Technical Notes

AC/DC Current Sensor CT7631/CT7636/CT7642, AC/DC Auto-Zero Current Sensor CT7731/CT7736/CT7742, Display Unit CM7290/CM7291

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Abstract—The AC/DC Current Sensor CT7631/CT7636/CT7642 and AC/DC Auto-Zero Current Sensor CT7731/CT7736/CT7742 are clamp-on current sensors equipped with Hioki's PL14 connector. The Display Unit CM7290/CM7291 can be connected to these sensors to supply power, display RMS values and other readings, and output waveforms, RMS values, and other data to a recorder or logger. This paper describes these products' features and functionality.

Appearance of the CT7631 (100 A) / CT7636 (600 A) / CT7642 (2000 A).

Appearance of the CT7731 (100 A) / CT7736 (600 A) / CT7742 (2000 A).

Appearance of the CM7290 and CM7291 (Bluetooth®).

I. Introduction

The newly introduced AC/DC Current Sensor CT7631/CT7636/CT7642 and AC/DC Auto-Zero Current Sensor CT7731/CT7736/CT7742 are clamp-type measuring instruments that can be connected to the Display Unit CM7290/CM7291, which serves to display values, with a cable and connector, allowing them to be used some distance away from the location at which the user is viewing values. With the current sensor and display unit connected in this manner, the sensor can be clamped onto a conductor that is not located in the immediate vicinity while measured values are reviewed at a distance. Clamp-on sensors such as these are often called upon to generate output for a recorder or logger in extended recording applications.

Until now, AC/DC sensors were subject to offset drift because the characteristics of the Hall elements they use to detect current vary with the ambient temperature, causing measured values to shift, even when measuring DC currents. Due to this phenomenon, current sensors that use Hall elements are poorly suited to measuring DC current over extended periods of time. In other words, it was not possible to distinguish between current value variations and offset variations in applications such measuring current in solar power systems over an extended period of time during which the temperature changes.

Hioki developed an auto-zeroing method that reduces offset variations to about 1/100 of their previous levels in order to eliminate the problem of offset variations caused by changes in temperature. In addition, the company developed current sensors and display units to meet a variety of customer needs.

II. Overview

The CT7631/CT7636/CT7642 is a conventional clamp-on current sensor that uses a Hall element, making it suitable for use in measurement and waveform observation applications in locations where there is little change in temperature.

The CT7731/CT7736/CT7742 incorporates Hioki's newly developed auto-zeroing circuit, making it suitable for current measurement in locations where the temperature varies.

The CM7290/CM7291 connects to a CT7000 series sensor and displays measured values from the sensor. It can either operate on battery power or utilize an AC adapter for extended use. The CM7291 adds Bluetooth® low energy (BLE) capability.

III. Functionality and Features

A. Auto-zeroing Circuit (Offset Drift Cancellation)

Like typical current sensors that use Hall element detection, the CT7731/CT7736/CT7742 measures currents by using a Hall element to detect the associated magnetic field. One characteristic of Hall elements is that they experience offset drift caused by temperature variations.

Hioki uses an auto-zeroing circuit to cancel this offset drift. Compared to a simple-drive Hall element, this circuit reduces the offset drift to about 1/100 of its original magnitude.

B. Sensor Rated Measurement Currents and Measurable Conductor Diameters

The larger a wire's cross-section is, the larger the current it can carry. Due to a tendency to install wires in as confined a location as their diameter permits, sensors with an aperture large enough to measure large currents do not fit into such confined spaces, making it impossible to clamp the sensor around wires with a small diameter in some cases. To address such issues, Hioki offers these sensors in three sizes (TABLE I). This approach lets users choose the sensor that's right for each measurement application.

C. Sensor Safety

Hioki designed these six newly developed clamp-on sensors so that they can be used in CAT IV (600 V) measurement category locations, including with hazardous live wires. Furthermore, the CT7636/CT7736 and CT7642/CT7742 can also be used in CAT III (1000 V) measurement category locations since they provide an even higher level of safety. These instruments deliver safety that is superior to that of the previous products' (the Clamp On AC/DC Sensor CT9691/CT9692/CT9693's) CAT III (600 V) level of performance. In addition, the output cables used by the new sensors have a withstand voltage that is equivalent to that of the sensor. This design ensures that no accident will occur even if the output cable comes into contact with a busbar, as long as the measurement category range is not exceeded.

