FLUKE®

Calibration

Calibrating the Agilent 3458A DMM with the 5730A Multifunction Calibrator

Application Note

Meeting the challenge

The calibration support of your most accurate workload has always been a formidable task. Although technical advances have digitized the world, many calibration standards have plateaued in their ability to reach higher and better accuracies. This is simply a reality when discussing instrument performance in single digit Parts Per Million (PPM). As a result, the metrologist must find practical ways to support workload that often pushes the capabilities of the standards available. The test uncertainty ratios (TURs) between the unit under test (UUT) and the standards used can be lower than those recommended by industry standards and practices. Yet, no one can afford to compromise the adequacy and traceability requirements of today's quality standards. Today's high-performance digital multimeters, like the popular 8½ digit Agilent 3458A, are excellent examples of such a challenging workload. This application note describes a process and procedure for fast, practical calibration using the new Fluke 5730A Calibrator. Guardbanding, as proposed in ISO 17025, and in other technical literature, offers a technique for addressing low TURs by providing a statistical means to assure, with sufficient confidence, that a calibration is adequate and complies with the manufacturer's requirements as well as good metrology guidelines. The fact that both the 3458A and the 5730A are conservatively specified, with small deviations from specification center points, and offer quiet and repeatable performance, makes the approach outlined here possible.

Agilent's recommended calibration procedures

Agilent publishes two calibration procedures for the 3458A. The first is the routine calibration published in the instrument's calibration manual. It is designed to verify the meter based on its hardware design. The second procedure is used in Agilent's service facilities, and is more rigorous from a metrology point of view. The fundamental difference between the two is that the procedure performed at Agilent service centers adds verification of the most accurate ac voltage mode, sychronous sub-sampling, and ac current. The procedures outlined here satisfy both approaches.

The simplest way to begin the discussion is to look at the procedure form included in the Agilent calibration manual. An example for direct voltage tests is shown in Figure 1.

The approach is quite straightforward. A signal is applied to the 3458A inputs. To pass, its reading must not exceed the limit called out in the "limit" columns. For most ranges and functions, the 5730A's output uncertainty is low enough to calibrate the 3458A directly. For those points that have low TURs, guard-banding principles can help you to calculate "new" limits so that the 5730A can be used to determine with sufficient confidence if any measurement point is in- or out-of-tolerance.

Guardbanding

Discrimination

The result of any calibration step falls into one of three classes: **in tolerance**, **out of tolerance** or **indeterminate**. The first step in guard-banding is to calculate test limits that assure that most, if not all, test results accurately fall within the in-tolerance or out-of-tolerance classes. The guardbanding technique explored in this paper is one of many methods. The calculation approach may differ between methods, but the concept remains the same.

Measurement statistics

Every calibration involves a measurement. All measurements are **estimates** of the true value of the measured parameter. And all measurements are subject to error, described as **uncertainty**.

For most measurements, the errors are normally distributed, described by the familiar "bell curve." Now, let's assume that a measured value, or offset, falls exactly at the upper specification limit for this calibration point, as shown in Figure 2. Given the uncertainty of the calibration standard used, which is described by the area under the bell curve, there is a 50 % probability that the **actual** value is really outside the specification for that calibration point. This is the case no matter how low the measurement uncertainty.

A 50 % probability that a measurement is in tolerance offers little in the way of a definitive statement about the UUT. Figure 3 shows what happens if the measured value falls between the specification center and the specification limit. Again, the area under the bell curve represents measurement uncertainty, but in this example, only 5 % of it falls to the right of the upper specification limit for the UUT. In this example, there is a 95 % probability that the measurement is in tolerance.

