

Calibration Certificates: Look Closer Before Filing

Mike Hutchins, Agilent Technologies UK Ltd., Winnersh, Berks. RG41 5DZ

The humble calibration certificate contains crucial evidence of the integrity of test equipment and the validity of the calibration. This is despite the fact that the need to calibrate equipment is considered by some to be simply a ‘necessary evil’ to attain quality. Companies in a variety of worldwide industries spend hundreds of millions of dollars annually to calibrate their instrumentation yet the tangible evidence of what has been obtained in return for this investment generally receives scant attention. Except for a cursory glance before consignment to the filing cabinet, where it lies awaiting retrieval in the unlikely event of scrutiny during an audit, the calibration record is rarely reviewed after its receipt. One reason is the mistaken assumption that all calibrations are alike, but another is a lack of knowledge about what to look for and its significance. This article aims to provide guidance by exploring the content of typical certificates.

Why is Calibration Necessary?

As components age and equipment undergoes changes in temperature or sustains mechanical stress, critical performance gradually degrades. This is called drift and, when it happens, test results obtained using measurement equipment become unreliable and both design and production quality suffers. Whilst drift cannot be eliminated, it can be detected and contained through the process of calibration.

Calibration is defined as a performance comparison against a standard of known accuracy. It may just involve determination of the deviation from nominal or include correction (adjustment) to minimize the observed error. Properly calibrated equipment promotes confidence that manufactured products and support services meet their specifications. In a nutshell, calibration:

- Increases production yields,
- Optimizes resources,
- Assures consistency,
- Is fundamental to compliance with international, regulatory or industry-sector specific standards that require measurements to be ‘traceable to national standards’ and, in doing so,
- Ensures measurements (and perhaps products) are compatible with those made elsewhere.

Traceability

A hierarchical relationship is achieved by calibrating equipment through the use of standards of better accuracy. It could be illustrated like this:

National Standard.....	Accurate to 0.02 %
Calibration Laboratory.....	0.13 %
Production Equipment.....	0.6 %
Manufactured Product.....	8 %

Of course, these calibrations need to be done on a planned, periodic basis with evidence of the comparison results maintained. This record must include identification of the specific standards used (which must be within their assigned calibration interval) and some means of knowing the method used and other test conditions. By examining these records, it should be possible to demonstrate an unbroken chain of comparisons that ends at the agency responsible for maintaining and developing a country's measurement standards (now generically known as a national metrology institute). This demonstrable linkage to national standards, with known accuracy, represents ‘traceability’.

In fact, it doesn't stop there because these laboratories routinely undertake international comparisons which help to establish worldwide consensus on the accepted value of the fundamental measurement units. The result of it all is a coherent measurement system that ensures the compatibility of components produced in multiple locations around the world.

Types of Certificate

When a calibration is performed, the certificate or report is the end product and represents the only tangible evidence of the service that the purchaser can link to the expenditure. Its importance is obvious for that reason alone. Not only does it show the results obtained but the scope of testing and is a key means of judging the quality of the calibration provider's service.

Most calibration laboratories offer several forms of certificate but the apparent similarity in their names can be confusing. Before placing an order, be sure to understand exactly what's on offer to ensure it meets your need. For example, what's the difference between a 'Certificate of Calibration' (or maybe a 'Measurement Report'), or certificates of 'Verification' or 'Conformance'?

Similar to the often-confused metrological terms accuracy and precision, there is a myth that calibration and verification are differentiated on the basis of quality or integrity. The perception being that 'verification' is a quick-check of performance, perhaps made without any real traceability, whereas 'calibration' provides genuine assurance that the product really met specification. In fact, the US national standard ANSI/NCSL-Z540 defines "verification" as being calibration and evaluation of conformity against a specification. This definition originated with the now obsolete ISO/IEC Guide 25 but neither its replacement, ISO/IEC17025:1999 [4] or the *International Vocabulary of Measurement* [1] currently have it or any alternative. The only relevant international standard that includes terminology covering the process of both calibrating and evaluating a measuring instrument's performance against established criteria is ISO10012:2003 which uses the rather cumbersome term "metrological confirmation".

As already mentioned, calibration is simply the process of comparing with a known standard and reporting the results. For example:

Applied = 1.30V, Indicated = 1.26V (or Error = -0.04V)

Calibration may include adjustment to correct any deviation from the value of the standard.

Verification, as it relates to calibration, is evaluation of these results against a specification, usually the manufacturer's published performance figures for the product for example:

Error = -0.04V, Spec. = $\pm 0.03V$, 'FAIL'

Some laboratories include a specification compliance status statement on the Certificate of Calibration. (i.e. the item did or did not comply with a particular specification).

