

# WT1600 DIGITAL POWER METER

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*We have developed the WT1600, a high-precision, wide-bandwidth power meter. The WT1600 can measure DC and AC signals from 0.5 Hz to 1 MHz with a basic power accuracy of 0.1%. With the maximum of six input elements installed, a single WT1600 can measure the efficiency of a three-phase inverter. In addition to the functions of conventional power meters, it has wider ranges and various functions including waveform display. This paper gives an outline of the WT1600.*

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## INTRODUCTION

Recently, demands for energy-saving equipment have been increasing in view of dealing with environmental problems and effectively using energy resources. There are several energy-efficient standards in place, such as the international Energy Star (1995) for home and office automation apparatus and the US Energy Policy Act of 1992 (EPA) for motors. Meeting these standards requires improving equipment efficiency, thus accurate efficiency measurement has attracted a great deal of attention. The new WT1600 is a power meter that was developed to cater to these demands, enabling the efficient measurement of inverter equipment with a single unit. Figure 1 shows an external view of the WT1600.

## FEATURES

### (1) High Precision and Wide Bandwidth

The basic power accuracy of the WT1600 is a measurement accuracy at commercial 50/60 Hz, of  $\pm$  (0.1% of reading + 0.05 of range). It can measure DC and 0.5 Hz to 1 MHz AC voltages. For current, it can measure DC, and 0.5 Hz to 1 MHz AC for a 5-A input element, 0.5 Hz to 100 kHz AC for a 50-A input element, and 0.6-Hz to 500-kHz AC for an external sensor common to the two elements. This wide bandwidth makes the WT1600 very useful for a wide variety of applications including the evaluation of illumination

inverters and inverter motors that start operation at slow-speed.

### (2) Wide Input Ranges

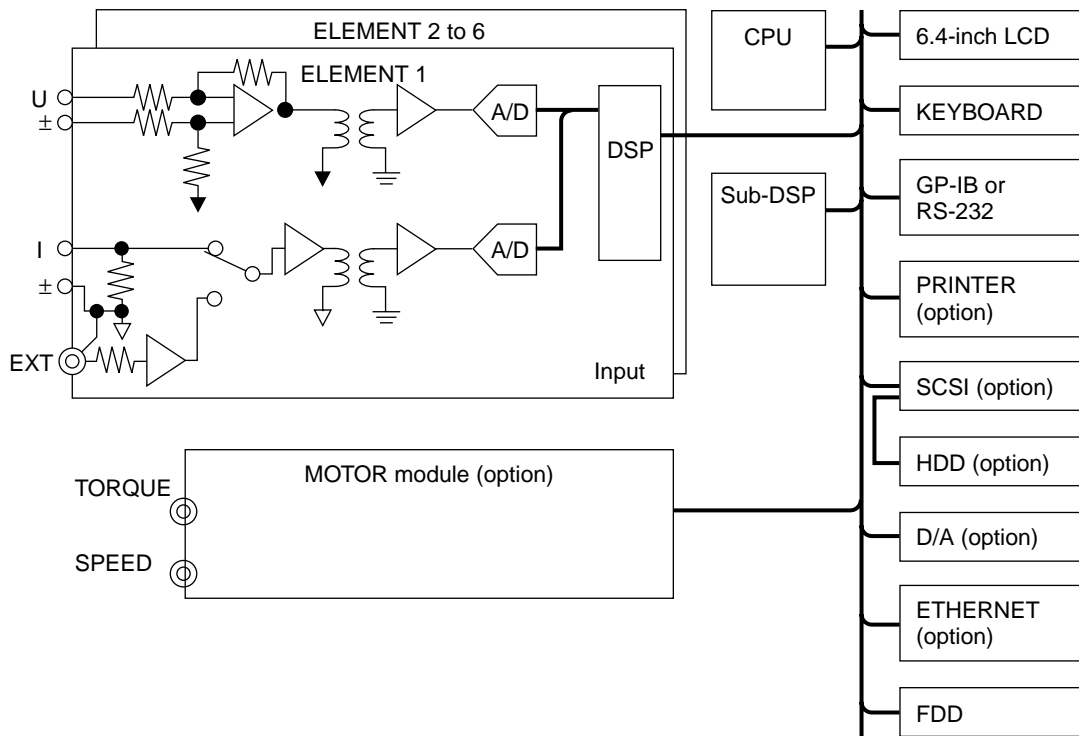
The WT1600 has two different input elements: 5 A and 50 A. Both elements are standard-equipped with direct voltage and current inputs, as well as a compatible current sensor input covering from a shunt resistor to various current probes. The measuring ranges are 1.5 V to 1000 V for voltage, and 10 mA to 5 A on the 5-A input element and 1 A to 50 A on the 50-A input element for current. The external current input can measure 50-mV to 10-V signals. The two elements can be installed together in the WT1600 and thus both extremely small and large currents can be measured with one unit. For



**Figure 1** WT1600 Digital Power Meter

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**Figure 2** Block Diagram of WT1600

example, it can monitor equipment's low standby current, while measuring high current which is essential for the evaluation of large-sized motors.