PERFORMANCE TEST CARD - 1 YEAR LIMITS

Agilent Model 3458A Digital Multimeter — Test Performed By ____________

Serial Number ____________ — Date ____________

DC VOLTAGE TESTS

CAL? 59 ____________

TEMP? ____________

Difference ____________ - (must be less than 5 degrees C)

Perform an ACAL DVC

Test #	3458A Input	3458A Range	Transfer Standard Reading	Unit Under Test Reading	Difference	Limit (Std)	Limit (Opt 002)	Pass	Fail
OFFSET TESTS	(NOTE: Math Null is Disabled)								
1	Short	100 mV	N/A	____	N/A	000.00106 mV	000.00106 mV	____	____
2	Short	1 V	N/A	____	N/A	0.00000106 V	0.00000106 V	____	____
3	Short	10 V	N/A	____	N/A	00.0000023 V	00.0000023 V	____	____
4	Short	100 V	N/A	____	N/A	000.000036 V	000.000036 V	____	____
5	Short	1000 V	N/A	____	N/A	0000.00010 V	0000.00010 V	____	____
GAIN TESTS									
1	100 mV	100 mV	____	____	____	000.00212 mV	000.00188 mV	____	____
2	1 V	1 V	____	____	____	0.00000998 V	0.00000740 V	____	____
3	1 V	10 V	____	____	____	00.0000111 V	00.0000085 V	____	____
4	-1 V	10 V	____	____	____	00.0000111 V	00.0000085 V	____	____
5	-10 V	10 V	____	____	____	00.0000892 V	00.0000624 V	____	____
6	10 V	10 V	____	____	____	00.0000892 V	00.0000624 V	____	____
7	100 V	100 V	____	____	____	000.001114 V	000.000853 V	____	____
8	1000 V	1000 V	____	____	____	0000.02396 V	0000.01934 V	____	____

Figure 1. Agilent 3458A Performance Test Card.

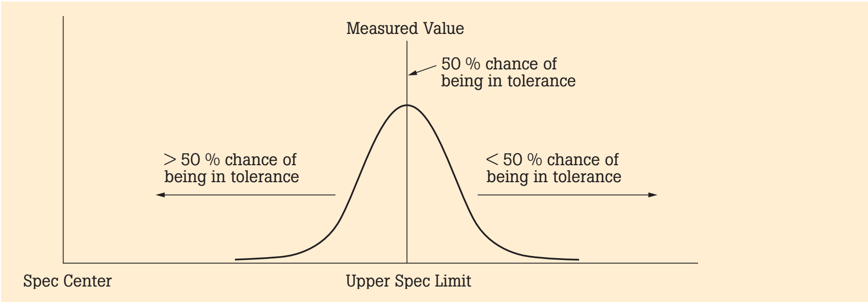

Figure 2. It is difficult to discriminate between in-tolerance and out-of-tolerance conditions when the measurement is made at the specification limit for the UUT.

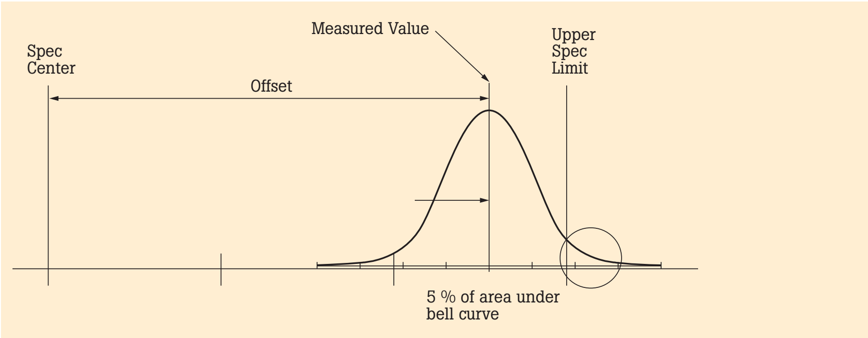

Figure 3. How guardbanding establishes a 95 % confidence in-tolerance test limit.

Range	Amplitude	Specifications		Adjustment to Test Limits	New Test Limits
		3458A, 1 year	5730A, 90 days		
220 mV	100 mV	14.65 ppm	10.00 ppm	8.22 ppm	6.43 ppm
220 mV	-100 mV	14.65 ppm	10.00 ppm	8.22 ppm	6.43 ppm
2.2 V	1 V	10.41 ppm	4.20 ppm	3.45 ppm	6.96 ppm
2.2 V	-1 V	10.41 ppm	4.20 ppm	3.45 ppm	6.96 ppm
11 V	10 V	10.13 ppm	2.75 ppm	2.26 ppm	7.87 ppm
11 V	-10 V	10.13 ppm	2.75 ppm	2.26 ppm	7.87 ppm
220 V	100 V	12.41 ppm	3.90 ppm	3.21 ppm	9.20 ppm
220 V	-100 V	12.41 ppm	3.90 ppm	3.21 ppm	9.20 ppm
1100 V	1000 V	24.18 ppm	4.90 ppm	4.03 ppm	20.15 ppm
1100 V	-1000 V	24.18 ppm	4.90 ppm	4.03 ppm	20.15 ppm

Table 1. Calculating the in-tolerance test points for direct voltage.