Where no judgment is made about compliance, or correction has not been made to minimize error, it has been suggested that 'Certificate of Measurement' would be a more descriptive title to aid recognition of the service actually performed. Some suppliers also use 'Certificate of Verification' where no measurements are involved in the performance testing (such as for certain datacomm/protocol analyzers), rather than 'Certificate of Functional Test' as this latter term is often considered to be limited, informal checks as might be performed following a repair (often termed 'operational verification').

So, what is a 'Certificate of Conformance'? Typically available when an instrument is purchased, it is now generally recognized that such a document has little value as an assurance of product performance. Of course, the manufacturer expects that the product conforms to its specification but, in this sense, the document simply affirms that the stipulations of the customer's purchase order or contract has been duly fulfilled.

More myths related to certificates are shown in *Table 2*.

Extent of Testing

Standards have existed for many years that define characteristics and qualification of certain measurement devices, such as ISO3650:1999 for metric gage blocks. In contrast, there is no such formality concerning what constitutes ‘calibration’ for the type of instrumentation used in the electronics industry, like spectrum analyzers and multimeters. Calibration requests often use a phrase like “calibrate to manufacturer’s specification” but this can be variably interpreted. If taken literally, it’s possible that the user would never see the item again as exhaustive testing against all of the published specifications could take a very long time and include probably irrelevant detail such as its weight, as well as being tested to destruction if shock-tests are involved! Clearly, there must be a compromise between gaining adequate confidence in the product’s performance and under- or over-testing. If the manufacturer publishes performance test recommendations, this can be a good guide for both the equipment user and the calibration laboratory but it shouldn’t be taken for granted that these are followed. Remember that the onus of responsibility that the calibration is adequate for the use made of the equipment rests with the user, not the supplier.

In or Out of Specification?

Despite what some suppliers may claim, no calibration is perfect! There is always some degree of uncertainty about the ‘true’ value of a measurement. Contributors to this ‘potential for inaccuracy’ include the performance of the equipment used to make the measurement, the test process itself and environmental effects.

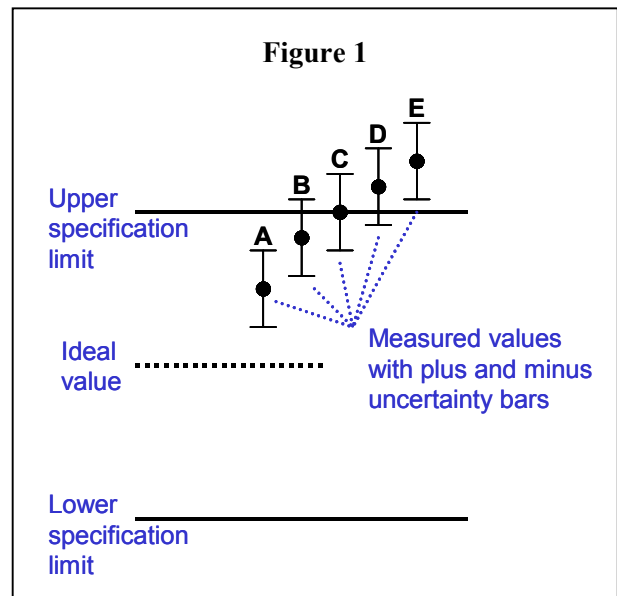
Additional imprecision may result from behavior of the phenomenon or item being measured. A skilled metrologist will assess and combine these various contributions in an uncertainty budget. To prove that a product complies with specification (or does not), the uncertainty must be less than the specification of the unit-under-test (UUT).

There are several practices regarding how uncertainty is treated when deciding whether a UUT meets specification. *Figure 1* shows measurements on 5 different items and, without considering measurement uncertainty, we could state that:

1. Devices A and B are within specification.
2. Device C is border line.
3. Devices D and E exceed the specification.

One of the traditional practices has been, in effect, to ignore uncertainty if it doesn’t exceed one quarter of the UUT specification. The justification for this approach originates from consumer and producer risk analysis about which David Deavor has written several respected papers [2]. Where this 4:1 *test uncertainty ratio* rule can’t be met, he explains how a guardband limit may be calculated to maintain consumer risk at the 4:1 level or as desired.

A shared-risk approach is not, however, acceptable to some equipment-users or accreditation bodies. The ILAC-G8 [3] requirement that has been adopted by European accreditation agencies, for example, is for the acceptance limit (for pass/fail determination) to be the difference between the specification and uncertainty.



