

The 2553A Precision DC Calibrator, Pursuing High Accuracy and Stability with Inherited Usability

Takuya Hiyoshi *1

Yokogawa Meters & Instruments Corporation has recently developed the 2553A precision DC calibrator. Functionally, the 2553A uses the same dial operation and seven-segment LED as those of the previous 2553 model, inheriting its excellent usability and visibility. Meanwhile, the 2553A has doubled the number of types of thermocouples that can be calibrated, from five to ten, in order to deal with a greater variety of thermometers and temperature controllers; and it has newly implemented a resistance output function for devices that use resistance temperature detectors. In terms of performance, the 2553A has achieved high-speed zero/full scale calibration and output correction of its digital to analog converter (DAC) by introducing a digitally assisted analog technology that uses a field-programmable gate array (FPGA). As a result, the 2553A offers a high accuracy of ± 75 ppm/year for DC voltage, ± 120 ppm/year for DC current and high stability of ± 15 ppm/hour for DC voltage. This paper introduces the major features and key technologies of the 2553A.

INTRODUCTION

Measuring instruments such as voltmeters, ammeters, and thermometers must be calibrated periodically in order to maintain accuracy. Yokogawa provided the 25xx series calibrators, which were well accepted due to their simple, easy-to-use functions compared with more expensive, multifunctional calibrators, and were used as standards for a long period of time in the calibration service industry. However, Yokogawa discontinued related developments in 1979 and terminated sales of all 25xx models in 2003. Since then, customers have strongly urged Yokogawa to develop successors to these products. In response to these requests, Yokogawa resumed development and sales of calibrators, and released the 2558A AC voltage current standard in 2013. Now, Yokogawa has developed the 2553A precision DC calibrator, which is the successor of the previous 2553 model.

Figure 1 shows the external view, and Table 1 shows the major specifications of the 2553A and 2553. The specifications indicated in bold are those that have been improved from the 2553.



Figure 1 External view of the 2553A

FEATURES OF THE 2553A

Improved Resolution, Stability, and Accuracy

Voltage and current to be generated can be set to 5.5 digits, an order of magnitude higher resolution than that of the previous model, to enable finer setting. In line with the improvement in resolution, its stability was also improved. The actual noise level within very low frequency ranges has been reduced to lower than one tenth that of the previous model. Accuracy has also been improved by more than a factor of three compared with that of the previous model as shown in Table 1.

*1 Development & Engineering Dept. 1,
Yokogawa Meters & Instruments Corporation

Table 1 Comparison of the major specifications of the 2553A and 2553

Item	2553A	2553	
Displayable digits	5.5	4.5	
Number of dials	5	3	
DC voltage generation	Range	10 mV, 100 mV, 1 V, 10 V, 30 V	10 mV, 100 mV, 1 V, 10 V
	Accuracy (1-V range)	±75 ppm (1 year)	±300 ppm (1 year)
DC current generation	Range	1 mA, 10 mA, 30 mA , 100 mA (current sinking available)	1 mA, 10 mA, 100 mA
	Accuracy (1-mA range)	±120 ppm (1 year)	±400 ppm (1 year)
Thermocouple	R, S, B, J, T, E, K, N, C, A, User-defined	R, J, T, E, K	
Resistance temperature detector	Pt100, User-defined	Not available	
Resistance generation range	400 Ω	Not available	
Reference junction compensation	By an internal sensor Pt100 at the output terminals or by an external sensor Pt100 at the reference junction	By an external sensor (optional accessory)	
Weight	Approx. 3 kg	Approx. 8 kg	

Dial Operation

The 2553A inherits the same dial operation as the 2553, the intuitive operability of which was broadly accepted. The dials, which have a moderate click feeling, allow users to change the output value without looking away from the display of the instrument being calibrated. The number of dials was increased from three to five to ensure there is one dial per digit. This enables output values to be set with fewer operations.

Functions for Calibrating Thermocouple Thermometers

In order to calibrate thermometers and temperature controllers using thermocouples, the 2553A has a function that generates a voltage equivalent to the thermoelectromotive force generated by various thermocouples at each temperature level. The output values can be set directly in terms of temperature, eliminating the need to use a conversion table of temperature and electromotive force. The previous model only accepted five types of thermocouples: R, J, T, E, and K, while the 2553A accepts all 10 thermocouple types specified in the IEC60584-1:2013.

