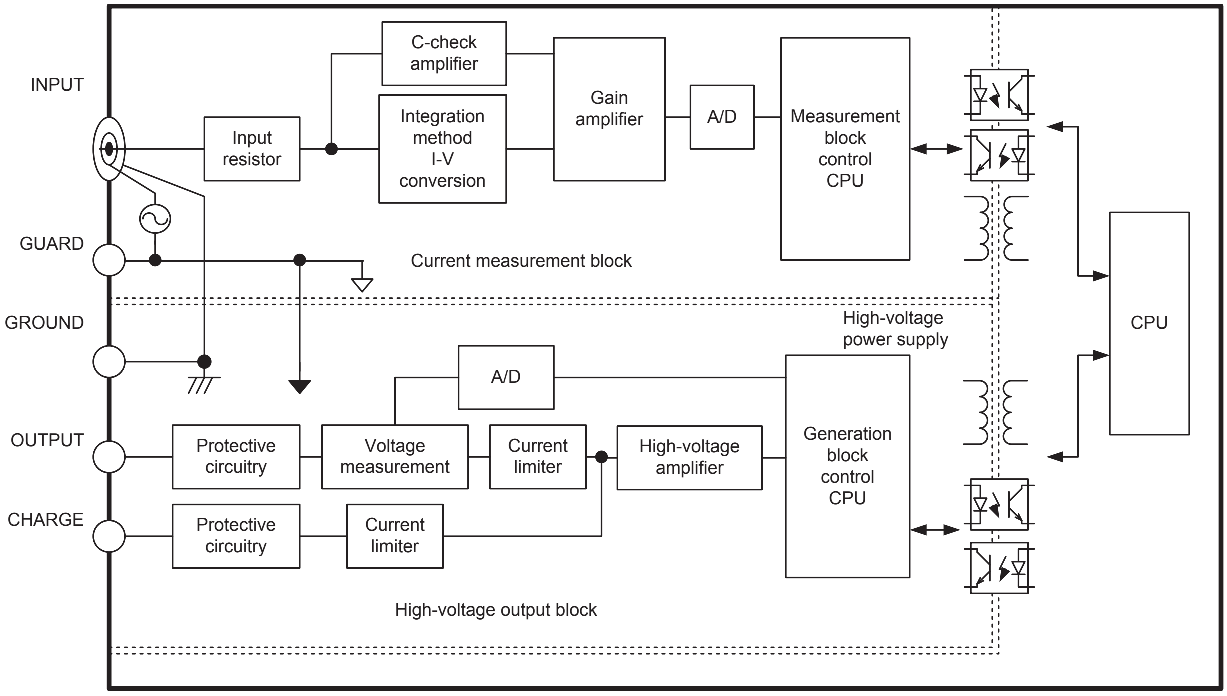

Fig. 1. Block diagram (analog circuitry).

the SM7110 series instruments allow the contact check judgment criterion to be set as low as 0.1 pF.

2) Reduced effects of interference: Users can select a contact check signal of either 245 kHz or 300 kHz to make erroneous judgments due to interference with other signals less likely when performing measurement across a large number of channels or in environments where the instrument is being used in conjunction with a mix of other equipment.

3) Cable length correction function: The SM7110 series provides functionality for automatically measuring the length of measurement cables. When an instrument has been embedded in a system, modifications to the system configuration that result in changes to the length of measurement cables can lead to changes in contact check measured values. Whereas it was necessary in the past to readjust settings when modifications led to such changes, the SM7110's cable length correction function eliminates the need for those adjustments, allowing the configuration of the host system to be freely modified without impacting contact check functionality.

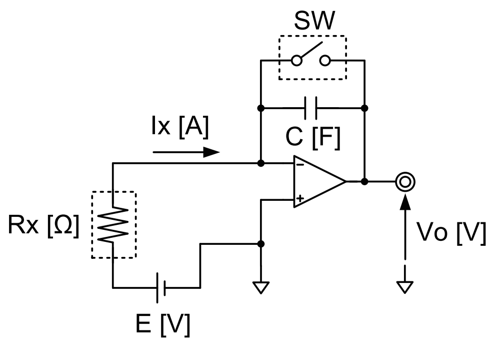

Fig. 2. Current measurement unit circuit.

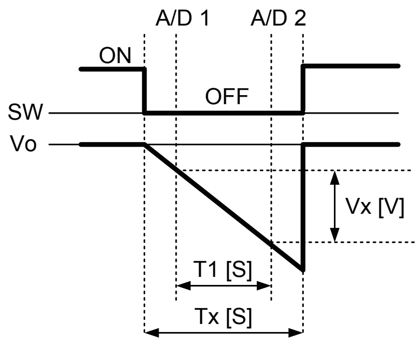

Fig. 3. Example current measurement operation.