(3) Up to Six Input Elements on One Unit

A single WT1600 unit can incorporate a maximum of six input elements, which allows simultaneous measurement of three-phase inverter's I/O signals with one unit. By measuring three-phase inverter's AC signals on a three-phase, three-wire system using two elements, inverter's internal DC signals can also be measured with the same WT1600 unit.

(4) Fast Data Updating

The data can be updated at up to intervals as short as 50 ms, twice the frequency of the conventional models. This is helpful for applications such as the evaluation of characteristics at motor startup, including torque and revolutions per minutes (rpm), measurement of rapidly fluctuating secondary voltage and lamp current when a light is turned on.

(5) Optional Motor Evaluation Function

The WT1600 can accept analog torque, analog rpms, or pulse signals from a torque meter. It can display torque and rpms, as well as use the inputs to calculate mechanical power, synchronous speed, slip, motor I/O efficiency, and total efficiency including inverter input and motor output. This enables complete measurement of inverter motors with a single WT1600 unit.

**BASIC CONFIGURATION AND PRINCIPLES**

Figure 2 shows the basic configuration of the WT1600. It consists of four main components—input, CPU, Sub-DSP, and display—and the floppy drive, hard drive, and others.

All the input signals are first processed by the input block. After being electrically insulated and digitally converted, signals are passed to the DSP to determine measured values such as root mean square (rms), average, and active power.

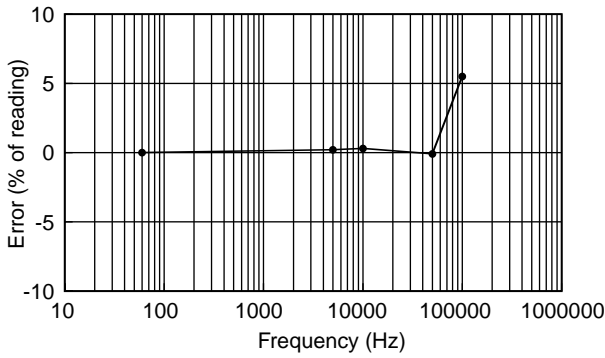
The CPU block receives the measured values from the DSP and prepares them for display, communication, D/A output, and other purposes.

The sub-DSP block performs calculations that require phase information between the elements, including harmonic measurement, and delta-Y conversion for three-phase, three-wire systems.

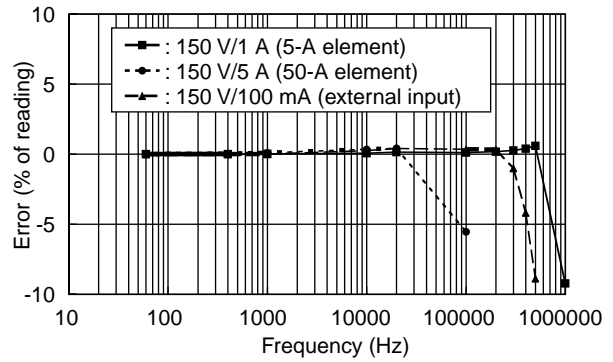
**Input Block**

The input block is divided into the analog block, which normalizes input signals, and the DSP which is in charge of processing the digitized signals. The voltage input circuit relies on a resistive voltage divider and the current input circuit employs a shunt resistor. Each of the input signals is normalized through operational amplifiers and fed to an A/D converter. The A/D converter handles the inputs at approximately 200 kHz.

The voltage input circuit uses a differential amplifier at the input stage in order to reduce capacitance against ground and achieve high insulation and withstand voltage values. The input



**Figure 3** Shunt Resistor Frequency Characteristics



**Figure 4** WT1600 Power Frequency Characteristics (power factor = 1)

stage of the current input circuit has separate systems for direct and external inputs for wider bandwidth. As performance of the current input circuit depends considerably on the high-gain amplifier, we adopted a hybrid amplifier as a discrete component and successfully attained high precision and wide bandwidth.

The DSP computes rms, active power, and other parameters using digital value output from the A/D converter. This real-time computation minimizes dead time during power measurement.

### Shunt Resistor

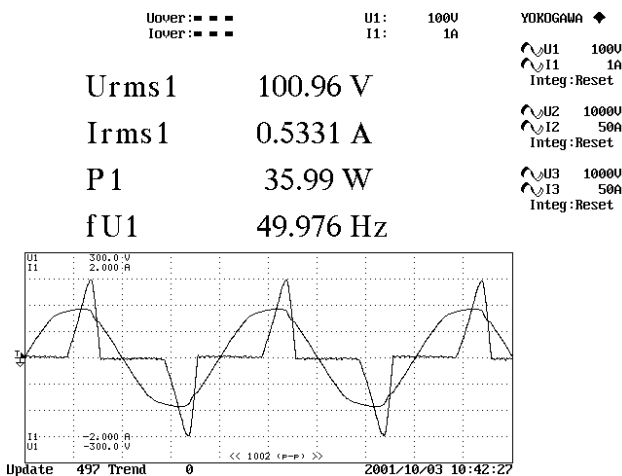
The 5-A input element utilizes the same 100-mΩ shunt resistor as used in the older model in order to cover wider bandwidth. For the 50-A element, we developed a 2-mΩ shunt resistor, which has low resistance but boasts high-accuracy with a temperature coefficient of 15 ppm/°C, a thermal electromotive force of 0.1 μV/°C, as well as a wide bandwidth. Figure 3 shows the frequency characteristics of the shunt resistor when used singly, and Figure 4 depicts the power frequency characteristics of the WT1600.