Functions for Calibrating Resistance Temperature Detector

For calibration of thermometers and temperature controllers using resistance temperature detectors (RTDs), which was not possible with the previous model, a new function has been implemented in the 2553A, which generates resistance corresponding to those of a Pt100 RTD at each temperature level. This function also enables setting of output values directly in terms of temperature and thus a conversion table of temperature and resistance is not required.

User-defined Function

In addition to the 10 thermocouples and the Pt100 RTD described above, the 2553A can calibrate user-defined thermocouples and RTDs. By inputting a polynomial equation defining the relationship between temperature and voltage, resistance for a thermocouple, or an RTD to be simulated, it can generate voltage or resistance at a specified temperature.

It is easy to make the setting to use this function. Users need only create a polynomial equation in a text file on a PC and send it to the mass storage drive of the 2553A via USB.

Reference Junction Compensation Function

When calibrating thermometers and temperature controllers using thermocouples, the temperature at the reference junction on the calibrator side must be known. Usually, a fixed temperature is prepared by using an ice or oil bath, and the reference junction is put into it. The measured electromotive force is corrected by using the known electromotive force at that temperature. This procedure is called reference junction compensation. The 2553A has a new function of internal reference junction compensation, in which a temperature sensor is built-in near the output terminals and measured temperature is used as the temperature of the reference junction. Because it automatically compensates for the output by using the electromotive force corresponding to the temperature measured at the output terminals, thermometers or temperature controllers can be calibrated while the 2553A and other devices are directly connected to thermocouples without preparing apparatuses for fixed temperature. This is expected to improve the efficiency of calibration work. External reference junction compensation is also available as with the previous model by using a temperature sensor (provided as an accessory) to measure temperatures at a point, such as a terminal block, instead of near the output terminals.

Current Sinking Function

The 2553A has a current sinking function that was not on the previous model. This function enables operation verification and calibration of devices such as a signal converter. For example, by sinking current from a distributor, the 2553A can simulate a two-wire transmitter that outputs a 4-20 mA signal.

