2558A an AC Voltage Current Standard with Unprecedented Efficiency in Calibration Work

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Yokogawa Meters & Instruments Corporation has developed 2558A, a new AC voltage current standard that offers a high accuracy of ±0.04% for AC voltage and ±0.05% for AC current, and a high stability of ±50 ppm/h. This instrument achieves high accuracy and stability through a redesign of the circuits and structure of the former 2558 model while maintaining its well-accepted operability and visibility. In addition, the 2558A can easily calibrate watt-hour meters including smart meters, which are recently attracting attention. This paper introduces the main features and internal circuits of the 2558A.

INTRODUCTION

In general, measuring instruments are calibrated periodically using standard instruments which are traceable to the international standards to ensure the reliability of the values they indicate.

In the calibration of analog instruments, operators usually manipulate the generators directly while watching the indicator needles of the instruments. For this reason, interfaces that provide intuitive operation using setting dials for each digit and seven segment LEDs are preferred to those using LCDs and push buttons of rubber keypads or others, all of which are often applied to recent instruments. Thanks to this well accepted operability, Yokogawa's model 2558, an AC voltage current standard, has been used as a standard in the industry for a long time.

Responding to heavy demands for a successor to the model 2558, Yokogawa has developed the model 2558A (referred to as "this model" hereafter) that has substantially higher accuracy, stability, and other basic performance features than the former model.

In addition, for easier calibration or other measurement of smart meters, which are indispensable to configuring the smart grid (recently attracting more attention), this model provides capability to output power while synchronizing or adjusting phases among the multiple sets of this module.

Figure 1 shows the external view, and Table 1 lists the main specifications of this model.

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Figure 1 External view of the 2558A

FEATURES

Features of this model are summarized below.

Synchronized operation

The synchronized operation between the two sets of the 2558 requires an external two phase oscillator. In contrast, this new model 2558A has external input and output terminals for two phase sine wave signals so that synchronized operation among multiple sets of this module (up to six) can be configured.

Thus, multiple sets of this module can synchronously output without an external oscillator.

Figure 2 shows an example of a connection configuration for synchronized operation.

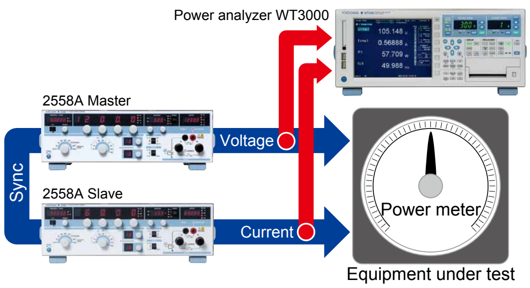


Figure 2 Example of a connection configuration for synchronized operation

Table 1 Comparison of main specifications between 2558A and 2558

		2558A	2558
AC voltage output	Output range (guaranteed operating range)	0.00 mV - 1440.0 V (1.00 mV - 1200.0 V)	1.00 mV - 1200.0 V
	Accuracy (guaranteed term)	± 400 ppm (6 months)	± 950 ppm (3 months)
	Guaranteed accuracy frequency range	40 - 1000 Hz	50/60/400 Hz
AC current output	Output range (guaranteed operating range)	0.00 mA - 72.00 A (1.00 mA - 60.00 A)	1.00 mA - 60.00 A
	Accuracy (guaranteed term)	± 500 ppm (6 months)	± 950 ppm (3 months)
	Guaranteed accuracy frequency range	40 - 1000 Hz	50/60/400 Hz
Output frequency	Output range	40 - 1000 Hz	40 - 500 Hz
	Accuracy	± 50 ppm	1%
Maximum output		Approx. 36 VA (60 A × 0.6 V)	Approx. 36 VA (60 A × 0.6 V)
Stability		± 50 ppm/h	± 0.03%/h
Adjustable phase range during synchronized operation		–180.000 - +359.999°	N/A (an external oscillator is required)
External dimensions [mm]		426 (W) × 132 (H) × 400 (D)	439 (W) × 149 (H) × 415 (D)
Weight		Approx. 20 kg	Approx. 23 kg

Using the phase adjusting function of this model, a calibration system for a power meter can be easily configured by connecting multiple sets of this model to a reference power meter. Three phase power meters can be calibrated by connecting multiple sets of this model. A current as large as 100 A can also be output by connecting two sets of this model in parallel (up to 144 A by two sets).

