Technical Notes

AC/DC Current Box PW9100

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***Abstract*—**The AC/DC Current Box PW9100 is a direct-input current measurement tool with a 50 A rating and a 3.5 MHz measurement band. It can be used in combination with Hioki's Power Analyzer PW6001 to deliver a measurement band of 2 MHz and power measurement accuracy of ±0.04%. This paper describes the product's features, architecture, and example characteristics.

Appearance of the PW9100.

I. Introduction

Demand has been growing in recent years for the ability to measure not only input and output efficiency of inverters and power conditioners, but also loss characterizing inverter components such as inductors. In addition, use of increasingly high switching frequencies by inverters means current and power measuring instruments with broad measurement bands and high accuracy are needed to measure inductor loss.

Shunt resistors are often used in the standard approach to current measurement. However, the measurement of comparatively large currents in excess of 5 A is affected by issues such as deterioration in the frequency characteristics of shunt resistors and drift in measured values caused by self-heating, making it difficult to conduct such measurements with a high degree of accuracy.

At the same time, use of current sensors poses a different set of issues, including the need to counter the effects of conductor position and of nearby conductors, making it difficult to measure high-frequency current with a high level of reproducibility.

Hioki developed the AC/DC Current Box PW9100 as a current measurement tool for use in power measurement applications that would make up for the disadvantages of the shunt resistance method and the current sensor method while simultaneously leveraging the advantages of both methods.

II. Features

A. *High-Current Broad-Band Measurement With Direct Input*

The PW9100 incorporates a series of newly developed current sensors with a high current rating of 50 A and a measurement band of 3.5 MHz (−3 dB).

B. *High Accuracy*

With basic current measurement accuracy of ±0.02%, the PW9100 offers more than twice the measurement performance of legacy products. Combined accuracy when used with the Power Analyzer PW6001 has been defined in the instrument's specifications, and the basic power accuracy is ±0.04%. There is no need to add the PW9100's f.s. error to the combined accuracy for either DC or 50 Hz/60 Hz measurement.

C. *High Noise Resistance*

By shielding its broad-band, high-accuracy AC/DC current sensors, the PW9100 achieves a high common-mode rejection ratio (CMRR) of 120 dB at 100 kHz. This level of performance allows it to measure today's increasing fast switching devices with a high degree of stability and accuracy.

Furthermore, a design that shields and anchors the current sensors and primary conductors inside the instrument's enclosure eliminates the susceptibility of measure values to the effects of conductor position and nearby conductors, key disadvantages of AC/DC current sensors.

D. *Low Input Impedance and Capacitance*

Thanks to its utilization of AC/DC current sensors, the PW9100 has lower input impedance than is possible with the shunt resistor method of measurement along with an input capacitance (as measured between measurement terminals and the enclosure) of 40 pF or less (100 kHz), an extremely low value. In this way, Hioki has minimized both instrument loss imposed by the PW9100 and the effects of the instrument on the object under measurement.

Additionally, the optional 5-meter Extension Cable CT9902 can be used to position the PW9100 close to the object under measurement and away from the power meter to which it is connected. In this way, the wiring used to measure current can be kept as short as possible, minimizing the effects of wiring impedance and parasitic capacitance.