## FUNCTIONS

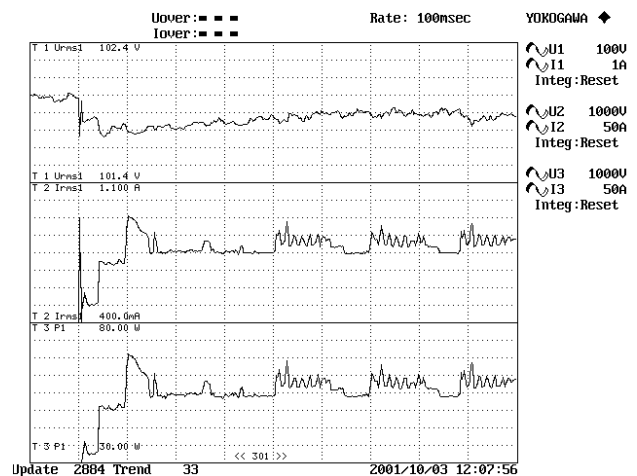
### Versatile Display Formats

In addition to computed numerical data, the WT1600 can display input signal waveforms, a function which was not supported by former models of the WT series. It also offers a variety of display formats; each numerical value can be displayed in a time series, and harmonic measurement results can be viewed as lists, bar graphs, or vectors. With eleven different display formats and double (upper and lower) display on a single screen, the WT1600 allows users to flexibly select a display suitable for their applications.

- Numerical display  
From four items (two when displayed with waveforms) for enhanced viewing, up to 78 items can be displayed simultaneously on the screen.
- Waveform display  
Input voltages and currents can be displayed in waveforms, so it is possible to measure voltage, current, and power while



**Figure 5** Example of Numerical and Waveform Data Display



**Figure 6** Example of Trend Display

observing waveforms without connecting to an external waveform viewer to do so (see Figure 5).

- **Trend display**  
The WT1600 displays measurements for each display updating interval in a time series. The time axis (T/div) can be set in the range of 3 seconds to 24 hours (one day). Changes in up to 16 different parameters, such as voltage, current, active power, and apparent power, can be observed simultaneously in long-term continuous tests (see Figure 6).
- **Harmonic data as lists, bar graphs, and vectors**  
The harmonic measurements function is capable of measuring waveforms with a fundamental frequency ranging from 10 Hz to 1 kHz. Analysis results up to the 100th order from 50/60 Hz fundamental waves can be displayed as lists or bar graphs. The WT1600 can display the phases and amplitudes (rms) of fundamental waves as vectors for voltage or current on each input element.

#### **Data Storing**

Since the WT1600 can refresh data at up to 50-ms (20 times per second) intervals, it is equipped with a data storing function which stores measurements on 11 MB of built-in memory for each updating interval, facilitating the fast collection of measurements. Not only the items to be stored but also the intervals in seconds to store them at can be specified. This enables data storage to start or stop synchronized with real time or with the integration function. In the integration synchronization mode, for instance, storing intervals and counts can be set, which is very useful for prolonged measurement of power consumption. Furthermore, measurements in the memory can be saved to a file on optional built-in hard drive after storage is completed.

#### **Integration Function**

Sampled voltages and currents are digitized by A/D converters with 16-bit resolution at as fast as approximately 200 kHz, so power can be measured even on rapidly fluctuating input signals. Communication commands are available for

starting/stopping integration for each input element.

#### **I/O Function**

Standard with the WT1600 is GP-IB or RS-232 and it can also be equipped with optional SCSI and Ethernet interfaces. Data can be transferred from the optional built-in hard drive through Ethernet FTP server/client services, thereby facilitating sending measurements to a personal computer in combination with the storing function. VGA video output, another standard function, can be used for displaying data on an external large screen. Additional optional functions include D/A output where up to 30 parameters can be output, and the built-in printer for printing screen images of measurement values and waveforms.

#### **CONCLUSION**

This paper has outlined the principles, functions, and features of the WT1600. We believe that with its superior basic performance, wide input ranges, and its abundance of functions, the WT1600 can greatly help power measurement applications, not to mention the measurement of the efficiency of inverter equipment by fully leveraging the six input elements. ◆

#### **REFERENCES**

- (1) Kazumi Masahiro, et al., "PZ4000 Power Analyzer," Yokogawa Technical Report, No. 30, 2000, pp. 15-18
- (2) Kazumi Masahiro, et al., "WT110/WT130 Digital Power Meters," Yokogawa Technical Report, No. 22, 1996, pp. 19-22
- (3) Kawabe Kiyoshi, et al., "Model 2531 Digital Power Meter with High Accuracy and a Wide Frequency Range," Yokogawa Technical Report, No. 19, 1994, pp. 31-35

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