CONFIGURATION OF THE 2553A

Figure 2 shows the block diagram of the overall 2553A. It

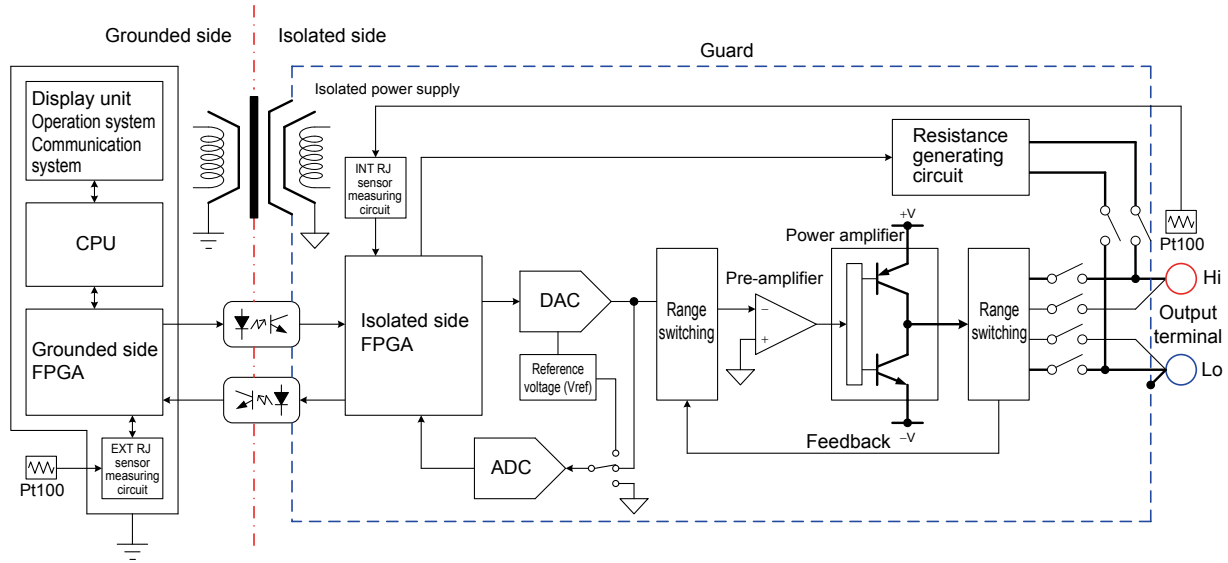


Figure 2 Overall block diagram

is composed of two portions. One is the grounded circuit side including a CPU, FPGA, display, and operation unit, and the other is the isolated circuit side including a digital-to-analog converter (DAC) for voltage/current generation, an analog-to-digital converter (ADC), amplifier, and a resistance generating circuit. On turning the output on/off or when the output setting value is changed, the value is transferred from the CPU to the grounded side FPGA, and to the FPGA on the isolated side. The FPGA on the isolated side converts it to a DAC code and sets it to the DAC while performing smoothing processing on them to suppress overshoot and reduce inrush current when connecting a capacitive load.

Meanwhile, the high-speed ADC that uses the pulse width modulation (PWM) method measures a DAC output, reference voltage, and zero voltage (ground potential) at all times in order to correct the DAC codes.

The digitally assisted analog technology described above has enabled more accurate and stable output than the existing models.

The DAC, ADC, and amplifier are described in detail below.

DAC Part

Figure 3 shows a detailed block diagram of the FPGA and DAC portion on the isolated side of Figure 2.

Two 12-bit DAC components are used together as a 13-bit DAC. To enhance DAC resolution, first-order $\Delta\Sigma$ modulation is applied to generate an intermediate level, which is an average of counts. This makes the DAC 24 bits equivalent. Transitions between DAC codes causing large glitches degrade linearity. Therefore, when such DAC codes are detected, two DAC codes are shifted to avoid such a situation.

The DAC output is measured by the ADC and corrected by using the measured value. When there is a difference between the output setting value and the ADC measurement, the DAC codes are corrected by using the difference, and the ADC measurement is controlled to eventually coincide with the output setting value.

Significant changes in the output setting can lead to slow response and increase in overshoot. To avoid such phenomena, the output setting is changed stepwise internally when the change is large. The analog low-pass filter (LPF) prepared after the DAC also causes delay in responding to the changes.

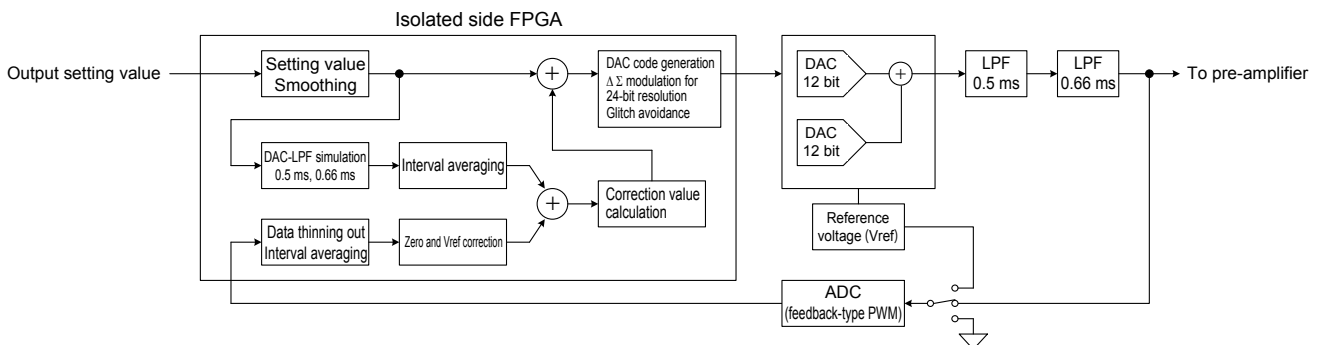


Figure 3 Block diagram of isolated FPGA and DAC

Accordingly, the time constant of the analog LPF is considered according to the changes made to the output setting.

ADC Part

Figure 4 shows a detailed block diagram of the ADC part in Figures 2 and 3.