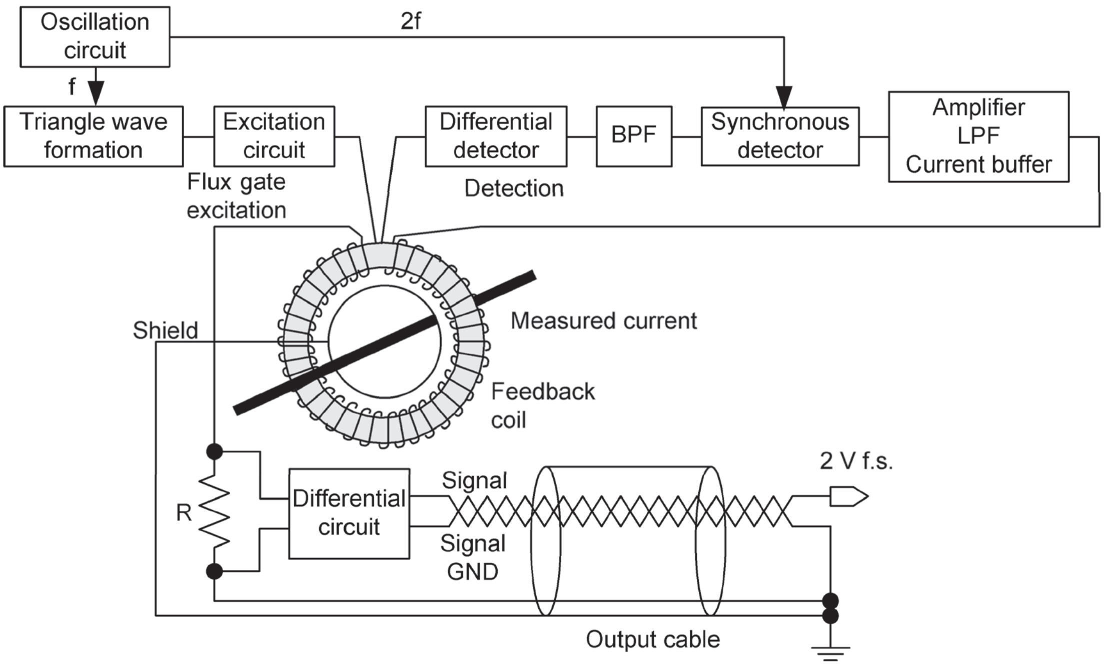

Fig. 1. Circuit architecture.

III. Architecture

A. *Measurement Circuitry [1],[2]*

Fig. 1 illustrates the architecture of the PW9100's AC/DC current sensors. Like the legacy product (the AC/DC Current Sensor CT6862), the instrument uses the flux gate method, which takes advantage of the nonlinearity of a magnetic material's B–H characteristics to detect magnetic fields. This method, which offers high sensitivity and extremely high temperature stability, is generally used to detect direction based on terrestrial magnetism.

An excitation current ($f = 10.4$ kHz) consisting of a triangle wave is generated so as to saturate a magnetic core around which a feedback coil is wrapped. When the current to be measured flows under these conditions, the instrument performs differential detection of changes in the voltage waveform induced in the winding by the resulting magnetic flux. By performing synchronous detection of this detection signal using a $2f$ signal that is synchronized with the excitation current, it is possible to obtain an output signal that is generally proportional to the current being measured. However, because the flux gate suffers from degraded sensitivity in the presence of large magnetic fields that cause its magnetic core to become saturated, Hioki incorporated a design known as the zero-flux method by adding a negative feedback circuit. This enhancement allows the instrument to measure large currents of up to 50 A.

Fig. 2 provides a block diagram.

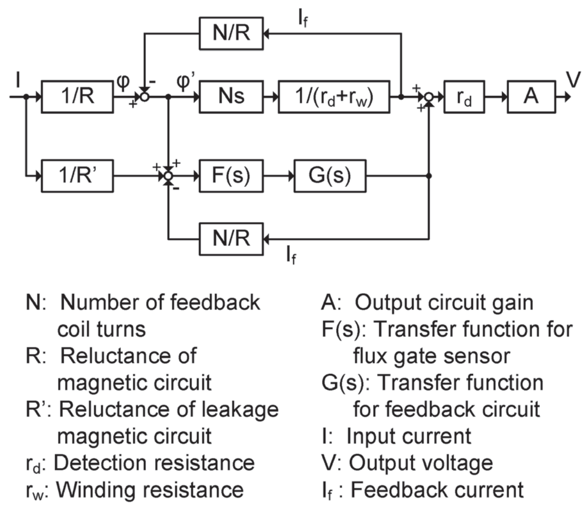

Fig. 2. Block diagram. [3]

To achieve the instrument's basic current measurement accuracy of ±0.02%, which significantly exceeds that of the legacy product, Hioki reduced noise by carefully selecting the magnetic material and optimizing the design of the flux gate excitation circuit's filter. Furthermore, stability was improved by adopting new components with excellent temperature characteristics and long-term stability for use in the output block's differential circuit.

