

# MODELS WT1010/WT1030/WT1030M DIGITAL POWER METERS

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*Using the latest digital sampling technology, we have developed the WT1000 series of broad-bandwidth digital power meters which can measure DC and AC signals at frequencies ranging from 0.5 Hz to 300 kHz. These models especially feature fast response, excellent accuracy and versatile functionality for motor testing. The WT1010 is a single-phase model; both the WT1030 and WT1030M are three-phase models, with the latter having a motor-characterizing capability. This paper presents an overview of these digital power meters.*

## INTRODUCTION

With the increased capacity of power devices to handle wattage and frequency, and with the advanced techniques developed to control these devices, modern motor-controlling inverters have been designed to consume less energy, perform at higher levels and have enhanced functionality. Because of such reasons as the need to conserve energy, an increase in carrier frequency, and motor control at lower speeds by means of advanced control techniques, power meters must be capable of measuring electrical energy with high accuracy, handling broader bandwidths, and measuring power at lower frequencies.

The recently developed WT1000 series of digital power meters (models WT1010, WT1030 and WT1030M) has a measuring accuracy and bandwidth high and wide enough to measure the power consumption of inverter-driven motors, as well as a generous functionality that can be applied to a wide range of uses. Figure 1 is an external view of a model in the series of WT1000 digital power meters.

## FEATURES

WT1000 digital power meters have the following main features:

### 1. Basic Performance

Fundamental accuracy is 0.2%, with the measurable voltage

and current bandwidths being DC and an AC range from 0.5 Hz to 300 kHz (or 200 kHz for power measurement). As noted earlier, advanced control techniques have made it possible to control inverter-driven motors at lower frequencies. The WT1000 series, therefore, is designed to be able to measure active power at frequencies as low as 0.5 Hz to keep pace with this trend. In this application, the power meters update their displays at 5-second intervals. In addition, these meters have a maximum voltage range of 1,000 V, wider than the conventional range of 600 V. This improvement has made possible high-voltage measurement that is essential in the development of lighting equipment.

