Test&Measurement

YOKOGAWA

Validated measurements for transformers

WT3000E Precision Power Analyzer Transformer Version

Precision Making

Bulletin WT3000ETR-01E-E

Transformers play a critical role in ensuring the efficient and reliable distribution of electricity to homes and businesses. In order to develop economical and ecologically friendly transformers for utility providers, manufacturers need to find ways to reduce losses and costs at every stage of the development cycle.

Every kilowatt of power loss exceeding the limits under no-load condition can cost a manufacturer tens of thousands of dollars in fines. The more precise the measurement, the less likely there will be penalties, and the greater the trust from the customer.

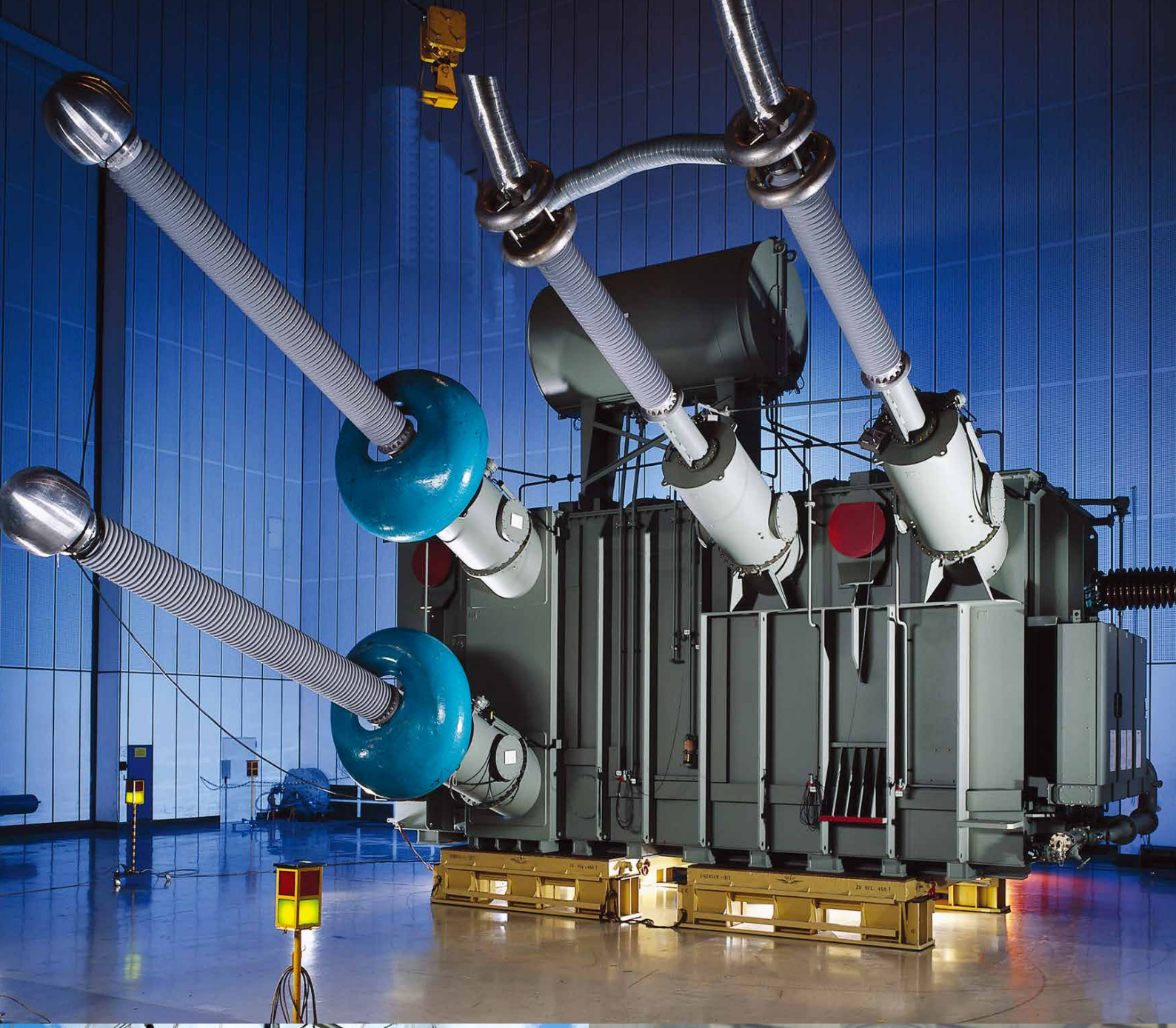
Yokogawa supports the transformer industry with a power analyzer designed specifically for their high accuracy needs . Whether it is during R&D or production testing, the WT3000E Transformer Version ensures the consistently reliable measurements needed by engineers to reduce the total cost of ownership for utility companies.

The WT3000E Transformer Version delivers:

Accuracy – With a guaranteed basic power accuracy of 0.01% of reading, the WT3000E Transformer Version is the world's most accurate power analyzer even at power factors as low as 0.001.

Reliability – The proven stability of the WT3000E Transformer Version ensures that consistent precision measurements are made for every one of your tests.

Trust – Complete with a calibration certificate from Yokogawa's ISO17025 accredited calibration laboratory, the WT3000E Transformer Version delivers the confidence needed in low power factor measurements to ensure compliance with the IEC60076-8 standard.



Minimize losses with the world's most accurate power analyzer

Unmatched accuracy – even at lower power factors

The WT3000E Transformer Version is the world's most accurate precision power analyzer, offering the best accuracies at low power factors for commercial frequencies of 44 to 66 Hz. Even at power factors as low as 0.01 at 100 V and 1 A, the WT3000E Transformer Version offers an accuracy of 0.5% of the reading. This makes the power analyzer ideal for the precision testing of transformer losses according to the IEC60076-8 standard.

Accuracy specifications

Range 100V 1A or 5A		
Frequency 44-66 Hz		
Specification value in % of reading, valid for 24 months		
Temperature 23 +/- 4° C		
Integration Time 2 seconds		
Voltage 100V range:		
20% to 60% of range	0.025%	
60% to 110% of range	0.005%	
Current 1A or 5A range:		
20% to 60% of range	0.025%	
60% to 110% of range	0.005%	
Phase 100V, 1A or 5A range:		
10 to 170°	0.002°	Normal mode
-10 to -170°	0.002°	Normal mode
Phase 100V, 1A or 5A range:		
0 to +/-180°	0.002°	Harmonics mode
Power 100V, 1A or 5A range:		
60% to 110% of range		
PF 1	0.01%	
PF <1 to 0.5	0.03%	
PF <0.5 to 0.05	0.15%	
PF <0.05 to 0.02	0.3%	
PF <0.02 to 0.01	0.5%	
PF <0.01 to 0.001	7%	
20% to 60% of range		
PF 1	0.03%	
PF <1 to 0.5	0.06%	
PF <0.5 to 0.05	0.15%	
PF <0.05 to 0.02	0.35%	
PF <0.02 to 0.01	0.6%	
PF <0.01 to 0.001	9%	

As shown in the table above, the WT3000E Transformer Version goes above and beyond the industry expectations by calibrating at power factors as low as 0.001.

Direct readout of corrected power for potential transformers

When small loads are connected to the potential transformers, the WT3000E Transformer Version directly supports both standard formulas used to calculate the correct power.

IEC76-1(1976), ANSI/IEEE C57.12.90-1993

$$P = \frac{P_m}{P_1 + k \cdot P_2}$$

$$k = \left(\frac{U'}{U}\right)^2$$

IEC76-1(1993)

$$P_0 = P_m (1 + d)$$

$$d = \frac{U - U'}{U'}$$

Where

P or P_0 = corrected power
P_m = measured power
P_1 = ratio of hysteresis loss to total iron losses
P_2 = ratio of eddy current losses to total iron losses
U' = mean value of voltage
U = rms value of voltage

Precision compensation functions

These functions compensate for the loss caused by the wiring of each element. The WT3000E Transformer Version provides the following three types of correction functions to measure power and efficiency.

- Wiring Compensation
- Efficiency Compensation
- Compensation for the Two-Wattmeter Method

For U-I Wiring
Compensated instantaneous voltage:
u'(n) = u(n) – Rixi(n)
The instantaneous current is i(n).

For I-U Wiring
Compensated instantaneous current:
i'(n) = i(n) – u(n)/Ru
The instantaneous voltage is u(n).

These compensation functions enable the WT3000E Transformer Version to measure power accurately and precisely.

Accredited calibration certificate

When every kilowatt lost beyond specified limits can cost thousands of dollars in fines, it becomes necessary to have confidence in the measurement of power losses, particularly under no load conditions and power factors as low as 0.01.

To address this, the WT3000E Transformer Version is calibrated, tested and measured at 53Hz at power factors of 1, 0.5, 0.05, 0.01 and 0.001. This enables the integrated transformer measurement system to measure power losses with great accuracy and capture any drift outside the limits described in the IEC60076-8 Standard.

As the only ISO 17025 certified non-governmental organization that offers calibration up to 100kHz, Yokogawa is uniquely equipped to guarantee the power accuracy specifications of the WT3000E Transformer Version and improve upon it with calibration.

Accreditation bodies

The calibration capabilities of the Yokogawa Calibration laboratory in the Netherlands are accredited by the Raad voor Accreditatie, a member of the European Co-operation for Accreditation (EA) and signatory to the ILAC Mutual Recognition Arrangements (MRA) for the mutual recognition of calibration Certificates. ILAC (International Laboratory Accreditation Cooperation) is the international organization for accreditation bodies.

