Digital Calibration of Analogue Instruments

Clive Davis, European Marketing Manager for Test & Measurement at Yokogawa Europe, describes the capabilities of AC and DC voltage and current standards

In general, measuring instruments are periodically calibrated using standards to ensure the values they indicate are accurate. To take accurate yet intuitive measurements, operators expect their instruments to offer comprehensive functions, yet at smaller sizes and lower cost.

The Yokogawa models 2558A and 2560A (Figures 1 and 2) described in this article are low-cost, high-precision instruments for calibrating electric meters, thermometers, temperature transmitters and data loggers among other analogue instruments. They've been tailored to meet specific requirements for measuring equipment, discussed in detail here.

Figure 1: The Yokogawa 2558A is an AC voltage current standard that offers a high accuracy of ±0.04% for AC voltage and ±0.05% for AC current, along with a high stability of ±50ppm/h

Output-Value Digital Display

In earlier calibrator models, the output was displayed on an analogue meter, which meant the actual output value could not be read directly when measuring a deviation, or successively outputting at division points of the main set value. In contrast, the 2558A and 2560A display the value of voltage or current digitally at the output terminal. This eliminates calculating the actual output value by using the main set value, deviation and number of divisions, making calibration more efficient.

The 2558A incorporates a new mode dedicated to calibrating frequency meters. The low- and high-frequency limits of a frequency meter can be set, and this mode also provides indication of voltage and current, and functions like output sweep, step-wise output, and measurement and preset of deviation. Thus, scale accuracy, needle sticking and similar tests can easily be performed in the same way as tests of voltage or current analogue meters.

Improved Deviation Measurements

When calibrating a meter, its full scale is often different from selectable preset ranges, which can exceed the full scale of the meter. For example, if the full scale of a meter is 150V, the instrument is used with a 300V range. However, because the 2558A and 2560A allow deviation measurements with a resolution of 100ppm, this function can fully be exploited for easy calibration, without considering the meter's full scale.

When the deviation preset function is applied during a stepwise output, it is possible to gradually approach the target calibration point – either from a lower or higher value – without overshooting. This is particularly useful when the friction of the moving part needs to be accounted for. For example, two selectable preset value settings of 2% and 5% can deal with the magnitude of the torque of meter needles. This function enables convenient scale accuracy tests conforming to national and international standards.

Operating Principles

Each of the two instruments has two sections (Figure 3): the primary side that controls the oscillator output, and the secondary side, which is isolated from the primary side by transformers and a photocoupler. The oscillator signal is multiplied with the digital signal from the amplitude control section, and then amplified to provide the final output.

For voltage output, the voltage detected between the output terminals of the secondary side is converted into a digital signal and fed back to the amplitude control section via the photocoupler.

For current output, the current

Figure 2: The 2560A is the DC equivalent to the 2558A AC calibrator; it combines precision performance and ease of use for the calibration of measuring instruments including analogue meters, thermometers, temperature transmitters and data loggers

transformer detects the output current while isolating it at the same time. The detected current is converted into voltage and then into digital form at the voltage level of the primary side, to be fed to the amplitude control section. The target output level is set remotely or from the instrument panel.

In cases of substantial changes in the set value, a smoothing operation is performed to prevent overshoot or bias magnetism in the transformers caused by sharp changes in the output. After operation starts, the amplitude is adjusted every 0.4 second 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-normalisation process. A weighted average of the ratio for a certain interval is then 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 output amplitude.

Although not shown in Figure 3, the value used for the output indicator is a weighted interval average, calculated directly from the signal fed to the amplitude control section, without passing through the level normalisation process. Averaging and display updates occur every 0.2 seconds.

Because both the output indicator and amplitude control section use the same ADC output, when the amplitude is under stable control, the difference between the digitally-calculated target value and the displayed output value is about ±1 in the lowest digit.

Common Use Of Current Output Terminals

Whereas earlier instruments had secondary windings built into the output transformer for each current range, the 2558A output transformer includes five windings for the 10A range and none for the 50A range. The connections between these windings are switched internally for common use. For example, five windings are connected in series for the 10A range and five in parallel for the 50A range,