TABLE I. Rated Currents and Conductor Diameters

Model	*Rated measurement current*	*Measurable conductor diameter*
CT7631, CT7731	100 A AC/DC	ϕ33 mm or less
CT7636, CT7736	600 A AC/DC	ϕ33 mm or less
CT7642, CT7742	2000 A AC/DC	ϕ55 mm or less

D. Direct Plug-in System

Customers prefer to be able to connect a sensor and make measurements immediately in the field. In response to this desire, Hioki developed a system in which each sensor carries an ID that is used by the host instrument to automatically set the rated measurement current, the distinction between AC/DC and AC-only sensors, and the output rate. In addition, the sensor is powered by the display unit. These features simplify measurement by eliminating the need to configure troublesome settings or run power lines.

E. Extension Cable

A standard 2-m-long extension cable is provided to connect the sensor and display unit. Other cables are available in lengths of up to 100 m.

F. Environmental Resistance

The CT7631/CT7731 provides IP40 protection against dust and water, reflecting the design focus on a compact size and low profile, while the CT7636/CT7736 and CT7642/CT7742 feature jaws (the yellow sensing portion of the instrument) and a barrier that delivers IP50 protection and a grip that delivers IP54 protection.

In addition, the instruments provide an operating temperature range of −25°C to 65°C (−13°F to 149°F).

G. Output Functionality

The CM7290/CM7291 can output three types of signals: waveform output (WAVE), RMS output (RMS), and peak output (PEAK). In addition, three types of output cords are available for selection according to the application in which the device is used: the L9094 for use with devices equipped with banana-type terminals such as DMMs, the L9095 for use with devices equipped with BNC terminals, and the L9096 for use with data loggers.

H. Bluetooth low energy (BLE) (CM7291 only)

The CM7291 provides Bluetooth low energy (BLE) capability, allowing Android™ and iOS devices to connect to it via the GENNECT Cross and GENNECT Field dedicated apps. In this way, a smartphone or tablet can be used at a distance from the sensor to observe current waveforms or capture measured values.

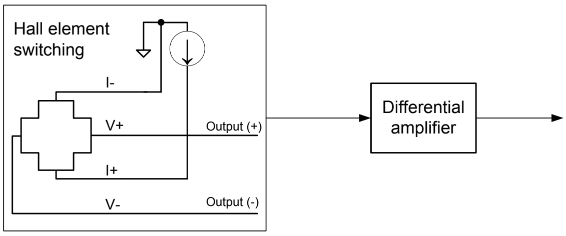

Fig. 1. Block diagram (CT7631/CT7636/CT7642).

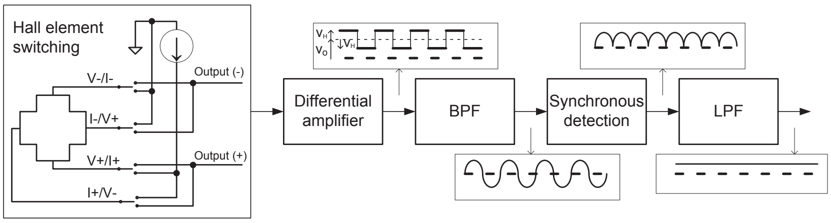

Fig. 2. Block diagram (CT7731/CT7736/CT7742).

IV. Architecture

A. Hardware Architecture

Figs. 1, 2, and 3 provide block diagrams for the CT7631/CT7636/CT7642, CT7731/CT7736/CT7742, and CM7290/CM7291, respectively.

1) CT7631/CT7636/CT7642 block diagram: The CT7631/CT7636/CT7642 implements a simple circuit architecture that is typically used with Hall elements. Since the CT7636/CT7642 has two Hall elements, an addition circuit has been added to the differential amplifier's rear stage.

2) CT7731/CT7736/CT7742 block diagram: The CT7731/CT7736/CT7742 has an auto-zeroing circuit (drift cancellation circuit) designed to limit drift. Since the CT7636/CT7642 has two Hall elements, an addition circuit has been added to the differential amplifier's rear stage. For more information, please see the separate section about auto-zeroing circuit.

3) CM7290/CM7291 block diagram: The power supply circuit supplies voltage to drive the device's internal circuitry as well as the sensor from either an external power supply such as an AC adapter or two AA-size batteries. The CM7290/CM7291 is designed so that it automatically turns on when power is supplied from an AC adapter, allowing it to be embedded in systems.

In addition to being able to display current values, the device can display frequencies measured by its comparator circuit. It can generate three types of output: waveform output (WAVE), RMS output (RMS), and peak output (PEAK).

The CM7290 and CM7291 differ only in whether they include a Bluetooth module.

B. Auto-zeroing Circuit (Drift Cancellation Circuit)

Fig. 2 provides a block diagram for the auto-zeroing circuit. The diagram indicates the signal waveforms that result during measurement of a DC current.