When uncertainty is taken into account using this simple rule:

1. We can say with high confidence that device A is within specification. Even if the uncertainty is added to the measured value, the tolerance is not exceeded.
2. Devices B, C and D could be either in or out-of-specification. The UUT's compliance is said to be 'indeterminate'.
3. Device E is out-of-specification.

However, for the majority who expect a simple 'good/bad' assessment, the 'indeterminate' status represents unhelpful over-complexity. In the case of situation D, because the measured value exceeded the test limit, an alternative is to report that the UUT did not comply which ensures minimal risk to the customer. For situation B or C, where the measurement lies in the measurement uncertainty guardband on the 'in-specification' side, confidence is lower than in case A but there is still high probability of compliance.

As mentioned, there is no common method amongst calibration suppliers for handling uncertainty and a supplier may implement different policies for various service offerings.

A Standard for Calibration Certificates

Although several accreditation bodies had prescribed the format and content for calibration certificates (and continue to do so) it wasn't until the publication of ISO/IEC 17025:1999 [4] that there was worldwide consensus in the form of a standard. However, it wouldn't be fair to say that all calibration certificates are identical, even if they comply with the standard. In fact, a deliberate amount of flexibility is allowed by the criteria depending upon customer requirements and commercial service-level options. Provided that there is customer agreement, these optional attributes are:

- The certificate may be of a "simplified" form where only limited detail is included (although the records must be complete).
- If a statement of compliance with a stated specification is made, it isn't necessary to report measured values or the uncertainty.
- The method of "taking uncertainty into account" in respect of compliance statements is not prescribed.
- Recommended re-calibration dates may be quoted on the certificate or label.
- Hardcopy *or* electronic format is acceptable.

Also, it's worth noting that the standard doesn't define all elements that might otherwise have been assumed to represent a calibration service.

- Adjustment to return a product to a state of specification compliance is not necessary.
- Inclusion of a compliance statement is not necessary; the measured values and uncertainties only are reported.
- A calibration label or integrity seals are not mandatory.
- The extent of testing or adequacy for particular applications.

Value and Limitation of Accredited Calibration

An independent, expert body may assess the technical competence and quality system of a calibration provider. The international standard, 17025, provides the principal criteria and some agencies have additional "amplification" documents that establish certain expectations where, it is considered, the standard lacks detail. A good example of this is UKAS-LAB5 [5] covering certificate and label style. Successful candidates are said to have gained the agency's *accreditation* for a specific measurement capability (i.e. parameter, range, method and uncertainty). The United Kingdom Accreditation Service has referred to the provision of accredited calibration as "authenticated traceability".

A worldwide agreement between such accreditation bodies, the so-called ‘ILAC Arrangement’, means that the validity of calibration certificates issued under the authority of any member is recognized in any other signatory’s country. Inclusion of the accreditation body’s logo on a calibration certificate aids its acceptance.

Initially it seems as though a certificate bearing the brand-mark of a *bona fide* accreditation body should be an ultimate solution for users wanting confidence in the performance of their equipment. Ideally, of course, it would be but seldom in life are things straightforward and accredited calibration is no exception. One potential danger for the unaware seeker of calibration services is that the extent of testing may be limited by the scope of accreditation. This could be in terms of tested functions or ranges or because the measurement uncertainty is larger than the specification. Furthermore, some accreditors dictate the proportion of measurements that may be included in the calibration certificate that are beyond the laboratory’s recognized scope, even if they are clearly annotated as such. The effect of this may be that separate certificates are provided for accredited and non-accredited tests which is cumbersome to deliver and confusing to the customer or, perhaps more likely, only limited testing is performed in comparison to the product’s potential capability. Accreditation bodies cannot stipulate what constitutes appropriate calibration for the majority of users so informed negotiation with the laboratory is necessary. The consequence of all this could be reduced confidence in the equipment’s overall performance. Much has been written about the challenges that accompany provision of accredited calibration outside the confines of the traditional standards laboratory and when dealing with complex, multifunctional equipment found in the traceability paths of modern manufactured products [6, 7].

Elements and Attributes

In conjunction with the accompanying examples, *Table 1* explains the key elements to look for on a calibration certificate and their significance.