III. Architecture

A. Voltage Source

Fig. 1 provides a block diagram for the SM7110's analog circuitry. The voltage source consists of a high-voltage power supply that generates a high voltage, a high-voltage amplifier that regulates the generated voltage at the specified level, and a constant-current circuit that limits the output current. The SM7110 also incorporates a voltage monitor circuit to provide highly accurate monitoring of the generated voltage. The high-voltage power supply generates a voltage in excess of 1000 V. This power supply must be compact and lightweight so that it fits inside limited

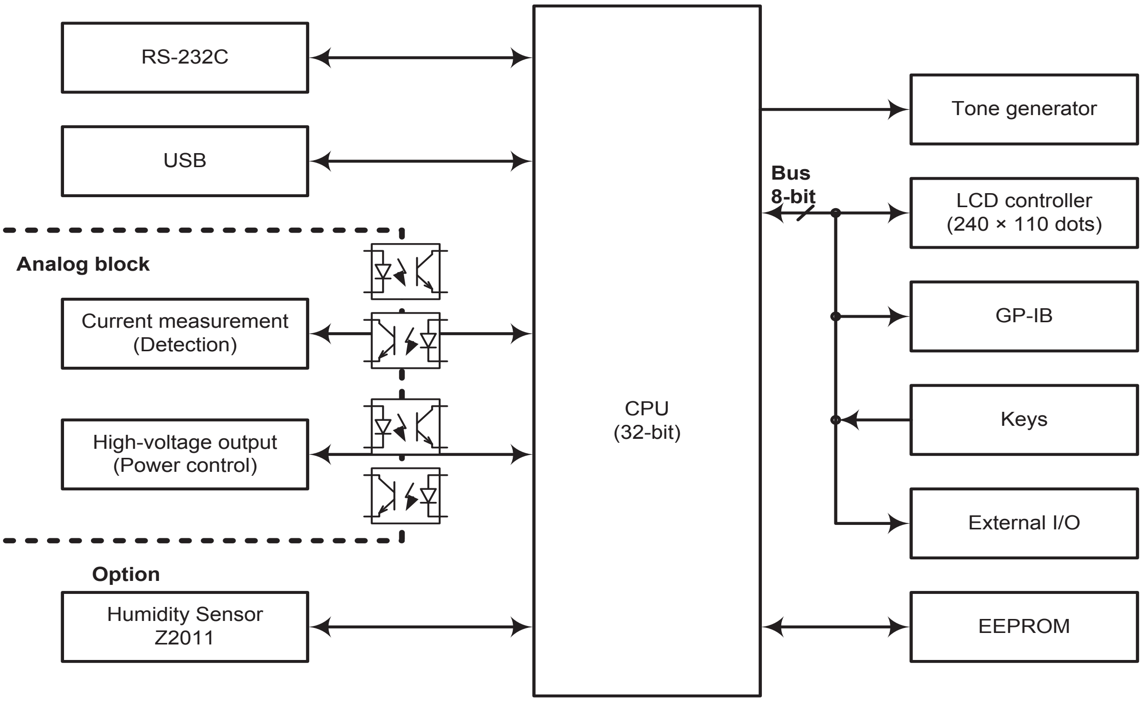

Fig. 4. Block diagram (digital circuit).

enclosure, and it must operate at a high level of efficiency so that the size of the main power supply circuit can be minimized. To meet these requirements, Hioki chose to use a switching-type high-voltage power supply. Instead of utilizing analog control as in legacy products, the company paired the switching power supply with high-efficiency digital switching control that responds to the load state.

B. Current Measurement Unit

The SM7110 series utilizes an integration-type current measurement circuit. Figs. 2 and 3 provide an example of how integration-type measurement is carried out. When measurement starts, the switch SW is opened so that the current Ix flows to the feedback capacitor C for the integration time Tx, charging C. The voltage is then measured and converted to a current.

The voltage generated as output of the amplification circuit can be calculated using (1):

$$Vx = -Ix \times T1/C \quad (1)$$

The integration time used in the actual calculation is indicated by $T1$. To facilitate stable measurement, a set standby time is allowed to elapse after the switch SW is tripped. This voltage is processed by the downstream CPU.