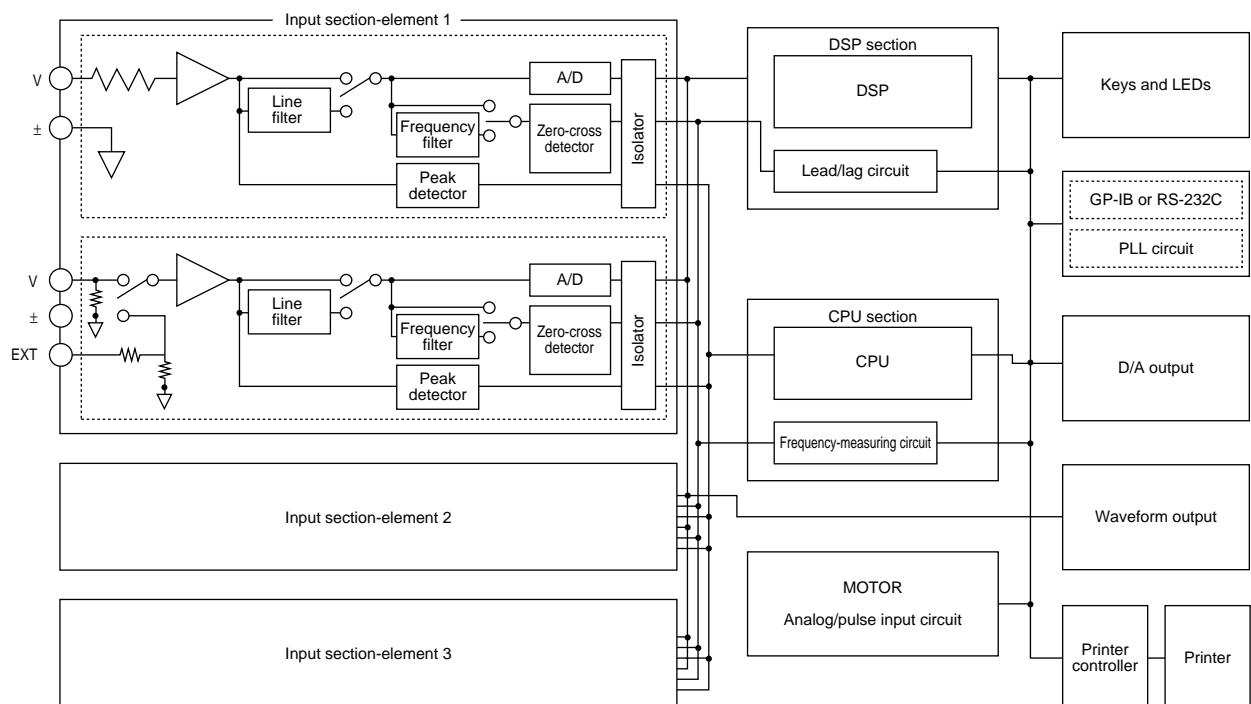
### 2. Fast Response

The display update rate of as fast as 100 ms enables the operator to go through the characterization of motors in a shorter period. The output for communication has also been speeded up so that the meters can provide either 10 ASCII or 64 binary data items at each display update interval.



Figure 1 A model in the series of WT1000

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**Figure 2** Block Diagram of WT1000 Series of Digital Power Meters

### 3. Motor-characterizing Capability (Model WT1030M)

In the characterization testing of motors, the WT1030M digital power meter measures torque and rotational speed, in addition to power consumption. This model has a motor-characterizing capability with which it can calculate such parameters as the output of motors or the efficiency between the input and output of motors. This is done by measuring analog signals proportional to the torque and rotational speed provided by a tachometer.

### 4. Filtering

A cutoff frequency of 0.5, 1, 2 or 6.5 kHz can be chosen to measure the rms value of the fundamental wave of the output voltage which affects the characterization of inverter-driven motors. The filter for this purpose is a fifth-order Butterworth filter, consisting of switched-capacitor component filters. It is also possible to configure a filter only for the frequency-measuring circuit which is essential in harmonics analysis.

### 5. Waveform Outputting (Optional)

The input voltage or a current's waveform can be isolated from the input signal to observe the waveform on an oscilloscope. This waveform is output by turning the input signal into digital values with the A/D converter in the input section and then, after having isolated the digital signal with the photo-isolator, converting the signal back to an analog signal with the D/A converter. The conversion speed is approximately 60 kHz, which is fast enough to observe the fundamental period of PWM waveforms provided by inverter-driven motors.

### 6. Harmonics Analysis (Optional)

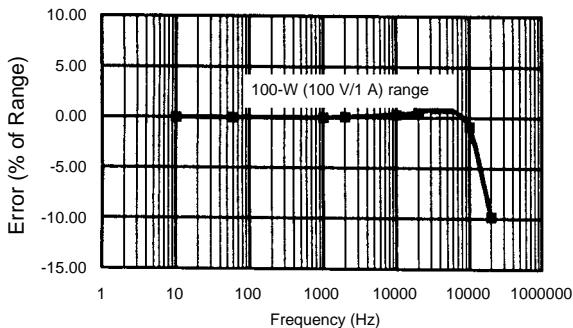
These power meters can analyze harmonics at fundamental frequencies from 10 to 440 Hz. This feature makes it possible to measure each harmonics component and the distortion factor, harmonics content, phase angle, and difference between the respective phases of a fundamental wave, and the active, reactive and apparent powers and power factor.

### 7. Integration (Optional)

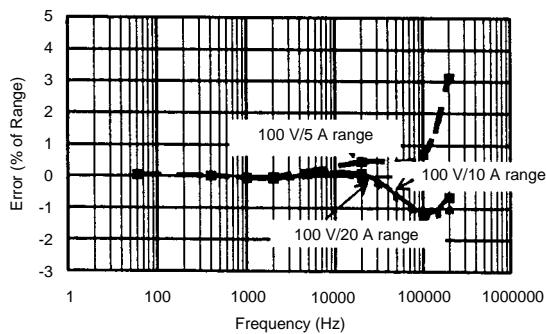
The continuous integration of momentary power with this feature permits highly accurate measurement against energy variations. Since integration is simultaneous with voltage, current and power measurements, this feature is as effective as the D/A output feature for the characterization of such equipment as refrigerators. This feature also allows polarity-specific integration in which the powers of positive- and negative-going waveforms are integrated separately.