Digital display for an output value

In the model 2558, the output is displayed on an analog meter, and so the actual output value cannot be read directly when measuring the deviation from the output or successively outputting at the division points of the main set value. In contrast, this new model digitally displays the value of voltage or current at the output terminal. This eliminates the necessity to calculate the actual output value by using the main set value, deviation, and the number of division, making calibration work more efficient.

Calibrating frequency meters

This model provides a new mode dedicated for calibrating frequency meters. Low and high frequency limits of a frequency meter can be set, and this mode provides the functions of output sweep, step-wise output, measurement of deviation and deviation preset, as with the mode of voltage and current. Thus, scale accuracy tests, needle sticking tests, and similar tests can be easily performed in the same way as tests for voltage or current analog meters.

Improved deviation measurement

When calibrating a meter, its full scale is often different from selectable ranges of this model, and a minimum range among the selectable ranges that exceed the full scale of the meter is usually selected. For example, if the full scale of a meter is 150 V, this model is used with a 300 V range. When the previous model which allows only a resolution of 100 ppm of the range is used, the meter cannot be calibrated with a resolution of 100 ppm of the full scale of the meter. In contrast, because this model allows deviation measurement with a resolution of 100 ppm of the main output set value, this function can be fully made use of for easy calibrations, without concern for the full scale of the meter.

Combined use of deviation preset and step-wise output

When the deviation preset function is applied during step-wise output, this module outputs the value behind the main set value by the preset value. This means that it is possible to finely approach the target calibration point, either from a lower value or a higher one, without exceeding it. This is particularly useful when the friction (hysteresis) of the moving part needs to be taken into consideration. Two selectable preset value settings of 2% and 5% can deal with the magnitude of the torque of meter needles. This function enables scale accuracy tests conforming to the Japanese Industrial Standards (JIS) to be easily conducted.

Sweep function

The sweep function, achieved by operating the deviation measurement and step-wise output functions together, enables needle sticking tests with high repeatability. The optimum sweep time for a meter can be selected from three times of 16 sec, 32 sec and 64 sec.

Intuitive operation with dials for each digit

To perpetuate the intuitive operability of having dials for each digit, well accepted in the previous model, new mechanical dials have been developed, providing for more compact size and higher durability.

CONFIGURATION OF THIS MODEL

Figure 3 shows the overall block diagram of this model.

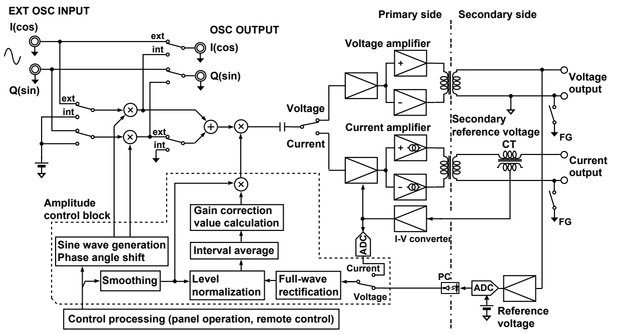


Figure 3 Block diagram of 2558A

Operation principles of the newly designed circuit

This model is composed of two parts: the primary side which controls the oscillator output, and the secondary side which is isolated from the primary side by using transformers and a photo coupler. The oscillator signal is multiplied with the digital signal from the amplitude control part, and then amplified by the voltage or current amplifier to provide the final voltage or current output. In the case of voltage output, the voltage detected between the output terminals of the secondary side is converted from analog to digital, and fed back to the amplitude control part via the photo coupler for isolation. In the case of current output, the current transformer (CT) detects the output current while isolating it at the same time. The detected current is converted to voltage and to digital at the voltage level of the primary side, and then fed back to the amplitude control part.

