

# AC/DC Current Probe CT6841/CT6843

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**Abstract**—The AC/DC Current Probe CT6841/CT6843 is a clamp-type current sensor that can measure current across a broad range of frequencies starting with DC and in a broad range of temperatures. This paper introduces the product's features, architecture, and characteristics.

## I. INTRODUCTION

Manufacturers of electric and hybrid electric vehicles, fuel cells, solar cells, and other energy-saving products are currently working aggressively to improve those devices, and that work requires high-precision current measurement across a broad range of frequencies, starting with DC.

There is rising demand for clamp-type current sensors that deliver the high accuracy and high heat resistance of a pass-through current sensor when making measurements of complex systems whose internal wiring cannot be removed, for example inside an automobile's engine compartment. Hioki's 9277 series has been used in the past as a high-accuracy clamp-type current sensor, but those devices did not deliver the level of performance demanded by the market in the area of heat resistance.

The CT6841 (rated for 20 A) and CT6843 (rated for 200 A) deliver higher heat resistance than legacy clamp-type current sensors along with significantly improved performance across the board.

## II. OVERVIEW

The CT6841/CT6843 are successors to the Universal Clamp On CT 9277/9278, which was launched in 1994. They deliver basic measurement accuracy of  $\pm 0.3\%$  rdg. and are capable of current measurement at frequencies extending from DC to 1 MHz (CT6841) or 500 kHz (CT6843). In addition to providing a robust locking mechanism and a clamp that can be closed and opened single-handedly, these devices are smaller than legacy models.

Furthermore, the CT6841/CT6843 features a significantly broader operating temperature range to enable use in harsh environments such as the interiors of automobile engine compartments. A reassessment of the sensor design has not only yielded improved measurement accuracy, but also limited the effects of conductor position, nearby conductors, and magnetization, all of which are disadvantages unique to clamp sensors. The result is a pair of current sensors that offer an extremely high level of reliability compared to legacy clamp-type current sensors.



Appearance of the CT6841

## III. FEATURES

- (1) High accuracy:  $\pm 0.3\%$  rdg.  $\pm 0.01\%$  f.s. (DC <math>f \le 100\text{ Hz}</math>)
- (2) Broad operating temperature range:  $-40^{\circ}\text{C}$  to  $85^{\circ}\text{C}$  ( $-40.0^{\circ}\text{F}$  to  $185.0^{\circ}\text{F}$ )
- (3) Broad frequency range:  
DC to 1 MHz ( $-3\text{ dB}$ ) (CT6841)  
DC to 500 kHz ( $-3\text{ dB}$ ) (CT6843)
- (4) Limited effects of conductor position, external magnetic fields, and magnetization
- (5) Robust locking mechanism
- (6) Improved operability and more compact design than legacy models
- (7) Easy-to-use voltage output type

## IV. ARCHITECTURE

### A. Circuit Architecture

Fig. 1 illustrates the CT6841/CT6843 circuit architecture. The sensors' basic circuit architecture is that of a zero-flux current sensor using the flux gate method, the same design used for the 9277 series.

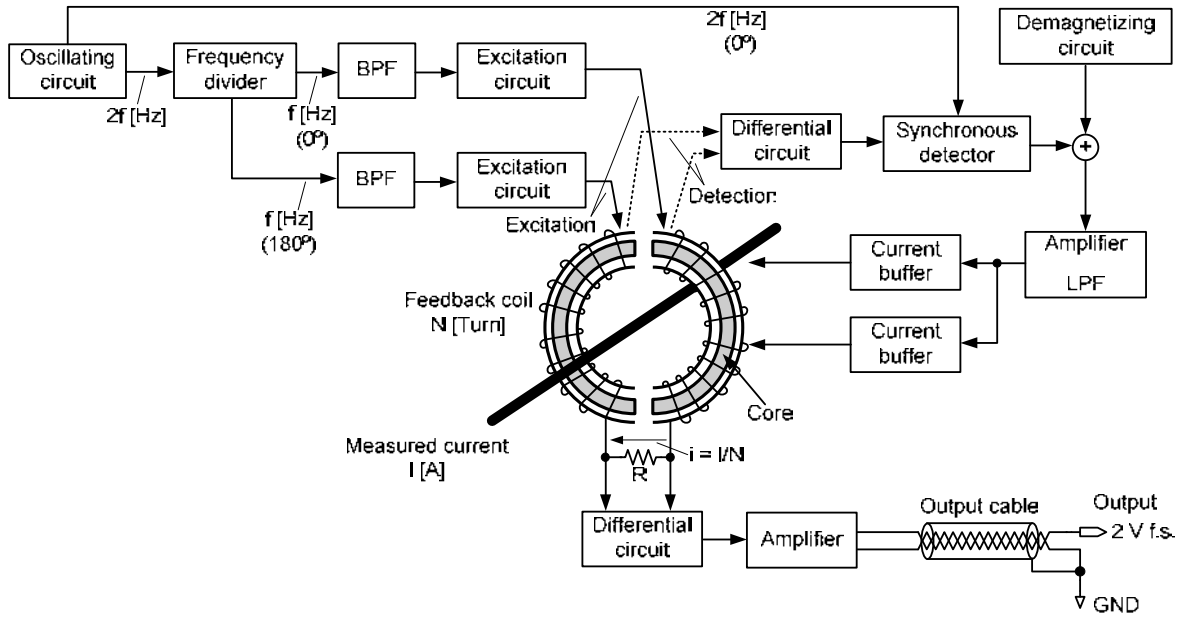


Fig. 1. Circuit Architecture

**B. Design**

Fig. 2 illustrates the sensor’s design. The CT6841/CT6843 uses a sliding clamp mechanism. Since the sensor head and grip are smaller than those of legacy models, the sequence of operations from opening/closing the sensor head to engaging the lock can easily be performed single-handedly. In addition, the new products’ use of a locking mechanism that is more robust than that employed by legacy models makes the lock less likely to be released if bumped or handled roughly.