Calculating the guardband

Guardbanding is a statistical method for setting in-tolerance and out-of-tolerance limits so that you can discriminate between them with adequate confidence when TURs are small. In Table 1, we've calculated in-tolerance limits by comparing the uncertainty of the calibration standard with the specifications of the UUT, then set test limits that give us a 95 % probability of being within the UUT's specification limits.

You can use Equation 1 to calculate each test limit:

$$\text{TestLimit}_{\text{In Tol}} = \text{UUT}_{\text{Spec}} - \left(\frac{\text{Standard}_{\text{Spec}}}{2}\right)*1.6448$$

Equation 1. Calculating the in-tolerance test limit.

StandardSpec is the 5730A's specification expressed with a 95 % confidence level, or two standard deviations (2). No assumptions are made about the UUT's confidence level or measuring bias. For example, at 1 V dc, the specified uncertainty for the 3458A is ± 10.4 ppm, and ± 4.2 ppm for the 5730A. The test uncertainty ratio is 2.4:1. Using Equation 1, we can increase the confidence of the measurement to a sufficiently high level, by testing the 3458A to a limit of ± 7.0 ppm.

For test uncertainty ratios greater than 1.2:1, the error contribution is one-sided, as expressed in Equation 1. As ratios become smaller, the probability can become two sided and additional care must be taken. However, for this application, the lowest test uncertainty ratio is 1.2:1 and Equation 1 will yield sufficient confidence that a measurement is truly in or out of tolerance, without relying on an arbitrary ratio that may be both unnecessary and difficult to achieve efficiently.

Out of tolerance is defined as the test limit that provides at least a 95 % probability that the UUT is outside of its specification. Calculating the out-of-tolerance limit is conceptually the same as calculating the in-tolerance limit; simply use Equation 2.

$$\text{TestLimit}_{\text{Out Tol}} = \text{UUT}_{\text{Spec}} + \left(\frac{\text{Standard}_{\text{Spec}}}{2}\right)*1.6448$$

Equation 2. Calculating the out-of-tolerance test limit.

Calibrating the 3458A

For the most part, the 5730A provides uncertainties sufficiently low to support the 3458A to its one year specifications with reasonable test limits.

There are exceptions, however, where additional equipment is required. The specifics are determined by whether you use the calibration procedure in the calibration manual, or the procedure used in Agilent's service centers. Both approaches are covered here.

In this application, we use the 5730A's 90 day, 95 % confidence level specifications, in accordance with internationally recognized industry practices, though higher or lower confidence levels could be used by adjusting the test limits.

Calibration according to the 3458A calibration manual

The following tables provide the in-tolerance and out-of-tolerance limits for each calibration point, calculated as described above. The Fluke 5730A can address all points directly except for ± 100 µA dc, ± 1 mA, ± 10 mA, and ± 100 mA dc. For those points, use a 1k resistor like the Fluke 742A-1k to characterize the ± 100 µA dc point. In the same way, a 10 Ω 742A-10 can be used to characterize the ± 10 mA dc point, a 100 Ω 742A-100 to characterize the ± 1 mA dc point, and a 1 Ω 742A-1 can be used to characterize the ± 100 mA dc point.

Perform the characterization by sourcing the current value from the 5730A into the Current terminals of the 742A. Then measure the voltage across the 742A's Sense terminals with the 3458A. Using Ohm's Law, you can calculate the actual output value:

$$\text{Current}_{\text{Actual}} = \frac{\text{VDC}_{\text{measured}}}{742\text{A}_{\Omega\text{Value}}}$$

Equation 3. Characterizing a dc current output with a standard resistor.

To perform the characterization, you can use an in-calibration 3458A or the unit under test after the dc voltage ranges have been verified. The characterization should be performed once a week.

