Updated Evaluation of Calibration Test Point Selection for Fluke 57XX products

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1.0 Abstract

The first Fluke 5700 series calibrator was manufactured in the late 1980's. The metrology and associated test point selection for calibrating the product was rigorous by any standards, then or now. However, the calibration procedure that has been in place essentially since its initial release pre-dates significant advances in hardware, such as the Fluke Calibration 792A and 5790A, as well as ISO 17025, and the popularization of voluntary calibration laboratory accreditation.

Fluke Calibration has re-visited the selection of test points in the calibration procedure to ensure that the result of any 5700 series calibrator would clearly demonstrate that all specifications have been verified, and that traceability for all functions is ensured. This was accomplished by an event that brought together representatives from Design Engineering, Test Engineering, Service Engineering, Service Metrology and Corporate Metrology. The group evaluated each specification, considered the internal architecture of the product, and reviewed and improved upon the test points. This paper presents the test points for the 5700 series calibrators and the technical information as to why they were chosen.

2.0 Learning objectives

The attendee will understand why the test points selected for the Fluke 5700 series calibrators verify all product specifications and ensure metrological traceability for all functions of the product.

3.0 Introduction

The Fluke 5700 family of multifunction calibrators is one of the cornerstone reference standards for electrical calibration laboratories around the world. This product is used in a wide array of applications and establishments, from National Measurement Institutes to field calibration laboratories; from factory production lines to onboard Navy ships. While some improvements have been made in performance and internal circuit design over the years, much of the basic design is the same as its original form. The 5700 series calibrators remain the world's most accurate multifunction calibrator.

For Fluke to ensure that each manufactured product meets all published specifications, a thorough metrology evaluation occurs during the design process. However, for the 5700 series, the evaluation took place in late 1980's. There have been significant developments in quality standards associated with metrology since then. The design and initial manufacture of the 5700 series predates ANSI/NCSL Z540-1-1994, ISO 17025, the European co-operation for accreditation, the ILAC Mutual Recognition Arrangement, and the CIPM Mutual Recognition Arrangement.

Over the years, accreditation bodies have questioned the test point selection associated with the calibration of the 5700 series product. While Fluke has always satisfied technical inquiries associated with our test point selection, we felt that it was time to revisit this issue. The first reason is that some of original designers of the product are nearing retirement age, and improving documentation associated with the calibration process is one of our knowledge capture functions. The second reason is to provide a succinct document for both customers and accreditation bodies to explain Fluke's test point selection strategy, so that this information can be shared and presented for peer review. Lastly, Fluke has a strong commitment to continuous improvement, and since the world of metrology has changed since the introduction of this product, we felt that it was important to apply our own critical eye on the original test point selection with regards to improvement opportunities.

Satisfactory selection of test points for the calibration of any test instrument requires intimate knowledge of the product's design and a sound background in metrology. It also helps to have an understanding of relevant quality standards. In June 2012, Fluke applied one of our lean manufacturing management tools, a Kaizen event, to help us evaluate and select the 5700 series product specifications. The Kaizen event brought together associates from Design Engineering, Test Engineering, Service Engineering, Corporate Metrology and Service Metrology to evaluate the present test points associated with calibration, to ensure that they adequately verify product specifications. One of the principles of lean manufacturing is to eliminate tasks that do not add value to the process. The team's goal was to ensure that the appropriate test points needed to validate the product were selected, but not to add unnecessary test points. These are the test points that are reported on the certificate of calibration, whether the calibration was produced during its initial manufacture, or if the product is returned for recalibration. It is important to note that there are many additional test points that the factory checks during the initial manufacturing of the instrument. These are one-time tests to ensure functionality of new circuit boards and are not required for routine recalibration. The results of the Kaizen for the calibration are presented below. This set of test points can be used to determine performance of the calibrator against the 24-hour, 90-days, 180-days or one-year specifications, or for the 99 percent or 95 percent level of confidence, because the formatting of these specifications is identical; the only difference is the test limits for each specification.

4.0 Discussion

4.1 DC voltage function

It is critical to perform thorough testing of the dc voltage function as it is interrelated to other outputs of the instrument. Table 1 presents the test points that are required to verify the product specifications of the 5700 series calibrators for dc voltage.