Changes to the position of the sensor’s internal flux-gate element and to its winding structure serve to minimize the unique disadvantages of current sensors.

Furthermore, use of a permalloy core and a comb tooth coupling mechanism give the coupling lower magnetic resistance, allowing the sensor to deliver a higher level of accuracy.

**C. Study of Heat Resistance of Component Parts**

TABLE I summarizes changes to parts used by the 9277 series. Although it would be possible to expand the operating temperature range on the low side with the component architecture used by the 9277 series, heat generation by internal components becomes problematic in expanding the range on the high side. Due to the low Curie temperature of the ferrite material used in the core, declining magnetic permeability near  $100^\circ\text{C}$  ( $212.0^\circ\text{F}$ ) causes a deterioration of its performance characteristics. As a result, Hioki chose permalloy, which has a high Curie temperature, for use in the CT6841/CT6843. The company used electrical components with high heat resistance so that they could withstand rising temperatures due to the heat given off by the sensor’s internal circuitry.

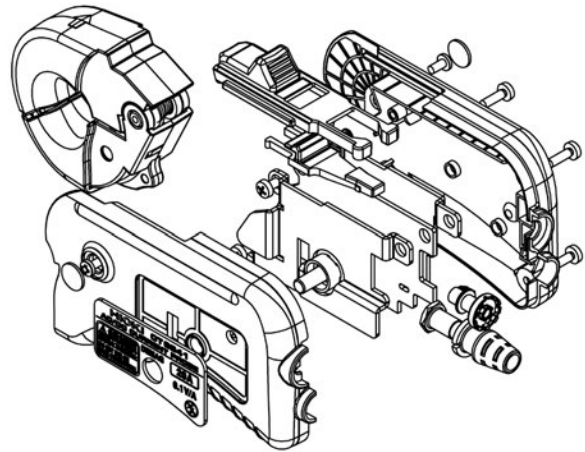
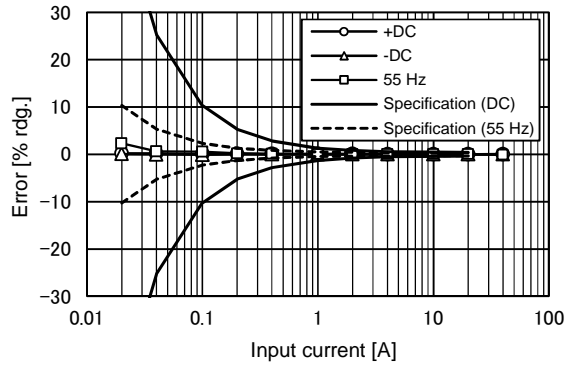


Fig. 2. Structural Drawing

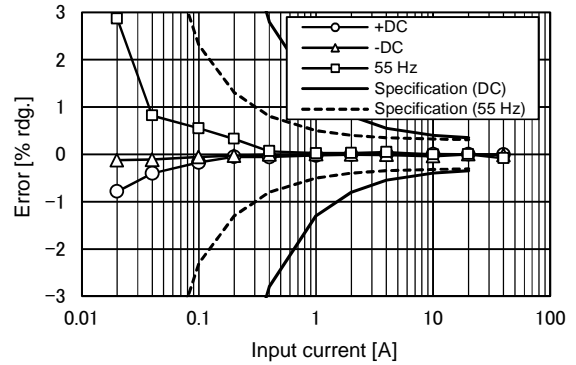
TABLE I. COMPARISON OF COMPONENTS WITH LEGACY MODELS

	9277/9278	CT6841/CT6843
Main core	Ferrite (Magnetic permeability of about 5,000)	Permalloy (PC) (Magnetic permeability of about 60,000)
Coupling structure	Surface	Comb gear
Feedback winding structure	Concentrated winding	Level winding
Electrical component heat resistance	$85^\circ\text{C}$ ( $185.0^\circ\text{F}$ )	$125^\circ\text{C}$ ( $257.0^\circ\text{F}$ )
Cable heat resistance	$80^\circ\text{C}$ ( $176.0^\circ\text{F}$ )	$105^\circ\text{C}$ ( $221.0^\circ\text{F}$ )
Case plastic	ABS	Polycarbonate (With glass fibers)

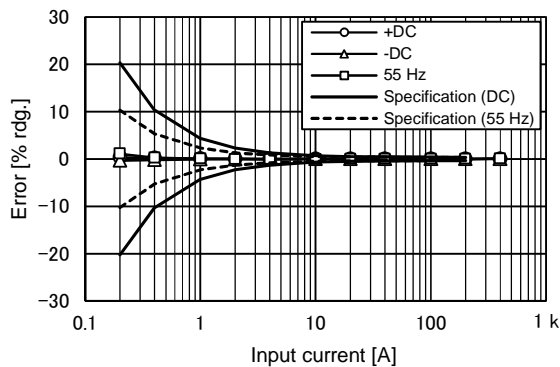


Overall

Fig. 3. CT6841 Linearity

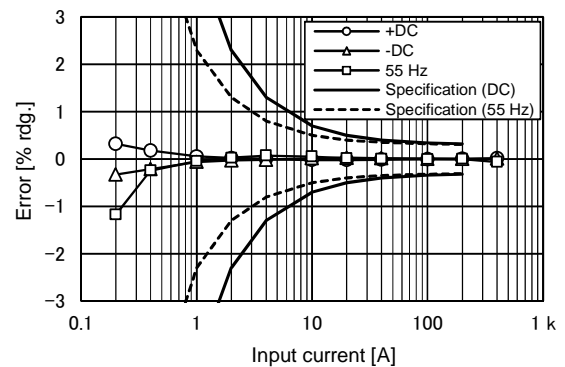


Enlarged view



Overall

Fig. 4. CT6843 Linearity



Enlarged view

Hioki also chose polycarbonate, which has high heat resistance, for the case and combined it with glass fibers to increase the case's mechanical strength.