The input and output terminals of the Hall elements, which are made from a single compound, can be switched. The offset voltage when the terminals are reversed is about the same as the offset voltage before the terminals were reversed [1]. Given a suitable drive current, this characteristic makes possible the following equations, where V_1 represents the output in the normal orientation; V_2, the output with the terminals reversed; V_H, the output proportional to the magnetic flux density; and V_O, the offset voltage:

$$V_1 = V_H + V_O$$

$$V_2 = -V_H + V_O$$

In other words, by periodically switching the Hall element's input and output, it is possible to alternately acquire V_H and $-V_H$ output centered around V_O. If V_O is eliminated by means of a band-pass filter (BPF), synchronous detection performed, and the result passed through a low-pass filter (LPF), the offset voltage can be mostly eliminated, allowing acquisition of output proportional to the magnetic flux density.

C. Construction

Fig. 4 illustrates the construction of the CT7636/CT7736. Apart from differences in its jaws, the CT7642/CT7742 has a similar construction. Incorporation of an inner enclosure and packing have allowed the grip to provide IP54 protection. The sensor provides IP50 protection, but the grip offers a higher level of protection due to the risk of electric shock when the sensor is wet. The CT7631/CT7731 utilizes roughly the same construction but with IP40 protection, reflecting its focus on delivering a smaller size.

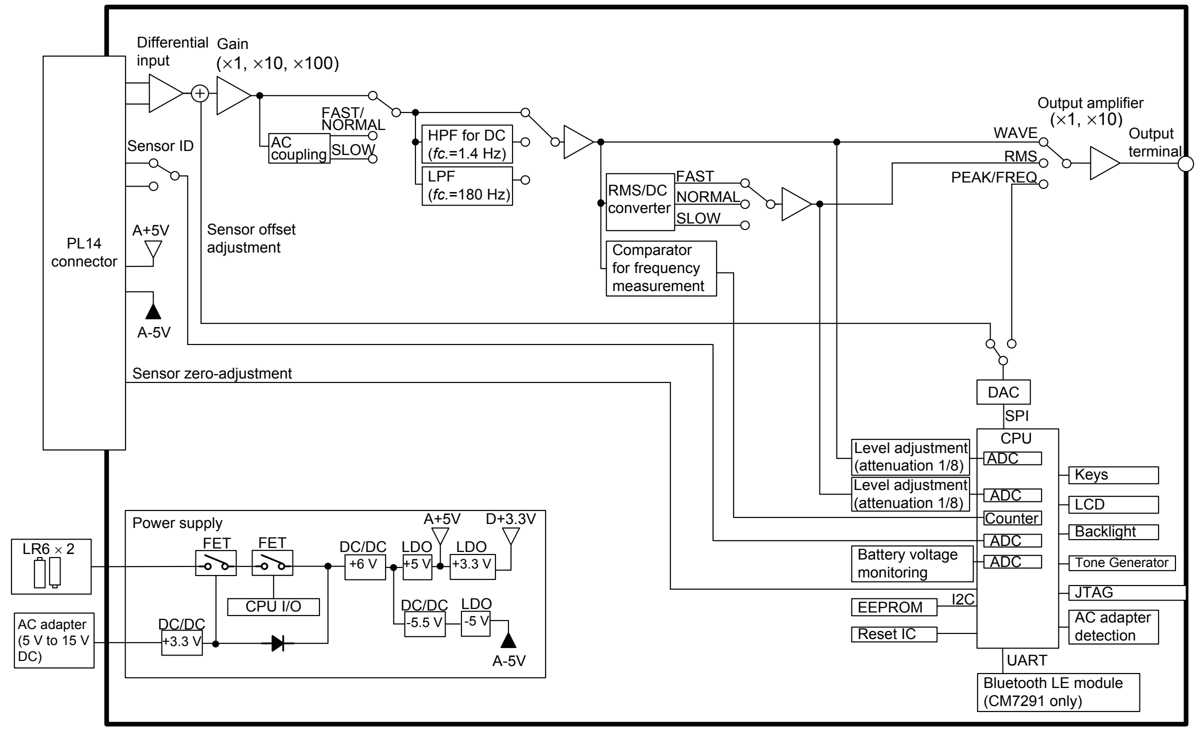

Fig. 3. Block diagram (CM7290/CM7291).