In addition, Hioki improved the winding method in order to achieve a measurement band of 3.5 MHz, 3.5 times that of the legacy product.

B. Construction

Fig. 3 provides an overview of the sensor's construction. The target current is measured by a toroidal current sensor via a busbar (conductor) inside the enclosure that is connected to a terminal block.

With each current sensor integrated into a shielded case with a proprietary shape, the PW9100 delivers noise resistance and a CMRR that is significantly better than the legacy product.

The fixed positions of the current sensors and busbars that serve as the measured conductors eliminate the effects of nearby conductors and conductor position, allowing highly reproducible current measurement.

Although the PW9100 utilizes direct input via terminal blocks, the current is detected internally by current sensors, allowing the instrument to provide extremely low input resistance compared to a shunt resistor. In addition, input capacitance is kept low thanks to a construction that separates each busbar from the shielded enclosure. This design reduces instrument loss and the effects on the object under measurement caused by interjection of the instrument into the measured circuit.

IV. Example Characteristics

Figs. 4 through 18 illustrate the PW9100's characteristics. The instrument delivers extremely favorable characteristics compared to the legacy product, including in terms of linearity, temperature stability, frequency (versus level and phase), CMRR, etc.

These excellent characteristics translate into significant improvements in measurement accuracy and reproducibility when measuring the input and output efficiency of inverters and power conditioners, which requires measurement of DC through harmonics.

These characteristics consist of reference data measured using a PW9100 owned by Hioki and do not constitute a guarantee of product performance. Current, active power, and phase characteristics are determined by adding the characteristics of the power meter with which the instrument is used.

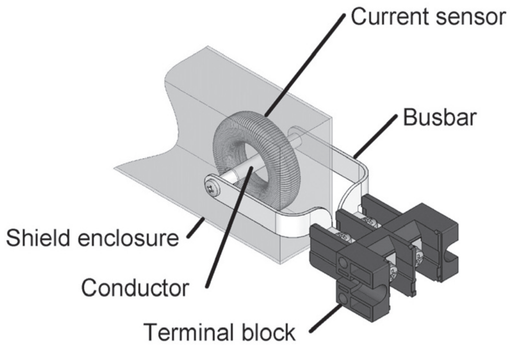

Fig. 3. Sensor construction.

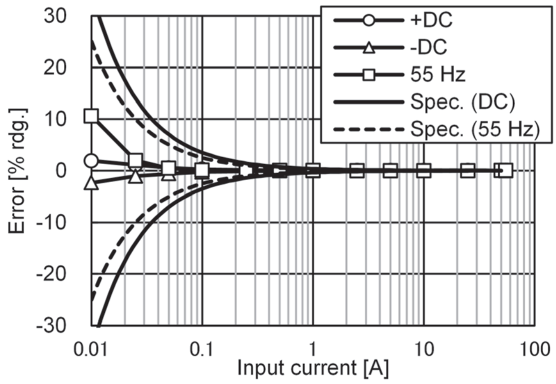

Fig. 4. Linearity.