Table 1

Feature	Relevant 17025 clause	Significance	Example
The supplier’s contact details.	5.10.2 b	Essential information in case of a query about the calibration.	1
Service type		Most suppliers offer a variety of service levels with different attributes. Should agree with the customer’s order.	2
Unique tracking and/or certificate number.	5.10.2 c	The supplier’s key to all their records. A crucial aspect of traceability.	3
Equipment identification.	5.10.2 f/k	Calibrations relate to an individual item of equipment, not a product sample.	4
Customer identification.	5.10.2 d 5.10.6	If the equipment was subcontracted, your supplier will be stated as the customer and there may also be indication that it was on your behalf.	5
Test location.	5.10.2 b	Identifies whether it was performed at the customer’s premises (“on-site” and perhaps in-situ which may limit the scope of testing), the supplier’s particular branch or depot, or whether a subcontractor was used. Measurements made by a subcontractor may or may not be transparent to the end-customer so it’s wise to seek assurances about your supplier’s policy.	6

Feature	Relevant 17025 clause	Significance	Example
Test date.	5.10.2 g	Some calibrations take more than 1 day so will generally be the calibration end-date. The date from which users determine the next due calibration. A calibration due date may also be included but may only be for general guidance based on the manufacturer's original suggested calibration interval rather than specifically for this item.	7
Test conditions.	5.10.4.1 a	Temperature, humidity and sometimes altitude (pressure) are most often found as they can affect equipment characteristics. A single value without a control limit is meaningless. Parenthesis are sometimes included to indicate that the control limit is not a measurement uncertainty but this format is by no means common.	8
Test methodology.	5.10.2 e	Reference to a documented procedure is an aspect of traceability. Like the record of calibration standards used, it enables precise repetition of the test in case of query.	9
Standards conformity.		Affirmation of compliance with, or independent certification against, international conformity assessment standards such as ISO9001 or ISO17025. This may, of course, depend upon the chosen service level.	10
Performance summary.	5.10.4.1 b 5.10.4.2 5.10.4.3	A statement that clearly indicates whether or not the equipment met stated criteria, upon receipt and at completion of calibration (i.e. after any repair/adjustment). May include concise details of tests that failed to meet defined criteria. May depend upon the chosen service level.	11
Scope of testing.	5.10.4.2 5.6.2.1.1- note 4	Indication of the tested functions and their status, maybe in conjunction with a measurement report. It should particularly identify significant omissions from the manufacturer's recommendations (if any), standards or known user requirements.	12 13
Confidence level.	Reference to the 'GUM' [8] in the Bibliography	Concerns the likelihood that a compliance decision is correct and relates to the measurement uncertainty and its adequacy in relation to the specification. Through international consensus this is typically 95% (a so-called 'coverage factor' of 2) but may need to be higher in usage applications with high sensitivity to risk (e.g. safety critical). Applications that are more tolerant may accept a lower probability.	14
Acceptance limits used or reference publication.	5.10.4.1 b	Often citing a published specification, it enables confirmation that the appropriate criteria was used for the customer's particular application.	15
Print or issue date.	5.10.9	If amendments are later found necessary, a later issue date should appear to maintain a chronological paper trail.	16
Page numbering.	5.10.2 c & Note 1	Enables confirmation that a complete record has been received.	17 18

Feature	Relevant 17025 clause	Significance	Example
Details concerning traceability to international measurement standards.	5.6.2.1.1 5.10.4.1 c	Usually an affirmation concerning the national metrology institutes to which, ultimately, the supplier's calibration standards can be related through an "unbroken chain of comparisons of stated accuracy".	19
Measured values, particularly for non-conforming tests.	5.10.2 i 5.10.4.3	Necessary if correctional data is to be used and also for test points that fail to meet specification. The degree of deviation is needed to establish whether re-work or product recall is necessary if integrity has been compromised. May be service level dependent.	20
Clarity of acceptance (or specification) limits and measured values.	5.10.8 & Note 1	Is it easy to verify the equipment's status? It is if measured values and test limits are in the same format and units. The measurement resolution must be appropriate to that of the test limit.	21 22

Conclusion

The aim of this article was to improve the perceived value of the tangible evidence resulting from calibration – the certificate or measurement report – by identifying the various components that may appear and explaining their significance to the equipment user. By doing this, it is hoped that a greater appreciation of good certificates will be developed and confidence gained to knowledgeably challenge a supplier when something else is provided.