The instrument is tested at the minimum output at all ranges for compliance to specification. For negative dc voltage values, a relay is employed to reverse the polarity of the voltage generation circuitry, so Fluke also tests the "negative zero" output, which is the minimum negative voltage value that can be sourced to ensure that the zero output on the negative range also performs to the product specifications. When a zero output is selected, the default position of the relay is in the positive voltage position. Note that the 1100 volt range has a minimum output of 100 volts because the high voltage range is sourced by rectifying the output of the high voltage step up transformer and is controlled by the 11 volt range of the digital-to-analog Converter (DAC) assembly, so testing at zero volts for this range is not possible.

The linearity of the DAC is verified on the 22 volt range where the instrument is tested from zero to positive and negative 19 volts. The same DAC circuitry is used for all voltage output functions, so a test of the linearity of this range is all that is required to test the linearity for the rest of the dc voltage output functions, making it only necessary to test a reduced set of points on the other ranges. Due to the very accurate specifications of the 5700 series calibrators, Fluke tests the rest of the ranges at outputs that are multiples of 10, as most calibration laboratories achieve their best measurement uncertainties at these points. Even though this output is only approximately 50 percent of the range output, since the linearity has been verified previously, this satisfactorily validates the product specification.

Range	Test Points
220 mV	0 mV
	-10 nV
	100 mV
	-100mV
2.2 V	0 V
	-100 nV
	1 V
	-1 V
11 V	0 V
	-1 µV
	10 V
	-10 V
22 V	0 V
	-1 µV
	10 V
	-10 V
	19 V
	-19 V
220 V	0 V
	-10 µV
	100 V
	-100 V
1100 V	100 V
	-100 V
	1000 V
	-1000 V

Table 1, dc voltage test points

4.2 AC voltage function

Linearity of the ac voltage output function is thoroughly verified on the 2.2 volt range at 0.5 volts, 1 volt and 2 volts, so the remaining functions only require single point amplitude checks.

In order to ensure that the ac voltage output meets its frequency response specifications, Fluke selected test points at the frequency break points for all specifications. For border specifications (specifications that are shared by two frequency ranges), the amplitude and frequency was only tested once, and assessed to the smaller of the two specifications. Since the range of ac voltage is in multiples of 2.2, the amplitude of 2 was primarily selected, as it is a both a convenient nominal test point and it is approximately 90 percent of full scale. This is adequate to ensure the gain of each range functions properly, and our reference standards are calibrated at these points allowing the best measurement uncertainties to be realized in the calibration process.

The 1100 volt range is tested at a high and low voltage value in order to verify the power coefficients of the components on this range. One test on the 2.2 millivolt range was added at 600 microvolts in order to test the floor noise of the calibrator. On the 220 volt range, the test voltages above 100 kHz are constrained by the volt-hertz limit of the calibrator.

Range	Frequency (Hz)							
	10 – 20	20 – 40	40 – 20k	20k – 50k	50k – 100k	100k – 300 k	300k – 500k	500k – 1M
2.2 mV	2 mV, 10	2 mV, 20	600 μV, 1k 2 mV, 40 2 mV, 1k 2 mV, 20k	2 mV, 50k	2 mV, 100k	2 mV, 300k	2 mV, 500k	2 mV, 1 M
22 mV	20 mV, 10	20 mV, 20	20 mV, 40 20 mV, 1k 20 mV, 20k	20 mV. 50k	20 mV, 100k	20 mV, 300k	20 mV, 500k	20 mV, 1 M
220 mV	200 mV, 10	200 mV, 20	200 mV, 40 200 mV, 1k 200 mV 20k	200 mV, 50k	200 mV, 100k	200 mV, 300k	200 mV, 500k	200 mV, 1 M
2.2 V	2 V, 10	2 V, 20	500 mV 40 1 V, 40 2 V, 40 500 mV 1k 1 V, 1k 2 V, 1k 500 mV, 20k 1 V, 20k 2 V, 20k	2 V, 50k	500 mV, 100k 1 V, 100k 2 V, 100k,	500 mV, 300k 1 V, 300 k 2 V, 300k	2 V, 500k	500 mV, 1M 1 V, 1 M 2 V, 1 M
22 V	20 V, 10	20 V, 20	20 V, 40 20 V, 1k 20 V, 20k	20 V, 50k	20 V, 100k	20 V, 300k	20 V, 500k	20 V, 1 M
220 V	200 V, 10	200 V, 20	200 v, 40 200 V, 1k 200 V 20k	200 V, 50k	200 V, 100k	50 V, 300k	30 V, 500k	22 V, 1 M
	15 – 50	50 – 1k						
1100 V	250 V, 15	500 V, 50 500 V, 1k 1000 V, 50 1000 V, 1k						

Table 2, ac voltage test points

4.3 Frequency

The frequency from internal oscillator on the Current/Hi Res (A7) assembly is fed through the oscillator output assembly when the calibrator is not being controlled by an external frequency reference through the PHASE LOCK IN connector. The synthesized frequency that is developed from the A7 assembly is verified at the following points which test the low and high end of the frequency range for the calibrator, break points for the frequency range for the oscillator and other sampled points.

