WHITE PAPER

Understanding Measurement Accuracy Specifications for Battery Testers

KEYSIGHT

Introduction

When you specify and purchase cell and battery test equipment for your R&D lab or production line, it is critical to have a thorough understanding of performance specifications. While it may be easy to state the price, the number of channels you need, and the current per channel, the accuracy of the equipment is the most critical specification. It can be challenging to specify your needs correctly.

In this white paper, you will learn how to define accuracy and error in the realm of test equipment, four ways to specify accuracy, and interpret an actual error versus a specified error.

Getting Started: What Are Accuracy And Error?

As a test equipment maker, Keysight specifies accuracy as the amount of error you will see concerning the parameter. For example, suppose we are talking about current measurement accuracy. In that case, we specify the amount of error you will encounter when making a current measurement, such as 100 µA of error or uncertainty on a current measurement of 5 A.

If we are talking about current programming or source error, this is the error in setting the desired current value. So, if you want to set a constant current charge rate of 10 A, the system may have a programming error of 25 mA. Therefore, you will not achieve 10 A but an output value within 25 mA of 10 A.

While the examples cover current sourcing and measurement, the concept applies to any measurable parameter, such as voltage in volts, current in amps, resistance in ohms, temperature in degrees, and pressure in various units. Similarly, you will have a sourcing or programming error for any parameter that can be sourced by the system, which is usually limited to voltage and current.

This topic appears to apply to channels in a cell, battery tester, or formation system. However, these accuracy specification concepts work with any measurement device, such as a voltmeter or internal resistance measurement instrument, or with any source device, such as a power supply, source-measure unit, or analog output signal generator.

Often, you will see measurement resolution turn up in discussions of measurement accuracy. We will cover measurement resolution at the end of this white paper.

Four Ways For Specifying Accuracy

There are four ways to specify accuracy. The actual number the accuracy specification establishes is the amount of error you will encounter. You can then determine the accuracy based on this amount of error and the true value of the desired parameter. While this white paper will refer to measurement accuracy for the remainder of the discussion, the concept applies equally to programming or source accuracy.

1. Fixed error

In the case of fixed error, the error is a fixed value, such as 10 mA. This means that no matter how large or small the parameter you measure is, you will encounter the same amount of error. For example, if the error is 2 mA, you will have 2 mA of error whether you are measuring 100 mA or 100A.

2. Fixed percent of range

In this case the error scales with the range of the measurement device and will be specified as a percent of full scale (% of FS) or % of range. For example, if the error is 0.2% of FS and the full-scale range is 10 A, you will have 0.2% of 10 A, which is 0.02 A or 20 mA of error. You will see ranges on many measurement devices; one benefit is that you can match the range to the size of the parameter you measure to ensure the lowest error in measurement.

For example, say you want to measure a 500-mA signal accurately. Your measurement device has three ranges: 1, 10, and 100. If the error is 0.2% of FS, the error will be 2 mA of error on the 1-A range, 20 mA of error on the 10-A range, and 200 mA of error on the 100-A range. While you can measure the 500-mA signal on any of those three ranges, you will get the lowest error when using the lowest range.

3. Gain and fixed offset

In the case of gain and fixed offset, there are two components to the error. There is a gain term that provides an error component that scales with the size of the parameter you are measuring, and a fixed term that is always present. This error shows up as something like “% of reading + value.” Accuracy specified as a gain and fixed offset can apply to a measurement device with a single range or multiple ranges. This is because the specification does not include “range” in the specification.

Once again, you are trying to measure a 500-mA signal accurately. Your measurement device has an accuracy specification of 0.1% + 750 µA. The gain term is 0.1%, so the gain-term component of error will be 0.1% of 500 mA or 500 µA. The fixed-term component is 750 µA. Therefore, the total error when measuring 500 mA is (500 µA + 750 µA) or 1.25 mA.

If you increase the measured signal to 1 A, the error also increases. At 1 A, the gain-term component of error will be 0.1% of 1 A or 1 mA. The fixed-term component would remain at 750 µA. The total error when measuring 1 A will be (1 mA + 750 µA) or 1.75 mA.

While it is more complex to calculate, this gain and fixed offset method is the best way to specify accuracy and it means the test equipment provider did a thorough job of characterizing the measurement device. In addition, the gain and fixed offset method will provide the lowest error for each value measurement made because the error scales with the size of the measurement.

4. Gain and offset as % of range

Fundamentally, this gain and offset as % of range example is the same as case 3, but you calculate the fixed term based on the range of the measurement. The third and fourth cases are identical if only one measurement range exists.