### 8. External Input for Current Sensors (Optional)

The maximum range of current for WT1000 digital power meters is 20 A. In order for the power meters to be able to measure currents exceeding 20 A, they are equipped with an external input for current sensors. The input accepts voltages ranging from 250 mV to 10 V, making the meters compatible with a wide variety of current sensors. These meters can also be operated in an auto-ranging mode.



**Figure 3** Power vs. Frequency Characteristics (Power Factor = 1)



**Figure 4** Power vs. Frequency Characteristics (Power Factor = 0)

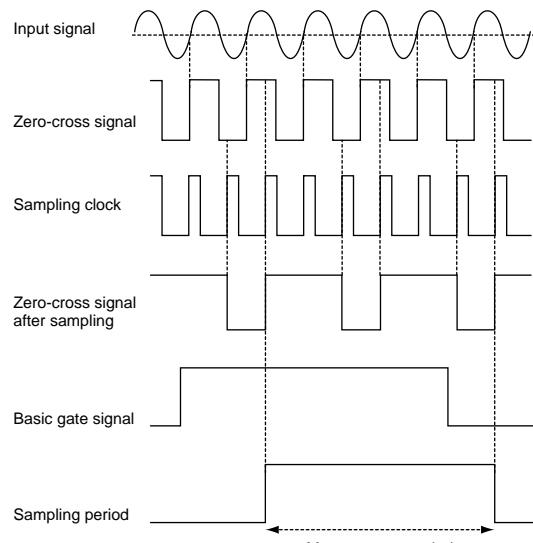
## BASIC CIRCUIT CONFIGURATION

Figure 2 is a basic block diagram of the WT1000 series of digital power meters. The entire circuitry consists of such building blocks as the input, DSP, CPU, display and power supply sections. In the input section, an input signal is converted to a digital value. Then, at the DSP, corrective calculation, square-law calculation, multiplication and addition are performed for each sampling interval to determine the rms values of voltage and current and the active power. When the power meter enters a display update interval, it calculates such parameters as voltage, current, and active, apparent and reactive powers, from the data resulting from the calculations noted earlier. Thus, the CPU processes these data to send to the display, communication line, printer and D/A output.

### 1. Input Sections

An input section consists of voltage- and current-input circuits, each isolated from each other. The voltage-input circuit employs a scheme of resistance-based potential division, while the current-input circuit uses a shunt-based scheme. Input to each circuit is normalized by an operational amplifier to turn it into digital values through a 16-bit A/D converter. The signals of these digital values are then isolated by the photo-isolator to be supplied to the DSP section. The A/D converter converts the input at a rate of approximately 60 kHz.

The input resistance of the voltage-input circuit is 2.4 M $\Omega$ , which comprises 24 units of 100-k $\Omega$  resistors. This configuration is employed in order to keep the voltage applied to each of these



**Figure 5** Measuring Principle

resistors low so that less expensive resistors can be used with this circuit. The shunt of the current-input circuit has a resistance of 5-m $\Omega$ , where two 10-m $\Omega$  resistors are connected in parallel so that currents with polarities opposite each other flow through these resistors. This configuration is employed in order to reduce the effects of a magnetic field formed by a large, high-frequency current, thus providing excellent frequency and phase characteristics. Figures 3 and 4 show the power vs. frequency characteristics.

### 2. DSP Section

Data converted to digital values at the input section undergo a corrective calculation against input-circuit errors, and the calculations of active power and the rms values of voltage and current, and then the calculations of apparent and reactive powers, power factor, and so on, at the DSP section. The following are the formulas for these calculations:

$$\text{Active power } r = \frac{1}{N} \sum_{k=1}^N v(k) \cdot i(k) \quad (1)$$

$$\text{Rms value of voltage} = \sqrt{\frac{1}{N} \sum_{k=1}^N v(k)^2} \quad (2)$$

