

# Supplementary Information



## Standards Laboratory Calibration

Order Number 1-xxxxxxxxxx-1

**Model Number** 3458A  
**Manufacturer** Keysight Technologies Inc  
**Description** Digital multimeter, 8.5 digit  
**Serial Number** /HERE SN/  
**Options Installed** 002

**Customer**  
Keysight Technologies Deutschland GmbH  
Herrenberger Strasse 130  
71034 BOEBLINGEN  
Germany

**Date of Calibration** 7 Jan 2020  
**Procedure**  
**Temperature** (23 ± 1) °C  
**Humidity** (40 ± 20) %RH

**Location of Calibration**  
Keysight Technologies UK Limited  
610 Wharfedale Road  
Winnersh Triangle  
Wokingham Berkshire RG41 5TP  
UNITED KINGDOM

### Remarks or Special Requirements

THIS COVER SHEET IS SUPPLEMENTARY TO THE ACCREDITED CALIBRATION CERTIFICATE.

### Calibration Equipment Used

Model Number	Model Description	Equipment ID	Cal Due Date	Order Number
100M	100 MOhm Resistance box	UK7709	18 Nov 2021	1-xxxxxxxxxx-1
1G	Resistance Std.	UK7708	12 Sep 2021	1-xxxxxxxxxx-1
3325A	Synthesizer/Function Generator	UK7740	1 Feb 2020	1-xxxxxxxxxx-1
3458A	Digital multimeter, 8.5 digit	UK11880	12 Feb 2020	1-xxxxxxxxxx-1
3458A	Digital multimeter, 8.5 digit	UK8606	19 Mar 2020	1-xxxxxxxxxx-1
4000A	Calibrator, Transconductance AMP	UK5802	22 Feb 2020	1-xxxxxxxxxx-1
4035-B	Standard Resistor	DE915	26 Mar 2021	1-xxxxxxxxxx-1
4200	AC Standard Calibrator	UK5906	25 Jan 2020	1-xxxxxxxxxx-1
5071A	Primary frequency standard	UK13623	18 Feb 2020	1-xxxxxxxxxx-1
5685A	AC/DC Standard Resistor	UK7301	25 Sep 2020	1-xxxxxxxxxx-1
5685A	AC/DC Standard Resistor	UK7677	26 Apr 2020	1-xxxxxxxxxx-1
5685A	AC/DC Standard Resistor	UK5564	26 Apr 2020	1-xxxxxxxxxx-1
5720A	Calibrator	UK15273	10 Mar 2020	1-xxxxxxxxxx-1
5790A	AC Voltmeter	UK15582	5 Jan 2021	1-xxxxxxxxxx-1
732A	DC Reference Standard	UK8509	20 Feb 2020	1-xxxxxxxxxx-1
752A	Reference Divider	UK11024	13 Nov 2020	1-xxxxxxxxxx-1
80010	Standard Resistor	UK4275	26 Apr 2020	1-xxxxxxxxxx-1
9330	Standard Resistor	UK5465	26 Sep 2020	1-xxxxxxxxxx-1
9330	Standard Resistor	UK5379	1 Oct 2020	1-xxxxxxxxxx-1
A40	Current Shunt	DE1748	1 Oct 2020	1-xxxxxxxxxx-1
RS3	Standard Resistor	UK5468	24 Apr 2020	1-xxxxxxxxxx-1
SR104	Standard Resistor	ITSVC311	16 Sep 2020	1-xxxxxxxxxx-1

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Mike Horsefield - Approved Signatory

# CERTIFICATE OF CALIBRATION



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APPROVED SIGNATORY

Mike Horsefield

Date Of Issue: 7 January 2020 Page 1 of 7 pages  
Instrument Description: Digital Multimeter  
Instrument Manufacturer: Keysight Technologies  
Model Number: 3458A  
Serial Number: -HERE SN-  
Our Reference Number: 1-xxxxxxxxxxx-1  
Customer: Keysight Technologies Deutschland GmbH, 71034 BOEBLINGEN, Germany  
Date Of Calibration: 7 January 2020  
Ambient Temperature: (23 ± 1) °C      Relative Humidity: (40 ± 20) %

### REMARKS:

This certificate records the **on-receipt** calibration status of the instrument, the item was returned in this condition.

