

2018 JULY AUGUST SEPTEMBER

0

Calculating the Frequency Response of an Oscilloscope from a Transition Duration Measurement

In Focus: Colorado Engineering Experiment Station (CEESI)

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	DS	200	DS600	DS2	2000	DS5000	
Primary Current, rms	200A		600A	20	2000A		
Primary Current, Peak	±3	00A	±900A	±30	A00	±7000A	
Turns Ratio	500:1		1500:1	150	00:1	2500:1	
Output Signal (rms/Peak)	0.4A/±0.6A <sup>†</sup>		0.4A/±0.6A	A† 1.33A	√±2A†	2A/±3.2A†	
Overall Accuracy	0.0	01%	0.01%	0.0	1%		
Offset	<20ppm <		<10ppm	pm <10ppm		<5ppm	
Linearity	<1	<1ppm <1ppm <1ppm		<1ppm			
Operating Temperature	-40 t	o 85°C	-40 to 85°(	C -40 to	o 85°C	0 to 55°C	<
Aperature Diameter	27.6mm		27.6mm	68	mm	150mm	
Bandwidth Bands for Gain and Phase Error	D\$200			DS600			
	<5kHz	<100kF	lz <1MHz	<2kHz	<10kHz	<100kHz	<500Hz
Gain (sensitivity) Error	0.01%	0.5%	20%	0.01%	0.5%	3%	0.01%

4°

30°

0.1°

0.5°

0

-5

(Degrees) 12-12

**bhas**-50 -52

-30

3°

0.01°



DANI/ENSE



**DS5000** 

<20kHz

1%

**1**°

<5kHz

0.01%

0.01°

DSSIU-4

<sup>†</sup>Voltage Output options available in ±1V and ±10V

0.2°

## **Gain / Phase**

**Phase Error** 



## **DSSIU-4 for Multi Channel Systems**

4-channel Transducer Interface Unit and Power Supply improved performance for Power Amplifiers

- Power and Signal connections for up to four Current Transducer heads
- Heads may be mixed (e.g.: One DS2000 Head and three DS200 Heads)

100 1000 10000 100000 Frequency (H2)

## Phase (DS200, typical)

**DS2000** 

<1kHz

0.05%

0.1°

<10kHz

3%

**1**°

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**ON THE COVER:** Anna M. Escarcega and Brian Valenti test a four stage compressor at Escarcega Technology Services, Inc. in Garden Grove, CA.

#### **UPCOMING CONFERENCES & MEETINGS**

Nov 12-16, 2018 International Conference on Precision Engineering (ICPE). Kamakura, Japan. The aim is to provide an international forum for experts to promote, share, and discuss various issues and developments in the field of the precision and related engineering. http://www.scoop-japan.com/kaigi/icpe2018/

**Nov 13-16, 2018 General Conference on Weights and Measures.** Paris, France. The kilogram, ampere, kelvin, and mole will be redefined at this meeting. It is expected that this meeting will agree the redefinition of the SI. As part of this Conference, BIPM will be organizing a number of activities, including a press conference, to mark the occasion and are looking to broadcast the event live. https://www.bipm.org/en/cgpm-2018/

Jan 20-23, 2019 ARFTG Conference. Orlando, FL. Co-located with Radio & Wireless Week The most important part of the ARFTG experience is the opportunity to interact one-on-one with colleagues, experts and vendors of the RF and microwave test and measurement community. http://arftg.org/

Mar 25-26, 2019 FORUMESURE. Nantes, France. FORUMESURE est un salon annuel, qui s'adresse aux sociétés et aussi aux institutions qui souhaitent présenter leur savoir-faire, leurs nouveaux produits et services à plusieurs centaines de visiteurs internationaux. Cet événement est organisé par le Comité Africain de Métrologie (CAFMET). http://www.forumesure.com/

Apr 8-10, 2019 Annual Meeting of the Council of Ionizing Radiation Measurements and Standards (CIRMS). Gaithersburg, MD. The 27th Annual Meeting of the Council on Ionizing Radiation Measurements and Standards will focus on Strengthening the Economy and Homeland Security with Radiation Measurements and Standards. http://cirms.org/

Apr 10-12, 2019 METROMEET – 15th International Conference on Industrial Metrololgy. Bilbao, Spain. We provide information about the latest technological, the progress made in the sector and we constitute a forum for debate on metrology and its development in a fast changing industry. Also, the latest news about; new digital & optical developments and the European & international norms. http://metromeet.org/

Apr 16-19, 2019 Measurement Science Conference (MSC) Training Symposium. Anaheim, CA. The conference is offering a series of excellent technical programs covering the various disciplines of the measurement sciences. http://www.msc-conf.com/





## **EDITOR'S DESK**

#### Community

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We initially purchased the magazine back in January of 2011 because we found it an effective means of advertising for our metrology software and consulting business. When we approached our accountant with the numbers, he recommended against it. But, the magazine meant more to us than just advertising; like the previous publisher, we felt it filled a void in the industry.