CALIBRATION
RvA K 164

ilac-MRA

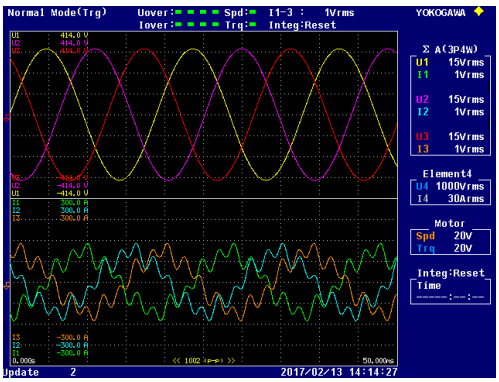
Power calibration 53 Hz 100 V & 1 A range PF = Inductive *(Excerpt from a sample calibration certificate from Yokogawa Europe)*

Range	Applied	Measured	±Uncertainty	Unit	Deviation %/VA
100 V 1A PF=1	100,000	100,001	0,004	W	0,0001
100V 1A PF=0.5	50,000	50,003	0,004	W	0,0007
100 V 1A PF=0.05	5,000	5,003	0,003	W	0,0009
100 V 1A PF=0.02	2,000	2,003	0,003	W	0,0008
100 V 1A PF=0.01	1,000	1,003	0,003	W	0,0009
100 V 1A PF=0.001	0,100	0,103	0,003	W	0,0009
80 V 1A PF=1	80,000	80,001	0,004	W	0,0009
80V 1A PF=0.5	40,000	40,003	0,003	W	0,0006
80 V 1A PF=0.05	4,0000	4,0022	0,0028	W	0,0008
80 V 1A PF=0.02	1,6000	1,6021	0,0028	W	0,0009
80 V 1A PF=0.01	0,8000	0,8023	0,0028	W	0,0006
80 V 1A PF=0.001	0,0800	0,0822	0,0028	W	0,0004
60 V 0.8A PF=1	48,000	48,001	0,003	W	0,0031
60V 0.8A PF=0.5	24,0000	24,0010	0,0021	W	0,0021
60 V 0.8A PF=0.05	2,4000	2,4011	0,0017	W	0,0012
60 V 0.8A PF=0.02	0,9600	0,9612	0,0017	W	0,0008
60 V 0.8A PF=0.01	0,4800	0,4813	0,0017	W	0,0008
60 V 0.8A PF=0.001	0,0480	0,0493	0,0017	W	0,0010
40 V 0.5A PF=1	20,0000	19,9995	0,0020	W	0,0030
40 V 0.5A PF=0.5	10,0000	10,0000	0,0013	W	0,0020
40 V 0.5A PF=0.05	1,0000	1,0003	0,0009	W	0,0010
40 V 0.5A PF=0.02	0,4000	0,4003	0,0009	W	0,0010
40 V 0.5A PF=0.01	0,2000	0,2003	0,0009	W	0,0010
40 V 0.5A PF=0.001	0,0200	0,0203	0,0009	W	0,0005

Features and benefits

Intuitive high resolution display

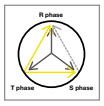
Compare up to 4 different input signals in numeric, waveform, vector or trend display modes on the 8.4inch TFT display of the WT3000E Transformer Version. Power readings are displayed with a resolution of up to six digits minimizing the uncertainties in calibration. Clear overload and safety indicators ensure that incidents are avoided.



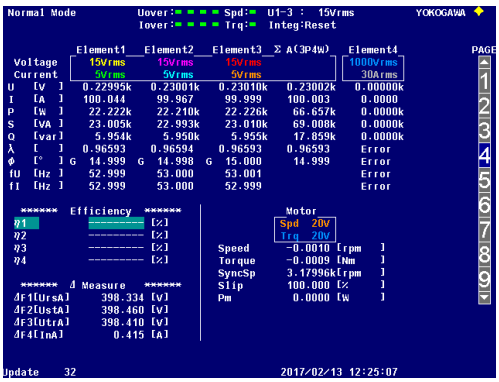
Intuitive high resolution display

Three phase delta calculation

Check line voltage and phase voltage simultaneously without changing wiring. The built-in delta computation function allows both star-delta and delta-star conversion. It allows users to calculate individual phase voltages from the line voltages measured in a three-phase, three-wire (3V3A) system.



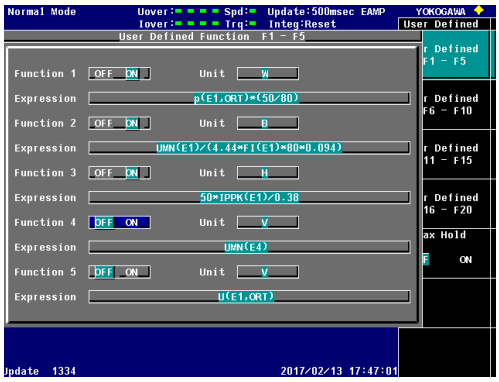
The R-S line-to-line voltage can be calculated in systems measured from a three-phase, three-wire method (using two input elements).



Delta calculation display

User-defined events and computations

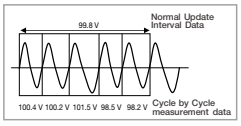
The WT3000E Transformer Version has an event trigger function that allows users to set limits for capture of readings that fall into or out of a specific range of power, current or other parameters . Data that meets the trigger conditions are stored, printed, saved to a USB memory device etc. Users can also define and use up to 20 expressions for custom calculations.



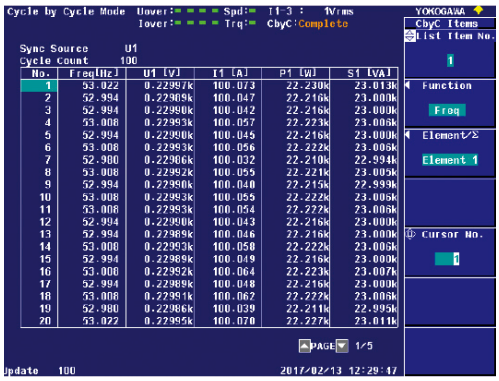
User-defined function - expression setting screen

Cycle by cycle trend analysis

This analysis function enables users to list the measurement parameters such as voltage, current, and active power for each cycle. Input frequencies from 0.1 Hz to 1000 Hz can be measured and up to 3000 data can be saved in .CSV format.



Also by using Yokogawa's PC application software users can graphically display the data by cycle.



Measurement data display

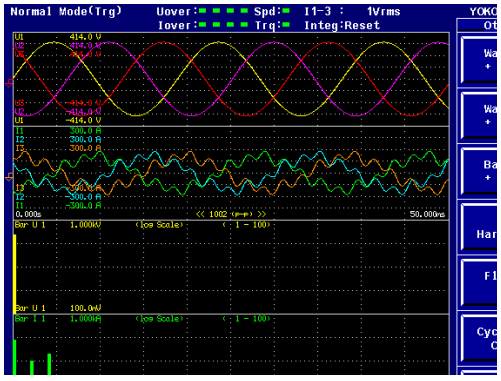
Advanced waveform analysis

Harmonic measurement in normal measurement mode
During the no-load loss test, the current will be a distorted waveform due to the eddy current and hysteresis in the core. The WT3000E Transformer Version enables users to measure harmonics and distortions while simultaneously measuring power.

Wide bandwidth harmonic measurement
The function is useful for ascertaining the distortion factor and harmonic components in measurements of fundamental frequencies from 0.1 Hz to 2.6 kHz.

FFT (Fast Fourier Transform)
The WT3000E Transformer Version can analyze and display a waveform's individual frequency components. It can also check signal components other than the integer multiples of the fundamental wave.

Save raw waveform sample data
WT3000E Transformer Version can save sampling raw data of input waveforms, waveform computations, and FFT computations. The saved data can be accessed for any kind of computation by PC software.



Advanced Waveform and Harmonic

Easy PC application software

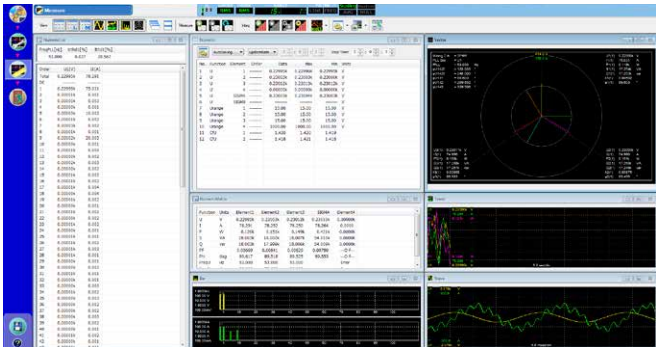
This application software is a free tool which is used to read numeric, waveform, and harmonic data from the WT3000E Transformer Version Precision Power Analyzer through a communications interface such as GP-IB,USB (/C12 option) or Ethernet.

Numeric data
The voltage, current, power and various other measured parameters can be simultaneously displayed for one to four elements and ∑A and ∑B calculations.

Harmonics measurement
The software can numerically or graphically display the results of measured harmonics up to the 100th order for parameters such as voltage, current, power and phase angle.

Waveform
Voltage and current waveforms can be monitored using the software and be used to confirm such things as phase differences between the voltage and current, and waveform distortion.

Viewing trends
The software can be used to capture and view various data measured using the WT3000E Transformer Version, on the PC in a graphical trend format. This feature enables the users to monitor power supply voltage fluctuations, changes in current consumption and other time-based variations.



