Technical Note

Digital Multimeter DT4261 and DC High Voltage Probe P2000

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Abstract—**The Digital Multimeter DT4261 is a handheld digital multimeter with enhanced safety and environmental resistance as well as improved ease of use. When paired with the optional Wireless Adapter Z3210, the DT4261 supports waveform display and harmonic analysis via wireless communications. The DC High Voltage Probe P2000 can be combined with compatible instruments to safely measure voltages of up to 2000 V DC. This paper provides an overview of the product, a description of its functionality and features, and an introduction to example measurements.**

I. Introduction

In recent years, the adoption of solar power generation has grown due to the conversion from fossil energy to renewable energy as part of an effort to realize a decarbonized society, spurring rising demand for the maintenance of generating equipment. Furthermore, the use of higher voltages by generating equipment is accelerating as a way to boost generating efficiency while reducing equipment costs, and it's becoming typical to use a DC circuit voltage of 1500 V. Voltages are expected to increase to 2000 V in the future.

However, there are almost no measuring instruments capable of safely measuring equipment operating at higher voltages, making it difficult to make such measurements safely. The standard governing photovoltaic module safety qualification (IEC 61730-1) classifies solar panels as overvoltage category III, necessitating the use of instruments that comply with measurement category (CAT) III. In addition, power quality problems caused by solar power systems are becoming more conspicuous. Furthermore, worker shortages caused by Japan's declining population are making it even more important to streamline maintenance work.

To address these and related problems, Hioki developed the Digital Multimeter DT4261 and the DC High Voltage Probe P2000. Fig. 1 depicts the external appearance of the DT4261 and the P2000.

II. Overview

The DT4261 is a handheld digital multimeter (DMM) designed for use in electrical equipment maintenance as well as confirmation and troubleshooting in electric work. Its shutter function boosts safety by preventing erroneous insertion of test leads, and the enclosure is IP54-compliant dustproof and waterproof.

DT4261.

P2000.

Fig. 1. External appearance of the DT4261 and P2000.

Fig. 2. The DT4261 and P2000 being used together.

When combined with the P2000, the DT4261 is capable of measuring high voltages of up to CAT III 2000 V, allowing it to safely measure solar panel strings carrying up to 2000 V DC (Fig. 2).

When equipped with the optional Wireless Adapter Z3210, the DT4261 supports **Bluetooth**® wireless

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TABLE I Comparison of Functionality and Specifications

	DT4250 series	DT4280 series	DT4261
Enhanced measurement functionality			
DC/AC automatic detection	None	None	OK
DC+AC measurement	None	OK	OK
LoZ V	None	None	OK
Enhanced safety			
Terminal shutter	None	OK	OK
Overload warning (red backlight)	None	OK	OK
DC High V Probe mode	None	None	OK
Environmental resistance			
IP54	None	None	OK
Operating temperature range	−25°C to 65°C (−13°F to 149°F)	−15°C to 55°C (5°F to 131°F)	−25°C to 65°C (−13°F to 149°F)

communications. It can connect to GENNECT Cross, Hioki's mobile app, to access convenient functionality including harmonic analysis and waveform display. This capability is useful when you need to measure harmonics in solar system equipment like power conditioners or analyze problems in a power supply system.

III. Functionality and Features

To ensure superior ease of use in electrical equipment installation and maintenance work, the DT4261 builds on the previous model (DT4250 series, DT4280 series) by enhancing measurement functionality and improving safety and environmental resistance to deliver the specifications listed in TABLE I.

A. Enhanced Measurement Functionality

1) DC/AC automatic detection function (Auto V, Auto A): If a user inadvertently measures an AC power supply line with a DMM's DC function, the instrument will typically display a measured value of 0 V. Similarly, measuring a DC power supply like a battery with the AC function will generally yield a reading of 0 V. If the user, erroneously assuming that the power is turned off, touches the measurement target, an electric shock could result. The DT4261 has a DC/AC automatic detection function (Auto V, Auto A) that detects whether the measurement target is DC or AC so that the instrument can display the correct measured value. This capability improves safety by preventing the user from making erroneous measurements.