Each quarter, as I compiled event dates, artwork, news, and articles, I was reminded of the whole of the community of which we are a part. The measurement sciences are at such a critical moment with technician and engineer attrition coinciding with the rapid acceleration of technology! Now, I've come to terms that our community is very fragile. I don't see a whole lot of common sentiment around measurement sciences. At least here in the states, I see people and businesses working against each other. The calibration community operates in a fractured and competitive environment.

The challenge we anticipated down the road was not what we expected. The challenge did not stem from the publication industry, but from within the calibration and metrology industry. I am expressing myself here because it's been wearing on me... and because I can. Maybe those reading this can commiserate and find a little relief that they are not alone in feeling the same.

On a brighter note, I got to take a drive out to the lovely green and blue world of the high plains for picture taking and a tour of the Colorado Engineering Experiment Station in the northern part of the state. I put together an article about CEESI for this issue, but first, we have a Metrology 101 article on "Calculating the Frequency Response of an Oscilloscope from a Transition Duration (Risetime or Falltime) Measurement," by Donald Larson of Entegra Corporation. Don is an interesting and smart guy who has helped us on an engineering project in the past. Sometimes an article we publish will pop up just at the time the reader needed it; so hopefully, this too will be one of those helpful, reference pieces for you.

We keep an article index of past articles online, with links out to the article posts. From the article posts, readers can download a PDF version. Please take advantage of past articles by visiting: https://www.callabmag.com/article-index/.

Happy Measuring,

Sita Schwartz

#### SEMINARS: Dimensional

**Dec 3-5, 2018 Dimensional Measurement Training: Level 1.** Telford, UK. Hexagon Metrology. A three day training course introducing measurement knowledge focusing upon dimensional techniques. Level 1 is applicable to all industrial sectors as a stand-alone qualification or as a building block for further NPL Dimensional Measurement Training Levels - 2 & 3. http://www. npl.co.uk/commercial-services/products-and-services/training/ training-courses/

**Dec 5-6, 2018 Hands-On Gage Calibration and Repair.** Oshkosh, WI. IICT. This 2-day hands-on workshop offers specialized training in calibration and repair for the individual who has some knowledge of basic Metrology. Course includes hands on calibration and repairs and adjustments of micrometers, calipers, indicators height gages, etc. http://www.iictenterprisesllc.com

**Dec 13-14, 2018 Hands-On Gage Calibration and Repair.** Bloomington, MN. IICT. This 2-day hands-on workshop offers specialized training in calibration and repair for the individual who has some knowledge of basic Metrology. Course includes hands on calibration and repairs and adjustments of micrometers, calipers, indicators height gages, etc. http://www. iictenterprisesllc.com **Jan 8-11, 2019 Gage Calibration.** Aurora, IL. Mitutoyo Institute of Metrology. Mitutoyo America's Gage Calibration course is a unique, active, educational experience designed specifically for those who plan and perform calibrations of dimensional measuring tools, gages, and instruments. https://www.mitutoyo. com/events/seminar-gage-calibration-3/

Jan 9-10, 2019 Gage Calibration & Repair. Omaha, NE. IICT. This 2-day training offers specialized training in calibration and repair for the individual who has some knowledge of basic Metrology. Approximately 75% of the workshop involves "Hands-on" calibration, repair and adjustments of micrometers, calipers, indicators height gages, etc. Course also covers NIST Traceability, Certificates of Conformance, Gage Management, Standards, etc. http://www.iictenterprisesllc.com

Jan 15-17, 2019 Gage Calibration Methods. Cincinnati, OH. QC Training. This 3-day hands-on workshop offers specialized training in calibration and repair for the individual who has some knowledge of basic Metrology. Attendees will be equipped with the knowledge to meet current and future calibration needs, be prepared to save the company money on calibrations and grow professionally. https://qctraininginc.com/courselist/



Jan 15-17, 2019 Dimensional Measurement Training: Level 1. Bristol, UK. INSPHERE Ltd. A 3-day training course introducing measurement knowledge focusing upon dimensional techniques. Level 1 is applicable to all industrial sectors as a stand-alone qualification or as a building block for further NPL Dimensional Measurement Training Levels - 2 & 3. http://www.npl.co.uk/ training