WTViewerEfree

The WT3000E Transformer Version in detail

1 External media slot
Settings, waveform display data, numerical data, and screen image data can be saved to external media

2 U/I range display
Choose voltage ranges from 15V to 1000 V and current ranges from 0.5A to 30 A in RMS, Mean, DC and RMEAN

3 Element setting
Choose the element(s) for your measurement settings

4 Display settings
Choose one or more display modes from numeric, waveform, vector or trend.

5 Measurement item selection
Choose measurement items and elements for readings

6 Integration settings
Integrate instantaneously measured values

7 Data saving
Save or store measurement data or images

8 Built-in printer
(option /B5) Print measurement data

9 USB port for storage and peripherals including keyboard, mouse etc.

1 Voltage Input terminals
150mv to 1100Vrms

2 Current input terminals
Direct input 30A element

3 GP-IB port - General purpose interface bus

4 BNC connector for two-system synchronized measurement

5 Ethernet port with RJ-45 connector for TCP/IP access.

6 USB port (option /C12) for PC connectivity

7 VGA port (option/V1)
Video signal output for enhanced display on analog RGB displays

Specifications

Key specifications for WT3000E Transformer Version

Range 100V 1A or 5A
Frequency 44-66 Hz

Specification value in % of reading, valid for 24 months
Temperature 23 +/- 4° C
Integration Time 2 seconds

Voltage 100V range:		
20% to 60% of range	0.025%	
60% to 110% of range	0.005%	
Current 1A or 5A range:		
20% to 60% of range	0.025%	
60% to 110% of range	0.005%	
Phase 100V, 1A or 5A range:		
10 to 170°	0.002°	Normal mode
-10 to -170°	0.002°	Normal mode
Phase 100V, 1A or 5A range:		
0 to +/-180°	0.002°	Harmonics mode
Power 100V, 1A or 5A range:		
20% to 60% of range		
PF 1	0.03%	
PF <1 to 0.5	0.06%	
PF <0.5 to 0.05	0.15%	
PF <0.05 to 0.02	0.35%	
PF <0.02 to 0.01	0.6%	
PF <0.01 to 0.001	9%	
60% to 110% of range		
PF 1	0.01%	
PF <1 to 0.5	0.03%	
PF <0.5 to 0.05	0.15%	
PF <0.05 to 0.02	0.3%	
PF <0.02 to 0.01	0.5%	
PF <0.01 to 0.001	7%	

Specifications for other conditions are described in subsequent sections.

Inputs

Input terminal type
- Voltage: Plug-in terminal (safety terminal)
- Current: Direct input: Large binding post
  External Current Sensor input: Insulated BNC connector

Input type
- Voltage: Floating input, resistive potential divider method
- Current: Floating input, shunt input method

Measurement range (rated value)
- Voltage: 15 V, 30 V, 60 V, 100 V, 150 V, 300 V, 600 V, 1000 V (for crest factor 3)
  7.5 V, 15 V, 30 V, 50 V, 75 V, 150 V, 300 V, 500 V (for crest factor 6)
- Current (30 A input element)
  - Direct input: 500 mA, 1 A, 2 A, 5 A, 10 A, 20 A, and 30 A (for crest factor 3)
    250 mA, 500 mA,1 A, 2.5 A, 5 A, 10 A, and 15 A (for crest factor 6)
  - External Current Sensor input
    50 mV, 100 mV, 200 mV, 500 mV, 1 V, 2 V, 5 V, and 10 V (for crest factor 3)
    25 mV, 50 mV, 100 mV, 250 mV, 500 mV, 1 V, 2.5 V, and 5 V (for crest factor 6)

Input impedance
- Voltage: Input resistance: Approx. 10 MΩ, input capacitance: Approx. 5 pF
  - External Current Sensor input
    Input resistance: Approx. 1 MΩ, input capacitance: Approx. 40 pF
- Current (30 A input element)
  - Direct input: Approx. 5.5 mΩ + approx. 0.03 μH
  - External Current Sensor input
    Input resistance: Approx. 1 MΩ, input capacitance: Approx. 40 pF

Instantaneous maximum allowable input (1s or less)
- Voltage: Peak value of 2500 V or RMS value of 1500 V, whichever is less.
  Peak value less than or equal to 10 times the measurement range.
- Current (30 A input element)
  - Direct input: Peak value of 150 A or RMS value of 50 A, whichever is less.
  - External Current Sensor input
    Peak value less than or equal to 10 times the measurement range.

Continuous maximum allowable input
- Voltage: Peak value of 1600 V or RMS value of 1100 V, whichever is less.
  Or up to 1500 Vdc. This is a reference value.
  - External Current Sensor input
    Peak value less than or equal to 5 times the measurement range.
- Current (30 A input element)
  - Direct input: Peak value of 90 A or RMS value of 33 A, whichever is less.
  - External Current Sensor input
    Peak value less than or equal to 5 times the measurement range.

Continuous maximum common mode voltage (50/60 Hz)
- Voltage input terminals: 1000 Vrms
- Current input terminals: 1000 Vrms (Maximum allowable voltage that can be measured)
  600 Vrms (Rated voltage of EN61010-2-030 standard)
- External current sensor input connector: 600 Vrms

Important Safety Note:
Do not touch the inside of the BNC connector of the External Current Sensor input for safety reasons.

Rated voltage to ground
- Voltage input terminals: 1000 V
- Current input terminals: 1000 V (Maximum allowable voltage that can be measured)
  600 V (Rated voltage of EN61010-2-030 standard)
- External current sensor input connector: 600 V

Important Safety Note:
Do not touch the inside of the BNC connector of the External Current Sensor input for safety reasons.

Influence from common mode voltage
Apply 1000 Vrms with the voltage input terminals shorted and the current input terminals open.
- 50/60 Hz: ±0.01% of range or less
- Reference value up to 200 kHz
  Voltage: ±3/range × f% of range or less. However, 3% or less.
  Current direct input and external current sensor input:
  ±(max. range/range) × 0.001 × f% of range or less.

However, 0.01% or more. The units of f are kHz. The max. range within equations is 30 A or 10 V.

Line filter	Select OFF, 500 Hz, 5.5 kHz, or 50 kHz.
Frequency filter	Select OFF, or ON
A/D converter	Simultaneous voltage and current conversion and 16-bit resolution. Conversion speed (sampling rate): Approximately 5 μs. See harmonic measurement items for harmonic display.
Range switching	Can be set for each input element.

Auto range functions
- Increasing range value
  - When the measured values of U and I exceed 110% of the range rating
  - When the peak value exceeds approximately 330% of the range rating (or approximately 660% for crest factor 6)
- Decreasing range value
  - When the measured values of U and I fall to 30% or less of the range rating, and Upk and Ipk are 300% or less of the lower range value (or 600% for crest factor 6)

Display

Display	8.4-inch color TFT LCD monitor
Total number of pixels*	640 (horiz.) × 480 (vert.) dots
Waveform display resolution	501 (horiz.) × 432 (vert.) dots

*Up to 0.02% of the pixels on the LCD may be defective.

Display update
Same as the data update rate.
Exceptions are listed below.
- The display update interval of numeric display (4, 8, and 16 items) is 250 ms when the data update rate is 50 ms or 100 ms.
- The display update interval of numeric display (ALL, Single List, and Dual List) is 500 ms when the data update rate is 50 ms to 250 ms.
- The display update rate of the trend display, bar graph display, and vector display is 1 s when the data update rate is 50 ms to 500 ms.
- The display update interval of the waveform display is approximately 1 s when the data update rate is 50 ms to 1 s. However, it may be longer depending on the trigger setting.

Calculation function

		Single-phase, 3 wire	3 phase, 3 wire	3 phase, 3 wire (3 voltage 3 current)	3 phase, 4 wire
UΣ [V]		(U1+U2)/2		(U1+U2+U3)/3	
IΣ [A]		(I1+I2)/2		(I1+I2+I3)/3	
PΣ [W]		P1+P2			P1+P2+P3
SΣ [VA]	TYPE1 TYPE2	S1+S2	$\frac{\sqrt{3}}{2}$(S1+S2)	$\frac{\sqrt{3}}{3}$(S1+S2+S3)	S1+S2+S3
	TYPE3	$\sqrt{P\Sigma^2+Q\Sigma^2}$			
QΣ [var]	TYPE1	Q1+Q2			Q1+Q2+Q3
	TYPE2	$\sqrt{S\Sigma^2-P\Sigma^2}$			
	TYPE3	Q1+Q2			Q1+Q2+Q3
PcΣ [W]		Pc1+Pc2			Pc1+Pc2+Pc3
WPΣ [Wh]		WP1+WP2			WP1+WP2+WP3
WP+Σ [Wh]		WP^+1+WP^+2			$WP^+1+WP^+2+WP^+3$
WP−Σ [Wh]		WP^-1+WP^-2			$WP^-1+WP^-2+WP^-3$
qΣ [Ah]		q1+q2			q1+q2+q3
q+Σ [Ah]		q^+1+q^+2			$q^+1+q^+2+q^+3$
q−Σ [Ah]		q^-1+q^-2			$q^-1+q^-2+q^-3$
WSΣ [VAh]		$\frac{1}{N}\sum_{n=1}^{N} S\Sigma(n) \times \text{Time}$ SΣ(*n*) is the n[th] apparent power Σ function, and N is the number of data updates.			
WQΣ [varh]		$\frac{1}{N}\sum_{n=1}^{N} \lvert Q\Sigma(n) \rvert \times \text{Time}$ QΣ(*n*) is the n[th] reactive power Σ function, and N is the number of data updates.			
λΣ		$\frac{P\Sigma}{S\Sigma}$			
ϕΣ [°]		$\cos^{-1}\left(\frac{P\Sigma}{S\Sigma}\right)$			

Note 1) The instrument's apparent power (S), reactive power (Q), power factor (λ), and phase angle (ϕ) are calculated using measured values of voltage, current, and active power.
(However, reactive power is calculated directly from sampled data when TYPE3 is selected.) Therefore, when distorted waveforms are input, these values may be different from those of other measuring instruments based on different measuring principals.

Note 2) The value of Q in the QΣ calculation is calculated with a preceding minus sign (−) when the current input leads the voltage input, and a plus sign when it lags the voltage input, so the value of QΣ may be negative.