The target output level is set to the amplitude control part from the panel operation or remote control. In cases of substantial changes in the set value, a smoothing processing is performed to prevent overshooting or bias magnetism in the transformers caused by sharp changes in the output. After the start of the operation, the amplitude is adjusted at every 0.4 sec using the voltage or current feedback signal.

The signal fed back to the amplifier is full-wave rectified, and the ratio of the output amplitude to the set value is obtained through a level normalization processing. Then, a weighted average of the ratio for a certain interval is calculated by an interval averaging process. This average reflects the gain and similar factors of the amplifier, but is not affected directly by the set value. A gain correction coefficient is calculated from this average value to control the amplitude of the voltage or current output. The amplitude is adjusted at every 0.4 sec.

Although not shown in the block diagram, the value used for the output indicator is a weighted interval average calculated directly from the signal fed back to the amplitude control part, without passing through the level normalization processing. Both the intervals for averaging and display updating are 0.2 sec to confirm the set value easily. Because both the output indicator and the amplitude control part use the output of the same analog-digital converter, the difference between the target value digitally calculated and the displayed output value is of the order of a rounding error (±1 in the lowest digit) when the amplitude is under stable control.

Common use of current output terminals

Although the previous model has output terminals for each current range, responding to the users' request for unification, this model provides those which can be used for all current ranges. In the previous model, secondary windings for each current range are built in to the output transformer. Instead, the output transformer of this model includes five windings for 10-A range, and none for 50-A range. The connections among those windings are switched internally for common use. For example, five windings are connected in a series for 10-A range and five windings in parallel for 50-A range. This makes the transformer more compact in size and wiring within the module easier at the same time.

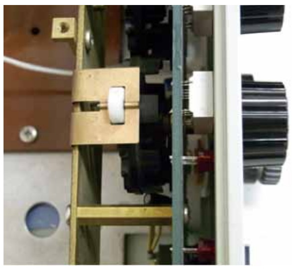
Newly developed dial mechanism

One of the requirements for this model is intuitive operability by dials. However, no commercially available rotary encoders meeting this requirement were to be found. Thus, a new dial mechanism has been developed.

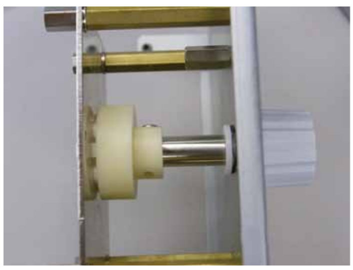
The new dial mechanism needs to be mechanistically more compact than before, as this model needs to accommodate more functions in a smaller case than the previous model. To achieve compact size and the mechanical operability close to that of the previous model at the same time, the new dial mechanism uses coil springs, spacers, and other parts.

The cost reduction of about 40% compared with the previous model is also achieved by actively using commodity parts. In addition, although the mechanism of the previous model is deficient in durability, the new dial mechanism with a new parts structure has been verified to have no problem in continuous operation of 500,000 rotations.

Figure 4 shows the dial mechanisms of the previous model and this model.



(a) The previous model



(b) This model (2558A)

Figure 4 Comparison of the new and the previous dial mechanisms

EVALUATION OF THE NEWLY DESIGNED CIRCUIT

High stability

The short-term stability of this model is substantially better than the previous model, since this model digitally processes the feedback control while converting the analog output to digital signals, as described in the previous section.

Figure 5 shows a measurement result by using the precision power analyzer, WT3000.