Its performance conformed to the manufacturer's specification at the points measured, due allowance having been made for measurement uncertainty.

### TEST DESCRIPTION:

The 1-year specification has been used to define the absolute test limits in this certificate. They include the original manufacturer's calibration uncertainty for NIST traceability as published in the product's Calibration Manual 03458-90017:Dec2000.

A minimum warm-up period of 4 hours was allowed before testing. In accordance with the manufacturer's recommended practice, the appropriate "ACAL" routines were invoked before testing each function.

The Firmware version reported by REV? was  
The value for CALNUM? reported by the 3458A PRIOR to testing was  
and at COMPLETION of testing was

7,2
138
138

Test location  Permanent lab     Mobile lab     Customer's building

The reported uncertainty is based on a standard uncertainty multiplied by a coverage factor k=2, providing a coverage probability of approximately 95%. Any quoted uncertainty refers only to the measured value and does not carry any implication regarding the long term stability of the instrument.

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**Applicable Specification :**

- Standard  
 Option 002

**DC Voltage Accuracy**

Last calibration internal temperature (Cal? 59) = **35.33** °C  
Present internal temperature (Temp?) = **34.6** °C

3458A set-up: NPLC 500, NDIG 8

**Zero Offsets**

A low thermal short was connected to the input terminals.

Applied	Range	Specification (applied ± limit)	Measured Value	Uncertainty	Status (if applicable)
0 mV	100 mV	± 0.9 µV	-0.00008 mV	± 0.3 µV	
0 V	1 V	± 1.0 µV	-0.00000009 V	± 0.3 µV	
0 V	10 V	± 2.0 µV	-0.0000001 V	± 0.3 µV	
0 V	100 V	± 30 µV	0.000012 V	± 1.0 µV	
0 V	1000 V	± 100 µV	0.00000 V	± 12 µV	

**Gain**

The following measurements used the multimeter's "Math Null" function to exclude thermal emf's and other internal offsets from the measured value.

Applied	Range	Specification (applied ± limit)	Measured Value	Uncertainty	Status (if applicable)
100 mV	100 mV	± 1.00 µV	99.99975 mV	± 0.34 µV	
-100 mV	100 mV	± 1.00 µV	-99.99983 mV	± 0.34 µV	
1 V	1 V	± 6.3 µV	0.99999940 V	± 1.7 µV	
-1 V	1 V	± 6.3 µV	-0.99999760 V	± 1.7 µV	
10 V	10 V	± 60.5 µV	9.9999810 V	± 15 µV	
-10 V	10 V	± 60.5 µV	-9.9999797 V	± 15 µV	
100 V	100 V	± 830 µV	99.999886 V	± 120 µV	
-100 V	100 V	± 830 µV	-99.999846 V	± 120 µV	
1000 V	1000 V	± 20.1 mV	999.99534 V	± 1.3 mV	
-1000 V	1000 V	± 20.1 mV	-999.99513 V	± 1.3 mV	

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**AC Voltage Accuracy (Synchronous mode)**

A voltage of substantially sinusoidal form was applied to the 3458A input.

3458A set-up: SETACV SYNC; RES .001

LFILTER ON; for frequencies <= 50 kHz, otherwise LFILTER OFF

ACBAND 10,1E6 for frequencies <= 1 MHz, except 10 mV @ 1 MHz which uses ACBAND 10,1E7