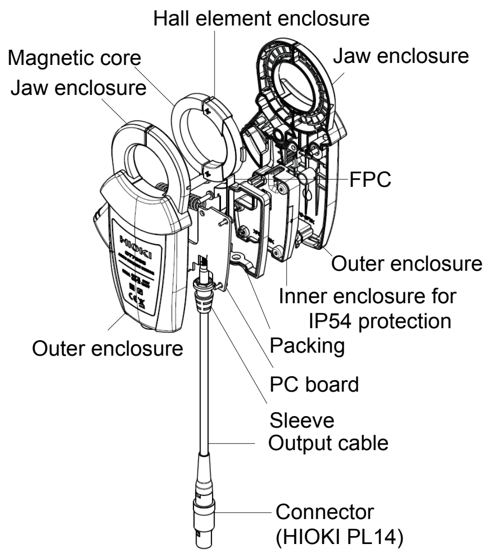

Fig. 4. CT7636/CT7736 construction.

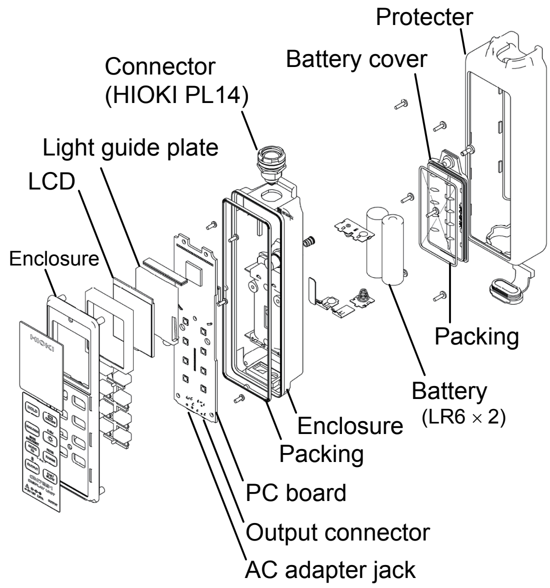

Fig. 5. CM7290/CM7291 construction.

Fig. 5 illustrates the construction of the CM7290/CM7291. Thanks to packing and a protector, the instrument achieves IP54 protection with a sensor connected. The product's enclosure is half the size of that of the Clamp On AC/DC HiTester 3290 (a legacy product), making it small enough to be held with one hand. In addition, holes in the protector can be used to affix an optional magnetic adapter that allows the instrument to be hung near the measurement location. It can also be used as an output device by connecting an optional output cord to its output connector (the L9094 for use with devices equipped with banana jacks, the L9095 for use with devices equipped with BNC connectors, or the L9096 for use with data loggers). In this application, the instrument's narrow width makes it easy to operate even when positioned alongside other devices.

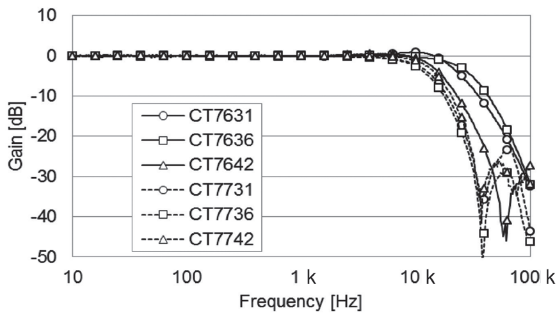

Fig. 6. Example sensor frequency characteristics.

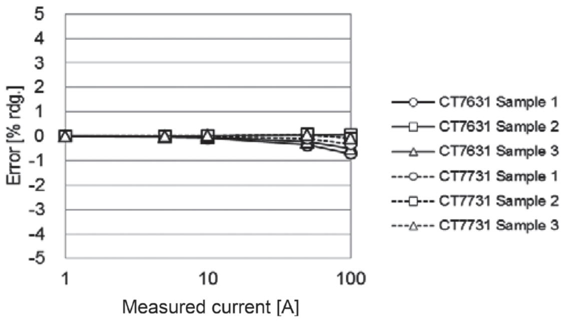

Fig. 7. Example 100 A sensor amplitude-accuracy characteristics.

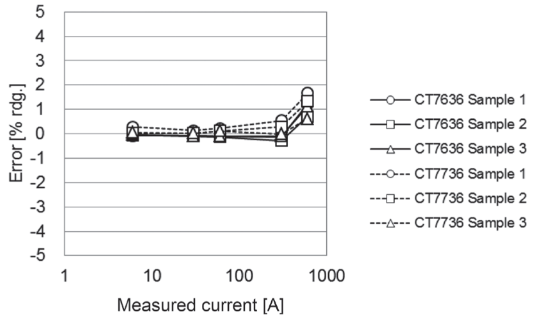

Fig. 8. Example 600 A sensor amplitude-accuracy characteristics.