Jan 24-25, 2019 Gage Calibration & Repair. Minneapolis, MN. IICT. This 2-day training offers specialized training in calibration and repair for the individual who has some knowledge of basic Metrology. Approximately 75% of the workshop involves "Hands-on" calibration, repair and adjustments of micrometers, calipers, indicators height gages, etc. Course also covers NIST Traceability, Certificates of Conformance, Gage Management, Standards, etc. http://www.iictenterprisesllc.com

Jan 30-31, 2019 Gage Calibration & Repair. Altoona, WI. IICT. This 2-day training offers specialized training in calibration and repair for the individual who has some knowledge of basic Metrology. Approximately 75% of the workshop involves "Hands-on" calibration, repair and adjustments of micrometers, calipers, indicators height gages, etc. Course also covers NIST Traceability, Certificates of Conformance, Gage Management, Standards, etc. http://www.iictenterprisesllc.com

**Feb 5-7, 2019 Dimensional Measurement Training: Level 1.** Bristol, UK. INSPHERE Ltd. A 3-day training course introducing measurement knowledge focusing upon dimensional techniques. Level 1 is applicable to all industrial sectors as a stand-alone qualification or as a building block for further NPL Dimensional Measurement Training Levels - 2 & 3. http://www.npl.co.uk/ training

Feb 5-7, 2019 Coordinate Measuring Machine (CMM) - Basics. Minneapolis, MN. QC Training. This course is designed for inspection personnel, engineering personnel, production personnel, entry level inspectors, and those who would like to enter into the field of dimensional measurement and CMM programming. https://qctraininginc.com/courselist/

**Feb 6-7, 2019 Dimensional Measurement Tools - Basics.** Minneapolis, MN. QC Training Services's Basic Dimensional Measurement Tools and Methods (BDMT) class is an introduction to some of the most common gages used on the shop floor. The purpose is to provide practical instruction on the different tools available and their proper use to build workers' skill and knowledge. https://qctraininginc.com/courselist/



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#### SEMINARS: Electrical

**Feb 13-14, 2019 Electrical Measurement. Australian NMI.** Lindfield, NSW. This two-day course covers essential knowledge of the theory and practice of electrical measurement using digital multimeters and calibrators; special attention is given to important practical issues such as grounding, interference and thermal effects. https://www.measurement.gov.au/

**Feb 18-22, 2019 MET-101 Basic Hands-On Metrology.** Everett, WA. Fluke Calibration. This course introduces the student to basic measurement concepts, basic electronics related to measurement instruments and math used in calibration. https:// us.flukecal.com/training

**Apr 22-25, 2019 MET-301 Advanced Hands-On Metrology.** Everett, WA. This course introduces the student to advanced measurement concepts and math used in standards laboratories. https://us.flukecal.com/training

#### **SEMINARS: Fundamentals**

Jan 17, 2019 Basic Uncertainty Concepts. NIST Webinar. This 2 hour webinar provides a very basic introduction to uncertainty calculations and reporting using the 8-step process published in NIST SOP 29 (NISTIR 6969), beginning with some definitions and concepts from the Guide to the Expression of Uncertainty in Measurement (GUM) with simple calculations. https://www.nist. gov/pml/weights-and-measures/about-owm/calendar-events

Feb 4-8, 2019 Fundamentals of Metrology. Gaithersburg, MD. NIST. The 5 day seminar is an intensive course that introduces participants to the concepts of measurement systems, units, good laboratory practices, data integrity, measurement uncertainty, measurement assurance, traceability, basic statistics and how they fit into a laboratory Quality Management System. https://www.nist.gov/pml/weights-and-measures/about-owm/ calendar-events

Feb 11-15, 2019 Fundamentals of Metrology. Gaithersburg, MD. NIST. The 5 day seminar is an intensive course that introduces participants to the concepts of measurement systems, units, good laboratory practices, data integrity, measurement uncertainty, measurement assurance, traceability, basic statistics and how they fit into a laboratory Quality Management System. https://www.nist.gov/pml/weights-and-measures/about-owm/ calendar-events

#### SEMINARS: Industry Standards

Dec 4, 2018 ISO/IEC 17025:2017 Bridging the Gap from 2005. Frederick, MD. QC Training Services, Inc. In this course, the participant will become aware of the significant and subtle changes to existing ISO/IEC 17025 laboratory system, as well as the necessary steps to ensure conformity to the new Standard. https://qctraininginc.com/courselist/

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#### SEMINARS: Industry Standards (continued)

Dec 4-5, 2018 ISO/IEC 17025:2017 for Testing and Calibration Labs. Chicago, IL. International Accreditation Service (IAS). Receive a complete overview of ISO/IEC Standard 17025:2017 with valuable insights and tools to help you implement the requirements of the standard. https://www.iasonline.org/training/ias-training-schedule/