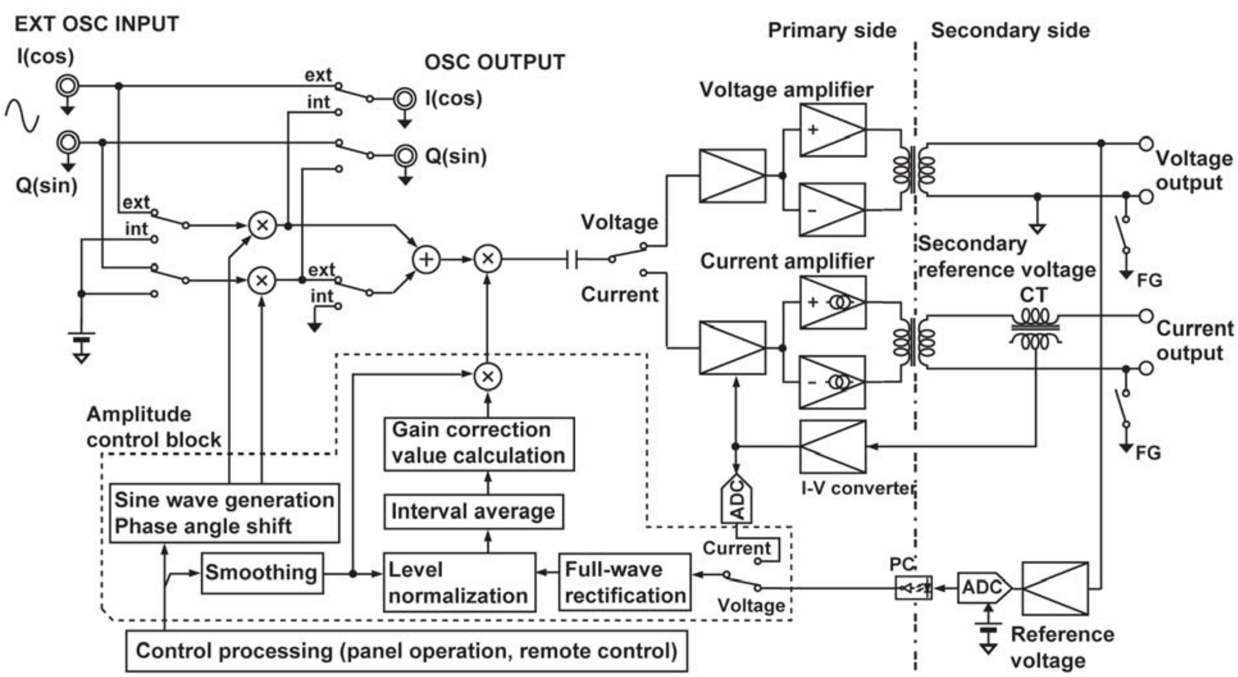

Figure 3: Block diagram of the Yokogawa 2558A

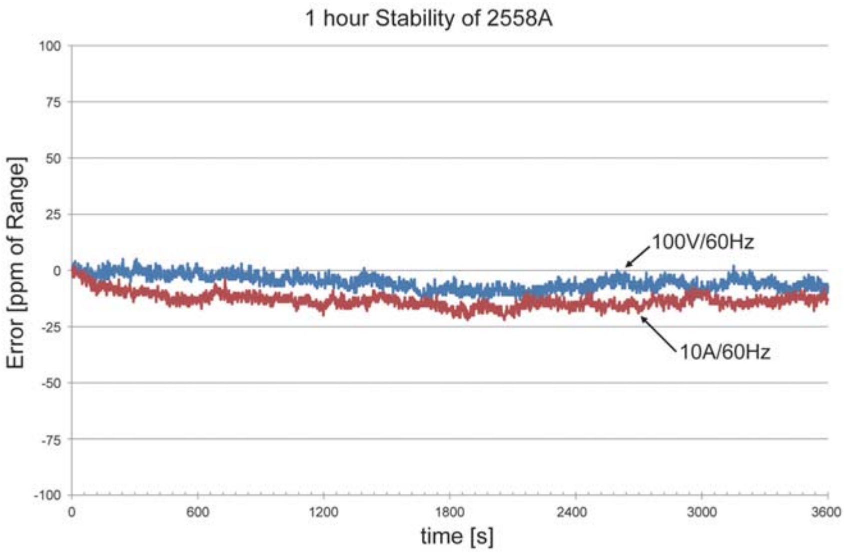

Figure 4: Measured stability of the 2558A over a one-hour period

making the transformer compact and simplifying the module's internal wiring.

Short-term stability of these units is substantially better than previous models, since they digitally process the feedback control while converting the analogue output to digital signals (Figure 4). The digital processing achieves a smooth output responding to the set value and smooth response in rising and falling waveforms, whereas earlier models sometimes exhibited overshoot or discontinuous response, depending on the load.

Dial Mechanism

In calibrating analogue instruments, operators usually manipulate the generators directly whilst watching the instrument's indicator needles. For this reason, interfaces that provide intuitive operation using setting dials and 7-segment LEDs for each digit are preferred to those using LCDs and rubber keypads.

Another requirement for these instruments is intuitive operation by dials. Because of the limited availability of rotary encoders capable of meeting this requirement, a different dial mechanism was developed. It is compact and uses miniature coil springs, spacers and other small parts, yet allows more instrument functionalities in a smaller enclosure and about 40% cheaper than previous models. These changes have also resulted in a more durable structure with continuous trouble-free operation for up to 500,000 rotations.

Applications

The 2558A allows synchronised operation of multiple units. As a result, a power calibration system can be assembled with WT3000E precision power analysers and two digital calibrators. By connecting the two instruments for synchronised operation via their rear-panel input and output terminals, the output phase of the slave can be adjusted from -180° to +360° relative to the master's output.

The phase value set on the 2558A does not guarantee the absolute phase of its output. However, this model offers very good phase stability (in practice 0.01° or less) and so it can be operated in calibration systems for watt-hour meters or other meters with the WT3000E used as a reference. The system can easily be expanded to three-phase power calibration by adding more sets.

For the direct calibration of low-frequency analogue power meters and domestic smart meters, a further development of the 2558A has been introduced – the LS3300 (Figure 5), which has a maximum frequency of 1200Hz. This instrument's key features are high phase guarantee and high power accuracy, a wide range of voltage output range up to 1250V and current output up to 62.5A, a colour LCD user interface and a choice of wiring configurations for multiphase measurements. It also allows calibration of clamp-on power meters with auxiliary outputs. ●

Figure 5: LS3300 analogue power meter calibrator