2) DC+AC measurement function (AC+DC V, AC+DC A): The typical instrument's AC and DC functions cannot accurately measure half-wave rectified or full-wave rectified waveforms. The DT4261's DC+AC function can accurately measure such waveforms since it measures RMS values using DC coupling.

3) LoZ V function: When measuring the voltage of an unconnected wire (a dead wire), instruments can display a voltage value other than 0 V if the wire undergoes capacitive coupling with a nearby AC power supply wire. (This phenomenon is known as a ghost voltage.) The higher an instrument's internal impedance, the more susceptible it is to the effects of capacitive coupling. By lowering the internal impedance to 1 MΩ, the DT4261's LoZ V function reduces the effects of capacitive coupling and prevents the display of ghost voltages.

B. Increased Safety

1) Terminal shutter designed to prevent erroneous lead insertion: The DT4261's terminals are protected by a shutter so that only the measurement terminals appropriate to the selected measurement function are open. Measuring a voltage line inadvertently while the current function is selected causes a short-circuit current to flow, instantaneously tripping the equipment's circuit breaker and resulting in a power outage; the terminal shutter prevents such accidents caused by inserting the leads into the wrong measurement terminal.

2) Red backlight: In addition to the previous product's white backlight, the DT4261 has a red backlight. The display flashes red in the event of an overload to warn the user of the potential hazard.

In addition, the continuity check function causes the red backlight to turn on continuously to signal continuity, communicating the continuous state of the measurement target to the user with both an audio tone and light. This capability improves ease of use by making it easy to ascertain the measurement results and conditions, even in noisy settings.

3) DC High V Probe mode: Although the DT4261 alone can measure line-to-ground voltages of up to 1000 V, that figure can be increased to 2000 V by using the instrument in conjunction with the P2000. The P2000 itself is a voltage attenuator, and ordinarily the attenuated voltage value is displayed by the DMM. When the instrument is used in DC High V Probe mode, the voltage attenuation is corrected and converted so that the user can read the measurement target's voltage value directly.

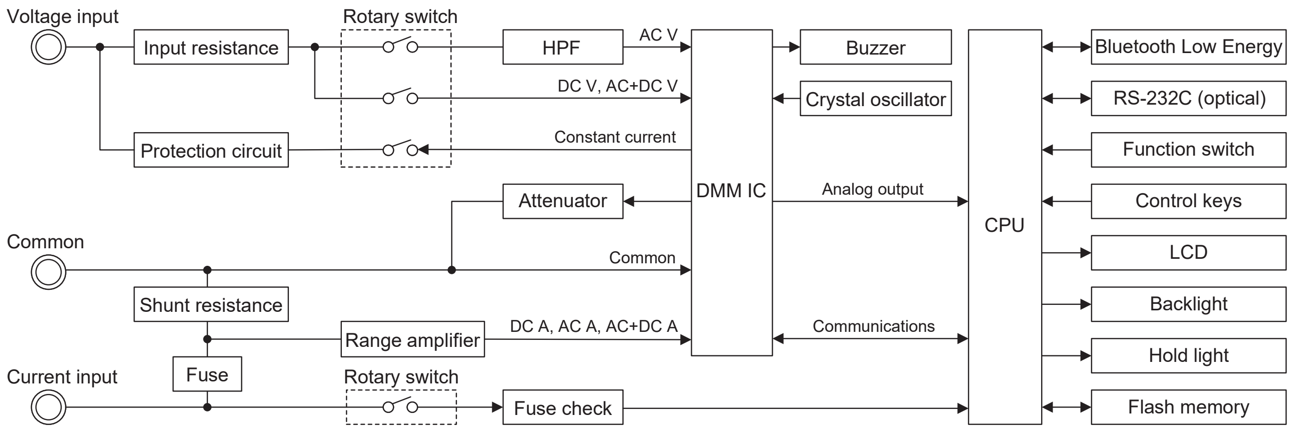

Fig. 3. Block diagram.