C. Contact Check Unit

The voltage source incorporates an AC signal source for use in performing contact checks. When a contact check is carried out, the AC signal is superposed onto the DC output voltage and applied to the DUT. The AC signal is detected in proportion to the magnitude of the DUT's AC impedance, and the measured value obtained with the DUT connected is compared to an open value that was measured before the DUT was connected. If the values differ sufficiently, the instrument determines that proper contact has been achieved between the DUT and the measurement terminals.

D. Digital Block

Fig. 4 provides a block diagram for the instrument's digital circuitry. A 32-bit reduced instruction set computing (RISC) chip is used as the main CPU, which is responsible for user interface control, communications, and external control. In order to allow voltage generation, measurement, and calculations to be performed at high speed, those processes are controlled by separate CPUs on the voltage generation board and the detection boards. Since the SM7420 is a four-channel model, that instrument incorporates four 1-channel detection boards, which are synchronized with each other in order to perform measurement.

E. Software

1) Automatic averaging function: Engineers found that during transient response to the charging current and when large variations are caused by unstable contact, measured values take a long time to stabilize. To address this issue, the SM7110 series implements an automatic averaging function that automatically varies the number of measured values that are included when calculating average values depending on the amount of variation in the measured values. This function, which gradually increases the number of data points when calculating average values, discards the data acquired up to the time when abrupt variations in measured values are encountered and acquires new data with which to calculate the average value. In this way, the instrument limits variability when measuring DUTs whose measured values tend to take time to stabilize.

2) Automatic electrode constant entry function: The SM7110 series uses electrodes that comply with Japanese Industrial Standards and other standards, allowing surface resistivity and volume resistivity to be calculated from measured resistance values. The instrument must be configured with the electrode constant in advance in order to calculate those values, and legacy super megohm meters required the user to manually enter constant values such as the diameter of the main electrode and the inside diameter of the counter electrode. By contrast, the SM7110 series provides functionality for automatic entry of electrode constants in order to simplify the process of configuring these values. Fig. 5 provides a screenshot of the screen used to set this information.

This function allows the instrument to automatically select electrode constants that have been registered in advance when the user chooses the model of electrode being used, facilitating simple and accurate entry of constants. Each instrument comes preconfigured with the five types of electrode constants that are available as options for the SM7110 series.

F. Triaxial Connector

The legacy DSM series used a measurement connector with a coaxial construction such that the center conductor was connected to the measurement input and the outer connector to the guard signal. This design was problematic in that it was prone to the effects of external noise, which prevented measured values from stabilizing when measuring high resistance values. The SM7110 series addresses this issue by utilizing Hioki's proprietary large-diameter triaxial connector, which has a three-axis design, for its measurement terminals (Fig. 6). An additional conductor outside the guard conductor is connected to ground in order to significantly reduce variability in measured values. In addition, the connector can accommodate 2000 V output to ensure safety.

IV. Performance

A. Current Measurement Linearity

Fig. 7 illustrates the current measurement linearity of the SM7110 series. Error has been minimized across all range input levels.

B. Voltage Generation Linearity

Fig. 8 illustrates voltage generation linearity. The graph indicates that the instrument's output characteristics

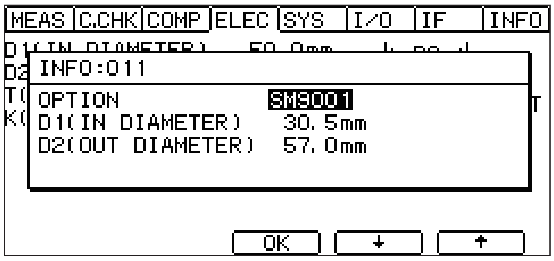

Fig. 5. Electrode constant settings screen.

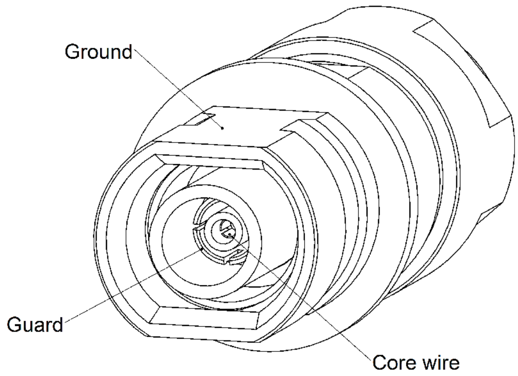

Fig. 6. Triaxial connector construction.

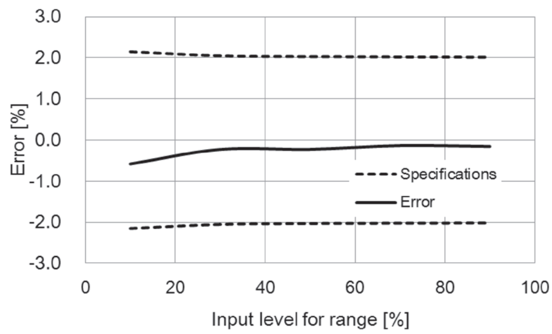

Fig. 7. Current measurement linearity.