With the fourth case, you are again looking to accurately measure a 500-mA signal on a system with a 5-A range. Your measurement device has an accuracy specification of 0.1% of reading + 0.1% of range. The gain term is 0.1%, so the gain-term component of error will be 0.1% of 500 mA or 500 µA. The fixed-term component is 0.1% of 5 A or 0.005 A. Therefore, the total error will be (500 µA + 5 mA) or 5.5 mA.

Actual Error Versus Specified Error

While the cases above explain how to interpret and apply accuracy specifications, what you really want to know is the error from your measurement. After calculating the error term, you want to compare it to your measurement. Now, we will revisit cases 2, 3 and 4.

In case 2, you are trying to measure a 500-mA signal accurately. The measurement device has three ranges: 1, 10, and 100 A. If the error is 0.2% of FS, the error will be 2 mA of error on the 1 A range, and you select the 1 A range to ensure the most accurate measurement.

If you compare this error term to the measurement you are making, you have 2 mA of error on a 500-mA measurement. This is 2 mA/500 mA = 0.4% error in your measurement, even though the accuracy specification was 0.2% of FS. Clearly, you cannot just say my measurement will be 0.2% accurate because the specification was 0.2% FS.

In case 3 and 4, you are trying to measure a 500-mA signal accurately. The measurement device has an accuracy specification of 0.1% of reading + 750 μA. The gain-term error component is 0.1% of the reading, so this component of error will be 0.1% of 500 mA or 500 μA. The fixed-term error component is 750 μA. Therefore, the total error will be (500 μA + 750 μA) or 1.25 mA.

Comparing this error term to the measurement you are making, there is a 1.25 mA of error on a 500-mA measurement. This is 1.25 mA/500 mA = 0.25% error in your measurement, even though the accuracy specification was 0.1% + 750 μA.

One important note is that you apply error terms as a ± to the measured value. Further, if the error term is 2 mA on a 500-mA measurement and you want to know the range of results, you must both add and subtract the error term from the measurement as follows:

- error term = ± 2 mA
- value you seek to measure = 500 mA
- resultant measurement minimum = 500 mA – 2 mA = 498 mA
- resultant measurement maximum = 500 mA + 2 mA = 502 mA

In other words, if the error is 2 mA on a 500-mA reading, the measurement device will return a measurement between 498 and 502 mA.

Table 1 compares how to calculate and apply the four cases.

Table 1. Type of accuracy specifications versus measurements at 10%, 50%, and 90% of full-scale ranges

	Based on measurement of current at 10% of full scale range	**Based on measurement of current at 50% of full scale range**	**Based on measurement of current at 90% of full scale range**
Measurement device range	1 Amp range	1 Amp range	1 Amp range
Measuring a current of	100 mA	500 mA	900 mA
CASE 1: Accuracy specification: Fixed error	± 2 mA	± 2 mA	± 2 mA
Error on measurement as % of measurement	2% error at 100 mA	0.4% error at 500 mA	0.22% error at 900 mA
Resultant measurement minimum	98 mA = 100 mA - 2 mA	498 mA= 500 mA - 2 mA	898 mA = 900 mA - 2 mA
Resultant measurement maximum	102 mA = 100 mA + 2 mA	502 mA = 500 mA + 2 mA	902 mA = 900 mA + 2 mA
CASE 2: Accuracy specification: Fixed Percent of Range	0.2% of Full Scale Range	0.2% of Full Scale Range	0.2% of Full Scale Range
Error term	± 2 mA	± 2 mA	± 2 mA
Error on measurement as a % of measurement	2% error at 100 mA	0.4% error at 500 mA	0.22% error at 900 mA
Resultant measurement minimum	98 mA = 100 mA - 2 mA	498 mA = 500 mA - 2 mA	898 mA = 900 mA - 2 mA
Resultant measurement maximum	102 mA = 100 mA + 2 mA	502 mA = 500 mA + 2 mA	902 mA = 900 mA + 2 mA
CASES 3 & 4: Accuracy specification: % reading + fixed offset	0.1% of reading + 750 µA	0.1% of reading + 750 µA	0.1% of reading + 750 µA
Gain error term at 0.1% of reading	100 µA = 0.1% of 100 mA	500 µA = 0.1% of 500 mA	900 µA = 0.1% of 900 mA
Fixed error term	750 µA	750 µA	750 µA
Total error term of gain + offset	± 850 µA	± 1250 µA	± 1650 µA
Error on measurement as a % of measurement	0.85% error at 100 mA	0.25% error at 500 mA	0.18% error at 900 mA
Resultant measurement minimum	99.15 mA = 100 mA - 0.85 mA	498.75 mA = 500 mA - 1.25 mA	898.35 mA = 900 mA - 1.65 mA
Resultant measurement maximum	100.85 mA = 100 mA + 0.85 mA	501.75 mA = 500 mA + 1.25 mA	901.65 mA = 900 mA + 1.65 mA

Note that the resultant error as a percent of the measurement diminishes significantly as the measured values increase toward the maximum of the measurement range. With the fixed errors such as cases 1 and 2, the resultant error as a percent of measurement suffers because the error is fixed. In contrast, with case 3 and 4, the resultant error scales with the reading, improving error as a percent of measurement at small measurement values.