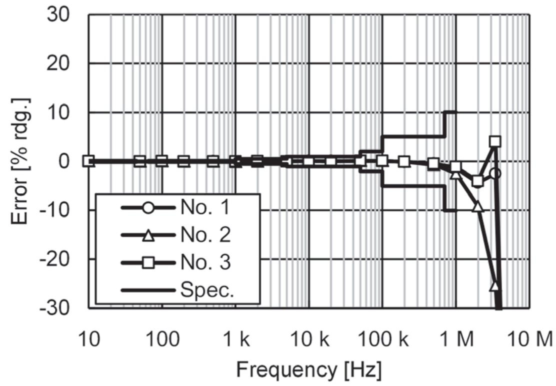

Fig. 5. Amplitude-frequency characteristics.

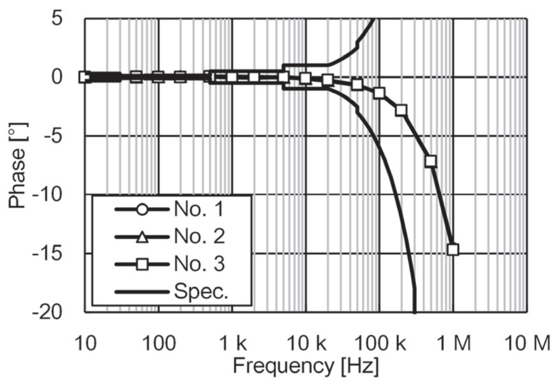

Fig. 6. Phase-frequency characteristics.

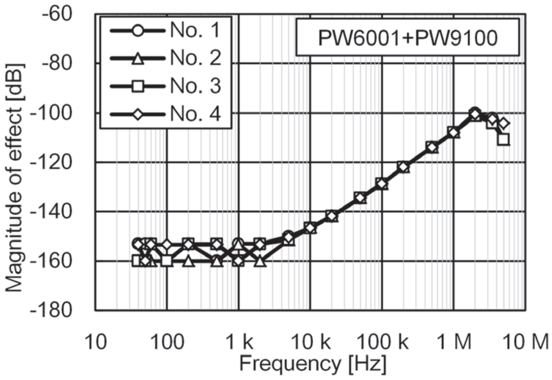

Fig. 7. Effects of common-mode voltage.

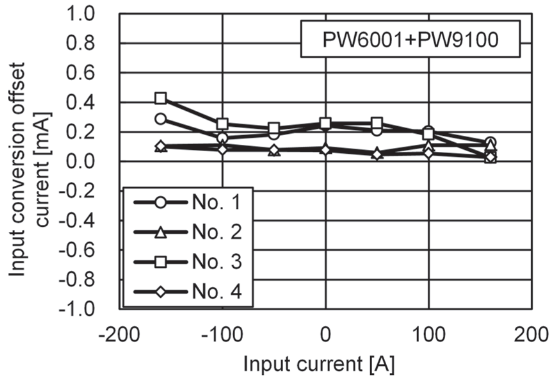

Fig. 8. Effects of a magnetization.

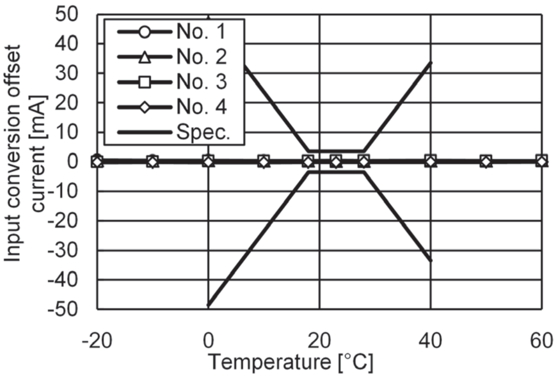

Fig. 9. Offset error-temperature characteristics.

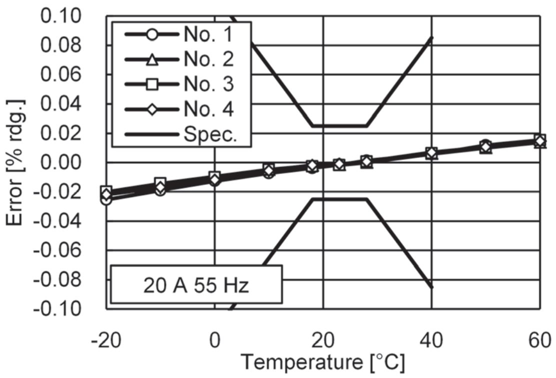

Fig. 10. Amplitude error-temperature characteristics.