C. Increased Environmental Resistance

1) IP54 compliance: The DT4261 is designed to withstand environments characterized by the presence of water and dust, and it complies with IP54 (while stored). However, it is prohibited to use the instrument while wet to prevent electric shock.

2) Broad operating temperature range: The DT4261 has an operating temperature range of −25°C to 65°C (−13°F to 149°F), allowing it to be used in various locations and at various times of year.

In addition, it inherits the previous product's features, including high-speed response made possible by a dedicated IC, high noise resistance, and compliance with the latest safety standards.

D. Hardware

Fig. 3 provides a block diagram. A dedicated IC measures voltage, current, and other parameters, and the instrument's CPU controls the display and key operations. The dedicated IC is a DMM-use ASIC that combines analog and digital circuitry. It incorporates a 14-bit ΔΣ-type A/D converter, and it performs RMS and averaging calculations.

E. Software

1) User setting-saver function: Anticipating that certain functions will be used frequently, the DT4261 stores the most recently used measurement parameter, range setting, and filter setting for each position of the rotary switch. These settings are retained, even if the instrument is turned off. The user setting-saver function can be enabled or disabled as desired.

For example, the following three steps are necessary when using the optional P2000 repeatedly: (1) setting the rotary switch to AUTO V, (2) setting the measurement parameter to High V Probe, and (3) pressing the RANGE key to select the 2000 V range. If the user setting-saver function is enabled, the measurement settings need to be configured just once. The next time, measurement can be started immediately simply by selecting AUTO V with the rotary switch, reducing the number of steps.

2) Improved work efficiency with the Bluetooth® communications function: The optional Z3210 can be added to the DT4261 to enable Bluetooth communications and allow the use of functionality provided by GENNECT Cross, Hioki's mobile app (including standard measurement, pass/fail measurement, and photo and drawing functionality). By combining GENNECT Cross functions and the instrument's auto hold function (which automatically stops updating display values once the measured value stabilizes), you can update the measured value display and send the measured value to GENNECT Cross simply by placing the probes in contact with the measurement target. By letting you take a photograph and define measurement points in advance, the photo and drawing function increases work efficiency by making it easy to record measurement results.

F. Enclosure Design

Hioki worked to develop an even more satisfying design for the DT4261 while drawing on the familiar design used by all DT series instruments.

Fig. 4 provides an exploded view of the DT4261. The part of the instrument that comes into contact with the user's hands adds an elastomer onto a base of modified polyphenylene ether (PPE) using two-color molding technology, giving the back surface of the product a stepped shape that makes it easier to grip.

1) Terminal shutter design: A terminal shutter that opens and closes test lead receptacles depending on the position of the rotary switch prevents the erroneous application of a voltage to the current terminal by keeping the user from accidentally inserting the test leads into the wrong terminal. To implement the shutter while maintaining dust and water protection (while stored: IP54), the bottom incorporates a water drainage hole so that any water that gets inside the mechanism will drain out. Ordinarily, the hole is used for the strap.

2) IP54-level dust and water protection: Gaskets are sandwiched between the upper and lower cases and between the lower case and the battery cover. The rotary switch also incorporates packing to ensure dust and water protection. To improve safety, energized areas are far enough away from areas of potential water ingress (gaskets and packing) to maintain insulation.

G. Test Lead L9300

The DT4261 includes the newly developed Test Lead L9300.

Under applicable safety standards (IEC 61010-31 and JIS 61010-31), the exposed length of metal pins must be limited compared to CAT II when measuring a CAT III or CAT IV measurement target with test leads in order to reduce the risk of a short-circuit. (The length of exposed metal is limited to 19 mm [0.75″] or less for CAT II and 4 mm [0.16″] or less for CAT III and IV.)

When measuring a CAT III or IV target with the previous product's test leads (primarily the L9207-10), the length of the exposed part of the metal pins is limited by placing the leads in a sleeve. However, the loss of the sleeve proved problematic as the leads were often used without the sleeve when measuring CAT II targets, and because the sleeve had to be stored apart from the test leads.