References

1. International Organization for Standardization; *International Vocabulary of Basic and General Terms in Metrology*. <www.iso.org>
2. Deavor, David; *Maintaining Your Confidence & Guardbanding with Confidence & Managing Calibration Confidence in the Real World*. NCSL Workshop & Symposia 1993/4/5. <www.fluke.com>
3. International Laboratory Accreditation Cooperation; *Guidelines on Assessment and Reporting of Compliance with Specification*. <www.ilac.org>
4. International Organization for Standardization & International Electrotechnical Commission; *General Requirements for the Competence of Testing and Calibration Laboratories*. <www.iso.org>
5. United Kingdom Accreditation Service; *Reporting of Calibration Results*. <www.ukas.com>
6. Hutchins, Mike; *Challenges of an Accreditation System in a High-volume, Production-oriented Environment*. NCSL Workshop & Symposium 1995. <www.agilent.com/metrology>
7. Abell, Dave; *Meeting 17025 Requirements for Complex Electronic Test Equipment*. NCSL International Workshop & Symposium 2002. <www.agilent.com/metrology>
8. International Organization for Standardization; *Guide to the Expression of Uncertainty in Measurement*. <www.iso.org>

Table 2

Calibration Certificate Myths and Reality	
<p>To comply with ISO9000 all equipment must be calibrated 'Before and after adjustment'.</p>	<p>A calibration service that provides assessment of the product's performance on-receipt and, if necessary, after adjustment or repair has been completed has two purposes. It enables analysis of the equipment's stability over time. More significantly, if the on-receipt performance did not meet the user's accuracy requirements, an investigation of its impact can be triggered that may result in product or work recall. These possibilities need only apply to equipment affecting the quality of the factory's product or service, for example that used for alignment or end-of-line inspection. Understanding the distinction can save a lot of money !</p>
<p>Accreditation bodies define the extent of testing for various products so that users can have confidence in their equipment's overall performance.</p>	<p>In some countries there are national and regulatory standards that are applicable to some measuring equipment. These usually relate to legal metrology (i.e. measurements made in the course of consumer trade) or statutory codes (e.g. safety) or are peculiar to certain sectors of industry. However, accreditation bodies do not stipulate that these must be used although labs would generally do so where applicable. Also, there are no standards concerning the typical general purpose instruments that may be used in the electronics industry, for example. Although accreditation criteria includes a need for calibration certificates to draw attention to limitations in the scope of testing performed versus the product's capability, it is left to the client and supplier to agree the content of the service. Whether the calibration utilizes any recommendations of the equipment's manufacturer is part of this negotiation.</p>
<p>ISO17025 requires that measured values and measurement uncertainty is reported on a certificate.</p>	<p>This is true if the certificate does not include a statement concerning the equipment's compliance to a stated specification. In this case, section 5-10-4 says that the results and uncertainty must be maintained by the lab.</p>
<p>The calibration certificate must state the measurement uncertainty in order for the user to be able to determine their own uncertainty.</p>	<p>If the calibration confirmed that the instrument met the manufacturer's (or user's) specification, the effect of uncertainty on that status decision has already been taken into account (as required by ISO17025, para.5-10-4-2). In this case, the user's own uncertainty budget starts with the product specification and the calibration uncertainty is not included again. If the calibrated item does not have a specification (i.e. the certificate provides only measured values) then the calibration lab's uncertainty will need to be included in the user's uncertainty analysis.</p>
<p>A Certificate of Calibration means that the instrument met its specification, at least when tested. AND Calibration means that the equipment was adjusted back to nominal.</p>	<p>Whether this is correct or not depends on the calibration laboratory's service definitions or what was agreed between the supplier and customer. The international meaning of 'calibration' does not require that errors detected by the measurement comparison process are corrected. It means that adjustment to return an item to specification compliance may, or may not, be performed. Unless the Certificate contains a statement affirming that the item met the published specification it is merely a report of the measurements made. In this case it is left to the equipment user to review the data against requirements. The equipment may have been found and returned to the user out-of-tolerance!</p>

 <p>1 Agilent Technologies</p>	<p>Agilent Technologies UK Ltd Eskdale Road, Winnersh Triangle Wokingham, BERKSHIRE RG41 5DZ Tel: + 44(0)7004 123123 Fax: 123124</p>	<p>AGILENT TECHNOLOGIES INTERNAL ASSESSMENT PROGRAM : AQ-SSU-12/95</p>
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Certificate of Calibration

2 → Agilent Full Calibration with Adjust
3 Certificate No. : 2-42097375-1

4	Manufacturer: Agilent/HP Model No: 83650B Serial No: 3722A00339	Description: SWEEP SIGNAL GENERATOR Options installed: 001,002,006,008 Customer asset No: UK13919
5	Customer: Any Company Ltd South Central Road Townsville Northshire	6

7	Customer PO No.: 8000 81BP 75 ETE UK13919	Agreement No: 2-21225330/U
9	Date of calibration: 30 Jan 2004 Temperature: (23 +/-3) °C Procedure: 5010-9066	Received date: 14 Jan 2004 Humidity: < 70 %RH

10 This certifies that the above product was calibrated in compliance with a quality system registered to ISO9001:2000 using applicable Agilent Technologies procedures.