Range (Hz)	Test Points (Hz)
10.000 – 119.99	2 V, 10
	2 V, 119.9
0.120 k – 1.1999 k	2 V, 120
	2 V, 400
	2 V, 1.199 k
1.200 k – 11.999 k	2 V, 1.2 k
	2 V, 11.99 k
12.00 k – 119.99 k	2 V, 12 k
	2 V, 119.9 k
120.0 k – 1.1999 M	2 V, 120 k
	2 V, 1 M
	2 V, 1.1999M

Table 3, Frequency test points

4.4 Resistance

Since the calibrator architecture consists of a short (0 ohms) and 17 fixed resistors, there is no subjectivity to selecting test points. The resistors' artifact-calibrated values are compared to limits for maximum deviation from nominal (no measurement required) and the actual values are measured against accuracy specifications. Since the nominal value is the test point, no table has been provided.

4.5 DC current

The dc current function is tested in a manner similar to the dc volts function, where the test points are selected at the minimum output and near full scale (positive and negative) for each range. The nominal value of 2 was selected for the sake of convenience and that it is approximately 90 percent of full scale for each range. Range linearity is tested on the 220 µA range. 100 mA on the 220 mA range and 1 A on the 2.2 A range were selected to check the power coefficient of the shunt resistors in the circuitry. Unlike the dc volts circuit, there is no need to test the negative zero output because it was verified appropriately during the dc voltage tests.

Range	Test points
220 µA	0 µA
	10 µA
	-10 µA
	200 µA
	-200 µA
2.2 mA	0 mA
	2 mA
	-2 mA
22 mA	0 mA
	20 mA
	-20 mA
220 mA	0 mA
	100 mA
	200 mA
	-200 mA
2.2 A	0 A
	1A
	2A
	-2A

Table 4, DC current test points

4.6 AC current

AC current linearity is verified on the 220 µA range by testing at 20 µA and 200 µA. In a manner similar to the ac voltage tests, frequency response is primarily tested at the frequency specification breakpoints, always to the better of the bordering specifications. The auxiliary terminal is also tested to ensure that it performs to specifications. The auxiliary terminal has a different specification for the 5720A on the 220 µA range, which also needs to be verified.

Range	Frequency (Hz)				
	10 – 20	20 – 40	40 – 1k	1k – 5k	5k – 10k
220 µA	200 µA, 10	200 µA, 20	20 µA, 1k 200 µA, 40 200 µA, 1k	200 µA, 5k	20 µA, 10k 200 µA, 10k
2.2 mA	2 mA, 10	2 mA, 20	2 mA, 40 2 mA, 1k	2 mA, 5k	2 mA, 10k
22 mA	20 mA, 10	20 mA, 20	20 mA, 40 20 mA, 1k	20 mA, 5k	20 mA, 10k
220 mA	200 mA, 10	200 mA, 20	200 mA, 40 200 mA, 1k	200 mA, 5k	200 mA, 10k
	20 – 1k			1k – 5k	5k – 10k
2.2 A	2 A, 20 Hz			2 A, 1k 2 A, 5k	2A, 10k
Aux terminals			20 µA, 1k 200 µA, 5 k 200 µA, 10 k		

Table 6, AC current test points

5.0 Conclusion

The implementation of the new test points is a carefully timed and coordinated event. Updates of calibration procedures in service manuals are in process. Service calibrations to the revised test points will commence in the second half of 2013 after the service manuals have been released. Factory calibrations of new products are scheduled to implement the revised test points in the last quarter of 2013.

If an end user of a Fluke 5700 series calibrator desires to be able to use any output function and have confidence that it performs to published specifications, an appropriate calibration is required. Fluke is providing this critical information on test points required for calibration of 5700 series calibrators so that both end users and organizations that calibrate this instrument will understand the proper test points required for its calibration. Additionally, the technical reasoning regarding test point selection is provided to organizations that seek to better understand how Fluke can disseminate traceability from all functions of this instrument.

6.0 References

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