To resolve this problem, the L9300 is designed so that the length of exposed metal at the tip of the metal pins can be changed without fitting or removing a sleeve.

Fig. 5 depicts the external appearance of the L9300. The grip has a flange known as a protective finger guard to protect the user from hazardous measurement targets. The grip with this protective finger guard slides to allow the selection of two metal pin tip lengths.

Fig. 4. Exploded view.

Fig. 5. L9300 external appearance.

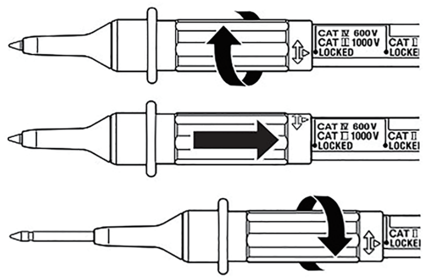

Fig. 6. Sliding the protective finger guard.

Fig. 6 illustrates how to slide the protective finger guard. Since the guard slides without coming off the test lead, users don't need to worry about losing the sleeve, allowing simple, safe measurement.

H. DC High Voltage Probe P2000

Hioki developed the P2000 as an option for the DT4261 and the CM4000-50 series. When connected to an instrument with an input impedance of 10 MΩ, the P2000 functions as a voltage attenuator with an output ratio of approximately 1/10. Since it is often used with DMMs, the output ratio was chosen based on DMMs' input impedance. Consequently, even a DMM with a maximum rating of 1000 V can safely measure a line-to-ground voltage of up to 2000 V (CAT III 2000 V) when used with the P2000.

The P2000 consists of (1) test pins, (2) primary-side cables, (3) a circuit box, and (4) secondary-side cables. The test pins, primary-side cables, and circuit box cannot be disconnected. This design ensures that neither test pins nor cables that do not satisfy CAT III 2000 V/CAT IV 1000 V requirements can be connected to the device. Since everything after the circuit box's secondary-side cable terminal consists of safe output, the circuit box and secondary-side cables can be disconnected. This design allows the secondary-side cables to be extended as necessary based on the measurement environment.

1) Electric circuitry: Fig. 7 provides a block diagram of the P2000's electric circuitry. The P2000 consists only of the passive resistor and capacitor components. The attenuation resistor is designed to satisfy the protective impedance requirements of the CAT III 2000 V/CAT IV 1000 V safety standard so that the secondary-side output poses no risk, even if touched directly by a person.

The intermediate resistor is designed to yield an output-to-input ratio of approximately 1/10 when connected to a DMM with an input impedance of 10 MΩ. When the attenuation resistor and intermediate resistor are designed to satisfy those conditions, the P2000 ends up with an input impedance of approximately 20 MΩ. Since this value is greater than previous DMMs' input impedance, the device is more susceptible to the effects of inductive noise. Consequently, a band-limiting capacitor is connected in parallel with the intermediate resistor to attenuate inductive noise.

2) Output ratio correction: As illustrated in Fig. 7, the P2000 consists only of passive components. As a result, its output ratio varies depending on the input impedance of the instrument to which it is connected. The DT4261 and CM4370-50 series offer a DC High V Probe mode that corrects the output ratio using the instrument's own input impedance. Figs. 8 and 9 provide linearity characteristics graphs for the DT4261, which has DC High V Probe mode, and the DT4256, which does not, when used with the P2000. DC High V Probe mode not only increases measured value readability, but also allows more accurate measurement.

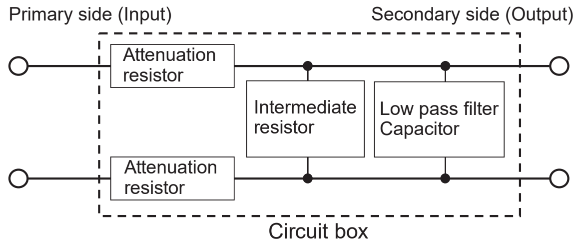

Fig. 7. P2000 circuit architecture.