## V. REFERENCE CHARACTERISTICS DATA: STANDALONE (Combined with the Sensor Unit 9555-10)

### A. Linearity

Figs. 3 and 4 illustrate the linearity of the CT6841 and the CT6843, respectively. Both devices exhibit extremely good linearity over a broad range of current magnitudes and provide dynamic characteristics that are twice the rated current. By adjusting the offset with the sensor's zero-adjustment knob prior to measurement, it is possible to measure even low-level DC current with a high degree of precision.

### B. Frequency Characteristics

Figs. 5 and 6 illustrate the CT6841's frequency characteristics, while Figs. 7 and 8 do the same for the CT6843. The devices exhibit flat characteristics over a broad range of frequencies, allowing them to be used to make measurements on the secondary side of an inverter.

In addition, the devices exhibit good phase characteristics, which are important when the sensor is being used with a power meter.

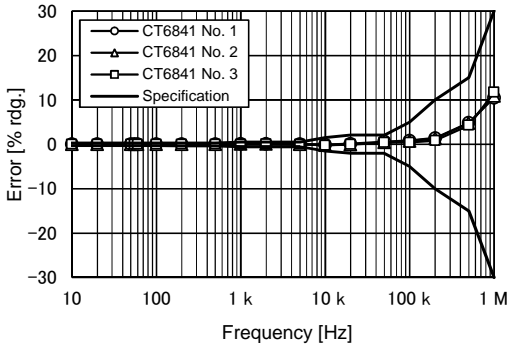
### C. Temperature Characteristics

Figs. 9 and 10 illustrate the temperature characteristics of the CT6841 and the CT6843, respectively. Both offset characteristics and sensitivity characteristics are stable across a broad range of temperatures. Concerning their offset characteristics, the devices exhibit temperature characteristics that are extremely stable compared to current sensors that use a Hall element thanks to their use of a flux gate design. Their stable sensitivity characteristics are made possible by a circuit architecture that is less susceptible to the effects of temperature.

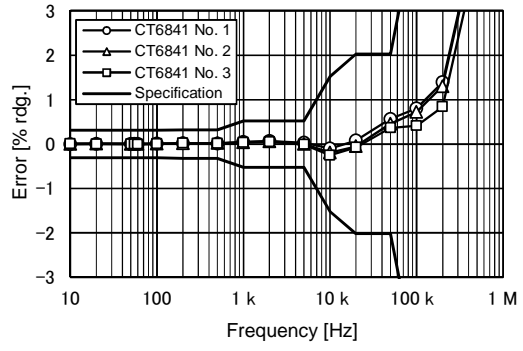
### D. Effects of Conductor Position

Fig. 11 illustrates the effects of conductor position during 55 Hz current measurement. Highly reproducible measurement is possible as the CT6841 and CT6843 are much less prone to the effects of conductor position than the legacy 9277 and 9278 sensors.

AC/DC Current Probe CT6841/CT6843

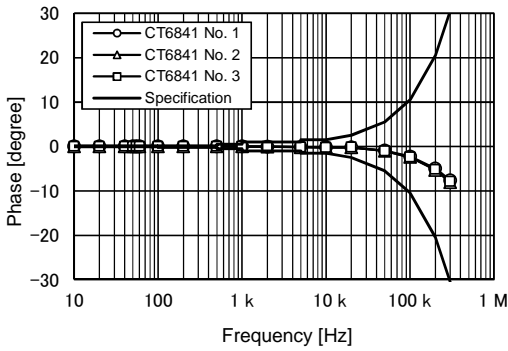


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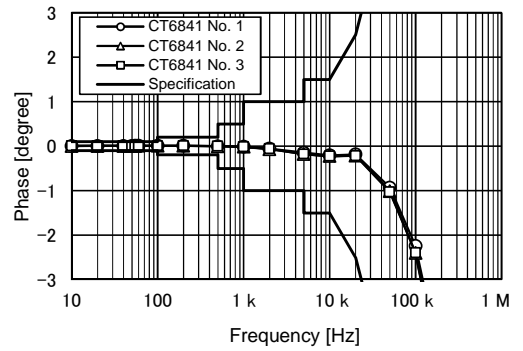


Enlarged view

Fig. 5. CT6841 Amplitude-Frequency Characteristics

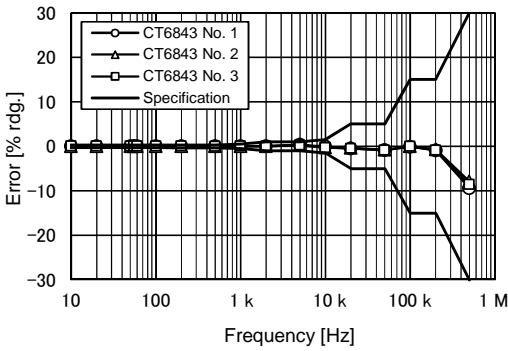


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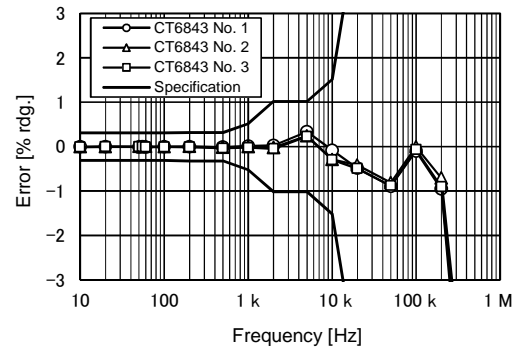