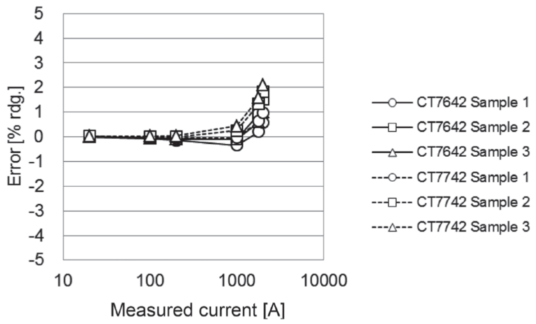

Fig. 9. Example 2000 A sensor amplitude-accuracy characteristics.

V. Characteristics

A. *Sensor Frequency Characteristics*

Fig. 6 provides an example of the sensors' frequency characteristics. The CT7631, CT7636, and CT7642 have frequency characteristics from DC to 10 kHz (−3 dB), while the CT7731, CT7736, and CT7742 have frequency characteristics from DC to 5 kHz (−3 dB).

B. *Sensor Amplitude-Accuracy Characteristics*

Figs. 7 through 9 provide examples of the sensors' amplitude-accuracy characteristics. The following sensor pairs, which each share the same respective core, exhibit roughly the same trend: CT7631 and CT7731, CT7636 and CT7736, and CT7642 and CT7742.

C. *Offset-Temperature Characteristics*

Figs. 10 through 15 provide examples of the sensors' offset-temperature characteristics. Figs. 10 through 12 illustrate the characteristics of the CT7631, CT7636, and CT7642, respectively, which exhibit some degree of variability with temperature. Figs. 13 through 15 illustrate the characteristics of the CT7731, CT7736, and CT7742, respectively, which exhibit almost no offset variation caused by temperature thanks to their auto-zeroing circuit (drift cancellation circuit).

D. *Effects of Conductor Position*

Fig. 16 illustrates the locations at which the effects of conduct position were measured, while Figs. 17 through 19 provide examples of the sensors' conductor position characteristics. Measured values for all sensors exhibit deviation from center of less than 1%.

E. *Display Unit Temperature Characteristics*

Figs. 20 through 23 illustrate the temperature characteristics of the two display units. Fig. 20 illustrates temperature characteristics when the units are operated in the 60.00 mV (×10) range. In this case, the units exhibit variability of 1% f.s. or less across the operating temperature range of −25°C to 65°C (−13°F to 149°F). Fig. 21 illustrates temperature characteristics when the units are operated in the 600.0 mV (×1) range. In this case, the units exhibit variability of 0.05% f.s. or less across the operating temperature range of −25°C to 65°C (−13°F to 149°F). Fig. 22 illustrates temperature characteristics when the units are given input of 54 mV/55 Hz in the AC 60.00 mV (×10) range. In this case, the units exhibit variability of 0.5% f.s. or less across the operating temperature range of −25°C to 65°C (−13°F to 149°F). Finally, Fig. 23 illustrates temperature characteristics when the units are given input of 540 mV with a frequency of 55 Hz in the AC 600.0 mV (×1) range. In this case, the units exhibit variability of 0.5% f.s. or less across the operating temperature range of −25°C to 65°C (−13°F to 149°F).

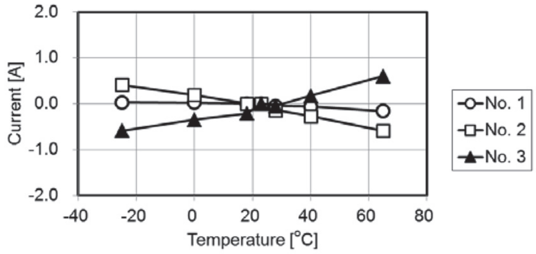

Fig. 10. Example CT7631 offset-temperature characteristics.

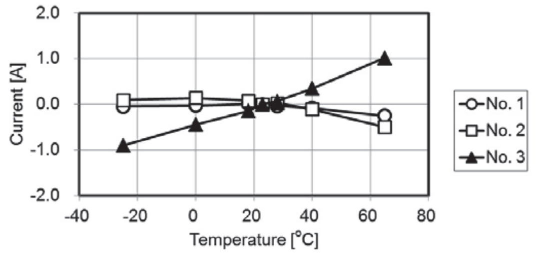

Fig. 11. Example CT7636 offset-temperature characteristics.