η [%]	Set a efficiency calculation up to 4
User-defined functions F1 to F20	Create equations combining measurement function symbols, and calculate up to twenty numerical data.

Waveform display (WAVE display)

Waveform display items	Voltage and current from elements 1 through 4

Accuracy

[Conditions] *These conditions are all accuracy condition in this section.
Temperature: 23±5°C, Humidity: 30 to 75%RH, Input waveform: Sine wave, Common mode voltage: 0 V, Crest factor: 3, Line filter: OFF, λ (power factor): 1, After warm-up.
After zero level, compensation or range value change while wired. f is frequency (kHz), 6-month

30 A input element, External current sensor input, Voltage input

	Voltage/current	Power
DC	0.05% of reading + 0.05% of range (U, 30 A, Sensor)	0.05% of reading + 0.1% of range
0.1 Hz ≤ f < 30 Hz	0.03% of reading + 0.05% of range	0.08% of reading + 0.1% of range
30 Hz ≤ f < 45 Hz	0.03% of reading + 0.05% of range	0.05% of reading + 0.05% of range
45 Hz ≤ f ≤ 66 Hz	0.01% of reading + 0.03% of range	0.01% of reading + 0.03% of range
66 Hz < f ≤ 1 kHz	0.03% of reading + 0.05% of range	0.05% of reading + 0.05% of range
1 kHz < f ≤ 10 kHz	0.1% of reading + 0.05% of range	0.15% of reading + 0.1% of range
10 kHz < f ≤ 50 kHz	0.3% of reading + 0.1% of range	0.3% of reading + 0.2% of range
50 kHz < f ≤ 100 kHz	0.012 × f % of reading + 0.2% of range	0.014 × f % of reading + 0.3% of range
100 kHz < f ≤ 500kHz	0.009 × f % of reading + 0.5% of range	0.012 × f % of reading + 1% of range
500 kHz < f ≤ 1 MHz	(0.022 × f – 7)% of reading + 1% of range	(0.048 × f – 19)% of reading + 2% of range

U: Voltage, sensor: external Current Sensor input, 30 A: 30 A direct current input

*The units of f in the reading error equation are kHz.

- When the external Current Sensor input range is 50 mV, add 0.01% of reading + 0.01% of range to the power accuracy at 45 Hz ≤ f ≤ 66 Hz.

30 A input element

- Accuracy of waveform display data, Upk and Ipk Add 3% of range to the accuracy above. However, add 3% of range + 5 mV for external current sensor input (reference value). Effective input range is within ±300% (within ±600% for crest factor 6)
- Influenced by changes in temperature after zero level correction or range value changes.
  Add 50 ppm of range/°C to the voltage DC accuracy, 0.2 mA/°C to the 30 A input current DC accuracy, 3 μA/°C
  and influence of voltage times influence of current to the power DC accuracy.
- For self-generated heat caused by current input on an DC input signal, add 0.00002 × I²% of reading + 3 × I² μA to the current accuracy.
- For self-generated heat caused by current input on an AC input signal, add 0.00002 × I²% of reading.

I is the current reading (A). The influence from selfgenerated heat continues until the temperature of the shunt resistor inside the WT3000E lowers even if the current input changes to a small value.

- Additions to accuracy according to the data update rate Add 0.05% of reading when it is 100 ms, and 0.1% of reading when 50 ms.
- Range of guaranteed accuracy by frequency, voltage, and current All accuracies between 0.1 Hz and 10 Hz are reference values.
  If the voltage exceeds 750 V at 30 kHz to 100 kHz, or exceeds {2.2 × 10⁴/ f (kHz)} V at 100 kHz to 1 MHz, the voltage and power values are reference values.
  If the current exceeds 20 A at DC, 10 Hz to 45Hz, or 400 Hz to 200 kHz; or if it exceeds 10 A at 200 kHz to 500 kHz; or exceeds 5 A at 500 kHz to 1 MHz, the current and power accuracies are reference values.
- Accuracy for crest factor 6: Range accuracy of crest factor 3 for two times range.

Total power accuracy with respect to the range for an arbitrary power factor λ (exclude λ = 1)

Power When λ = 0 (500 mA to 30 A range)
Apparent power reading × 0.03% in the 45 to 66 Hz range

All other frequencies are as follows (however, these are only reference values):
Apparent power reading × (0.03 + 0.05 × f (kHz))%

When λ = 0 (5 mA to 200 mA range)
Apparent power reading × 0.1% in the 45 to 66 Hz range

All other frequencies are as follows (however, these are only reference values):
Apparent power reading × (0.1+ 0.05 × f (kHz))%

0 < λ < 1 (45 Hz to 66 Hz)
(Power reading) × [(power reading error %) + (power range error %) × (power range/apparent power indication value) + [tanϕ × (influence when λ = 0)%}.
ϕ is the phase angle between the voltage and current.
Value of "influence % when λ = 0" will be changed by frequency according to above expressions.

Influence of line filter

Voltage/Current

	When cutoff frequency is 500 Hz	Under 45 Hz: Add 0.5% of reading 45 to 66 Hz: Add 0.2% of reading
	When cutoff frequency is 5.5 kHz	66 Hz or less: Add 0.2% of reading 66 to 500 Hz: Add 0.5% of reading
	When cutoff frequency is 50 kHz	500 Hz or less: Add 0.2% of reading 500 to 5 kHz: Add 0.5% of reading
Power	When cutoff frequency is 500 Hz	Under 45 Hz: Add 1% of reading 45 to 66 Hz: Add 0.3% of reading
	When cutoff frequency is 5.5 kHz	66 Hz or less: Add 0.3% of reading 66 to 500 Hz: Add 1% of reading
	When cutoff frequency is 50 kHz	500 Hz or less: Add 0.3% of reading 500 to 5 kHz: Add 1% of reading

Lead/Lag detection (d (LEAD)/G (LAG) of the phase angle and symbols for the reactive power QΣ calculation)

*The s symbol shows the lead/lag of each element, and "–" indicates leading.

Voltage/Current and Power
The phase lead and lag are detected correctly when the voltage and current signals are both sine waves, the lead/lag is 50% of the range rating (or 100% for crest factor 6), the frequency is between 20 Hz and 10 kHz, and the phase angle is ±(5° to 175°) or more.

Temperature coefficient

Voltage/Current and Power: 0.02% of reading/°C at 5 to 18°C or 28 to 40°C.

Effective input range

Voltage/Current and Power
Udc and Idc are 0 to ±130% of the measurement range
Urms and Irms are 1 to 130%* of the measurement range (or 2% to 130% for crest factor 6)
Umn and Imn are 10 to 130% of the measurement range
Urmn and Irmn are 10 to 130%* of the measurement range
Power is 0 to ±130%* for DC measurement, 1 to 130%* of the voltage and current range for AC measurement, and up to ±130%* of the power range.
However, when the data update rate is 50 ms, 100 ms, 5 sec, 10 sec, or 20 sec, the synchronization source level falls below the input signal of frequency measurement.

*110% for maximum range of direct voltage and current inputs. The accuracy at 110 to 130% of the measurement range is the reading error × 1.5.
The accuracy over 110% to 150% of DC voltage input under 1000 V range is adding the reading error × 1.5. It is a reference value.

Max. display

Voltage/Current and Power
140%* of the voltage and current range rating.

*160% when the voltage range is 1000 V.

Min. display

Voltage/Current and Power
Urms and Irms are up to 0.3% relative to the measurement range (or up to 0.6% for a crest factor of 6).
Umn, Urmn, Imn, and Irmn are up to 2% (or 4% for a crest factor of 6).
Below that, zero suppress. Current integration value q also depends on the current value.

Measurement lower limit frequency

Voltage/Current and Power

Data update rate	50 ms	100 ms	250 ms	500 ms	1 s	2 s	5 s	10 s	20 s
Measurement lower limit frequency	45 Hz	25 Hz	20 Hz	10 Hz	5 Hz	2 Hz	0.5 Hz	0.2 Hz	0.1 Hz

Accuracy of apparent power S

Voltage accuracy + current accuracy

Accuracy of reactive power Q

Accuracy of apparent power + $(\sqrt{(1.0004-\lambda^2)} - \sqrt{(1-\lambda^2)}) \times 100\%$ of range

Accuracy of power factor λ

$\pm[(\lambda - \lambda/1.0002) + |\cos\phi - \cos\{\phi + \sin^{-1}$(influence of power factor of power when λ = 0%)/100}|] ±1 digit when voltage and current is at rated input of the measurement range.
ϕ is the phase difference of voltage and current.

Accuracy of phase difference ϕ

$\pm[|\phi - \cos^{-1}(\lambda/1.0002)| + \sin^{-1}${(influence of power factor of power when λ = 0%)/100}]deg ±1 digit when voltage and current is at rated input of the measurement range

One-year accuracy

Voltage/Current and Power
Add the accuracy of reading error (Six-month) × 0.5 to the accuracy Six-month

Functions

Measurement method	Digital multiplication method
Crest factor	3 or 6 (when inputting rated values of the measurement range), and 300 relative to the minimum valid input. However, 1.6 or 3.2 at the maximum range (when inputting rated values of the measurement range), and 160 relative to the minimum valid input.
Measurement period	Interval for determining the measurement function and performing calculations. Period used to determine and compute the measurement function. • The measurement period is set by the zero crossing of the reference signal (synchronization source) when the data update interval is 50 ms, 100 ms, 5 s, 10 s, or 20 s (excluding watt hour WP as well as ampere hour q during DC mode). • Measured through exponential averaging on the sampled data within the data update interval when the data update interval is 250 ms, 500 ms, 1 s, or 2 s. • For harmonic measurement, the measurement period is from the beginning of the data update interval to 9000 points at the harmonic sampling frequency.
Wiring	You can select one of the following five wiring settings. 1P2W (single phase, two-wire), 1P3W (single phase, 3 wire), 3P3W (3 phase, 3 wire), 3P4W (3 phase, 4 wire), 3P3W (3V3A) (3 phase, 3 wire, 3 volt/3 amp measurement). However, the number of available wiring settings varies depending on the number of installed input elements. Up to four, or only one, two, or three wiring settings may be available.
Compensation functions	• Efficiency compensation Compensation of instrument loss during efficiency calculation • Wiring compensation Compensation of instrument loss due to wiring • 2 Wattmeter method compensation (Delta Function) Compensation for 2 wattmeter method
Scaling	When inputting output from external current sensors, VT, or CT, set the current sensor conversion ratio, VT ratio, CT ratio, and power coefficient in the range from 0.0001 to 99999.9999.
Input filter	Line filter or frequency filter settings can be entered.