Enlarged view

Fig. 6. CT6841 Phase-Frequency Characteristics

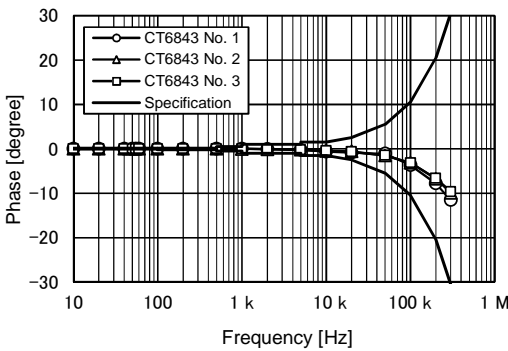


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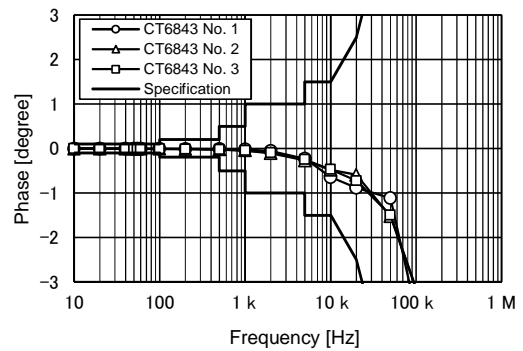


Enlarged view

Fig. 7. CT6843 Amplitude-Frequency Characteristics



Overall



Enlarged view

Fig. 8. CT6843 Phase-Frequency Characteristics

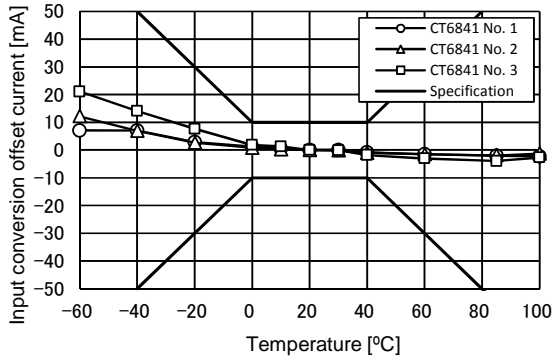


Fig. 9. CT6841 Temperature Characteristics

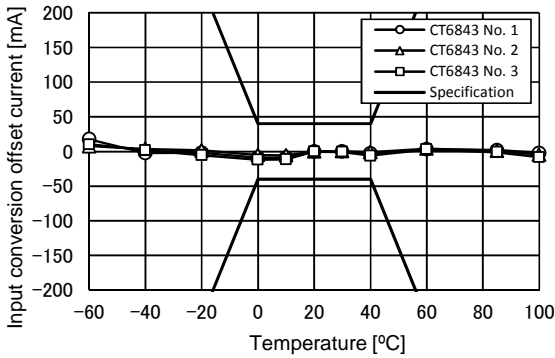
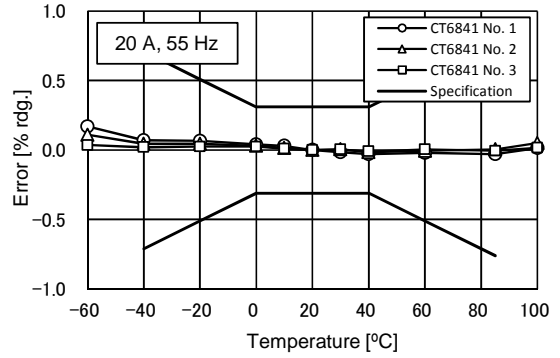


Fig. 10. CT6843 Temperature Characteristics

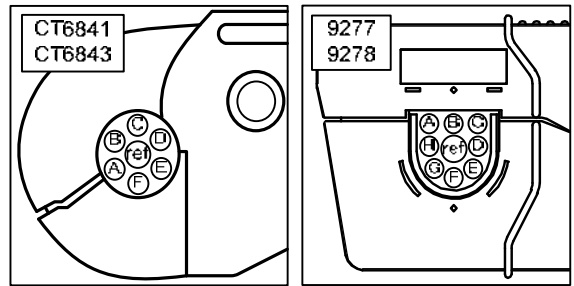
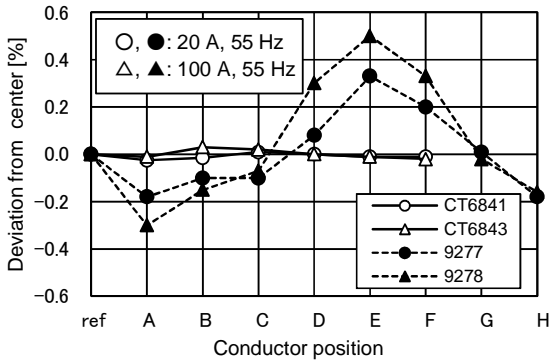
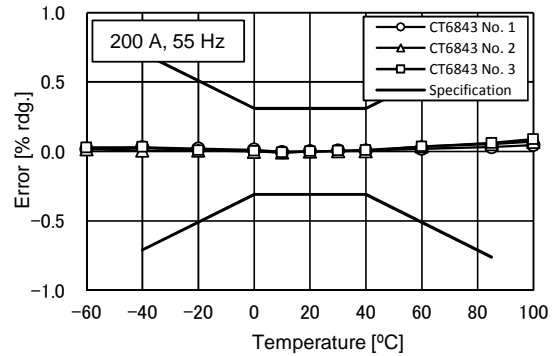