Basic equipment requirement

The equipment required to perform the 3458A procedure in the Agilent calibration manual includes:

- Fluke Calibration 5730A Calibrator with 5700A-03 wideband ac voltage option
  - Verification of voltage, current and resistance ranges
- Fluke Calibration 742A-1, 742A-10, 742A-100, and 742A-1k Resistance Standards
  - Characterization of ± 100 µA dc, ± 1 mA, ± 10 mA, and ± 100 mA dc current outputs of the 5730A
- Fluke Calibration 5790A AC Measurement Standard
- Agilent 3325A Function Generator
  - Frequency calibration (optional, for verifying frequency accuracy, not described in this application note)
- Fluke Calibration 5730A-7003 Low Thermal Test Lead set
  - Connecting the calibrator, standards and unit under test
- Copper wire
  - Offset tests

Additional equipment to perform the Agilent service center procedures

To verify the functions called out in the Agilent service center procedure, the following additional equipment is required:

- Fluke 5790A AC Measurement Standard. A 792A AC/DC Transfer Standard can be substituted.
  - Characterization of 12 ac V calibration output points.

Each ac V point is measured weekly with the 5790A and a correction is applied to the 5730A's output as described below.

Guardbanded test limits

Direct voltage verification

The 5730A can directly support the verification of the 3458A's direct voltage specifications. Table 2 lists each verification point and the required test limits.

Resistance verification

Likewise, the 5730A is capable of directly supporting the 3458A's resistance specifications, as shown in Table 3.

Alternating voltage verification—analog mode

When using the procedure called out in the Agilent 3458A calibration manual, the 5730A can directly support the analog mode alternating voltage specifications (see Table 4).

Alternating voltage verification—synchronous sub-sample mode

The output uncertainties of the 5730A must be characterized at 12 points (marked with an asterisk in Table 5) to meet the verification requirements of the 3458A's synchronous sub-sample mode. Those points are derived from a combination of the 5730A's short term stability and the 90-day uncertainty of the 5790A.

Alternating current verification

The 3458A calibration manual does not call for independent verification of the alternating current measurement ranges. They are verified in Agilent's service centers, and the test limits shown in Table 6 reflect those values. The 5730A is capable of supporting the 3458A's alternating current specifications directly.

Direct current verification

The direct current output uncertainties of the 5730A must be characterized at ± 100 µA, ± 1 mA, ± 10 mA and ± 100 mA. These characterized uncertainties are listed in Table 7 and are derived from a combination of the 5730A's short term stability and the 1 year specifications of the 742A-1, 742A-10, 742-100, and 742A-1k resistors and the 3458A. The specifications were combined using the "root sum square" or "RSS" technique. Characterization is performed by sourcing the desired current value into the current inputs of the 742A, and measuring the voltage at the sense terminals of the 742A with the 3458A. The characterized value can then be calculated using Ohm's Law. **(See "Calibration according to the 3458A calibration manual" on page 4.)**

The characterization should be performed once per week. Table 8 lists the test limits based on the characterized values.

Automating the process

Fluke Calibration has created an automated procedure for verifying the 3458A using MET/CAL® Calibration Software. Using a personal computer with two IEEE-488 interface cards, the MET/CAL procedure tests all the functions of the 3458A (including the optional frequency tests not discussed here) using the guardbanded test limits described above. In addition, it performs the necessary characterizations using the 742A Resistors and 5790A AC Measurement Standard. Operators have the choice of running the Agilent calibration manual's procedure or the full Agilent service center procedure.

MET/CAL dramatically reduces the time to fully verify the 3458A. After completing the ACal procedure recommended by Agilent, MET/CAL completes the verification in approximately 30 minutes, as little as a tenth of the time compared with more conventional approaches.