Averaging	The average calculations below are performed on the normal measurement parameters of voltage U, current I, power P, apparent power S, reactive power Q. Power factor λ and phase angle Φ are determined by calculating the average of P and S. Select exponential or moving averaging. • Exponential average Select an attenuation constant of 2, 4, 8, 16, 32, or 64. • Moving average Select the number of averages from 8, 16, 32, 64, 128, or 256. The average calculations below are performed on the harmonic display items of voltage U, current I, power P, apparent power S, reactive power Q. Power factor I is determined by calculating the average of P and Q. Only exponential averaging is performed. Select an attenuation constant of 2, 4, 8, 16, 32 or 64.
Data update rate	Select 50 ms, 100 ms, 250 ms, 500 ms, 1 s, 2 s, 5 s, 10 s, or 20 s.
Response time	At maximum, two times the data update rate (only during numerical display)
Hold	Holds the data display.
Single	Executes a single measurement during measurement hold.
Zero level compensation/Null	Compensates the zero level.

Integration	
Mode	Select a mode of Manual, Standard, Continuous (repeat), Real Time Control Standard, or Real Time Control Continuous (Repeat).
Timer	Integration can be stopped automatically using the integration timer setting. 0000 h 00 m 00 s to 10000 h 00 m 00 s
Count over	If the count over integration time reaches the maximum integration time (10000 hours), or if the integration value reaches max/min display integration value (±999999 M), the elapsed time and value is saved and the operation is stopped.
Accuracy	±[power accuracy (or current accuracy) + time accuracy]
Time accuracy	±0.02% of reading

Display	
Numerical display function	
Display resolution	600000
Number of display items	Select 4, 8, 16, all, single list, or dual list.
Waveform display items	
No. of display rasters	501
Display format	Peak-peak compressed data
Time axis	Range from 0.5 ms to 2 s/div. However, it must be 1/10th of the data update rate.
Triggers	
Trigger type	Edge type
Trigger mode	Select Auto, Normal or OFF. Triggers are turned OFF automatically during integration.
Trigger source	Select from the voltage or current applied to the input element and external clock.
Trigger slope	Select (Rising), (Falling), or (Rising/Falling).
Trigger level	When the trigger source is the voltage or current input to the input elements. Set in the range from the center of the screen to ±100% (top/bottom edge of the screen). Setting resolution: 0.1% When the trigger source is Ext Clk, TTL level.
Vertical axis zoom	Voltage and current input to the waveform vertical axis zoom input element can be zoomed along the vertical axis. Set in the range of 0.1 to 100 times.
ON/OFF	ON/OFF can be set for each voltage and current input to the input element.
Format	You can select 1, 2, 3 or 4 splits for the waveform display.
Interpolation	Select dot or linear interpolation.
Graticule	Select grid or cross scale display.
Other display ON/OFF	Upper/lower limit (scale value), and waveform label ON/OFF.
Cursor measurements	When you place the cursor on the waveform, the value of that point is measured.
Zoom function	No time axis zoom function

*Since the sampling frequency is approximately 200 kHz, waveforms that can be accurately reproduced are those of about 10 kHz.

Vector display/Bar graph display (requires /G6 option)	
Vector display	Vector display of the phase difference in the fundamental waves of voltage and current. (without Single Input Element model)
Bar graph display	Displays the size of each harmonic in a bar graph.
Trend display	Number of measurement channels Up to 16 parameters. Displays trends (transitions) in numerical data of the measurement functions in a sequential line graph.
Simultaneous display	Two windows can be selected (from numerical display, waveform display, bar graph display, or trend display) and displayed in the upper and lower parts of the screen.

Saving and loading data

Settings, waveform display data, numerical data, and screen image data can be saved to media.*
Saved settings can be loaded from a medium.

*PC card, USB memory

Store function	
Internal memory size	Approx. 30 MB
Store interval (waveform OFF)	Maximum 50 msec to 99 hour 59 minutes 59 seconds.

Guideline for Storage Time (Waveform display OFF, Integration function OFF)

Number of measurement channels	Measured items (Per CH)	Storage interval	Storable Amnt. of data
2 ch	3	50 ms	Approx. 10 hr 20 m
2 ch	10	1 sec	Approx. 86 hr
4 ch	10	50 ms	Approx. 2 hr 30 m
4 ch	20	1 sec	Approx. 24 hr

Note: Depending on the user-defined math, integration, and other settings, the actual measurement time may be shorter than stated above.
Store function can't use in combination with auto print function.

Delta calculation function

	Item	Specifications
Voltage (V)	difference	ΔU1: Differential voltage determined by computation u1 and u2
	3P3W -> 3V3A	ΔU1: Line voltage that are not measured but can be computed for a threephase, three-wire system
	DELTA -> STAR	ΔU1, ΔU2, ΔU3: Line voltage that can be computed for a three phase, three-wire (3V3A) system
	STAR -> DELTA	ΔU1, ΔU2, ΔU3: Neutral line voltage that can be computed for a three phase, four-wire system
Current (A)	difference	ΔI1: Differential current determined by computation
	3P3W -> 3V3A	Phase current that are not measured but can be computed
	DELTA -> STAR	Neutral line current
	STAR -> DELTA	Neutral line current

Cycle-by-cycle measurement	
Measurement items	Freq (Synch source frequency), U, I, P, S, Q, λ
Synch source	Select an external source of U1, I1, U2, I2, U3, I3, U4, or I4. (the above parameters are measured continuously for each cycle of the one sync source signal)
Number of measurements	10 to 3000
Timeout time	0, 1 to 3600 seconds (set in units of seconds). (when it is set to 0, it is approx. 24 hours)
Synch source frequency range	1 Hz to 1000 Hz (for U and I) 0.1 Hz to 1000 Hz (for Ext Clk)
Accuracy	
U, I, P	Add [(0.3 + 2 × f)% of reading + ((0.05 + 0.05 × f)% of range] to the accuracy for normal measurement. For external current sensor input, Add (100 + 100 × f) μV to the accuracy.
Freq	Add [(0.3 + 2 × f)% of reading to the accuracy for normal measurement.

*f is kHz

Added frequency measurement (/FQ Optional)

Device under measurement	If the frequency option (/FQ) is installed, the frequencies of the voltages and currents being input to all input elements can be measured.
Measurement method	Reciprocal method

Measurement range

Data update rate	Measuring range
50 ms	45Hz ≤ f ≤ 1 MHz
100 ms	25Hz ≤ f ≤ 1 MHz
250 ms	10 Hz ≤ f ≤ 500 kHz
500 ms	5 Hz ≤ f ≤ 200 kHz
1 s	2.5 Hz ≤ f ≤ 100 kHz
2 s	1.5 Hz ≤ f ≤ 50 kHz
5 s	0.5 Hz ≤ f ≤ 20 kHz
10 s	0.25 Hz ≤ f ≤ 10 kHz
20 s	0.15 Hz ≤ f ≤ 5 kHz

Accuracy

±0.05% of reading
When the input signal levels are greater than or equal to 25 mV (external current sensor input) and 150 mA (current direct input of 30 A input element) respectively, and the signal is greater than or equal to 30% (0.1 Hz to 440 Hz, frequency filter ON), 10% (440 Hz to 500 kHz), or 30% (500 kHz to 1 MHz) of the measurement range. However, when the measuring frequency is smaller or equal to 2 times of above lower frequency, the input signal is greater than or equal to 50%.
Add 0.05% of reading when external current input is smaller than or equal to 50 mV input signal level for each is double for crest factor 6.

Built-in printer (/B5 Optional)	
Printing method	Thermal line-dot
Dot density	8 dots/mm
Paper width	112 mm
Effective recording width	104 mm
Recorded information	Screenshots, list of measured values, harmonic bar graph printouts, settings
Auto print function	Measured values are printed out automatically. However, auto print function can't use in combination with store function.

RGB video signal (VGA) output section (/V1 Optional)	
Connector type	15-pin D-Sub (receptacle)
Output format	VGA compatible

Advanced calculation (/G6)	

Wide bandwidth harmonic measurement

Measured source All installed elements

Format
- PLL synchronization method
  When the PLL source is not set to Smp Clk
- External sampling clock method
  When the PLL source is set to Smp Clk

Frequency range
- PLL synchronization method
  Fundamental frequency of the PLL source is in the range of 10 Hz to 2.6 kHz.
- External sampling clock method
  Input a sampling clock signal having a frequency that is 3000 times the fundamental frequency between 0.1 Hz and 66 Hz of the waveform on which to perform harmonic measurement. The input level is TTL. The input waveform is a rectangular wave with a duty ratio of 50%.

PLL source
- Select the voltage or current of each input element (external current sensor range is greater than or equal to 500 mV) or the external clock (Ext Clk or Smp Clk).
- Input level
  Greater than or equal to 50% of the measurement range rating when the crest factor is 3
  Greater than or equal to 100% of the measurement range rating when the crest factor is 6
- Turn the frequency filter ON when the fundamental frequency is less than or equal to 440 Hz.