Fig. 11. Effects of Conductor Position (Comparison with legacy models; wire diameter of 5 mm)

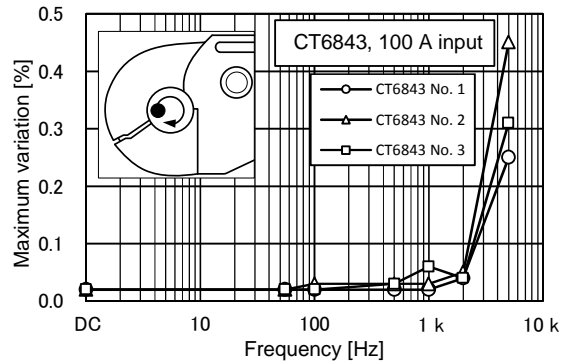
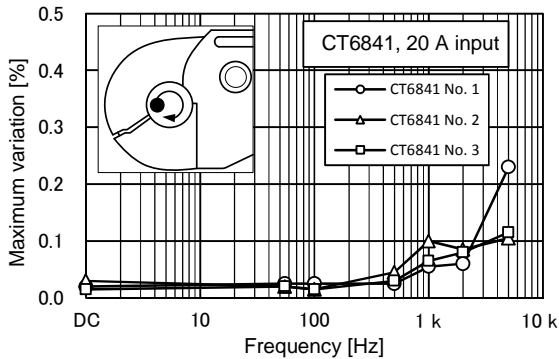


Fig. 12. Effects of Conductor Position (Effects of frequency; wire diameter of 5 mm)

AC/DC Current Probe CT6841/CT6843

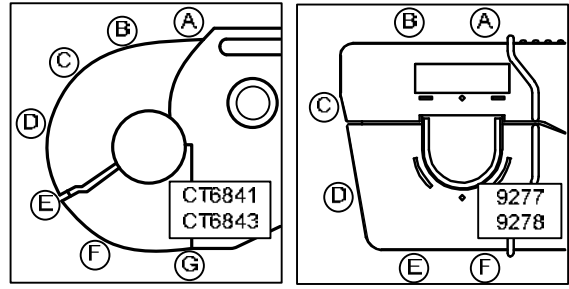
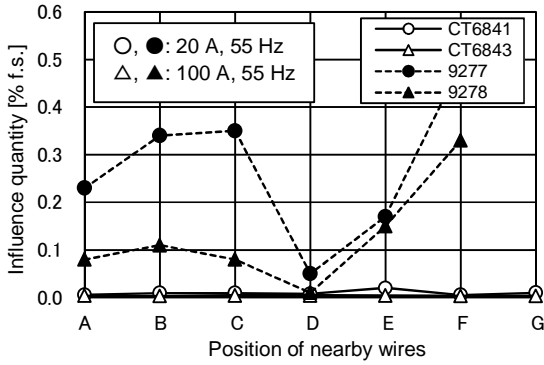


Fig. 13. Effects of Nearby Conductors (Comparison with legacy models; wire diameter of 5 mm)

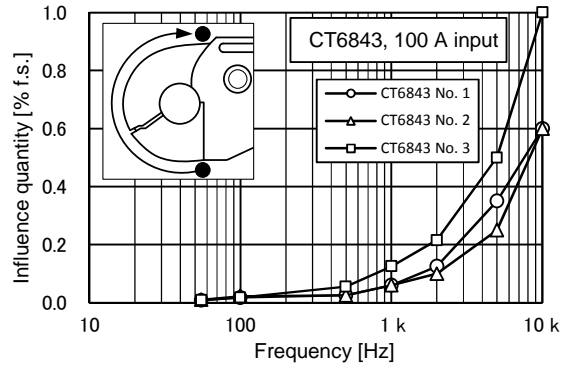
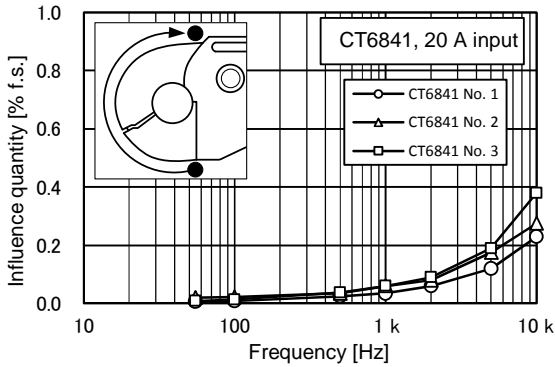


Fig. 14. Effects of Nearby Conductors (Effects of frequency; wire diameter of 5 mm)

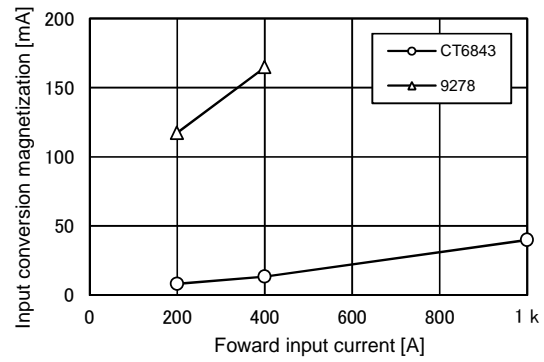
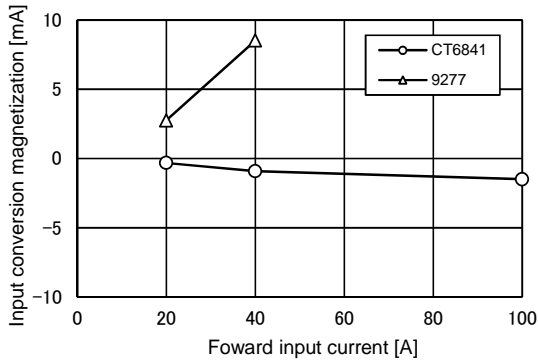