Dec 5-6, 2018 Internal Auditing. Frederick, MD. A2LA. This course introduces participants to the internationally-recognized approaches of ISO 19011 Guidelines for Auditing Management Systems for conducting effective internal audits. The course includes easy-to-implement methods for involvement of personnel, and continual improvement of the audit process. https://www.a2la.org/ events/internal-auditing

Dec 18-19, 2018 ISO/IEC 17025:2017 - The New Standard for Laboratory Competence (MS 111). Frederick, MD. A2LA. This course is a comprehensive review of the philosophies and requirements of this international Standard. The participant will gain an understanding of conformity assessment using the risks and opportunities-based approach. https://www.a2la.org/events

Jan 17-18, 2019. Introduction to ISO/IEC 17025. Las Vegas, NV. ANAB. The 1.5-day training course will help attendees understand

and apply the requirements of ISO/IEC 17025:2017. Attendees will examine the origins of the standard and learn practical concepts such as document control, internal auditing, proficiency testing, traceability, measurement uncertainty, and method witnessing. https://www.anab.org/training

Jan 29-31, 2019 Calibration Certificate Evaluation. NIST Webinar. This 4-hour webinar is conducted on two days, with a 2-hour session on each day. The learning event will introduce concepts necessary to successfully implement ISO/IEC 17025:2017 compliant calibration certificates. https://www.nist.gov/pml/weights-and-measures/ about-owm/calendar-events

Feb 21, 2019 Internal Auditing Best Practices. NIST Webinar. This 2 hour webinar will consider internal auditing techniques and best practices that are used by a metrology laboratory to comply with ISO/IEC 17025:2017 criteria. https://www.nist.gov/pml/weights-and-measures/about-owm/calendar-events

Mar 11-13, 2019 Internal Auditing to ISO/IEC 17025. Indianapolis, IN. ANAB. The 2.5-day training course prepares the internal auditor to clearly understand technical issues relating to an audit. Attendees of this course will learn how to coordinate a quality management system audit to ISO/IEC 17025:2017 and collect audit evidence and document observations. https://www.anab.org/training



Commercial Lab Management Software

#### SEMINARS: Management & Quality

Dec 4-5, 2018 Measurement Systems Analysis Using Excel Statistical Tools (EMU 110). Frederick, MD. A2LA. This course provides the participant with essential tools to be efficient in laboratory operations, including making continual measurement process improvements in the calibration and testing environment. Industry-proven Statistical tools such as Statistical Process Control (SPC), False Accept Risk, Hypothesis Testing and others are covered in this workshop. https://www.a2la.org/events

Feb 7, 2019 Conducting an Effective Management Review. NIST Webinar. This 2-hour webinar introduces the Laboratory Management Review process, an important tool to foster communication between top management and laboratory personnel to improve laboratory operations to produce quality calibrations and highly satisfied customers. https://www.nist. gov/pml/weights-and-measures/about-owm/calendar-events

Apr 30, 2019 Implementing Metrology and SPC concepts with MS Excel. York, PA. Morehouse Instrument Company. This oneday workshop prepares the metrology professional to apply the power of Microsoft Excel's mathematical and statistical tools to assist in managing the laboratory's Quality Management System including Measurement Uncertainty. http://www.mhforce.com/ Training/TrainingCourses

#### SEMINARS: Mass

Mar 11-22, 2019 Mass Metrology Seminar. Gaithersburg, MD. NIST. The Mass Metrology Seminar is a 2 week, "hands-on" seminar. It incorporates approximately 30 percent lectures and 70 percent demonstrations and laboratory work in which the trainee performs measurements by applying procedures and equations discussed in the classroom. https://www.nist.gov/pml/ weights-and-measures/about-owm/calendar-events

**Apr 29-May 9, 2019 Advanced Mass Seminar.** Gaithersburg, MD. NIST. This 9 day, hands-on mass calibration seminar focuses on the comprehension and application of the advanced mass dissemination procedures, the equations, and associated calculations. https://www.nist.gov/pml/weights-and-measures/ about-owm/calendar-events

#### SEMINARS: Measurement Uncertainty

**Dec 4, 2018 Introduction to Estimating Measurement Uncertainty.** Port Melbourne, VIC. Australian NMI. This one-day course (9 am to 5 pm) will give you a clear step-by-step approach to uncertainty estimation with practical examples; you will learn techniques covering the whole process from identifying the sources of uncertainty in your measurements right through to completing the uncertainty budget. https://www.measurement.gov.au/