FFT data length	9000
FFT processing word length	32 bits
Window function	Rectangular
Anti-aliasing filter	Set using a line filter (OFF, 500 Hz, 5.5 kHz, or 50 kHz).

Sample rate (sampling frequency), window width, and upper limit of measured order

PLL source synchronization method

Fundamental frequency of the PLL source (Hz)	Sample rate (S/s)	Window width against the FFT data length (Frequency of the fundamental wave)	Upper limit of the measured order
10 to 20	f × 3000	3	100
20 to 40	f × 1500	6	100
40 to 55	f × 900	10	100
55 to 75	f × 750	12	100
75 to 150	f × 450	20	62
150 to 440	f × 360	25	62
440 to 1100	f × 150	60	62
1100 to 2600	f × 60	150	20

External sampling clock method

Fundamental frequency of the PLL source (Hz)	Sample rate (S/s)	Window width against the FFT data length (Frequency of the fundamental wave)	Upper l imit of the measured order
0.1 to 66	f × 3000	3	100

Accuracy

±(Reading error + Range error)

When the line filter (500 Hz) is ON

Frequency	Voltage and Current	Power
0.1 Hz ≤ f < 10 Hz	0.7% of reading + 0.3% of range	1.4% of reading + 0.4% of range
10 Hz ≤ f < 30 Hz	0.7% of reading + 0.3% of range	1.4% of reading + 0.4% of range
30 Hz ≤ f < 66 Hz	0.7% of reading + 0.05% of range	1.4% of reading + 0.1% of range

When the line filter (5.5 kHz) is ON

Frequency	Voltage and Current	Power
0.1 Hz ≤ f < 10 Hz	0.25% of reading + 0.3% of range	0.5% of reading + 0.4% of range
10 Hz ≤ f < 30 Hz	0.25% of reading + 0.3% of range	0.5% of reading + 0.4% of range
30 Hz ≤ f ≤ 66 Hz	0.3% of reading + 0.05% of range	0.45% of reading + 0.1% of range
66 Hz < f ≤ 440 Hz	0.6% of reading + 0.05% of range	1.2% of reading + 0.1% of range
440 Hz < f ≤ 1 kHz	1% of reading + 0.05% of range	2% of reading + 0.1% of range
1 kHz < f ≤ 2.5 kHz	2.5% of reading + 0.05% of range	5% of reading + 0.15% of range
2.5 kHz < f ≤ 3.5 kHz	8% of reading + 0.05% of range	16% of reading + 0.15% of range

If the fundamental frequency is between 1 kHz and 2.6 kHz
- Add 0.5% of reading to the voltage and current accuracy for frequencies greater than 1 kHz.
- Add 1% of reading to the power accuracy for frequencies greater than 1 kHz.

When the line filter (50 kHz) is ON

Frequency	Voltage and Current	Power
0.1 Hz ≤ f < 10 Hz	0.25% of reading + 0.3% of range	0.45% of reading + 0.4% of range
10 Hz ≤ f < 30 Hz	0.25% of reading + 0.3% of range	0.45% of reading + 0.4% of range
30 Hz ≤ f ≤ 440 Hz	0.3% of reading + 0.05% of range	0.45% of reading + 0.1% of range
440 Hz < f ≤ 1 kHz	0.7% of reading + 0.05% of range	1.4% of reading + 0.1% of range
1 kHz < f ≤ 5 kHz	0.7% of reading + 0.05% of range	1.4% of reading + 0.15% of range
5 kHz < f ≤ 10 kHz	3.0% of reading + 0.05% of range	6% of reading + 0.15% of range

If the fundamental frequency is between 1 kHz and 2.6 kHz
- Add 0.5% of reading to the voltage and current accuracy for frequencies greater than 1 kHz.
- Add 1% of reading to the power accuracy for frequencies greater than 1 kHz.

When the line filter is OFF

Frequency	Voltage and Current	Power
0.1 Hz ≤ f < 10 Hz	0.15% of reading + 0.3% of range	0.25% of reading + 0.4% of range
10 Hz ≤ f < 30 Hz	0.15% of reading + 0.3% of range	0.25% of reading + 0.4% of range
30 Hz ≤ f ≤ 1 kHz	0.1% of reading + 0.05% of range	0.2% of reading + 0.1% of range
1 kHz < f ≤ 10 kHz	0.3% of reading + 0.05% of range	0.6% of reading + 0.15% of range
10 kHz < f ≤ 55 kHz	1% of reading + 0.2% of range	2% of reading + 0.4% of range

If the fundamental frequency is between 400 Hz and 1 kHz
- Add 1.5% of reading to the voltage and current accuracy for frequencies greater than 10 kHz.
- Add 3% of reading to the power accuracy for frequencies greater than 10 kHz.

If the fundamental frequency is between 1 kHz and 2.6 kHz
- Add 0.5% of reading to the voltage and current accuracy for frequencies greater than 1 kHz and less than or equal to 10 kHz.
- Add 7% of reading to the voltage and current accuracy for frequencies greater than 10 kHz.
  Add 1% of reading to the power accuracy for frequencies greater than 1 kHz and less than equal to 10 kHz.
  Add 14% of reading to the power accuracy for frequencies greater than 10 kHz.

However, all the items below apply to all tables.
- When the crest factor is set to 3
- When λ (power factor) = 1
- Power figures that exceed 440 Hz are reference values.
- For external current sensor range, add 0.2 mV to the current accuracy and add (0.2 mV/external current sensor range rating) × 100% of range to the power accuracy.
- For 30 A direct current input range, add 0.2 mA to the current accuracy and add (0.2 mA/direct current input range rating) × 100% of range to the power accuracy.
- For n^{th} order component input, add {n/(m+1)}/50% of (the n^{th} order reading) to the $n+m^{th}$ order and $n-m^{th}$ order of the voltage and current, and add {n/(m+1)}/25% of (the n^{th} order reading) to the $n+m^{th}$ order and $n-m^{th}$ order of the power.
- Add (n/500)% of reading to the n^{th} component of the voltage and current, and add (n/250)% of reading to the n^{th} component of the power.
- Accuracy when the crest factor is 6: The same as when the range is doubled for crest factor 3.
- The accuracy guaranteed range by frequency and voltage/current is the same as the guaranteed range of normal measurement.

Frequency measurement range	• PLL synchronization method: 2.5 Hz ≤ f ≤ 100 kHz • External sampling clock method: 0.15 Hz ≤ f ≤ 5 kHz
Display update (Depends on the PLL source)	• PLL synchronization method: 1 s or more • External sampling clock method: 20 s or more
PPL timeout value (Depends on the PLL source)	• PLL synchronization method: 5 s or more • External sampling clock method: 40 s or more

IEC Harmonic Measurement (IEC Harmonic/Flicker measurement software 761922 is required.)

Measured source	Select an input element or an ∑ wiring unit
Format	PLL synchronization method
Frequency range	Fundamental frequency of the PLL source is in the range of 45 Hz to 66 Hz.
PLL source	• Select the voltage or current of each input element (external current sensor range is greater than or equal to 500 mV) or the external clock (fundamental frequency). • Input level Greater than or equal to 50% of the measurement range rating when the crest factor is 3 Greater than or equal to 100% of the measurement range rating when the crest factor is 6 • Be sure to turn the frequency filter ON.
FFT data length	9000
FFT processing word length	32 bits
Window function	Rectangular
Anti-aliasing filter	Set using a line filter (cut off is 5.5 kHz).
Interharmonic measurement	Select OFF, Type1, or Type2.

Sample rate (sampling frequency), window width, and upper limit of measured order

Fundamental frequency of the PLL source (Hz)	Sample rate (S/s)	Window width against the FFT data length (Frequency of the fundamental wave)	Upper limit of the measured order
45 to 55	f × 900	10	50
55 to 66	f × 750	12	50

Accuracy
±(Reading error + Range error)
When the line filter (5.5 kHz) is ON

Frequency	Voltage and Current	Power
45 Hz ≤ f ≤ 66 Hz	0.2% of reading + 0.04% of range	0.4% of reading + 0.05% of range
66 Hz < f ≤ 440 Hz	0.5% of reading + 0.05% of range	1.2% of reading + 0.1% of range
440 Hz < f ≤ 1 kHz	1% of reading + 0.05% of range	2% of reading + 0.1% of range
1 kHz < f ≤ 2.5 kHz	2.5% of reading + 0.05% of range	5% of reading + 0.15% of range
2.5 kHz < f ≤ 3.3 kHz	8% of reading + 0.05% of range	16% of reading + 0.15% of range

However, all the items below apply.• When the crest factor is set to 3

- When λ (power factor) = 1
- Power figures that exceed 440 Hz are reference values.
- For external current sensor range, add 0.03 mV to the current accuracy and add (0.03 mV/ external current sensor range rating) × 100% of range to the power accuracy.
- For 30 A direct current input range, add (0.1 mA/direct current input range rating) × 100% of range to the power accuracy.
- For direct current input in a range less than or equal to 200-mA on the 2-A input element, add 0.02% of reading + 0.01% of range to the current accuracy in the range of 45 Hz ≤ f ≤ 66 Hz and add 0.03% of reading + 0.01% of range to the power accuracy.
- For n^{th} order component input, add {n/(m+1)}/50% of (the n^{th} order reading) to the n+m^{th} order and n–m^{th} order of the voltage and current, and add {n/(m+1)}/25% of (the n^{th} order reading) to the n+m^{th} order and n–m^{th} order of the power (only when applying a single frequency).
- Accuracy when the crest factor is 6: The same as when the range is doubled for crest factor 3.
- The accuracy guaranteed range by frequency and voltage/current is the same as the guaranteed range of normal measurement.