	Specifications					
			Test Limit			
			In-tolerance		Out-of-tolerance	
Direct Voltage (Input)	3458A (1 year)	5730A (90 days, 95 %)		% of spec		% of spec
100 mV	14.7 ppm	10.0 ppm	6.4 ppm	44 %	22.9 ppm	156 %
-100 mV	14.7 ppm	10.0 ppm	6.4 ppm	44 %	22.9 ppm	156 %
1 V	10.4 ppm	4.2 ppm	7.0 ppm	67 %	13.9 ppm	133 %
-1 V	10.4 ppm	4.2 ppm	7.0 ppm	67 %	13.9 ppm	133 %
10 V	10.1 ppm	2.8 ppm	7.9 ppm	78 %	12.4 ppm	122 %
-10 V	10.1 ppm	2.8 ppm	7.9 ppm	78 %	12.4 ppm	122 %
100 V	12.4 ppm	3.9 ppm	9.2 ppm	74 %	15.6 ppm	126 %
-100 V	12.4 ppm	3.9 ppm	9.2 ppm	74 %	15.6 ppm	126 %
1000 V	24.2 ppm	4.9 ppm	20.2 ppm	83 %	28.2 ppm	117 %
-1000 V	24.2 ppm	4.9 ppm	20.2 ppm	83 %	28.2 ppm	117 %

Table 2. DC voltage verification points and required test limits.

Resistance (Input)	Specifications 3458A (1 year)	5730A (90 days, 95 %)	Test Limit In-tolerance	In-tolerance % of spec	Out-of-tolerance	Out-of-tolerance % of spec
10 Ω	24.9 ppm	21 ppm	7.63 ppm	0.31 %	42.17 ppm	1.69 %
100 Ω	21.9 ppm	9 ppm	14.50 ppm	0.66 %	29.30 ppm	1.34 %
1 kΩ	13.7 ppm	5.7 ppm	9.01 ppm	0.66 %	18.39 ppm	1.34 %
10 kΩ	13.7 ppm	5.5 ppm	9.18 ppm	0.67 %	18.22 ppm	1.33 %
100 kΩ	13.7 ppm	7.5 ppm	7.53 ppm	0.55 %	19.87 ppm	1.45 %
1 MΩ	20.3 ppm	11 ppm	11.25 ppm	0.55 %	29.35 ppm	1.45 %
10 MΩ	63.4 ppm	31 ppm	37.91 ppm	0.60 %	88.89 ppm	1.40 %
100 MΩ	534.7 ppm	95 ppm	456.57 ppm	0.85 %	612.83 ppm	1.15 %

Table 3. Resistance verification points and required test limits.

Alternating Voltage (Input)	Frequency	Specifications 3458A (1 year)	5730A (90 days, 95 %)	Test Limit In-tolerance	In-tolerance % of spec	Out-of-tolerance	Out-of-tolerance % of spec
100 mV	1 kHz	0.03 %	0.013 %	0.020 %	0.66 %	0.040 %	1.34 %
1 V	1 kHz	0.03 %	0.005 %	0.026 %	0.87 %	0.034 %	1.13 %
1 V	50 kHz	0.55 %	0.007 %	0.544 %	0.99 %	0.556 %	1.01 %
1 V	1 MHz	25 %	0.18 %	24.852 %	0.99 %	25.148 %	1.01 %
10 V	10 Hz	0.42 %	0.026 %	0.399 %	0.95 %	0.441 %	1.05 %
10 V	20 Hz	0.17 %	0.0095 %	0.163 %	0.96 %	0.177 %	1.04 %
10 V	200 Hz	0.03 %	0.004 %	0.026 %	0.88 %	0.034 %	1.12 %
10 V	500 Hz	0.03 %	0.004 %	0.026 %	0.88 %	0.034 %	1.12 %
10 V	1 kHz	0.03 %	0.004 %	0.026 %	0.88 %	0.034 %	1.12 %
10 V	20 kHz	0.03 %	0.004 %	0.026 %	0.88 %	0.034 %	1.12 %
10 V	50 kHz	0.19 %	0.007 %	0.184 %	0.97 %	0.196 %	1.03 %
10 V	100 kHz	0.68 %	0.01 %	0.672 %	0.99 %	0.688 %	1.01 %
10 V	1 MHz	7 %	0.162 %	6.867 %	0.98 %	7.133 %	1.02 %
100 V	1 kHz	0.04 %	0.005 %	0.036 %	0.89 %	0.044 %	1.11 %
700 V	1 kHz	0.089 %	0.007 %	0.084 %	0.94 %	0.094 %	1.06 %

Table 4. AC voltage (analog mode) verification points and required test limits.