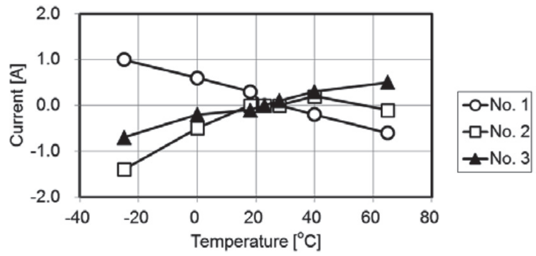

Fig. 12. Example CT7642 offset-temperature characteristics.

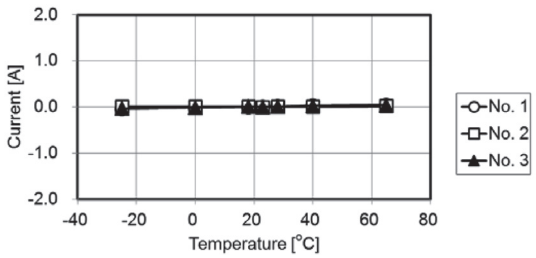

Fig. 13. Example CT7731 offset-temperature characteristics.

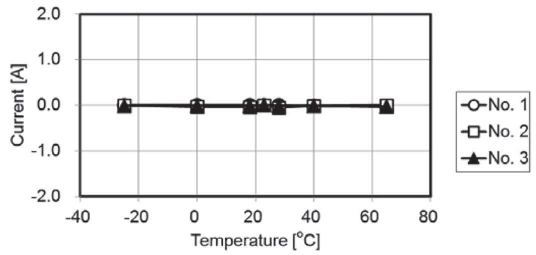

Fig. 14. Example CT7736 offset-temperature characteristics.

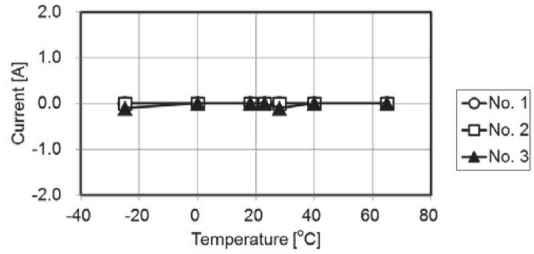

Fig. 15. Example CT7742 offset-temperature characteristics.

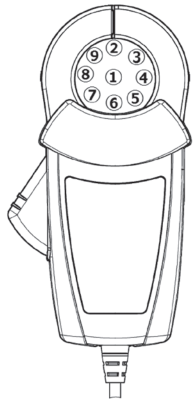

Fig. 16. Locations at which the effects of conductor position were measured.

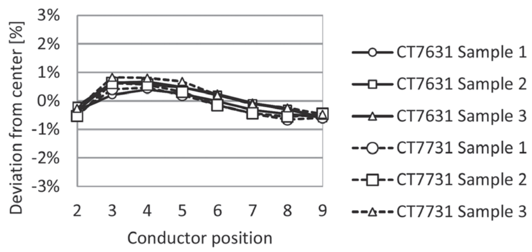

Fig. 17. Example 100 A conductor position characteristics.

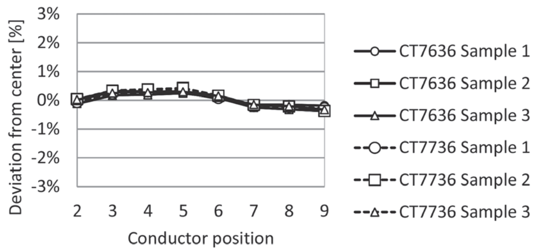

Fig. 18. Example 600 A conductor position characteristics.

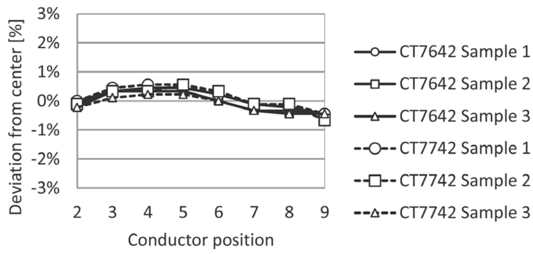

Fig. 19. Example 2000 A conductor position characteristics.

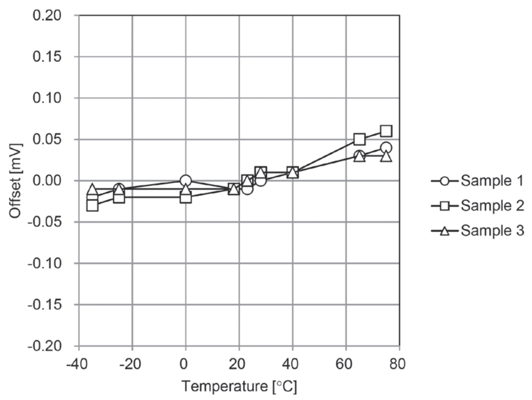

Fig. 20. Temperature characteristics (DC 60.00 mV range, no input).