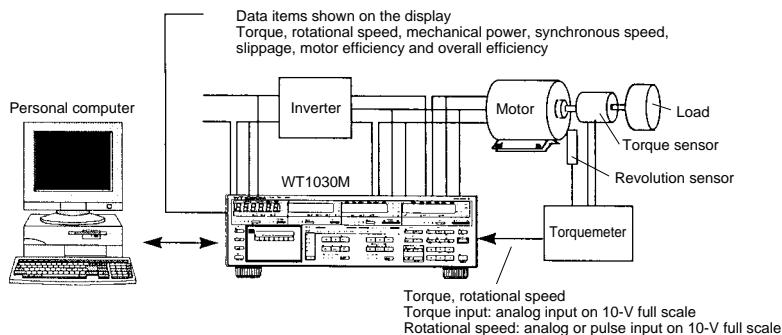
$$\text{Rms value of current} = \sqrt{\frac{1}{N} \sum_{k=1}^N i(k)^2} \quad (3)$$

where

$v(k)$  = instantaneous value of voltage in  $k$  th sampling interval

$i(k)$  = instantaneous value of current in  $k$  th sampling interval

$N$  = number of sampling cycles over an integral multiple of the period of the input signal



**Figure 6** Example of WT1030M Digital Power Meter Wired for Motor-characterizing Capability

The active power and rms values are calculated using data sampled over an integral multiple of the period of the input signal. This interval is determined by the zero-cross signal derived from the input signal. If the input signal frequency becomes more than half as high as the sampling frequency, the period of the input signal fails to match that of the waveform reproduced after sampling, resulting in an error in the measured value. To solve this problem, the zero-cross signal of the input signal is synchronized with the sampling clock of the A/D converter to produce another zero-cross signal for the waveform being reproduced. The interval over which calculations are performed is thus determined from the period of this zero-cross signal. Figure 5 shows the measuring principle represented by the time relationships.

## FUNCTIONALITY

### 1. Motor-characterizing Capability

Traditionally, power consumption, torque and rotational speed have been measured separately in the characterization testing of motors. In this method, the time at which torque and rotational speed were measured was not consistent with that at which power was measured, requiring adjustments between these times.

The motor-characterizing capability of the new WT1030M digital power meter measures both power and torque almost simultaneously if the torquemeter's response is fast enough, compared with 100 ms, eliminating the need for such adjustments. The power meter can calculate the output of motors from the torque and rotational speed to figure out the efficiency between the input and output of a motor, or the efficiency between the inputs and outputs of an inverter and its inverter-driven motor system in the case of a single-phase input inverter. The meter can also calculate synchronous speed and slippage, enabling users to obtain all required data only from their power meter. Using the motor-characterizing capability, users can test motors with ease to characterize them. Figure 6 is an example of the WT1030M digital power meter wired for its motor-characterizing capability.

### 2. Harmonics Analysis

Along with an increasing concern over harmonic current measurements, the latest sampling power meters have been provided with a harmonics-analyzing capability. The WT1000 series discussed in this paper also has this capability. The harmonics-analyzing capability of these power meters can measure not only the conventional harmonics components, harmonics content and distortion factor but also phase angles formed between elements, as well as the apparent and reactive powers and the power factor of a fundamental wave which are difficult to measure in normal measurement. The measurable range of fundamental frequencies has been extended to a low of 10 Hz, compared with the conventional limit of 40 Hz. This improvement has made it possible to use these power meters not only in harmonics current measurements of commercial power sources but also in other areas of application. In addition, the D/A output can provide signals of harmonic components, distortion factors and harmonics content, permitting logging of variations over a prolonged period of time using a recorder.

## CONCLUDING REMARKS

In this paper, we have described the measuring principle, functionality and features of the WT1000 series of digital power meters. With a higher basic performance and generous functionality, these power meters are expected to find application in a wide range of fields, from the measurement of power consumption at commercial sources to the measurement of output of inverter-driven equipment. Especially in the characterization testing of inverter-driven motors, we are confident the motor-characterizing capability (of Model WT1030M) will help increase users' work efficiency in characterization. ♦

## REFERENCES

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- (2) Kazumi, M., et al. WT110/WT130 Digital Power Meters. Yokogawa Technical Report, No. 22, pp. 19 to 22 (1996).