11 **As received conditions:** Initial testing found the equipment to be **OUT-OF-SPECIFICATION** at one or more points tested. Adjustment and/or Repair was necessary.

11 **As shipped conditions:** At the completion of the calibration, measured values were **IN-SPECIFICATION** at the points tested.

12 **Remarks or special requirements:** FM BANDWIDTH TEST NOT DONE AT CUSTOMER REQUEST.

14 Our calibration procedures are designed to provide measurement uncertainty of less than or equal to one quarter of the specification of the unit under test, where possible, with a coverage factor of 2.

15 The test limits stated in the report correspond to the published specifications of the equipment, at the points tested.

This certificate is composed of 2 pages containing a summary of calibration information.

Based on the manufacturer recommended or user requested calibration interval, the next calibration is due on 30 Jan 2006 . The User should determine the suitability of this instrument for its intended use.

16 Issue date: 31 Jan 2004

D. Trotman
 Dave Trotman - European Support Manager



Agilent Technologies

Agilent Technologies UK Ltd
Eskdale Road, Winnersh Triangle
Wokingham, BERKSHIRE RG41 5DZ
Tel: + 44(0)7004 123123 Fax: 123124

AGILENT TECHNOLOGIES
INTERNAL ASSESSMENT
PROGRAM : AQ-SSU-12/95

Certificate of Calibration

Agilent Full Calibration with Adjust

Certificate No. : 2-42097375-1

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Traceability information:

Technician ID number: 778877

Traceability is to National Standards administered by Euromet members (NPL, PTB, BNM, etc.), the US NIST or other recognized national standards laboratories.

Some measurements are traceable to natural physical constants, consensus standards or by ratio type measurements.

Supporting documentation relative to traceability is available for review by appointment.

This certificate shall not be reproduced, except in full, without prior written approval of the laboratory.

Calibration equipment used:

Model number:	Model description:	Trace number:	Cal due date:	Certificate number:
3456A	DIGITAL VOLTMETER	UK4691	1 Dec 2004	2-39766377-1
11970K	HARMONIC MIXER	UK12248	5 Jun 2006	2-12881205-1
8447A	AMPLIFIER	UK1043	12 Jun 2004	80652238101
3325A	SYNTHESIZER/FUNCTION GENERATOR	UK13985	27 May 2004	80653210801
8116A	PULSE GENERATOR	UK5887	19 Jun 2004	2-822446-1
54501A	100 MHZ DIGITIZING OSCILLOSCOP	UK14778	15 Oct 2004	2-25628238-1
8902A	MEASURING RECEIVER	UK8645	28 Aug 2004	2-12748604-1
11792A	SENSOR MODULE	UK7605	6 Jul 2004	8065Z868001
11970A	HARMONIC MIXER	UK7711	2 Dec 2005	80653254201
11975A	POWER AMPLIFIER	UK7650	30 Apr 2005	2-43637474-1
11970U	HARMONIC MIXER	UK12249	12 Mar 2005	80651327801
8903B	AUDIO ANALYZER	UK14845	11 Mar 2005	2-40056160-1
3458A	MULTIMETER	UK8660	8 Aug 2004	2-16267521-1
3335A	SYNTH LEV GENERATOR	UK7288	20 Jun 2004	2-13738869-1
MTOPAT1	SAFETY TESTER	UK10504	25 Jul 2004	80652327001
83650A	SYNTHESIZED SWEEP GENERATOR	UK12975	2 Dec 2005	2-28208140-1
54124T	DIGITIZING OSCILLOSCOPE SYSTEM	UK12619	3 Jun 2004	2-12479737-1
8116A	PULSE GENERATOR	UK8944	18 Aug 2004	2-5502664-1
437B	POWER METER	UK12470	12 Mar 2005	2-18617046-1
436A	POWER METER	UK6006	5 Feb 2005	2-19455161-1
8487A	POWER SENSOR	UKD0112	31 Jan 2005	2-18044535-1
85660B	SPECTRUM ANALYZER	UK5256	12 Aug 2004	2-12317907-1
3325A	FUNCTION GENERATOR	UK8381	12 Feb 2004	80652314301

Report Number: 2-42097375-1
 Model Number: HP83650B Options: 001,002,006
 Serial Number: 3722A00339

Test Date: 30 Jan 2004

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PERFORMANCE TEST RESULTS SUMMARY