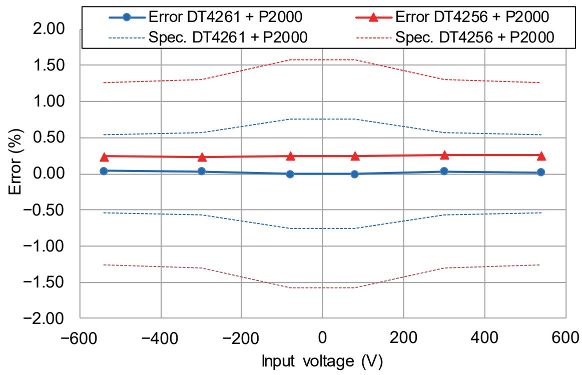

Fig. 8. P2000 linearity characteristics (600 V range).

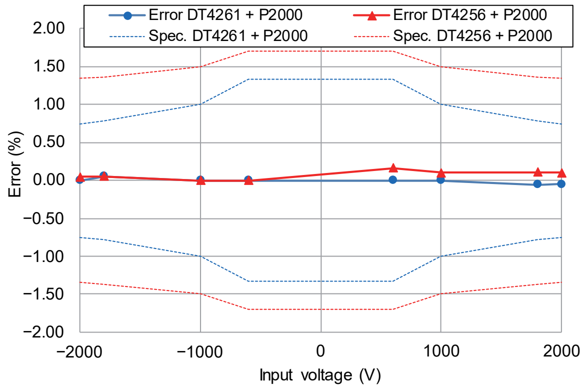

Fig. 9. P2000 linearity characteristics (2000 V range).

3) Enclosure design: Fig. 10 provides an exploded view of the P2000. Inside the circuit box, a bellows-shaped circuit board fits between the ribs of the enclosure. The design is intended to allow an easily-handled size for the circuit box while maintaining sufficient safety in the event that a high voltage of 2000 V from a CAT III circuit is input to the device. The result is a compact enclosure that ensures safety by maintaining enough distance between energized areas and areas that can be touched by the user's hands, and between components on the circuit board.

Since the input side measures high voltages, the cables there connect directly and cannot be disconnected to eliminate the possibility that cables that don't satisfy measurement category requirements could be connected. Since the output side outputs the voltage attenuated inside the box, 4 mm (0.16″) banana terminals are used there, reflecting the low level of risk.

The included Connection Cable Set L4943 can be used with the included strap to connect the circuit box to a compatible instrument, allowing measurements to be made while the circuit box is hanging from the instrument.

4) Probe design: Fig. 11 illustrates the external appearance of the P2000 probes. Since the probes are expected to be used primarily in the maintenance of solar power systems, the tips are shaped so that they can be easily connected to fuse-type switches and covered terminals.

The base part of the probes, which needs to be strong, is made from polypropylene (PP), while the areas with which the user's hands come into contact during measurement and areas near the cable connection, which need to exhibit increased bend resistance, are made from thermoplastic elastomer (TPE).

The grip incorporates grooves so that the probes fit more comfortably into the hand when held.

Although a narrow probe tip is desirable from the standpoint of increasing measurement efficiency, such designs inevitably involve a trade-off in terms of strength. Hioki made the following design tweaks to provide as much strength as possible while keeping the tips narrow:

- Material: Brass, which is readily workable, is often used to fabricate pins, but in this case, stainless steel was used to provide greater strength.
- Shape: The design prevents the concentration of stress at particular points when a load is placed on the pin by varying the diameter continually instead of incorporating one or more discrete steps. In this way, the risk of the pins' shape deforming has been reduced.

The probes have approximately twice the strength of the Breaker Pin L9788-91, the previous product, which has a similar shape.

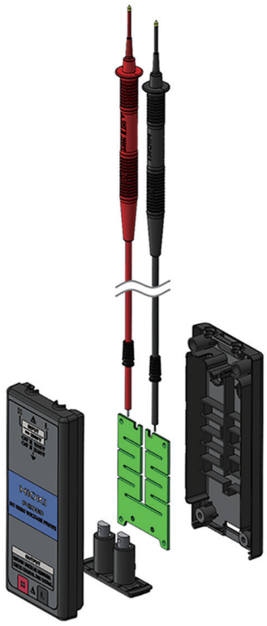

Fig. 10. P2000 exploded view.