Dec 20-21, 2018 Applied Measurement Uncertainty for Calibration Laboratories (EMU 202). Frederick, MD. A2LA. During this workshop, the participant will be introduced to several tools and techniques that can be applied in the calibration laboratory environment to efficiently and effectively create measurement uncertainty budgets which comply with ISO/IEC 17025 requirements. https://www.a2la.org/events

**Feb 28, 2019 Introduction to Estimating Measurement Uncertainty.** Brisbane, QLD. Australian NMI. This one-day course (9 am to 5 pm) will give you a clear step-by-step approach to uncertainty estimation with practical examples; you will learn techniques covering the whole process from identifying the sources of uncertainty in your measurements right through to completing the uncertainty budget. https://www.measurement.gov.au/

Mar 5-6, 2019 Understanding & Evaluating Measurement Uncertainty. Teddington, UK. National Physical Laboratory (NPL). The course includes an introduction to the philosophy behind the Guide to the expression of uncertainty in measurement (GUM) and the first Supplement to the GUM concerned with using a Monte Carlo method for uncertainty evaluation, and covers material contained within those documents. http://www. npl.co.uk/commercial-services/products-and-services/training/ training-courses/

Mar 14-15, 2019 Fundamentals of Measurement Uncertainty. Indianapolis, IN. ANAB. Attendees of this 2-day training course will learn a practical approach to measurement uncertainty applications, based on fundamental practices. https://www.anab.org/training

#### **SEMINARS: Pressure**

Mar 4-8, 2019 Principles of Pressure Calibration. Phoenix, AZ. Fluke Calibration. A five-day training course on the principles and practices of pressure calibration using digital pressure calibrators and piston gauges (pressure balances). The class is designed to focus on the practical considerations of pressure calibrations. https:// us.flukecal.com/training

#### SEMINARS: Software

**Dec 3-7, 2018 TWB 1051 MET/TEAM® Basic Web-Based Training.** Fluke Calibration. This web-based course presents an overview of how to use MET/TEAM® Test Equipment and Asset Management Software in an Internet browser to develop your asset management system. You will learn a systematic approach to recording the information you need to manage your lab assets routinely, consistently and completely. https://us.flukecal.com/training

Dec 10-14, 2018 TWB 1031 MET/CAL® Procedure Development Web-Based Training. Fluke Calibration. Learn to create procedures with the latest version of MET/CAL, without leaving your office. This web seminar is offered to MET/CAL users who need assistance writing procedures but have a limited travel budget. https:// us.flukecal.com/training

Feb 11-15, 2019 TWB 1051 MET/TEAM® Basic Web-Based Training. Fluke Calibration. This web-based course presents an overview of how to use MET/TEAM® Test Equipment and Asset Management Software in an Internet browser to develop your asset management system. You will learn a systematic approach to recording the information you need to manage your lab assets routinely, consistently and completely. https://us.flukecal.com/training

Mar 11-15, 2019 MC-206 Basic MET/CAL® Procedure Writing. Everett, WA. Fluke Calibration. In this five-day course, you will learn to configure MET/CAL software to create, edit, and maintain calibration solutions, projects and procedures. http://us.flukecal. com/training

Mar 18-22, 2019 Metrology.NET® Advanced User Training. Aurora, CO (Denver). Cal Lab Solutions, Inc. This 5-day training will provide an understanding of Metrology.NET and demonstrate how it can be optimized for your lab, covering: hands-on creation & configuration of a test project, development of device drivers, debugging techniques, creating and using resources in Metrology. NET, and more! http://www.metrology.net/5-day-advanced-user/

**Apr 8-12, 2019 MC-205 MET/TEAM®** Asset Management. Everett, WA. Fluke Calibration. This five-day course presents a comprehensive overview of how to use MET/TEAM® Test Equipment and Asset Management Software in an Internet browser to develop your asset management system. http://us.flukecal.com/ training

Apr 11, 2019 Software Verification and Validation, Part 1. NIST Webinar. 2 hour session on Software Verification and Validation will focus on the use of Microsoft Excel in calibration laboratories and examine the ISO/IEC 17025:2017 requirements related to software. https://www.nist.gov/pml/weights-and-measures/about-owm/ calendar-events

**Apr 25, 2019 Software Verification and Validation, Part II.** NIST Webinar. 2 hour session on Software Verification and Validation will focus on the use of Microsoft Excel in calibration laboratories and

examine the ISO/IEC 17025:2017 requirements related to software. https://www.nist.gov/pml/weights-and-measures/about-owm/ calendar-events

#### **SEMINARS: Temperature**

Mar 5-7, 2019 Practical Temperature Calibration Training. American Fork, UT. Fluke Calibration. Three day course loaded with valuable principles and hands-on training designed to help calibration technicians and engineers get a solid base of temperature calibration fundamentals. http://us.flukecal.com/training

#### **SEMINARS: Vibration**

Feb 25-27, 2019 Fundamentals of Random Vibration and Shock Testing. Equipment Reliability Institute. After this short course, you will be able to measure vibration and shock, calibrate vibration and shock measurement systems, convert field measured data into a test program, interpret vibration and shock test requirements, supervise vibration and shock tests, specify and experimentally evaluate vibration and shock test fixtures, perform ESS, HALT and HASS. https://equipment-reliability.com/upcoming-training/

Visit **www.callabmag.com** for upcoming metrology events & webinars!