Test Name	Status
INITIAL SETUP	DONE
SELF TEST	PASSED
INTERNAL TIMEBASE AGING RATE	DONE
SWEPT FREQUENCY ACCURACY	PASSED
FREQUENCY SWITCHING TIME	PASSED
POWER ACCURACY	*FAILED*
POWER FLATNESS - LOW BAND	PASSED
POWER FLATNESS - HIGH BAND	PASSED
POWER FLATNESS - 20 TO 40 GHz	PASSED
POWER FLATNESS - >40 GHz	PASSED
MAX LEVELED POWER	PASSED
ATTENUATOR ACCURACY - LOW BAND	PASSED
ATTENUATOR ACCURACY - HIGH BAND	PASSED
ATTENUATOR ACCURACY - 20 TO 26.5 GHz	PASSED
ATTENUATOR ACCURACY - 26.5 TO 40 GHz	PASSED
ATTENUATOR ACCURACY - 40 TO 50 GHz	PASSED
EXTERNAL LEVELING	PASSED
HARMONICALLY RELATED SPURIOUS SIGNALS	PASSED
FIXED SPURIOUS SIGNALS	PASSED
LOW BAND OFFSET SPURIOUS SIGNALS	PASSED
LOW BAND MIXER SPURS	PASSED
LINE-RELATED SPURIOUS SIGNALS	PASSED
SINGLE-SIDEBAND PHASE NOISE	DONE
PULSE ON/OFF RATIO	PASSED
PULSE RISE/FALL TIME <=20 GHz	PASSED
PULSE RISE/FALL TIME >20 GHz	PASSED
PULSE LEVEL ACCURACY <=20 GHz	PASSED
PULSE LEVEL ACCURACY >20 GHz	PASSED
PULSE VIDEO FEEDTHROUGH	PASSED
INTERNAL PULSE ACCURACY	PASSED
AM ACCURACY <20 GHz	PASSED
AM ACCURACY >20 GHz	PASSED
AM ACCURACY - INTERNAL <20 GHz	PASSED
AM ACCURACY - INTERNAL >20 GHz	PASSED
AM BANDWIDTH	PASSED
AM DYNAMIC RANGE	PASSED
DEEP AM DYNAMIC RANGE	PASSED
MAXIMUM FM DEVIATION <=100 Hz	PASSED
MAXIMUM FM DEVIATION >100 Hz	PASSED
FM ACCURACY	PASSED
FM ACCURACY - INTERNAL	PASSED
FM BANDWIDTH	*NOT DONE*

Report Number: 2-42097375-1
 Model Number: HP83650B Options: 001,002,006
 Serial Number: 3722A00339

Test Date: 30 Jan 2004

FREQUENCY SWITCHING TIME PASSED

TEST CONDITIONS	MEASURED	MAXIMUM
CW Frequency Switching	46.48 ms	50.00
Stepped Sweep Frequency Switching	4.648 ms	5.000
Frequency List Switching	34.18 ms	50.00

POWER ACCURACY FAILED

22

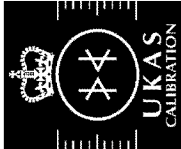
TEST CONDITIONS	MINIMUM	MEASURED	MAXIMUM
0.1 GHz, <= 8.5 dBm	-0.60	-0.06 dB	+0.60
1.0 GHz, <= 8.5 dBm	-0.60	-0.17 dB	+0.60
6.0 GHz, <= 8.5 dBm	-0.70	-0.59 dB	+0.70
10.0 GHz, <= 8.5 dBm	-0.70	-0.75 dB	+0.70
18.0 GHz, <= 8.5 dBm	-0.70	-0.20 dB	+0.70
23.0 GHz, <= 8.5 dBm	-0.90	-0.20 dB	+0.90
28.0 GHz, <= 3.0 dBm	-0.90	-0.37 dB	+0.90
36.0 GHz, <= 3.0 dBm	-0.90	-0.19 dB	+0.90
45.0 GHz, <= 2.5 dBm	-1.70	-0.25 dB	+1.70

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POWER FLATNESS - LOW BAND PASSED

TEST CONDITIONS	MEASURED	MAXIMUM
0.15 GHz - 2.00 GHz	0.33 dB	1.00
Maximum power measured	0.19 dB at 1.95 GHz	
Minimum power measured	-0.14 dB at 1.85 GHz	

CERTIFICATE OF CALIBRATION



0147

Agilent Technologies UK Ltd.