ACBAND 10,1E7 for frequencies > 1 MHz

Applied		Range	Specification (applied ± limit)	Measured Value	Uncertainty	Status (if applicable)
10 mV	1 kHz	10 mV	± 3.12 µV	9.99990 mV	± 0.72 µV	
10 mV	20 kHz	10 mV	± 4.12 µV	9.99860 mV	± 1.1 µV	
10 mV	100 kHz	10 mV	± 51.12 µV	9.97591 mV	± 4.2 µV	
10 mV	300 kHz	10 mV	± 402.02 µV	9.79952 mV	± 6.6 µV	
100 mV	1 kHz	100 mV	± 9.2 µV	100.0045 mV	± 4.6 µV	
100 mV	20 kHz	100 mV	± 16.2 µV	99.9993 mV	± 4.7 µV	
100 mV	100 kHz	100 mV	± 82.2 µV	99.9882 mV	± 5.4 µV	
100 mV	300 kHz	100 mV	± 310.2 µV	99.9767 mV	± 19 µV	
1 V	1 kHz	1 V	± 92 µV	1.000002 V	± 30 µV	
1 V	20 kHz	1 V	± 162 µV	0.999963 V	± 36 µV	
1 V	50 kHz	1 V	± 322 µV	0.999968 V	± 33 µV	
1 V	100 kHz	1 V	± 822 µV	0.999933 V	± 34 µV	
1 V	300 kHz	1 V	± 3.102 mV	1.000513 V	± 0.15 mV	
1 V	500 kHz	1 V	± 10.102 mV	1.001560 V	± 0.11 mV	
3 V	100 kHz	10 V	± 2.602 mV	2.99827 V	± 0.12 mV	
10 V	10 Hz	10 V	± 1.12 mV	10.00003 V	± 0.49 mV	
10 V	20 Hz	10 V	± 1.12 mV	10.00005 V	± 0.44 mV	
10 V	40 Hz	10 V	± 0.92 mV	10.00004 V	± 0.32 mV	
10 V	1 kHz	10 V	± 0.92 mV	10.00018 V	± 0.32 mV	
10 V	10 kHz	10 V	± 1.62 mV	9.99978 V	± 0.36 mV	
10 V	20 kHz	10 V	± 1.62 mV	9.99967 V	± 0.36 mV	
10 V	50 kHz	10 V	± 3.22 mV	9.99860 V	± 0.33 mV	
10 V	100 kHz	10 V	± 8.22 mV	9.99467 V	± 0.33 mV	
10 V	300 kHz	10 V	± 31.02 mV	9.97940 V	± 1.7 mV	
10 V	500 kHz	10 V	± 101.02 mV	9.97829 V	± 1.3 mV	
10 V	1 MHz	10 V	± 101.02 mV	10.04881 V	± 3.9 mV	
100 V	1 kHz	100 V	± 0.0222 V	99.9988 V	± 0.0036 V	
100 V	20 kHz	100 V	± 0.0222 V	99.9977 V	± 0.0043 V	
100 V	50 kHz	100 V	± 0.0372 V	99.9931 V	± 0.0037 V	
100 V	100 kHz	100 V	± 0.1222 V	99.9581 V	± 0.0038 V	
700 V	1 kHz	1000 V	± 0.301 V	699.789 V	± 0.031 V	

The reported uncertainty is based on a standard uncertainty multiplied by a coverage factor k=2, providing a coverage probability of approximately 95%.  
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## AC Voltage High Frequency

3458A set-up: SETACV SYNC; RES .001; ACBAND 10, 1E7

Input Voltage Freq.	Expected Value	Measured Value	Difference	Tolerance	Uncertainty	Status (if applicable)
<b>10 mV Range</b>						
0.01 V 1 MHz	0.00994712 V	0.01001237 V	0.00006525 V	± 0.00012512 V	± 0.013 mV	
0.01 V 4 MHz	0.00983988 V	0.00983164 V	-0.00000824 V	± 0.00070712 V	± 0.017 mV	
<b>100 mV Range</b>						
0.1 V 1 MHz	0.09988071 V	0.10039834 V	0.00051763 V	± 0.0010112 V	± 0.093 mV	
0.1 V 4 MHz	0.09964671 V	0.09916272 V	-0.00048399 V	± 0.0040712 V	± 0.15 mV	
0.1 V 8 MHz	0.09907932 V	0.10091415 V	0.00183483 V	± 0.0040812 V	± 0.15 mV	
0.1 V 10 MHz	0.09904819 V	0.09565761 V	-0.00339058 V	± 0.0151012 V	± 0.15 mV	
<b>1 V Range</b>						
1 V 1 MHz	0.9980527 V	1.0040416 V	0.0059889 V	± 0.010112 V	± 0.58 mV	
1 V 4 MHz	0.9949922 V	1.0117189 V	0.0167268 V	± 0.040712 V	± 1.5 mV	
1 V 8 MHz	0.9920771 V	1.0101398 V	0.0180627 V	± 0.040812 V	± 1.5 mV	
1 V 10 MHz	0.9918953 V	0.9187248 V	-0.0731705 V	± 0.151012 V	± 1.5 mV	
<b>10 V Range</b>						
3 V 2 MHz	2.993055 V	3.013390 V	0.020335 V	± 0.127036 V	± 2.6 mV	
3 V 4 MHz	2.987794 V	3.067920 V	0.080126 V	± 0.127036 V	± 4.4 mV	
3 V 8 MHz	2.988944 V	3.039258 V	0.050314 V	± 0.128036 V	± 4.4 mV	
3 V 10 MHz	3.010787 V	2.810488 V	-0.200299 V	± 0.460036 V	± 4.4 mV	