## INDUSTRY AND RESEARCH NEWS

#### Helping the Microchip Industry Go (Very Low) with the Flow

August 22, 2018, NIST News - A new study by scientists at the National Institute of Standards and Technology (NIST) has uncovered a source of error in an industry-standard calibration method that could lead microchip manufacturers to lose a million dollars or more in a single fabrication run. The problem is expected to become progressively more acute as chipmakers pack ever more features into ever smaller space.

The error occurs when measuring very small flows of exotic gas mixtures. Small gas flows occur during chemical vapor deposition (CVD), a process that occurs inside a vacuum chamber when ultra-rarefied gases flow across a silicon wafer to deposit a solid film. CVD is widely used to fabricate many kinds of highperformance microchips containing as many as several billion transistors. CVD builds up complex 3D structures by depositing successive layers of atoms or molecules; some layers are only a few atoms thick. A complementary process called plasma etching also uses small flows of exotic gases to produce tiny features on the surface of semiconducting materials by removing small amounts of silicon.

The exact amount of gas injected into the chamber is critically important to these processes and is regulated by a device called a mass flow controller (MFC). MFCs must be highly accurate to ensure that the deposited layers have the required dimensions. The potential impact is large because chips with incorrect layer depths must be discarded.

"Flow inaccuracies cause nonuniformities in critical features in wafers, directly causing yield reduction," said Mohamed Saleem, Chief Technology Officer at Brooks Instrument, a U.S. company that manufactures MFCs among other precision measurement devices. "Factoring in the cost of running cleanrooms, the loss on a batch of wafers scrapped due to flow irregularities can run around \$500,000 to \$1,000,000. Add to that cost the process tool downtime required for troubleshooting, and it becomes prohibitively expensive."

Modern nanofabrication facilities cost several billion dollars each, and it is generally not cost-effective for a company to constantly fine tune CVD and plasma etching. Instead, the facilities rely on accurate gas flows controlled by MFCs. Typically, MFCs are calibrated using the "rate of rise" (RoR) method, which makes a series of pressure and temperature



Process Engineer Richard Kasica of NIST's Center for Nanoscale Science and Technology holds a wafer of the type typically produced in the plasma-enhanced chemical vapor deposition chamber at center. Credit: Curt Suplee/NIST

measurements over time as gas fills a collection tank through the MFC.

"Concerns about the accuracy of that technique came to our attention recently when a major manufacturer of chip-fabrication equipment found that they were getting inconsistent results for flow rate from their instruments when they were calibrated on different RoR systems," said John Wright of NIST's Fluid Metrology Group, whose members conducted the error analysis.

Wright was particularly interested because for many years he had seen that RoR readings didn't agree with results obtained with NIST's "gold standard" pressure/volume/temperature/time system. He and colleagues developed a mathematical model of the RoR process and conducted detailed experiments. [https://www.nist.gov/ publications/errors-rate-rise-gasflow-measurements-flow-work] The conclusion: conventional RoR flow measurements can have significant errors because of erroneous temperature values. "The gas is heated by flow work as it is compressed in the collection tank, but that is not easily accounted for: it is difficult to measure the temperature of nearly stationary gas." Wright and colleagues found that without corrections for these temperature errors, RoR readings can be off by as much as 1 percent, and perhaps considerably more. That might not seem like a lot, but low uncertainty is critical to attaining uniformity and quality in the chip manufacturing process. And the challenge is growing. Current low-end flow rates in the semiconductor industry are in the range of one standard cubic centimeter (1 sccm)—about the volume of a sugar cube-per minute, but they will soon shrink by a factor of 10 to 0.1 sccm.

Precise flow measurement is a particularly serious concern for manufacturing processes that use etching of deposited layers to form trench-like features. In that case, the MFC is often open for no more than a few seconds.

"A tiny amount of variation in the flow rate has a profound effect on the etch rate and critical dimensions of the mensor

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structures" in very large-scale integrated circuits, said Iqbal Shareef of Lam Research, a company headquartered in California that provides precision fabrication equipment to microchip manufacturers.