Frequency measurement range	45 Hz ≤ f ≤ 1 MHz
Display update	Depends on the PLL source (Approx. 200 ms when the frequency of the PLL source is 45 Hz to 66 Hz.)

Waveform computation function
(Waveform calculation function (MATH) cannot be used with FFT calculation at the same time.)

Computed source	Voltage waveform, current waveform, analog input waveform of torque and speed waveform calculation, FFT performing data
Data type	Voltage, current, and active power of each input element;
Equation	Two equations (MATH1 and MATH2
Operator	+, –, ×, /, ABS (absolute value), SQR (square), SQRT (square root), LOG (natural logarithm), LOG10 (common logarithm), EXP (exponent), NEG (negation), AVG2, AVG4, AVG8, AVG16, AVG32, AVG64 (exponential average).
Sampling clock	Fixed to 200 kHz
Display update	Data update interval + computing time

FFT function specifications
(Waveform calculation function (MATH) cannot be used with FFT calculation at the same time.)

Computed source	Voltage, current, active power, and reactive power of each input element. Active power and reactive power of an ∑ wiring unit.
Type	PS (power spectrum)
Number of computations	Two computations (FFT1 and FFT2)
Maximum frequency of analysis	100 kHz
Number of points	20000 points or 200000 points
Measurement period for the computation	100 ms or 1 s* *The measurement period is 1 s when the number of FFT points is 200 k (when the frequency resolution is 1 Hz). The measurement period is 100 ms when the number of FFT points is 20 k (when the frequency resolution is 10 Hz).
Frequency resolution	10 Hz or 1 Hz
Window function	Rectangular, Hanning, or Flattop
Anti-aliasing filter	Set using a line filter (OFF, 500 Hz, 5.5 kHz, or 50 kHz).
Sampling clock	Fixed to 200 kHz
Display update	Data update rate or (measurement period of the FFT + FFT computing time), whichever is longer

Harmonic measurement in normal measurement
(To measure and display harmonic data requires a data update rate of 500 ms or more)

Measured source	All installed elements
Format	PLL synchronization method
Frequency range	Range in which the fundamental frequency of the PLL source is 10 Hz to 2600 Hz

PLL source

- Select the voltage or current of each input element (external current sensor range is greater than or equal to 500 mV) or the external clock (Ext Clk).
- Input level
  Greater than or equal to 50% of the measurement range rating when the crest factor is 3
  Greater than or equal to 100% of the measurement range rating when the crest factor is 6
- Turn the frequency filter ON when the fundamental frequency is less than or equal to 440 Hz.

FFT data length	9000
FFT processing word length	32 bits
Window function	Rectangular
Anti-aliasing filter	Set using a line filter (OFF. 5.5 kHz or 50 kHz).

Sample rate (sampling frequency), window width, and upper limit of measured order during PLL synchronization

Fundamental the PLL source (Hz)	Sample rate (S/s)	Window width against the FFT data length (Frequency of the fundamental wave)	Upper limit of the measured order
10 to 20	f × 3000	3	100
20 to 40	f × 1500	6	100
40 to 55	f × 900	10	100
55 to 75	f × 750	12	100
75 to 150	f × 450	20	50
150 to 440	f × 360	25	15
440 to 1100	f × 150	60	7
1100 to 2600	f × 60	150	3

Accuracy
±(Reading error + Range error)
When the line filter (5.5 kHz) is ON

Frequency	Voltage and Current	Power
10 Hz ≤ f < 30 Hz	0.25% of reading + 0.3% of range	0.5% of reading + 0.4% of range
30 Hz ≤ f ≤ 66 Hz	0.2% of reading + 0.15% of range	0.4% of reading + 0.15% of range
66 Hz < f ≤ 440 Hz	0.5% of reading + 0.15% of range	1.2% of reading + 0.15% of range
440 Hz < f ≤ 1 kHz	1.2% of reading + 0.15% of range	2% of reading + 0.15% of range
1 kHz < f ≤ 2.5 kHz	2.5% of reading + 0.15% of range	6% of reading + 0.2% of range
2.5 kHz < f ≤ 3.5 kHz	8% of reading + 0.15% of range	16% of reading + 0.3% of range

If the fundamental frequency is between 1 kHz and 2.6 kHz, add 0.5% of reading to the voltage and current accuracy and 1% of reading to the power accuracy when the frequency exceeds 1 kHz.

When the line filter (50 kHz) is ON

Frequency	Voltage and Current	Power
10 Hz ≤ f < 30 Hz	0.25% of reading + 0.3% of range	0.45% of reading + 0.4% of range
30 Hz ≤f ≤ 440 Hz	0.2% of reading + 0.15% of range	0.4% of reading + 0.15% of range
440 Hz < f ≤ 2.5 kHz	1% of reading + 0.15% of range	2% of reading + 0.2% of range
2.5 kHz < f ≤ 5 kHz	2% of reading + 0.15% of range	4% of reading + 0.2% of range
5 kHz < f ≤ 7.8 kHz	3.5% of reading + 0.15% of range	6.5% of reading + 0.2% of range

If the fundamental frequency is between 1 kHz and 2.6 kHz, add 0.5% of reading to the voltage and current accuracy and 1% of reading to the power accuracy when the frequency exceeds 1 kHz.

When the line filter is OFF

Frequency	Voltage and Current	Power
10 Hz ≤ f < 30 Hz	0.15% of reading + 0.3% of range	0.25% of reading + 0.4% of range
30 Hz ≤ f ≤ 440 Hz	0.1% of reading + 0.15% of range	0.2% of reading + 0.15% of range
440 Hz < f ≤ 2.5 kHz	0.6% of reading + 0.15% of range	1.2% of reading + 0.2% of range
2.5 kHz < f ≤ 5 kHz	1.6% of reading + 0.15% of range	3.2% of reading + 0.2% of range
5 kHz < f ≤ 7.8 kHz	2.5% of reading + 0.15% of range	5% of reading + 0.2% of range

If the fundamental frequency is between 1 kHz and 2.6 kHz, add 0.5% of reading to the voltage and current accuracy and 1% of reading to the power accuracy when the frequency exceeds 1 kHz.

However, all the items below apply to all tables.

- When averaging is ON, the averaging type is EXP, and the attenuation constant is greater than or equal to 8.
- When the crest factor is set to 3
- When λ (power factor) = 1
- Power exceeding 440 Hz are reference value.
- For external current sensor range, add 0.2 mV to the current accuracy and add (0.2 mV/ external current sensor range rating) × 100% of range to the power accuracy.
- For 30 A direct current input range, add 0.2 mA to the current accuracy and add (0.2 mA/ direct current input range rating) × 100% of range to the power accuracy.
- For n^{th} order component input, add {n/(m+1)}/50% of (the n^{th} order reading) to the n+m^{th} order and n–m^{th} order of the voltage and current, and add {n/(m+1)}/25% of (the n^{th} order reading) to the n+m^{th} order and n–m^{th} order of the power.
- Add (n/500)% of reading to the n^{th} component of the voltage and current, and add (n/250)% of reading to the n^{th} component of the power.
- Accuracy when the crest factor is 6: The same as when the range is doubled for crest factor 3.
- The accuracy guaranteed range by frequency and voltage/current is the same as the guaranteed range of normal measurement.

If the amplitude of the high frequency component is large, influence of approximately 1% may appear in certain orders. The influence depends on the size of the frequency component. Therefore, if the frequency component is small with respect to the range rating, this does not cause a problem.

Waveform sampling data saving function

Parameters	Voltage waveform, current waveform, FFT performing data
Data type	CSV format, WVF format
Storage	PCMCIA, USB memory (/C5)

GP-IB Interface

Use one of the following by NATIONAL INSTRUMENTS:

- GPIB-USB-HS
- PCI-GPIB and PCI-GPIB+
- PCMCIA-GPIB and PCMCIA-GPIB+

Use driver NI-488.2M version 1.60 or later excepting version 2.3.

Conforms electrically and mechanically	IEEE St'd 488-1978 (JIS C 1901-1992).

Functional specification	SH1, AH1, T6, L4, SR1, RL1, PP0, DC1, DT1, and C0.
Conforms to protocol	IEEE St'd 488.2-1992.
Encoding	ISO (ASCII)
Mode	Addressable mode
Address	0 to 30
Clear remote mode	Remote mode can be cleared using the LOCAL key (except during Local Lockout).

Ethernet communications (/C7)	
Number of communication ports	1
Connector type	RJ-45 connector
Electrical and mechanical specifications	Conforms to IEEE 802.3.
Transmission system	100BASE-TX/10BASE-T
Transmission rate	10 Mbps/100Mbps
Protocol	TCP/IP
Supported Services	FTP server, FTP client (network drive), LPR client (network printer), SMTP client (mail transmission), Web server, DHCP, DNS, Remote control

USB port (PC) (/C12 optional)	
Connector	Type B connector (receptacle)
Electrical and mechanical specifications	Conforms to USB Rev.1.1
Speed	Max. 12 Mbps
Number of ports	1
Supported service	Remote control
Supported systems	Models with standard USB ports that run Windows Vista, Windows7 or Windows8/8.1 with USB port as a standard. (A separate device driver is required for connecting to a PC.)