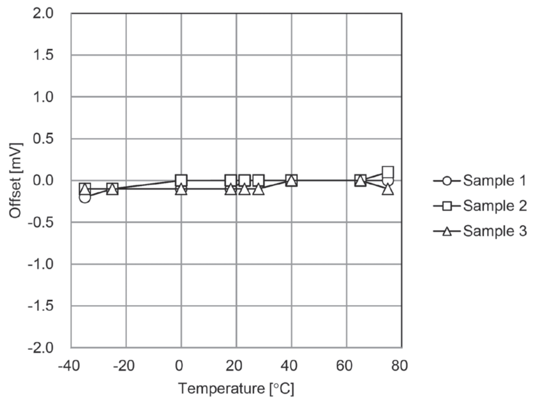

Fig. 21. Temperature characteristics (DC 600.0 mV range, no input).

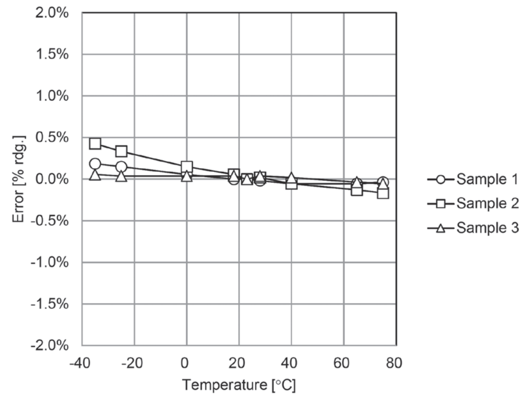

Fig. 22. Temperature characteristics (AC 60.00 mV range, 54 mV/55 Hz input).

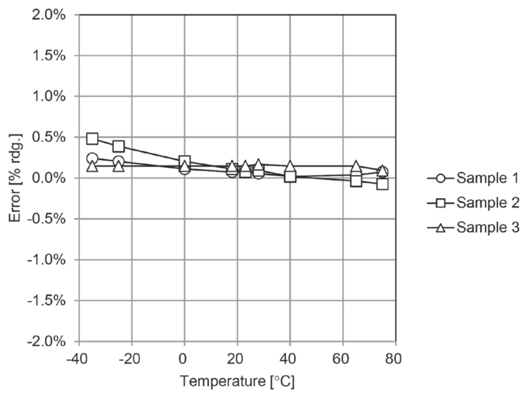

Fig. 23. Temperature characteristics (AC 600.0 mV range, 540 mV/55 Hz input).

F. Display Unit RMS Output

Figs. 24 through 26 illustrate the display units' RMS output characteristics. When the response speed (SLOW, NORMAL, or FAST) has not been set appropriately for the waveform under measurement, which results in insufficient integration time, a ripple waveform appears. Output satisfies the specifications when the frequency of the waveform under measurement is 1 Hz or greater (for the SLOW speed setting), 10 Hz or greater (for the NORMAL speed setting), or 45 Hz or greater (for the FAST speed setting).

G. Display Unit PEAK Output

Figs. 27 and 28 illustrate the display units' PEAK output characteristics. When a 10 Hz waveform is measured at the FAST setting, the measurement and output interval is too short, resulting in a ripple waveform like that from RMS output. Consequently, it is necessary to choose an appropriate response speed (SLOW, NORMAL, or FAST), as with RMS output.

Conclusion

Hioki has developed a series of clamp-on sensors with output functionality that can be operated using either an AC adapter or batteries. To eliminate the effects of offset temperature drift, long an issue with this type of instrument, the company also developed a series of auto-zero sensors with integrated auto-zeroing circuit (offset drift cancellation circuit). Hioki expects the sensors to see broad use in measurement in a variety of fields.

References

[1] T. Takeda, "High-Performance Magnetic Sensor Technologies Using Si Hall Elements," *Toshiba Rebyu (Toshiba Review)*, vol. 65, no. 1, 2010. (Japanese, also available in English).

[2] K. Hirota, "Clamp On AC/DC HiTester 3290," *Hioki Giho*, vol. 25, no. 1, pp. 39-46, 2004. (Japanese).