"So, we are extremely concerned about flow rates being accurate and consistent from chamber to chamber and wafer to wafer," Shareef said. "Our industry is already headed toward very small flow rates."

"We are talking about wafer uniformity today on the nanometer and even subnanometer scale," Shareef said.

That's very small. But it's what the complexity of three-dimensional chip manufacturing increasingly demands. Not so long ago, "a 3D integrated circuit used to have four layers of metals," said William White, Director of Advanced Technology at HORIBA Instruments Incorporated, a global firm that provides analytical and measurement systems. "Now companies are regularly going to 32 layers and sometimes to 64. Just this year I heard about 128." And some of those chips have as many as 3,000 process steps.

"Each 300 mm wafer can cost up to \$400, and contains 281 dies for a die size of 250 to 300 mm2," Brooks' Saleem said. "Each die in today's high-end integrated circuits consists of about three to four billion transistors. Each wafer goes through 1 or 2 months of processing that includes multiple runs of separate individual processes," including chemical vapor deposition, etch, lithography and ion implantation. All those processes use expensive chemicals and gases.

Many companies are already reexamining their practices in light of the NIST publication, which provides needed theoretical explanations for the source of RoR flow measurement errors. The theory guides designers of RoR collection tanks and demonstrates easy-to-apply correction methods. RoR theory shows that different temperature errors will occur for the different gases used in CVD processes. The NIST publication also provides a model uncertainty analysis that others can use to know what level of agreement to expect between MFCs calibrated on different RoR systems.

"NIST serves as a reliable reference for knowledge and measurement where industry can assess agreement between their systems," Wright said. "As manufacturers' measurement needs push to ever lower flows, so will NIST calibration standards."

Note: Any mention or depiction of commercial products is for information only; it does not imply recommendation or endorsement by NIST.

Source: https://www.nist.gov/newsevents/news/2018/08/helping-microchipindustry-go-very-low-flow

#### Dynamic Calibration of Force Transducers

PTB-News 2.2018 - Good agreement between the results of different calibration methods (shock or sine) has been achieved for the first time. This was made possible by a mathematical model of a measuring setup with the force transducers elastically coupled on both sides.

The reliable measurement of dynamic forces plays an important

role in industry. To provide the metrological infrastructure required, PTB has been pursuing an approach that describes the dynamic behavior of the force transducer by means of a mathematical model. The transducer and the calibration device are modeled as a series arrangement of massspringdamper elements. The mass, the stiffness and the damping parameters of the force transducer are identified applying the model equation to dynamic measurement data. The goal is the general characterization of the dynamic behavior, irrespective of the particular measuring application or the type of force excitation. Calibrations with shock or sine excitations should provide consistent parameters.

Earlier tests using a high-bandwidth force transducer did not give consistent results. A new model offers a thorough explanation. The force transducer used as a case study (measuring range  $\pm 1$  kN, force introduction via two threaded rods) was subjected to shock or sine forces. Intended variations of the dynamic behavior could be realized by using additional load masses. The pulse duration ranged from 0.1 ms to 1 ms. The maximum excitation frequency was 30 kHz.



Comparison of measured and modeled resonant frequencies of the force transducer investigated as a case study for dynamic calibrations with different load masses. The diagram shows the modeled resonant frequencies and the resonant frequencies determined experimentally with shock and sine excitation as a function of the load mass. The measurement point for1 kg represents a typical sinusoidal calibration with large masses and excitations up to a few kHz. In addition, the resonances determined experimentally at shock excitations are also plotted. Credit: PTB

## **INDUSTRY NEWS**

The force transducer has two dominant resonances whose characteristics depend on the size of the coupled mass. In the case of a typical shock excitation without load masses, the lowest resonant frequency is caused by the vibrating transducer housing, whereas it is due to the elastically coupled mass itself in the case of a sinusoidal excitation with high mass values. The new model of three elastically coupled masses considers a two-sided elastic coupling of the transducer. The resonant frequencies measured with the different measurement setups were compared with those of the model, and the stiffness parameters of the transducer were thus identified.

The improved model-based dynamic calibration now provides consistent parameters from measurement data with sinusoidal and pulse-shaped force excitation. This proves the suitability of this new calibration methodology. Complementary investigations with finite-element methods have confirmed these results. The dynamic measurement behavior of the force transducer can therefore be transferred to a specific measurement application by extending the model correspondingly.