Alternating Voltage (Input)	Specifications						
				Test Limit			
				In-tolerance		Out-of-tolerance	
	Frequency	3458A (1 year)	5730A (90 days, 95 %)		% of spec		% of spec
10 mV	1 kHz	0.032 %	0.0475 %	-0.007 %	-0.22 %	0.071 %	2.221 %
10 mV	20 kHz	0.042 %	0.0475 %*	0.003 %	0.07 %	0.081 %	1.930 %
10 mV	100 kHz	0.512 %	0.096 %	0.433 %	0.85 %	0.591 %	1.154 %
10 mV	300 kHz	4.021 %	0.19 %	3.865 %	0.96 %	4.177 %	1.039 %
10 mV	1 MHz	1.25 %	0.45 %	0.880 %	0.70 %	1.620 %	1.296 %
100 mV	1 kHz	0.01 %	0.0125 %*	-0.000 %	-0.03 %	0.020 %	2.028 %
100 mV	20 kHz	0.017 %	0.0125 %*	0.007 %	0.40 %	0.027 %	1.605 %
100 mV	100 kHz	0.083 %	0.0468 %*	0.045 %	0.54 %	0.121 %	1.464 %
100 mV	300 kHz	0.311 %	0.0783 %*	0.247 %	0.79 %	0.375 %	1.207 %
100 mV	1 MHz	1.02 %	0.295 %	0.777 %	0.76 %	1.263 %	1.238 %
1 V	1 kHz	0.01 %	0.0047 %*	0.006 %	0.61 %	0.014 %	1.387 %
1 V	20 kHz	0.017 %	0.0047 %	0.013 %	0.77 %	0.021 %	1.227 %
1 V	50 kHz	0.033 %	0.0073 %	0.027 %	0.82 %	0.039 %	1.182 %
1 V	100 kHz	0.083 %	0.0111 %*	0.074 %	0.89 %	0.092 %	1.109 %
1 V	300 kHz	0.311 %	0.038 %	0.280 %	0.90 %	0.342 %	1.100 %
1 V	500 kHz	1.011 %	0.11 %	0.921 %	0.91 %	1.101 %	1.089 %
1 V	1 MHz	1.011 %	0.18 %*	0.863 %	0.85 %	1.159 %	1.146 %
3 V	100 kHz	0.088 %	0.0146 %	0.076 %	0.86 %	0.100 %	1.136 %
10 V	10 Hz	0.012 %	0.026 %*	-0.009 %	-0.78 %	0.033 %	2.782 %
10 V	20 Hz	0.012 %	0.0095 %*	-0.009 %	-0.78 %	0.033 %	2.782 %
10 V	40 Hz	0.01 %	0.0044 %	0.006 %	0.64 %	0.014 %	1.362 %
10 V	1 kHz	0.01 %	0.0044 %	0.006 %	0.64 %	0.014 %	1.362 %
10 V	10 kHz	0.017 %	0.0044 %	0.013 %	0.79 %	0.021 %	1.213 %
10 V	20 kHz	0.017 %	0.0044 %	0.013 %	0.79 %	0.021 %	1.213 %
10 V	50 kHz	0.033 %	0.0073 %	0.027 %	0.82 %	0.039 %	1.182 %
10 V	100 kHz	0.083 %	0.01 %	0.075 %	0.90 %	0.091 %	1.099 %
10 V	300 kHz	0.311 %	0.0303 %	0.286 %	0.92 %	0.336 %	1.080 %
10 V	500 kHz	1.011 %	0.11 %	0.921 %	0.91 %	1.101 %	1.089 %
10 V	1 MHz	1.011 %	0.162 %*	0.878 %	0.87 %	1.144 %	1.132 %
100 V	1 kHz	0.023 %	0.0053 %	0.019 %	0.81 %	0.027 %	1.190 %
100 V	20 kHz	0.023 %	0.0053 %	0.019 %	0.81 %	0.027 %	1.190 %
100 V	50 kHz	0.038 %	0.0085 %	0.031 %	0.82 %	0.045 %	1.184 %
100 V	100 kHz	0.123 %	0.0155 %	0.110 %	0.90 %	0.136 %	1.104 %
700 V	1 kHz	0.044 %	0.0065 %*	0.007 %	0.15 %	0.081 %	1.850 %

Table 5. AC voltage (synchronous sub-sample mode) verification points and required test limits.
*Value calculated using a Fluke 5790A AC Measurement Standard and automated MET/CAL software procedures to improve the 5730A accuracy.