Fig. 15. Effects of Magnetization

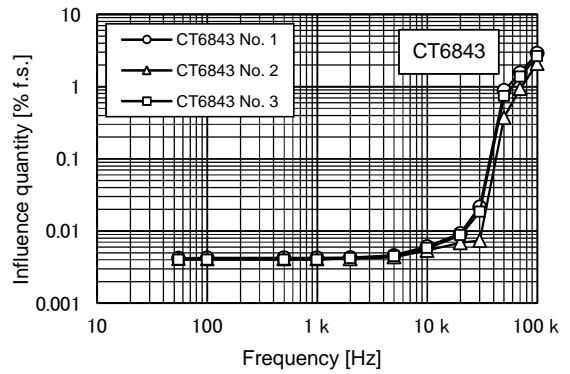
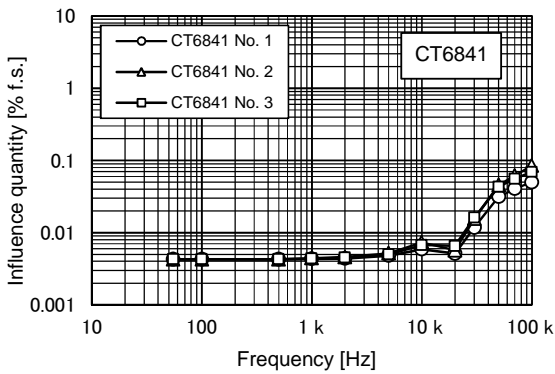


Fig. 16. Effects of Common-mode Voltage

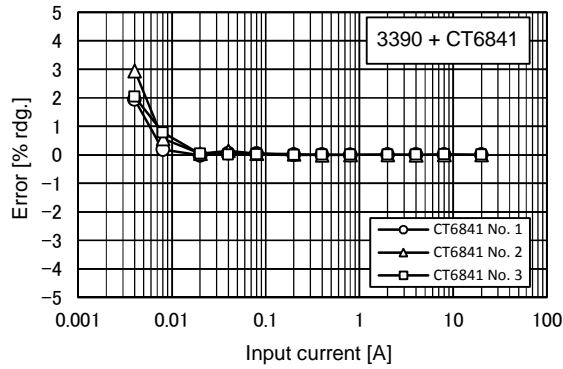


Fig. 17. AC Current (55 Hz) Linearity (Auto range)

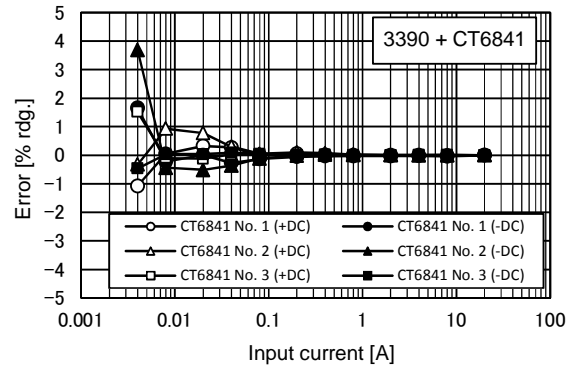


Fig. 18. DC Current Linearity (Auto range)

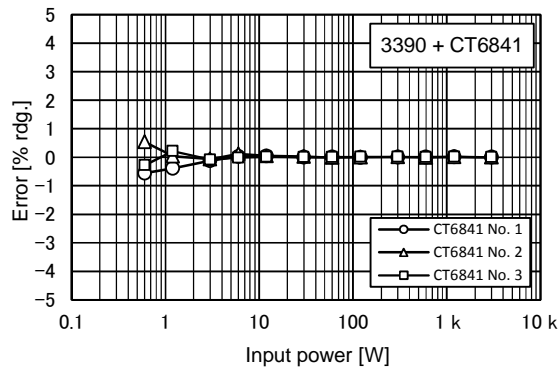
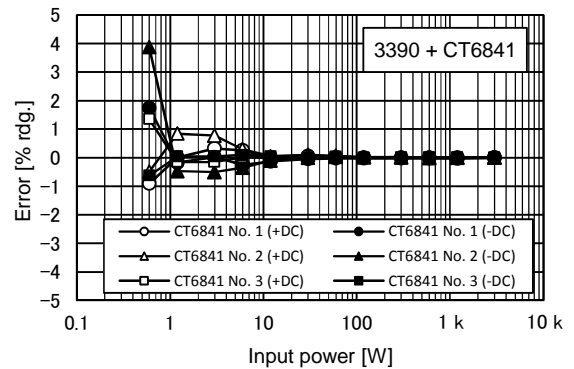
Fig. 19. AC Power (55 Hz) Linearity (Auto range)  
Voltage (150 V range), Current (Auto range), Power Factor of 1Fig. 20. DC Power Linearity (Auto range)  
Voltage (150 V range), Current (Auto range), Power Factor of 1

Fig. 12 illustrates the difference between the minimum and maximum values inside the sensor's hole diameter when the frequency is varied. Although the effects of conductor position increase at high frequencies, the effects are slight at frequencies of 1 kHz and lower. When measuring high-frequency current, it is desirable to ensure that the conductor being measured passes through the center of the sensor in order to reduce the effects of conductor position.