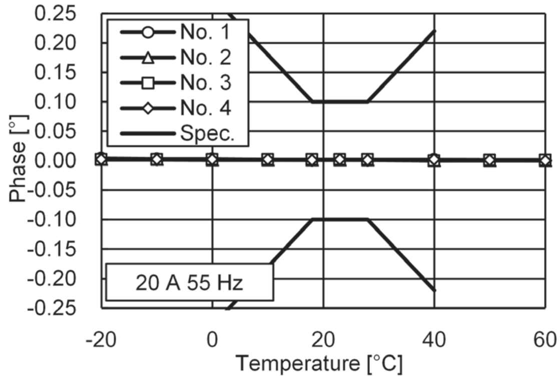

Fig. 11. Phase error-temperature characteristics.

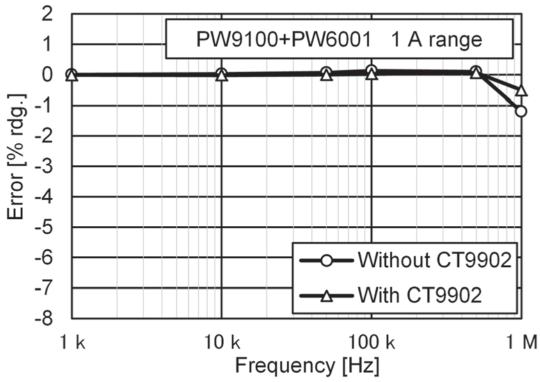

Fig. 12. Current frequency characteristics (with the PW6001).

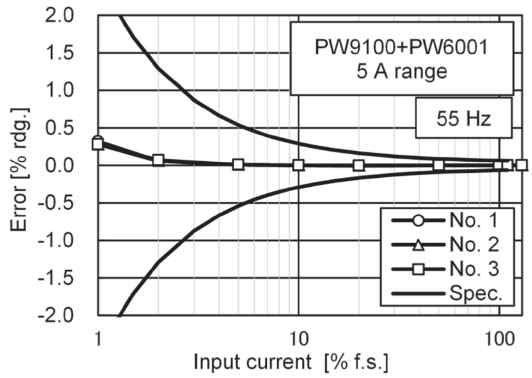

Fig. 13. Current linearity (with the PW6001).

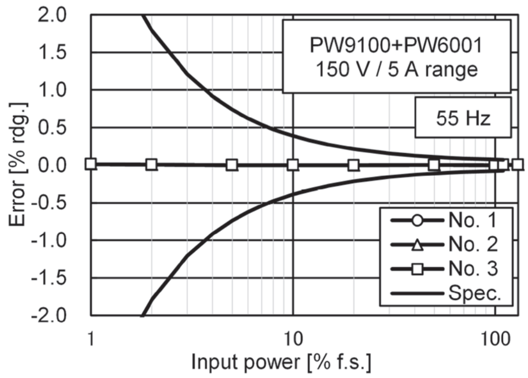

Fig. 14. Power linearity (with the PW6001).

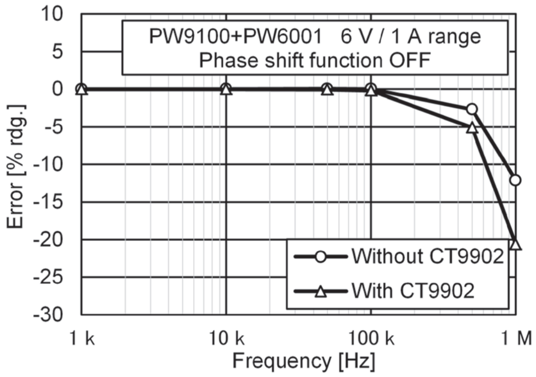

Fig. 15. Power frequency characteristics (with the PW6001; phase correction function off).