## Frequency Accuracy

Applied Frequency	Specification (applied ± limit)	Measured Value	Uncertainty	Status (if applicable)
1 Hz 10 MHz	± 0.0005 Hz ± 0.001 MHz	0.999997 Hz 9.99997 MHz	± 0.000020 Hz ± 10 Hz	

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## AC Voltage Accuracy (Analog mode)

A voltage of substantially sinusoidal form was applied to the 3458A input.

3458A set-up: SETACV ANA; NPLC 500; ACBAND 10,1E6

Applied		Range	Specification (applied $\pm$ limit)	Measured Value	Uncertainty	Status (if applicable)
1 V	50 kHz	10 V	$\pm 5.502$ mV	0.99873 V	$\pm 0.62$ mV	
1 V	1 MHz	10 V	$\pm 250$ mV	0.89026 V	$\pm 28$ mV	
10 V	10 Hz	10 V	$\pm 42.02$ mV	9.98291 V	$\pm 4.9$ mV	
10 V	200 Hz	10 V	$\pm 3.02$ mV	10.00077 V	$\pm 0.51$ mV	
10 V	500 Hz	10 V	$\pm 3.02$ mV	10.00078 V	$\pm 0.49$ mV	
10 V	50 kHz	10 V	$\pm 19.02$ mV	9.99756 V	$\pm 2.2$ mV	
10 V	1 MHz	10 V	$\pm 700.02$ mV	10.02759 V	$\pm 79$ mV	

## AC Current Accuracy

The applied current was of substantially sinusoidal form.

3458A set-up: ACBAND 10,1E4; LFILTER ON; NPLC 100

Note: The 100 mA and 1 A currents were applied for 5 minutes before measurement.

Applied		Range	Specification (applied $\pm$ limit)	Measured Value	Uncertainty	Status (if applicable)
10 $\mu$ A	1 kHz	100 $\mu$ A	$\pm 36.05$ nA	10.0161 $\mu$ A	$\pm 8.7$ nA	
100 $\mu$ A	1 kHz	100 $\mu$ A	$\pm 90.5$ nA	100.0030 $\mu$ A	$\pm 20$ nA	
1 mA	1 kHz	1 mA	$\pm 505$ nA	1.000246 mA	$\pm 155$ nA	
10 mA	1 kHz	10 mA	$\pm 5.05$ $\mu$ A	10.00229 mA	$\pm 1.1$ $\mu$ A	
100 mA	1 kHz	100 mA	$\pm 50.5$ $\mu$ A	100.0220 mA	$\pm 11$ $\mu$ A	
1 A	1 kHz	1 A	$\pm 1.205$ mA	0.999899 A	$\pm 0.15$ mA	

The reported uncertainty is based on a standard uncertainty multiplied by a coverage factor  $k=2$ , providing a coverage probability of approximately 95%.

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**Resistance Accuracy**

3458A set-up:

Below 100 megohm:                   4-wire ohms; OCOMP ON; Delay 1; NPLC 100; NDIG 7  
10 megohm and higher:           2-wire ohms; NPLC 500; NDIG 6

Last calibration internal temperature (Cal? 60) = 35.35 °C  
Present temperature (Temp?) = 34.6 °C