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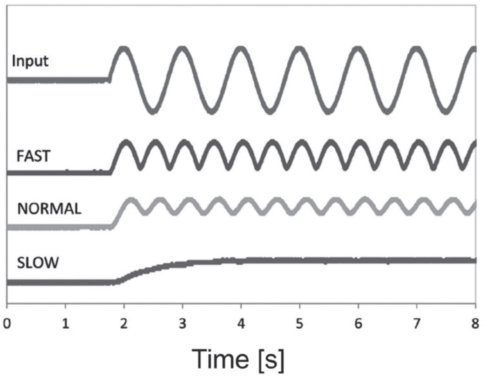

Fig. 24. RMS output with 1 Hz input.

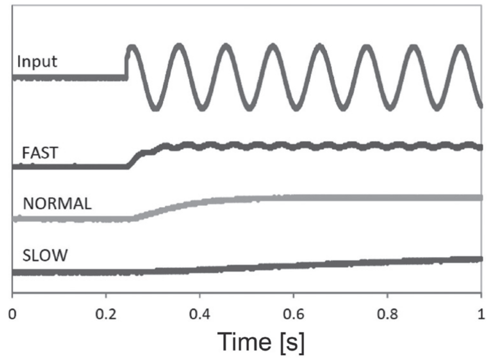

Fig. 25. RMS output with 10 Hz input.

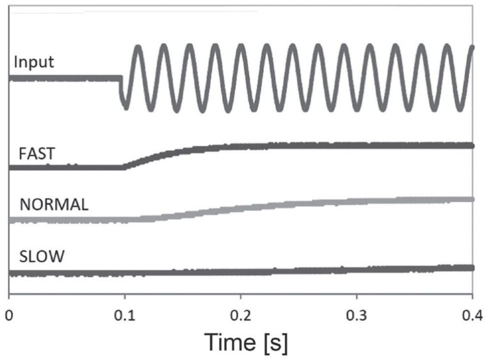

Fig. 26. RMS output with 45 Hz input.

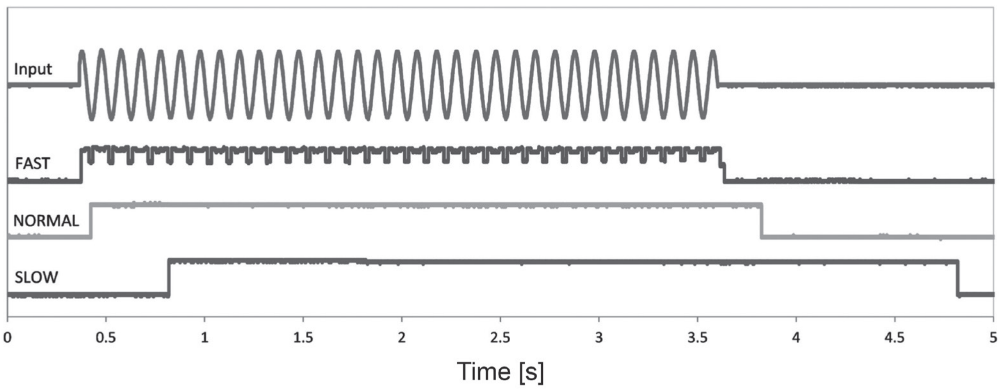

Fig. 27. PEAK output with 10 Hz input.

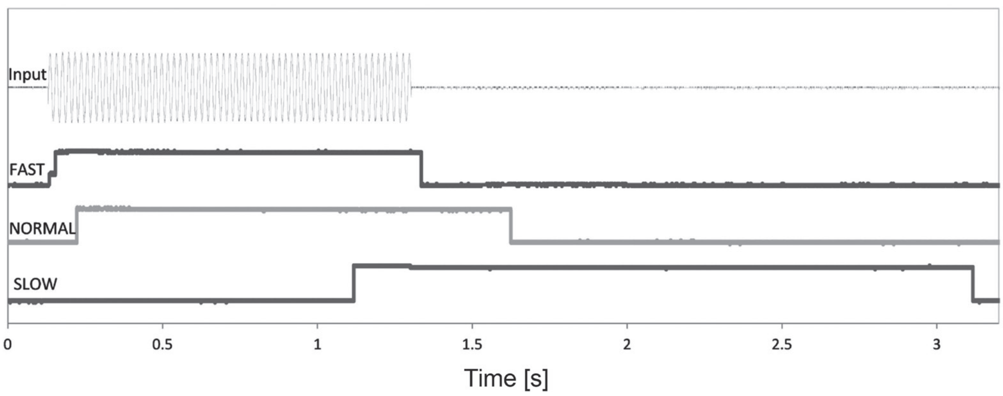

Fig. 28. PEAK output with 50 Hz input.

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