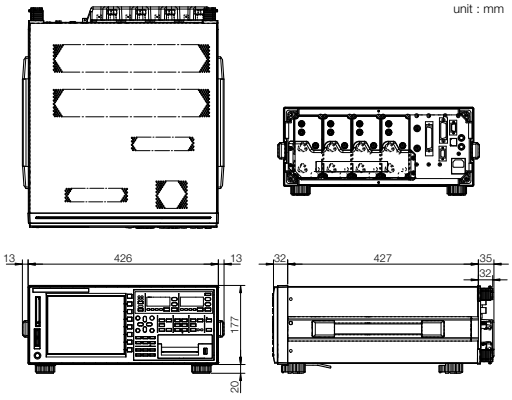
USB port (Peripheral) (/C5)	
Connector	Type A connector (receptacle)
Electrical and mechanical specifications	Conforms to USB Rev.1.1
Speed	Max. 12 Mbps
Number of ports	2
Supported keyboards	104 keyboard (US) and 109 keyboard (Japanese) conforming to USB HID Class Ver.1.1devices
Supported USB memory devices	USB (USB memory) flash memory
Power supply	5 V, 500 mA* (per port) *However, device whose maximum current consumption exceeds 100 mA cannot be connected simultaneously to the two ports.

External I/O	
I/O Section for master/slave synchronization signals	
Connector type	BNC connector: Both slave and master
External clockinput section	
Connector type	BNC connector
Input level	TTL
Inputting the synchronization source as the Ext Clk of normal measurement.	
Frequency range	Same as the measurement range for frequency measurement.
Input waveform	50% duty ratio square wave
Inputting the PLL source as the Ext Clk of harmonic measurement.	
Frequency range	10 Hz to 2.6 kHz
Input waveform	50% duty ratio square wave
Inputting the external sampling clock (Smp Clk) of wide bandwidth harmonic measurement.	
Frequency range	3000 times the frequency of 0.1 Hz to 66 Hz
Input waveform	50% duty ratio square wave
For triggers	
Minimum pulse width	1 µs
Trigger delay time	Within (1 µs + 1 sample rate)
PC card interface	TYPE II (Flash ATA card)

General specifications	
Warm-up time	Approx. thirty minutes.
Operating temperature	+5 to +40°C
Operating humidity	20 to 80% (when printer not used), 35 to 80% RH (when printer is used) (no condensation)
Operating altitude	2000 m or less
Installation location	Indoors
Storage environment	–25 to +60°C
Storage humidity	20 to 80% RH (no condensation)
Rated supply voltage	100 to 240 VAC
Allowed supply voltage fluctuation range	90 to 264 VAC
Rated supply frequency	50/60 Hz
Allowed supply frequency fluctuation	48 to 63 Hz
Maximum power consumption	150 VA (when using built-in printer)
Weight	Approx. 15 kg (including main unit, 4 input elements, and options)
Battery backup	Setup information and internal clock are backed up with the lithium battery

Exterior

unit : mm



Adapters and Cables

758917
Measurement leads
Two leads in a set.
Use 758917 in combination with 758922 or758929.
Total length: 75 cm
Rating: 1000 V, 32 A

758922
Small alligator adapters
For connection to measurement leads (758917).
Two in a set.
Rating: 300 V

758929
Large alligator adapters
For connection to measurement leads (758917).
Two in a set.
Rating: 1000 V

758923*1
Safety terminal adapter set
(spring-hold type)
Two adapters in a set.

758931*1
Safety terminal adapter set
Screw-fastened adapters.
Two adapters in a set. 1.5 mm Allen wrench included for tightening.

758921
Fork terminal adapter
Two adapters (red and black) to a set. Used when attaching banana plug to binding post.

701959
Safety mini-clip set (hook type)
2 pieces (red and black) in one set. Rating 1000 V

758924
Conversion adapter
For conversion between male BNC and female banana plug

366924/25*2
BNC cable
(BNC-BNC 1 m/2 m)
For connection to simultaneously measurement with 2 units, or for input external trigger signal.

B9284LK*3
External sensor cable
For connection the external input of the WT3000E to current sensor.
Length:50 cm

Due to the nature of this product, it is possible to touch its metal parts. Therefore, there is a risk of electric shock, so the product must be used with caution.

*1 Maximum diameters of cables that can be connected to the adapters
758923 core diameter: 2.5 mm or less; sheath diameter: 4.8 mm or less
758931 core diameter: 1.8 mm or less; sheath diameter: 3.9 mm or less

*2 Use with a low-voltage circuit (42 V or less)

*3 The coax cable is simply cut on the current sensor side. Preparation by the user is required.

Model and Suffix code

Model	Suffix Code	Description
WT3003E_T-2A0-30A3		WT3000E Transformer Version, 3 input elements
WT3004E_T-2A0-30A4		WT3000E Transformer Version, 4 input elements
Power Cord		
	-F	VDE Standard
	-Q	BS Standard
Options	/C12	Communication with PC by USB connection type B
	/FQ	Frequency measurements on every element
	/V1	VGA output to external monitor
	/B5	Internal printer
Standard in the WT3000E Transformer Version		GPIB communication
		Advanced calculation and harmonics
		Ethernet port (100BASE-TX/10BASE-T)
		USB ports, for screenshots, data and settings on USB memory.

Standard accessories

Power cord, spare power fuse, rubber feet, current input protective cover, user's manual, expanded user's manual, communication interface user's manual, printer roll paper(provided only with / B5), Safety terminal adapter 758931(provided two adapters in a set times input element number)

**Cable B9284LK (light blue) for external current sensor input is sold separately. Safety terminal adapter 758931 is included with the WT3000E Transformer Version. Other cables and adapters must be purchased by the user..

Safety terminal adapter 758931

Accessory (sold separately)

Model/parts number		Product	Description	Order Q'ty
758917		Test lead set	A set of 0.8 m long, red and black test leads	1
758922	⚠	Small alligator-clip	Rated at 300 V and used in a pair	1
758929	⚠	Large alligator-clip	Rated at 1000 V and used in a pair	1
758923		Safety terminal adapter	(spring-hold type) Two adapters to a set.	1
758931		Safety terminal adapter	(screw-fastened type) Two adapters to a set. 1.5 mm hex Wrench is attached	1
758921	⚠	Fork terminal adapter	Banana-fork adapter. Two adapters to a set	1
701959		Safety mini-clip	Hook type. Two in a set	1
758924	⚠	Conversion adapter	BNC-banana-jack (female) adapter	1
366924	⚠*	BNC-BNC cable	1 m	1
366925	⚠*	BNC-BNC cable	2 m	1
B9284LK	⚠	External sensor cable	Current sensor input connector. Length 0.5 m	1
B9316FX	⚠	Printer roll pager	Thermal paper, 10 meters (1 roll)	10

⚠ Due to the nature of this product, it is possible to touch its metal parts. Therefore, there is a risk of electric shock, so the product must be used with caution.
*Use these products with low-voltage circuits (42V or less).

Application Software

Model	Product	Description	Order Q'ty
760122	WTViewer Software	Data acquisition software	1

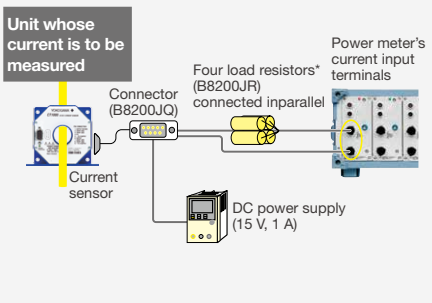
Rack Mount

Model	Product	Description
751535-E4	Rack mounting kit	For EIA
751535-J4	Rack mounting kit	For JIS

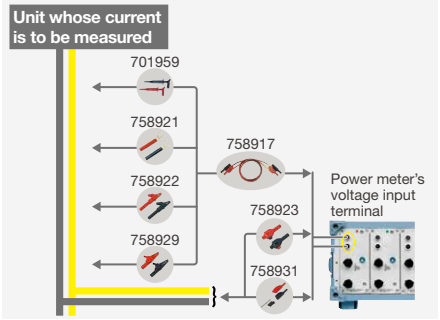
Typical voltage/current connections

Measurement using current sensor

Connection example



Measurement using voltage input terminal



Yokogawa's Approach to Preserving the Global Environment

- Yokogawa's electrical products are developed and produced in facilities that have received ISO14001 approval.
- In order to protect the global environment, Yokogawa's electrical products are designed in accordance with Yokogawa's Environmentally Friendly Product Design Guidelines and Product Design Assessment Criteria.

NOTICE

● Before operating the product, read the user's manual thoroughly for proper and safe operation.

YOKOGAWA

YOKOGAWA METERS & INSTRUMENTS CORPORATION
Global Sales Dept. /Phone: +81-422-52-6237 Facsimile: +81-422-52-6462
E-mail: tm@cs.jp.yokogawa.com

[Ed: 01]
Printed in Japan, 506(KP)

YOKOGAWA CORPORATION OF AMERICA	Phone: +1-770-253-7000	Facsimile: +1-770-254-0928
YOKOGAWA EUROPE B.V.	Phone: +31-88-4641000	Facsimile: +31-88-4641111
YOKOGAWA SHANGHAI TRADING CO., LTD.	Phone: +86-21-6239-6363	Facsimile: +86-21-6880-4987
YOKOGAWA ELECTRIC KOREA CO., LTD.	Phone: +82-2-2628-3810	Facsimile: +82-2-2628-3899
YOKOGAWA ENGINEERING ASIA PTE. LTD.	Phone: +65-6241-9933	Facsimile: +65-6241-2606
YOKOGAWA INDIA LTD.	Phone: +91-80-4158-6000	Facsimile: +91-80-2852-8656
YOKOGAWA ELECTRIC CIS LTD.	Phone: +7-495-737-7868	Facsimile: +7-495-737-7869
YOKOGAWA AMERICA DO SUL LTDA.	Phone: +55-11-5681-2400	Facsimile: +55-11-5681-4434
YOKOGAWA AUSTRALIA PTY. LTD.	Phone: +61-2-8870-1100	Facsimile: +61-2-8870-1111
YOKOGAWA MIDDLE EAST & AFRICA B.S.C(c)	Phone: +973-17-358100	Facsimile: +973-17-336100

http://tmi.yokogawa.com/