Beware Of Accuracy Specified As A Percent Only

There is another method to specify accuracy, but use caution when encountering it. For example, the specification is misleading if you see accuracy defined as a percent only — such as 0.2% accuracy. While the method may be easy to understand and calculate, it is unrealistic.

Why? If you are trying to measure 500 mA with a measurement device specified at 0.2% accuracy, the error term of 0.2% of 500 mA is 1 mA of error. If instead, you are trying to measure 1 A, the error would be 2 mA, as it simply scales.

But what about the other direction? So if instead of measuring 500 mA, what if you wanted to measure 50 mA? Would the error be 100 µA? And what about measuring 5 mA? Would the error be 10 µA? If you are trying to measure an open circuit with a current of 0 mA, does this mean the system will report 0 mA with 0 µA of error, indicating a perfect measurement?

It is unrealistic to assume that any measurement instrument can provide a constant error of 0.2% regardless of the size of the signal. When the accuracy is specified as a percent of reading, something is missing that describes the limitation of the measurement device at its low end. Therefore, you cannot trust this measurement device's performance, especially at the low end of its measurement range.

And Finally, What About Resolution?

Resolution is often perceived as more important than accuracy, but this is not the case. While resolution can be a figure of merit that offers some indication of the quality and performance of a measurement device, as in 18 bits is better than 16 bits, the accuracy is the actual governing specification on how good a measurement you can make.

For example, if your measurement device has a high resolution of 10 µA and an accuracy of 50 µA, the 10 µA has no real bearing on the measurement as the measurement error will be ± 50 µA. The 10-µA resolution does not impact or improve the accuracy of the measurement device, nor will it provide a higher level of confidence in the measurement, which will never be better than ± 50 µA.

Having high resolution can be helpful to see the relative relationship between consecutive measurements, such as watching temperature drift, where you might see a 0.1 °C change over time on a 25 °C measurement that has ± 2 °C of accuracy. But on an absolute basis, you cannot say, for instance, that the temperature is 25.7 °C versus 25.8 °C with complete certainty because the measurement accuracy of any individual reading is ± 2 °C. Figure 1 below shows the measurement of temperature drift versus time using a high-resolution temperature measurement system, taking measurements at 30-second intervals. In this case, while the absolute accuracy of the temperature measurement is ± 2 °C, the resolution is better than 0.01 °C. This makes it possible to see minimal changes in temperature relative to one another. However, the absolute accuracy of any measurement point remains ± 2 °C.

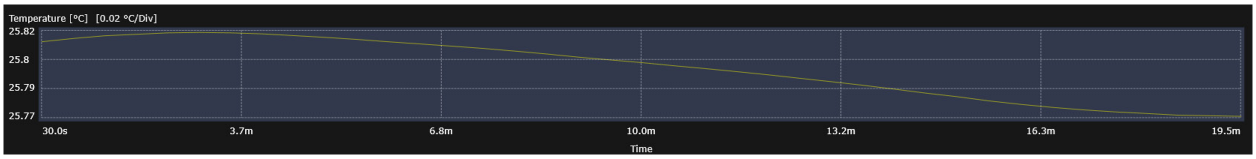

Figure 1. A sample graph of temperature measurement versus time

Summary

It is critical to understand the performance specifications of your cell or battery test system. By developing a robust understanding of how to interpret and apply accuracy specifications, you can be more certain of requesting the right capabilities without over-specifying or under-specifying your needs when requesting a quote. When reading a datasheet or a statement of work for a customized system, you will know what you are buying and how well it fits your needs.

Learn More

Keysight has a broad range of test equipment for you to choose from to best meet the battery test requirements for your R&D lab or production line.

Learn more about Keysight 34465A and 34470A Truevolt digital multimeters for high-level accuracy specifications for nine types of measurement functions, the DAQ970A, DAQ973A, and 34980A data acquisition system for temperature measurements, N6705C DC power analyzer, and BV9210B / 11B PathWave BenchVue advanced battery test and emulation software.

For dedicated battery test systems, please visit Keysight Scienlab battery test systems, BT2152B Lithium-Ion cell self-discharge measurement solutions, and BT2200 Lithium-Ion cell charger-discharger solutions.

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