Alternating Current (Input)	Specifications						
				Test Limit			
				In-tolerance		Out-of-tolerance	
	Frequency	3458A (1 year)	5730A (90 days, 95 %)		% of spec		% of spec
10 µA	1 kHz	0.36 %	0.090 %	0.286 %	0.79 %	0.434 %	1.205 %
100 µA	1 kHz	0.091 %	0.018 %	0.076 %	0.84 %	0.106 %	1.162 %
1 mA	1 kHz	0.051 %	0.013 %	0.040 %	0.78 %	0.062 %	1.216%
10 mA	1 kHz	0.051 %	0.013 %	0.040 %	0.78 %	0.062 %	1.216 %
100 mA	1 kHz	0.051 %	0.012 %	0.041 %	0.80 %	0.061 %	1.200 %
1 A	1 kHz	0.121 %	0.026 %	0.100 %	0.82 %	0.142 %	1.176 %

Table 6. AC current verification points and required test limits.

	3458A (@ 0.1 V) (1 year)	5730A (Stability) (24 hours)	742A		
			Value (Ω)	Specification (1 year)	Total Specification
100 µA	14.7 ppm	15 ppm	1k	6.5 ppm	22.0 ppm
-100 µA	14.7 ppm	15 ppm	1k	6.5 ppm	22.0 ppm
1 mA	14.7 ppm	10 ppm	100	6.8 ppm	19.0 ppm
-1 mA	14.7 ppm	10 ppm	100	6.8 ppm	19.0 ppm
10 mA	14.7 ppm	10 ppm	10	8.6 ppm	19.7 ppm
-10 mA	14.7 ppm	10 ppm	10	8.6 ppm	19.7 ppm
100 mA	14.7 ppm	11 ppm	1	8.6 ppm	20.3 ppm
-100 mA	14.7 ppm	11 ppm	1	8.6 ppm	20.3 ppm

Table 7. Characterized dc current uncertainties.

Direct Current (Input)	Specifications					
	3458A (1 year)	Composite 742A, 3458A 5730A (Stability)	Test Limit			
			In-tolerance		Out-of-tolerance	
				% of spec		% of spec
100 µA	50.0 ppm	22.0 ppm	31.9 ppm	64 %	68.1 ppm	136 %
-100 µA	50.0 ppm	22.0 ppm	31.9 ppm	64 %	68.1 ppm	136 %
1 mA	47.0 ppm	19.0 ppm	31.4 ppm	67 %	62.6 ppm	133 %
-1 mA	47.0 ppm	19.0 ppm	31.4 ppm	67 %	62.6 ppm	133 %
10 mA	36.2 ppm	19.7 ppm	20.0 ppm	55 %	52.4 ppm	145 %
-10 mA	36.2 ppm	19.7 ppm	20.0 ppm	55 %	52.4 ppm	145 %
100 mA	51.2 ppm	20.3 ppm	34.5 ppm	67 %	67.9 ppm	133 %
-100 mA	51.2 ppm	20.3 ppm	34.5 ppm	67 %	67.9 ppm	133 %
1 A	131.2 ppm	72.0 ppm	72.0 ppm	55 %	190.5 ppm	145 %
-1 A	131.2 ppm	72.0 ppm	72.0 ppm	55 %	190.5 ppm	145 %

Table 8. DC current verification points and required test limits.

Fluke Calibration
PO Box 9090, Everett, WA 98206 U.S.A.

Fluke Europe B.V.
PO Box 1186, 5602 BD
Eindhoven, The Netherlands

For more information call:
In the U.S.A. (877) 355-3225 or
Fax (425) 446-5116
In Europe/M-East/Africa +31 (0) 40
2675 200 or Fax +31 (0) 40 2675 222
In Canada (800)-36-FLUKE or
Fax (905) 890-6866

From other countries +1 (425) 446-5500 or
Fax +1 (425) 446-5116
Web access: http://www.flukecal.com