Eskdale Road
 Winnersh Triangle
 WOKINGHAM
 Berkshire
 RG41 5DZ
 Tel: 07004 123123
 Fax: 07004 123124

Agilent Technologies

CERTIFICATE

NUMBER
8065000001A
 APPROVED SIGNATORY

Mike Hutchins

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28 January 2003

Instrument Description: ESA-E 9 kHz-26.5 GHz Spectrum Analyzer

Instrument Manufacturer: Agilent Technologies

Model Number: E4407B (Options 1DR, 1DS, 1D5, 1D6 & AYX)

Serial Number: US39000000 Our Reference Number: 8065-00000

Customer: The Cal Company, Anytown

Date Of Calibration: 26 January 2003

Ambient Temperature: 23 ± 3 ° C Relative Humidity: <70 %

REMARKS:

This certificate records the on-receipt calibration status of the instrument.

The instruments performance conformed to the manufacturers specification at the points measured with due allowance having been made for measurement uncertainties, except at some points identified 'Guardband' where it is not possible to confirm compliance when the measured values are extended by the uncertainty.

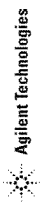
Calibrations marked 'Not UKAS Accredited' in this Certificate have been included for completeness.

Specifications taken from the manufacturers published Specification Guide E4401-90434:AUG02.

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

This certificate is issued in accordance with the laboratory accreditation requirements of the United Kingdom Accreditation Service. It provides traceability of measurement to recognised national standards, and to the units of measurement realised at the National Physical Laboratory or other recognised national standards laboratories. This certificate may not be reproduced other than in full, except with the prior written approval of the issuing laboratory.

CERTIFICATE OF CALIBRATION



CERTIFICATE
 NUMBER
8065000001A

UKAS Accredited Calibration Laboratory No. 0147

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Resolution BW Accuracy

Test Conditions	Minimum Specification	Measured Values	Maximum Specification	Measurement Uncertainties	Status (if applicable)
Resolution Bandwidth					
5 MHz	3.50 MHz	4.85 MHz	6.50 MHz	± 0.08 MHz	
3 MHz	2.55 MHz	3.01 MHz	3.45 MHz	± 0.04 MHz	
1 MHz	0.85 MHz	1.03 MHz	1.15 MHz	± 0.01 MHz	
300 kHz	255 kHz	307 kHz	345 kHz	± 5 kHz	
100 kHz	85 kHz	98 kHz	115 kHz	± 1 kHz	
30 kHz	25.5 kHz	30.2 kHz	34.5 kHz	± 4 kHz	
10 kHz	8.5 kHz	9.9 kHz	11.5 kHz	± 0.1 kHz	
3 kHz	2.55 kHz	3.00 kHz	3.45 kHz	± 0.03 kHz	
1 kHz	0.850 kHz	1.007 kHz	1.150 kHz	± 0.025 kHz	
120 kHz	102 kHz	122 kHz	138 kHz	± 7 kHz	
9 kHz	7.65 kHz	9.20 kHz	11.50 kHz	± 0.77 kHz	

Frequency Response

Test Conditions	Minimum Specification	Measured Values	Maximum Specification	Measurement Uncertainties	Status (if applicable)
DC COUPLED					
Band 0 : 9 kHz to 3.0 GHz					
Peak-to-peak response		0.64 dB	0.92 dB	± 0.25 dB	
Max response @ 9 kHz		0.27 dB	0.46 dB	± 0.26 dB	Guardband
Min response @ 350.0 MHz	-0.46 dB	-0.15 dB		± 0.25 dB	
Band 0A : 800 MHz to 1.0 GHz					
Peak-to-peak response		0.40 dB	0.92 dB	± 0.25 dB	
Max response @ 940.0 MHz		0.31 dB	0.46 dB	± 0.25 dB	Guardband
Min response @ 860.0 MHz	-0.46 dB	0.20 dB		± 0.25 dB	
Band 0B : 1.7 GHz to 2.0 GHz					
Peak-to-peak response		0.67 dB	0.92 dB	± 0.25 dB	
Max response @ 1.75 GHz		0.17 dB	0.46 dB	± 0.25 dB	

Spurious Responses - TOI (Not UKAS Accredited)

Test Conditions	Minimum Specification	Measured Values	Maximum Specification	Measurement Uncertainties	Status (if applicable)
Centre Frequency					
300 MHz (1 kHz RBW)	12.5 dBm	15.0 dBm		± 2.8 dBm	Guardband
300 MHz (30 Hz RBW)	12.5 dBm	18.0 dBm		± 0.7 dBm	
5 GHz	11.0 dBm	17.0 dBm		± 2.0 dBm	
8 GHz	7.5 dBm	13.0 dBm		± 1.3 dBm	

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

Pages from an example UKAS calibration certificate