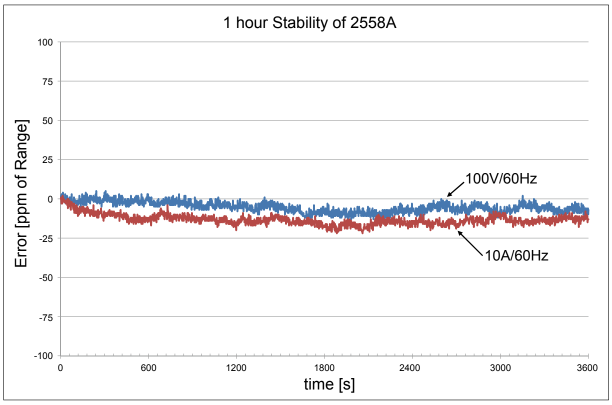


Figure 5 Measured stability in one hour

Output response

The digital processing described above achieves a smooth output responding to the set value. The previous model sometimes shows rather large overshooting or discontinuous response, depending on the load. In contrast, this model shows smooth response waveform both during rising and falling, owing to the output waveform control using digital processing.

Figure 6 shows an example of a rising response waveform.

APPLICATION EXAMPLES

Application to power calibration systems

This model allows synchronized operation among multiple sets as described earlier.

Figure 2 and Figure 7 show a power calibration system composed of the WT3000 and two sets of this model. By connecting two sets of this model via their input and output terminals onto the rear panel for synchronized operation, the output phase of the slave can be adjusted from −180° to +360° relative to the output of the master.

The phase value set to this module does not guarantee the absolute phase of its output. However, this model offers very good phase stability, practically 0.01° or less, and so it can be operated in calibration systems for watt-hour meters or other meters with the WT3000 used as a reference.

Figure 7 (a) shows the case in which the phase of the slave is adjusted to approximately 90° so that the power factor of WT3000 is zero, while Figure 7 (b) shows the case in which the phase is adjusted to approximately 0° so that the power factor is 1.

This system can be easily expanded to three-phase power calibration by adding more sets.

CONCLUSION

For meter calibration use, the model 2558A has been developed to provide the functions taking the current standards into consideration, while maintaining the operability and visibility for which the previous model 2558 enjoyed its good reputation. Significantly improving basic performance, this model provides the specifications that can be used for the inspection of high precision analog instruments, transformers and so forth.

This model provides functions for easily adjusting and calibrating watt-hour meters, including smart meters which are expected to be widely used in the future. Yokogawa looks forward to seeing this model being fully made use of across its potential markets.

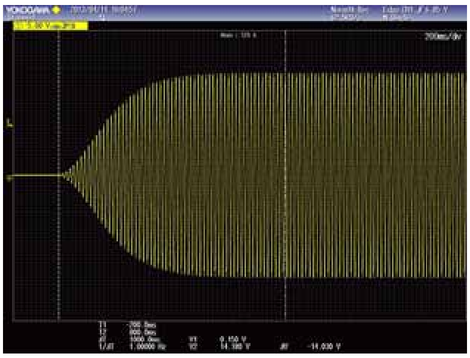
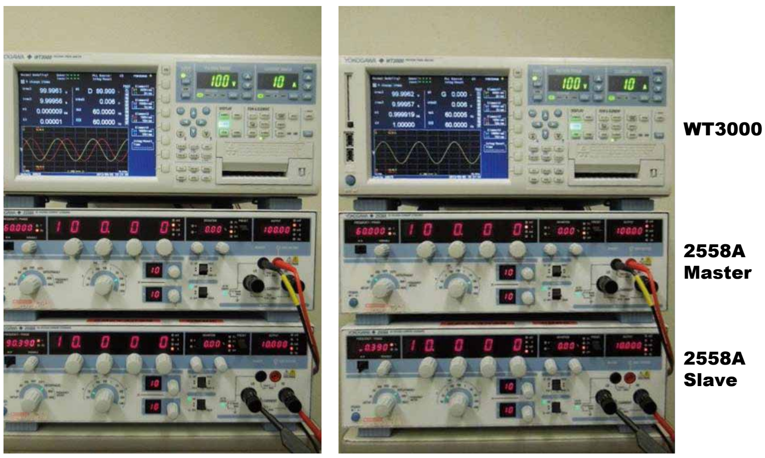


Figure 6 Example of a rising response waveform



(a) Adjusting power factor to 0 (b) Adjusting power factor to 1

Figure 7 Example of a power calibration system composed of the two 2558A and WT3000