#### E. Effects of Nearby Conductors

Fig. 13 illustrates the effects on sensor performance when a wire carrying a current (55 Hz) is placed near the sensor head at positions A through G. Since the extent of these effects is much smaller than with the legacy 9277 and 9278 sensors, it is possible to make measurements with the CT6841 and CT6843 without being affected by nearby wires.

Fig. 14 illustrates the effects of frequency. Although the effect of frequencies of 1 kHz or less is slight, the magnitude of the effect increases at high frequencies. In environments in which the sensor must be positioned close to a high-frequency current, it is desirable to separate it from nearby conductors.

#### F. Effects of Magnetization

Fig. 15 illustrates the effects of magnetization. These effects are much less pronounced than with the legacy 9277 and 9278 sensors. When measuring a minuscule current after measuring a large DC current, the effects of magnetization can be canceled out by pressing the DEMAG button on the sensor to degauss the device.

#### G. Effects of Common-mode Voltage

Fig. 16 illustrates the effects of common-mode voltage. The output values shown were obtained by passing a 1,000 V rms line carrying no current through the sensor. There is almost no effect at low frequencies. Output begins to appear at frequencies of 10 kHz and greater, but the effect is not problematic at the voltage levels typically used by inverter-driven equipment.

### VI. REFERENCE CHARACTERISTICS DATA: WHEN USED IN COMBINATION WITH A POWER METER

This section describes the characteristics of the CT6841 and CT6843 when used in combination with the Power Analyzer 3390, a typical power meter. The 3390 is designed to tap the full performance of the current sensors with which it is used. Consequently, no adjustment is necessary in order to use them together, and the sensors can be used to their full performance potential.

AC/DC Current Probe CT6841/CT6843

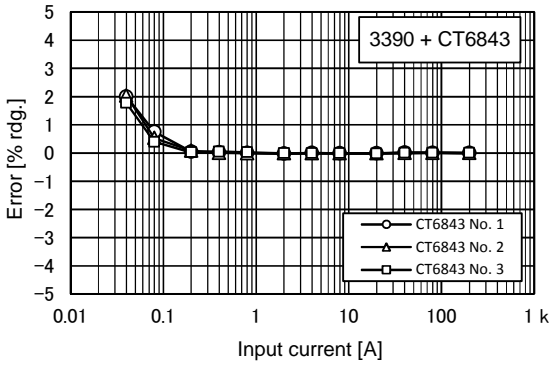


Fig. 21 AC Current (55 Hz) Linearity (Auto range)

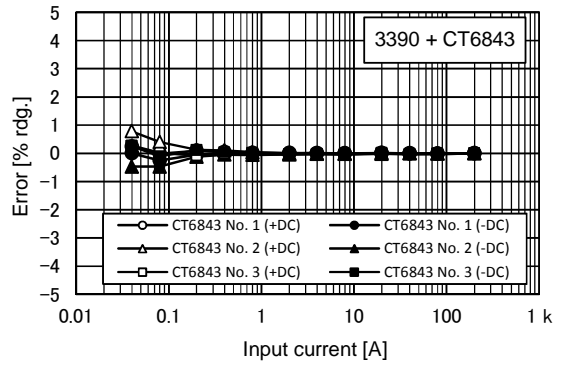


Fig. 22 DC Current Linearity (Auto range)

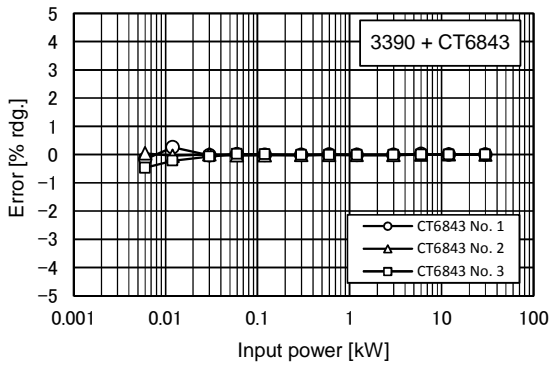


Fig. 23 AC Power (55 Hz) Linearity  
Voltage (150 V range), Current (Auto range), Power Factor of 1

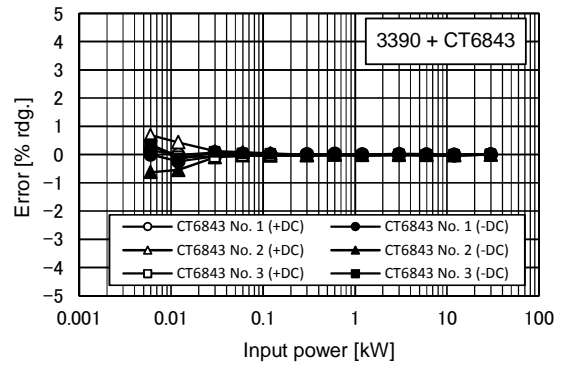


Fig. 24 DC Power Linearity (Auto range)  
Voltage (150 V range), Current (Auto range), Power Factor of 1

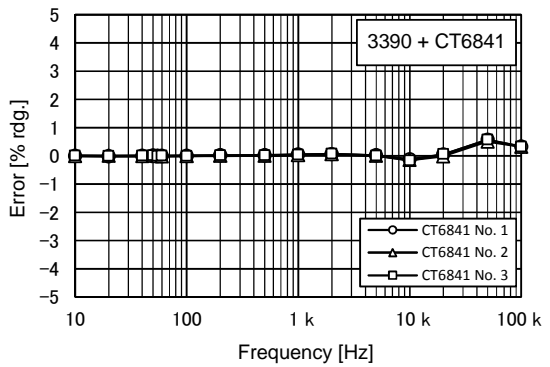


Fig. 25 Current Frequency Characteristics (0.4 A)