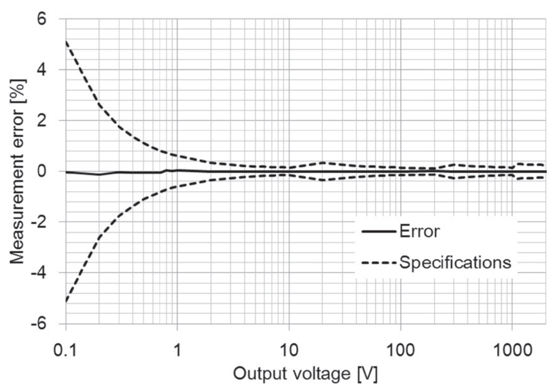

Fig. 8. Voltage generation linearity.

provide ample margin relative to the accuracy specifications for voltages ranging from 0.1 V to 2000 V.

C. Contact Check Linearity

Fig. 9 illustrates contact check linearity. The graph shows the instrument's ability to accurately measure capacitance of 1 pF and less.

D. Noise Resistance

Fig. 10 illustrates noise resistance. The graph shows that repeatability when measuring 10 pA is significantly improved compared to the legacy DSM series.

E. Measured Value Variability

Fig. 11 illustrates variability in measured values when measuring 100 GΩ. The graph indicates extremely low variability (±10 MΩ) when measuring 100 GΩ.

V. Conclusion

The SM7110 series of Super Megohm Meters delivers high speed and high stability. Hioki expects these instruments to see broad use in applications ranging from research and development of materials and electronic components such as MLCCs, which boast increasingly high dielectric withstand voltages, to high-resistance measurement on production lines.

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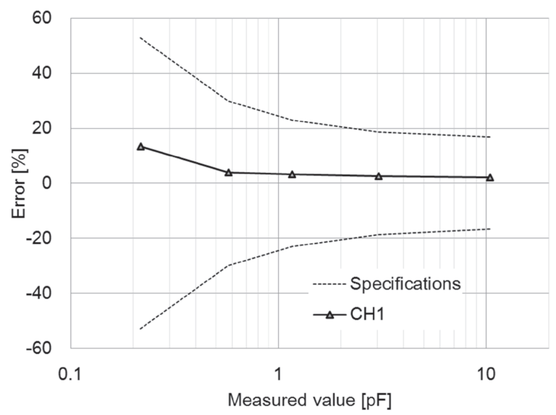

Fig. 9. Contact check linearity.

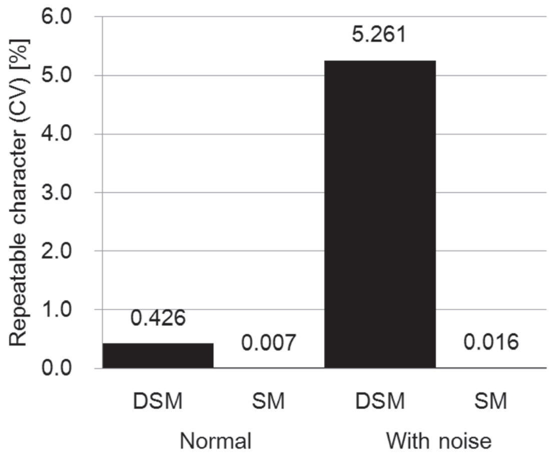

Fig. 10. Repeatability for 10 pA measurement (1 V applied, SLOW2 setting).

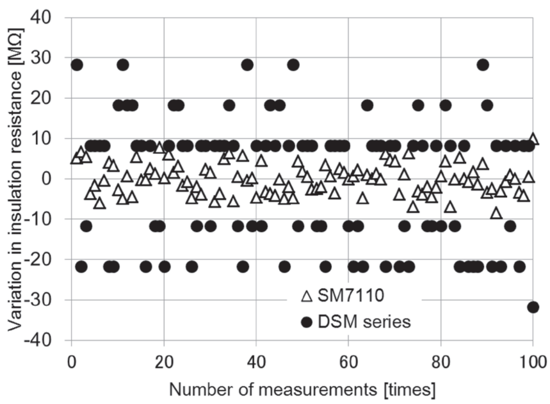

Fig. 11. Measured value variability during 100 GΩ measurement (100 V applied, SLOW2 setting).

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