Applied	Range	Spec.	Measured Value	Error	Uncertainty	Status (if applicable)
<b>2-Wire Mode</b>						
Front Input Shorted	10 Ω	± 0.25 ohms	0.08695 ohms	87.0 m ohm	± 0.5 m ohm	
Rear Input Shorted	10 Ω	± 0.25 ohms	0.05740 ohms	57.4 m ohm	± 0.5 m ohm	
<b>4-Wire Mode</b>						
Front Input Shorted	10 Ω	± 50 μ ohms	0.00000 ohms	0 μ ohm	± 20 μ ohm	
Rear Input Shorted	10 Ω	± 50 μ ohms	0.00000 ohms	0 μ ohm	± 20 μ ohm	
10.000000 Ω	10 Ω	± 23.0 ppm	10.000004 Ω	0.4 ppm	± 2.2 ppm	
100.00000 Ω	100 Ω	± 20.0 ppm	100.00009 Ω	0.9 ppm	± 2.1 ppm	
1.0000000 k Ω	1 kΩ	± 13.5 ppm	0.9999996 kΩ	-0.4 ppm	± 1.7 ppm	
10.000000 k Ω	10 kΩ	± 13.5 ppm	10.000015 kΩ	1.5 ppm	± 0.50 ppm	
100.00000 k Ω	100 kΩ	± 13.5 ppm	99.99997 kΩ	-0.3 ppm	± 3.9 ppm	
1.0000000 M Ω	1 MΩ	± 20.0 ppm	0.9999980 MΩ	-2.0 ppm	± 6.4 ppm	
10.000000 M Ω	10 MΩ	± 63.0 ppm	9.999868 MΩ	-13.2 ppm	± 13 ppm	
<b>2-Wire Mode</b>						
10.000000 M Ω	10 MΩ	± 63.0 ppm	9.999970 MΩ	-3.0 ppm	± 13 ppm	
100.0000 M Ω	100 MΩ	± 513 ppm	100.0053 MΩ	53 ppm	± 50 ppm	

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## DC Current Accuracy

3458A set-up: NPLC 500; NDIG 7

Note: The 100 mA and 1 A currents were applied for 5 minutes before measurement.

Applied	Range	Specification (applied $\pm$ limit)	Measured Value	Uncertainty	Status (if applicable)
Front Input Open	100 $\mu$ A	$\pm$ 800 pA	-0.00024 $\mu$ A	$\pm$ 70 pA	
Front Input Open	1 mA	$\pm$ 5 nA	-0.000011 mA	$\pm$ 0.20 nA	
Front Input Open	10 mA	$\pm$ 50 nA	-0.000011 mA	$\pm$ 2.0 nA	
Front Input Open	100 mA	$\pm$ 500 nA	-0.00004 mA	$\pm$ 15 nA	
Front Input Open	1 A	$\pm$ 10 $\mu$ A	-0.000015 A	$\pm$ 1.9 $\mu$ A	
100 $\mu$ A	100 $\mu$ A	$\pm$ 3.3 nA	99.99986 $\mu$ A	$\pm$ 0.52 nA	
-100 $\mu$ A	100 $\mu$ A	$\pm$ 3.3 nA	-99.99986 $\mu$ A	$\pm$ 0.52 nA	
1 mA	1 mA	$\pm$ 30 nA	0.9999965 mA	$\pm$ 5.0 nA	
-1 mA	1 mA	$\pm$ 30 nA	-0.9999979 mA	$\pm$ 5.0 nA	
10 mA	10 mA	$\pm$ 0.3 $\mu$ A	9.999951 mA	$\pm$ 0.050 $\mu$ A	
-10 mA	10 mA	$\pm$ 0.3 $\mu$ A	-9.999947 mA	$\pm$ 0.050 $\mu$ A	
100 mA	100 mA	$\pm$ 4.5 $\mu$ A	99.99911 mA	$\pm$ 0.51 $\mu$ A	
-100 mA	100 mA	$\pm$ 4.5 $\mu$ A	-99.99949 mA	$\pm$ 0.51 $\mu$ A	
1 A	1 A	$\pm$ 125 $\mu$ A	1.0000216 A	$\pm$ 11 $\mu$ A	
-1 A	1 A	$\pm$ 125 $\mu$ A	-1.0000207 A	$\pm$ 11 $\mu$ A	

The reported uncertainty is based on a standard uncertainty multiplied by a coverage factor  $k=2$ , providing a coverage probability of approximately 95%. Any quoted uncertainty refers only to the measured value and does not carry any implication regarding the long term stability of the instrument.

Find us at [www.keysight.com](http://www.keysight.com)

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