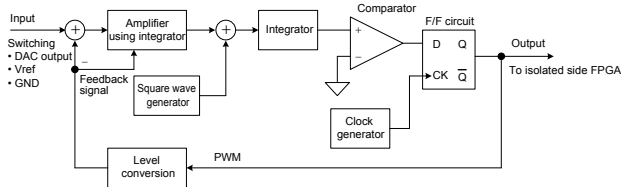


Figure 4 Detailed block diagram of the ADC Part

The ADC part was developed on the basis of a feedback-type PWM method using an integrator, which was used in the previous model, however, it is different due to the fact it has two integrators connected in a cascade formation. Thanks to the two-stage integration in front of the comparator, second-order noise shaping characteristics have been achieved in which the quantization noise attenuates at 12 dB/oct in a low frequency region as with a $\Delta\Sigma$ type ADC. This enables output with higher resolution and speed than before.

The output correction of the DAC, of which resolution has been improved to 24 bits, became possible. The increase in processing speed made it possible to measure the reference voltage with excellent temperature characteristics, zero level (ground potential), and DAC output within 200 ms in order to perform zero/full scale calibration at every measurement. This ensures stable output of the 2553A.

Amplifier Part

The amplifier is composed of the pre-amplifier that receives the DAC output, and the power amplifier as shown in Figure 2. The pre-amplifier is a chopper amplifier and exhibits highly stable characteristics, being largely unaffected by temperature. The power amplifier is a push-pull amplifier that uses power transistors, and the current sinking function, which was not part of the previous model, has been newly added. Because mechanical switches are not used for polarity inversion, no glitches caused by it are generated.

CHARACTERISTIC EVALUATION RESULTS

Highly Stable Output

Figure 5 shows the stability of the 2553A in the case of the 10-V range setting, in which outputs of +10 V, 0 V and -10 V are measured by a digital multi-meter at one second intervals for a period of one hour. The ratios of output variations to the range are plotted over time after the output has stabilized.

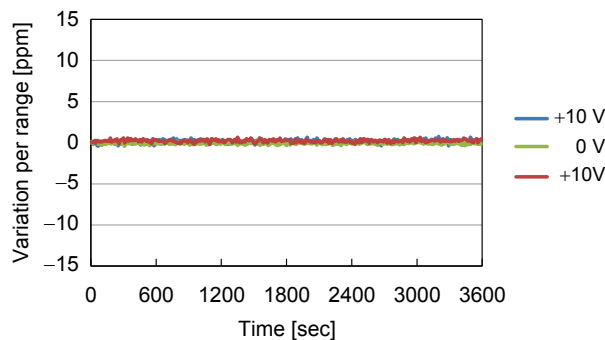


Figure 5 Stability measurement results for one hour in the case of the 10-V range setting

The minimum output setting resolution for the 10-V range is 10 ppm of the range, while the observed variations are approximately 1 ppm, proving the high stability of the 2553A.

Excellent Temperature Characteristics

Figure 6 shows the variation of outputs of +10 V, 0 V, and -10 V assuming no variation at 23 °C in the case of the 10-V range setting, in which the ambient temperature is changed from 5 °C and 40 °C, which are the lower and upper limits of the operating temperature specification.

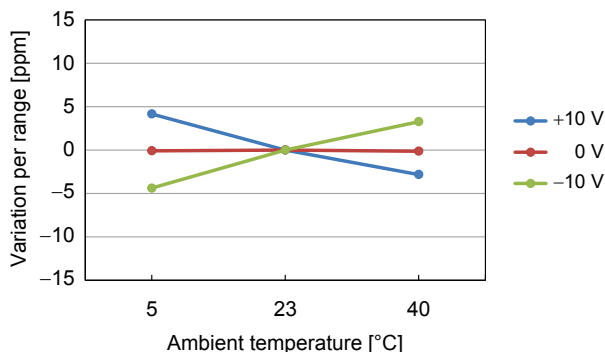


Figure 6 Temperature characteristic measurement results in the case of the 10-V range setting

Even if the ambient temperature is changed within the limits of the specification, the output variations in the case of the 10-V range setting are less than the minimum output setting resolution of 10 ppm, exhibiting the excellent temperature characteristics of the 2553A. In particular for 0-V output, the output barely fluctuates thanks to the zero calibration explained above.

CONCLUSION

Although the external view of the 2553A, which inherits the excellent level of usability of the previous model, is not so different from that of the previous model, all of its designs have been updated in order to substantially improve output accuracy and stability. Yokogawa will continue to expand its product lineup of calibrators that are differentiated by technology and that provide excellent usability.