Introduction

The Arbiter Systems® Model 1133A Power Sentinel™ uses a design philosophy that is based on the use of a small number of critical and highly-stable components in its signal paths. This approach results in a low and predictable (in a statistical sense) drift rate.

The basic accuracy specification of the Model 1133A Power Sentinel is 0.025% (for power and energy) for a one-year calibration interval. This specification is based on the error analysis of Table 1.

For high-quality analog components, drifts with time are known to follow an approximately square-root relationship. This means, for example, that the drift expected from a given component for four years will be twice what it is for one year. So, using this relationship, we can predict the performance to be expected for calibration intervals longer than one year.

Error Analysis

All identified sources of error in the Model 1133A have been quantified using worst-case manufacturers' performance data. These have then been combined using a root-sum-of-squares (RSS) method to yield performance estimates. Effects due to initial calibration, measurement noise, temperature, and aging are all included. The reason for using RSS analysis is beyond the scope of this paper. However, we have found in our many years' experience building calibration instruments that this method yields the most realistic estimate of actual worst-case performance, provided that numerous errors contribute significantly to the overall performance (i.e., no one error dominates), and provided that actual worst-case data is used in the analysis.

The error analysis for the Model 1133A for power or energy measurements for a one-year calibration interval is shown in Table 1. Similar analyses have been performed for the other functions of the instrument, and include most of the same factors shown here.

Table 1 - Power/Energy Error Analysis (One Year)

Temperature Errors, 0-50° C:	**Error, ppm**
Current input, resistor TCR	63
Voltage input, resistor ratio	50
Voltage reference (x2)	50
Cal. source, resistor ratio (x2)	25
Time Stability, 1 year:	
Current input, resistor	25
Voltage input, resistor ratio	<20
Voltage reference (x2)	36
Cal. source, resistor ratio (x2)	<40
Measurement Noise	**10**
Total RSS Error, Basic	**117**
Calibration Errors:	
Cal. artifact, Rotek MSB-001A	50
Traceability to National Standards	50
Total Error, RSS	**136**
Specification (0.025%)	250

Extrapolation for Longer Calibration Intervals

The sources of error in Table 1 are broken down into time-invariant errors (due to temperature, noise, and calibration) and time-variant errors (time stability). These can be analyzed in a slightly different fashion, showing the total RSS error broken down into time-variant and time-invariant components (Table 2).

Note that the overall result (136 ppm) is the same, as would be expected. However, we now have the time-variant errors (drifts) broken out into a separate component, of 63 ppm RSS for a one-year period. By simply multiplying by the square root of the time period in years, we can see how much additional drift is expected, and the effect on overall performance (Table 3).

Table 2 - Power/Energy Error Analysis (One Year)

Temperature Errors, 0-50° C:	**Error, ppm**
Current input, resistor TCR	63
Voltage input, resistor ratio	50
Voltage reference (x2)	50
Cal. source, resistor ratio (x2)	25
Measurement Noise	**10**
Calibration Errors:	
Cal. artifact, Rotek MSB-001A	50
Traceability to National Standards	50
Total RSS Error, Time Invariant	**121**
Time Stability, 1 year:	
Current input, resistor	25
Voltage input, resistor ratio	<20
Voltage reference (x2)	36
Cal. source, resistor ratio (x2)	<40
Total RSS Error, Time Variant	**63**
Total Error, RSS	**136**
Specification (0.025%)	250

Table 3 - Power/Energy Error Analysis (One, Five, and 25 Years)

Calibration Interval, Years	**1**	**5**	**25**
Time-Variant Errors	63	141	315
Time-Invariant Errors	121	121	121
Total RSS Error	**136**	**186**	**337**
Specification, ppm	250	500	1000
Specification, percent	**0.025**	**0.05**	**0.10**

This shows that for calibration intervals of five and 25 years, performance can be conservatively specified at 0.05% and 0.10%, for power and energy.

Voltage and Current

By degrading the specified accuracy as shown in Table 4, the calibration interval for voltage and current can also be extended to five and 25 years. This is based on an error analysis very similar to Tables 1, 2, and 3 using slightly different data. The accuracy for current is slightly worse than for voltage since current is derived from the ratio of power to voltage, the basic standards used to establish traceability for the Model 1133A.

Phase Angle, Harmonics, Flicker

The error mechanisms that contribute to the specifications for phase angle, harmonics, and flicker, as well as quantities derived from phase angle such as frequency and system time offset, do not have a significant time-variant component. They should not be expected to degrade above the margin already allowed for these specifications.

Table 4 - Other Specifications for Five and 25 Year Calibration Cycles

Calibration Interval, Years	**1**	**5**	**25**
Voltage, percent[1]	0.02	0.04	0.08
Current, percent[1]	0.03	0.05	0.10
Phase Angle, between channels[1]	0.01°		
Power Factor[1]	0.0002 * sin(Φ)		
Phase Angle, absolute[1]	0.03° plus [timebase error * 360° * frequency]		
Harmonics	0.05% or 5% of reading (whichever is greater)		
Flicker	Per IEC 61000-4-15		
Timebase error	1 µs, locked; 10ppm typical, unlocked		

[1] Affected by underrange conditions as shown in the Model 1133A Technical Data.

Conclusion

Based on this projection and analysis, we can recommend relaxed calibration intervals for applications where the full accuracy of the Model 1133A is not required. For systems requiring 0.05% accuracy for power and energy, Arbiter Systems, Inc. recommends a 5-year calibration cycle and for 0.1% accuracy, we recommend a 25-year calibration cycle.

The performance of the Model 1133A over a 25-year period exceeds that of most other products on the market for a one-year period, eliminating or greatly reducing the need for calibration and the resulting cost of support. **For many applications of the Model 1133A, thanks to its highly-stable design, calibration will not be required at all for the design life of the system.**

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