Fig. 11. Probe external appearance.

IV. Example Measurements

A. *Making Measurements Using the IoT*

In Japan, the growing workload being shouldered by workers due to the aging and shrinking of the workforce involved in the management and maintenance of electrical equipment is becoming problematic. Efforts to use the Internet of Things (IoT) to boost work efficiency as one way to reduce this workload are attracting attention.

The DT4261 can be equipped with the Z3210 to enable Bluetooth wireless communications with a smartphone or tablet. GENNECT Cross can be used to facilitate simple harmonic analysis and waveform display functionality. Technicians can use this capability to determine whether it's necessary to take an instrument such as an oscilloscope with them when dealing with problems in the field. In addition, harmonics lurking in power supply circuits can cause equipment malfunctions and damage and reductions in equipment service life and efficiency. GENNECT Cross can help analyze power supply circuit issues like these. Furthermore, the Z3210's HID function can be enabled to allow measurement data to be directly entered into a user's Excel spreadsheet, helping improve the efficiency of work at sites in the field.

B. Measuring the Voltage of Solar Panels

When performing inspections after the completion of installation work for solar power systems and subsequent regular inspections, technicians measure the open-circuit voltage and operating voltage of panels' strings to check for wire breaks and other issues. Measurement of high-voltage components poses risks, but the P2000 can be used to safely measure even systems that remain operational (Fig. 12).

Megasolar plants and other large solar power installations have enormous numbers of strings that must be measured, making measurement work both time- and labor-intensive. The standard measurement function provided by GENNECT Cross lets technicians send measured values to a smartphone each time they're held with the DT4261, allowing measured values to be recorded efficiently.

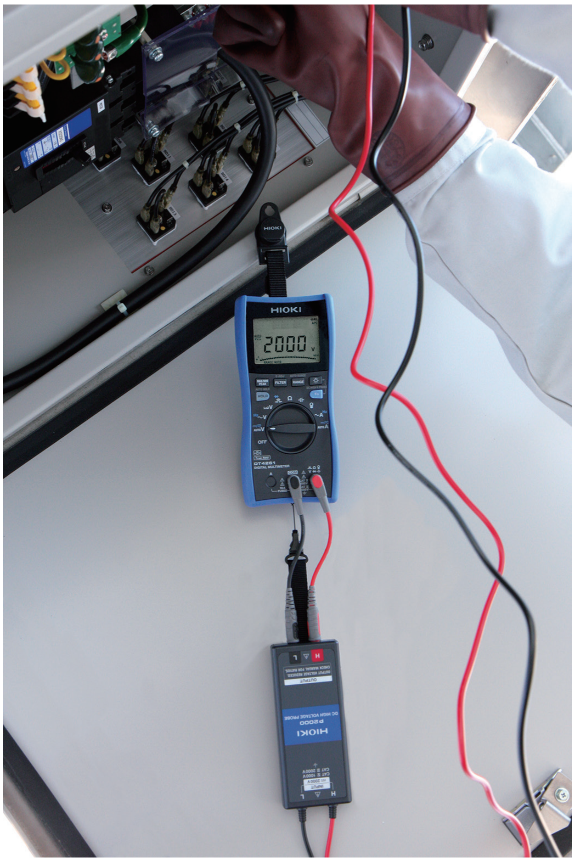

Fig. 12. Solar panel voltage measurement.

V. Conclusion

The DT4261's terminal shutter and dustproof, waterproof design make the instrument durable while facilitating safe measurement. Its harmonic analysis and waveform display functions allow troubleshooting of issues immediately at sites in the field. Furthermore, the DT4261 can be used with the P2000 to safely measure solar power equipment operating at DC voltages in excess of 1000 V.

Hioki hopes that numerous personnel involved in the installation and maintenance of electric equipment at solar power installations and other sites will be able to use the DT4261 and P2000, helping to reduce the incidence of serious accidents like electric shocks and burns.

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