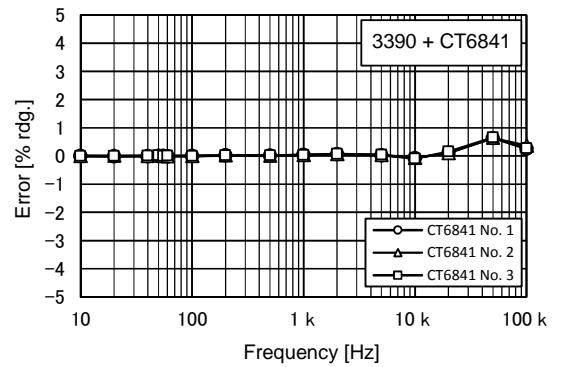


Fig. 26 Power Frequency Characteristics (150 V x 0.4 A, Power factor of 1)

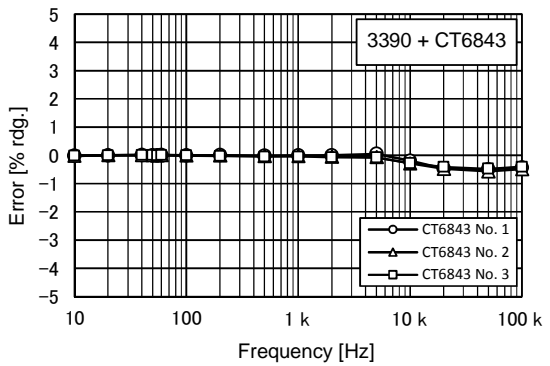


Fig. 27 Current Frequency Characteristics (4 A)

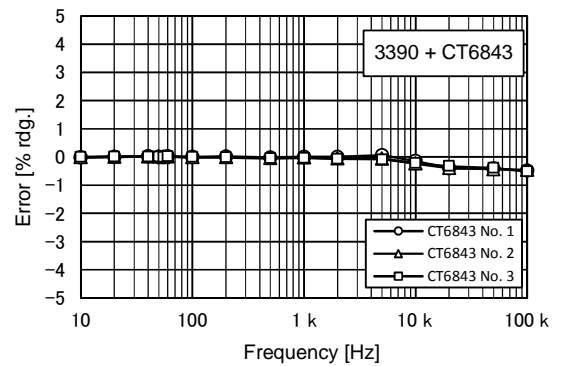


Fig. 28 Power Frequency Characteristics (150 V x 4 A, Power factor of 1)



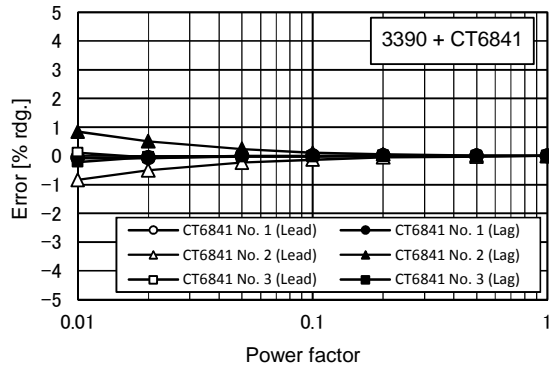


Fig. 29 Power Factor Effects (150 V × 20 A, 55 Hz)

Current ranges when used with CT6841  
(0.4 A, 0.8 A, 2 A, 4 A, 8 A, 20 A ranges)

Current ranges when used with the CT6843  
(4 A, 8 A, 20 A, 40 A, 80 A, 200 A ranges)

#### A. Linearity

Figs. 17 through 20 and Figs. 21 through 24 illustrate linearity when the 3390 is used in combination with the CT6841 and the CT6843, respectively. Current has been input within the range of 0.02% f.s. to 100% f.s. The graphs precise measurement can be carried out even with low input currents.

More precise measurement of low DC current inputs is possible since the 3390's zero-adjustment function can be utilized to cancel out the sensor's minuscule offset.

#### B. Frequency Characteristics

Figs. 25 and 26 and Figs. 27 and 28 illustrate the frequency characteristics when the 3390 is used in combination with the CT6841 and CT6843, respectively. Both sensors exhibit good, flat characteristics at frequencies of 100 kHz and lower. At frequencies of 100 kHz and above, performance is limited by the 3390's frequency characteristics.

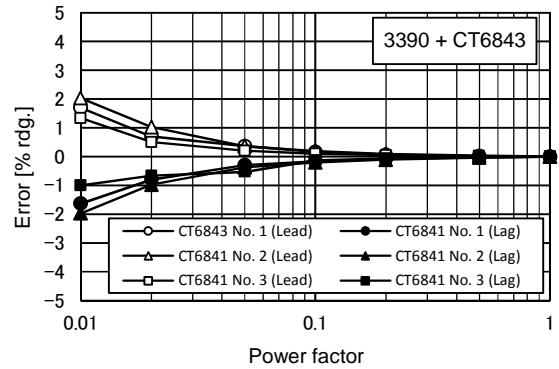


Fig. 30 Power Factor Effects (150 V × 200 A, 55 Hz)

#### C. Effects of Power Factor

Figs. 29 and 30 illustrate the effects of power factor when the 3390 is used in combination with the CT6841 and CT6843, respectively. Good characteristics can be obtained even with low power factors by combining the sensors with the 3390.

### VII. CONCLUSION

The CT6841 and CT6843 offer significantly improved performance compared to legacy models. Since they can be used across a broad range of temperatures, from low to high, these sensors can be expected to contribute to current measurement in a variety of environments.

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Tetsuya Komiyama<sup>\*2</sup>

#### REFERENCE

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

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