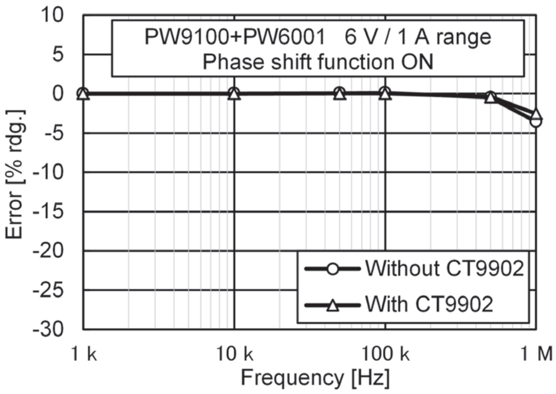

Fig. 16. Power frequency characteristics (with the PW6001; phase correction function on).

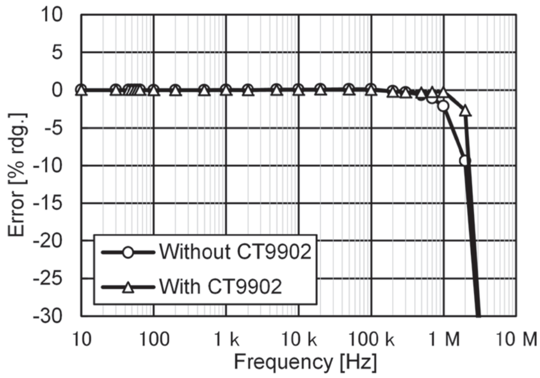

Fig. 17. Amplitude-frequency characteristics (with Extension Cable CT9902).

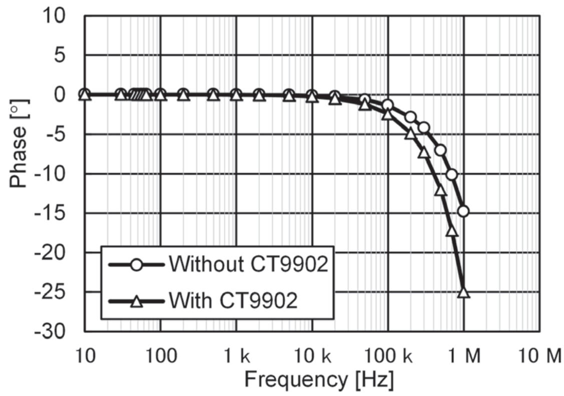

Fig. 18. Phase-frequency characteristics (with Extension Cable CT9902).

V. Conclusion

Devices such as inverters and power conditioners are subject to increasingly high conversion efficiency requirements. In recent years, it has become necessary to measure loss on the component level in order to pursue additional gains in efficiency. Hioki has developed current measurement tools that draw on the latest technologies and the company's expertise in an effort to offer the best possible solutions to customers who need to perform broadband high-accuracy measurement in applications such as these. It is Hioki's hope that the PW9100 will help protect the environment by helping manufacturers worldwide increase energy efficiency.

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References

[1] K. Yamagishi, "AC/DC Current Sensor 9709," *Hioki Giho*, vol. 27, no. 1, pp. 33-40, 2006. (Japanese).

[2] K. Yamagishi, "AC/DC Current Sensor CT6862/CT6863," *Hioki Giho*, vol. 31, no. 1, pp. 25-34, 2010. (Japanese).

[3] Y. Suzuki and others, "Clamp On Sensor and Current Monitor," *Hioki Giho*, vol. 16, no. 1, pp. 37-49, 1995. (Japanese).

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