#### Contact

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#### Scientific publication

M. Kobusch, S. Eichstädt: A case study in model-based dynamic calibration of small strain gauge force transducers. ACTA IMEKO 6, 3–12 (2017)

Source: https://www.ptb.de/cms/en/presseaktuelles/journalsmagazines/ptb-news.html

#### EURAMET Publishes New Guidelines for Vector Network Analyzers

EURAMET News, April 5, 2018 – As the speed of digital communications increases, radiofrequency and microwave components must perform at ever higher data transmission rates. Achieving increased speeds relies on the reliable characterization of new component configurations during design development and prototype testing. Vector Network Analyzers are used for this purpose.

The newly revised EURAMET calibration guideline no. 12 on the 'Evaluation of Vector Network Analysers (VNA)' gives advice on how to measure the reflection and transmission of guided electromagnetic waves with a vector network analyzer in accordance with best measurement practices.

"Advances in VNA measurements over the last years prompted the need for a revision of this important calibration guide," says Luca Callegaro (INRIM, Italy), chair of EURAMET's Technical Committee for Electricity and Magnetism. "This guide is intended to become a reference for all users aiming at traceable and accurate measurements with vector network analyzers: National Metrology Institutes, calibration laboratories and scientific and industrial research centers."

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What are vector network analyzers? Vector network analyzers measure reflection and transmission of electromagnetic signals in amplitude and phase. These are fundamental quantities in radiofrequency and microwave measurements.

"Translated into simple words, a VNA determines how smoothly a high frequency electric signal travels through a component, for example a cable. At high frequencies the transmission of signals can be influenced by all sorts of effects, for example by deviations from ideal geometry: The impedance of a transmission line is determined to a large part by the geometry of the line and a change in the geometry leads to a change in impedance. This leads to a reflection of the signal travelling along the transmission line," explains Markus Zeier from METAS in Switzerland, one of the authors of 'Evaluation of Vector Network Analysers (VNA).'

"It is important to characterize this behavior, because many modern communication technologies depend on the reliable transmission of fast electromagnetic signals."

Content of the calibration guideline The EURAMET calibration guideline 'Evaluation of Vector Network Analyzers (VNA)' provides:

- information on establishing measurement traceability to the International System of Units using reference standards,
- advice on VNA calibration and verification schemes,
- an instruction for the evaluation of measurement uncertainties and
- focuses on best measurement practice.

This calibration guideline concentrates on linear VNA measurements in the coaxial line system up to 110 GHz and although it is limited to one-port or twoport VNA measurements, extension of the measurement principles to higher numbers of ports is generally straightforward. Many of the guide's principles can be adopted to other line types such as waveguide or on-wafer.

Appendices contain further details and examples are given to illustrate measurement concepts. A glossary is provided and references are cited for further reading.

The EURAMET guide is published to increase calibration result equivalence and enhance the mutual recognition between measurement laboratories certifying the performance of vector network analyzers. **Authors** 

The revision of calibration guideline 'Evaluation of Vector Network Analyzers (VNA)' has been developed by EURAMET's Technical Committee for Electricity and Magnetism. Authors are Markus Zeier (METAS, Switzerland), Djamel Allal (LNE, France) and Rolf Judaschke (PTB, Germany).

All EURAMET calibration guidelines are available on EURAMET's website: https://www.euramet.org/calibrationguidelines

Source: https://www.euramet.org/ publications-media-centre/news/?tx\_ news\_pi1[news]=662.

#### **Calibration Certificates Go Digital**

PTB-News 2.2018 - Conventional calibration certificates could soon become history. To furnish proof that a measuring instrument has been calibrated and of how this has been done, metrology institutes throughout the world could, in the near future, use digital calibration certificates (DCCs) rather than their analog version. Especially the fact that they are machine-readable speaks in favour of DCCs for production and quality monitoring processes in which digitalization is becoming ever more important. The ultimate goal consists in developing universal DCC exchange formats valid for all areas of metrology.

In industrial production, the quality of products can only be guaranteed if the measuring equipment used is calibrated at regular intervals – i.e. if it is traced directly or indirectly to the national standards. Ensuring that this is possible is one of the central tasks of national metrology institutes. In this context, calibration certificates play a decisive role in each metrological quality management system.

But digital calibration certificates can do more than just serve as a proof of metrological traceability. Since





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the newly developed DCC is based on the internationally accepted and approved exchange format XML (Extensible Markup Language), it is machine-readable; moreover all indications, including the numerical calibration curves, can be directly and automatically transferred into all digitally supported processes. At the same time, cryptographic signatures are used as security procedures to guarantee that the integrity and the authenticity of a calibration certificate is still ensured. The cryptographic procedures used for DCCs have proven their worth in other areas such as the civil register office ("Standesamt"), waste management or in the purchasing department of the German federal administration.

The digital calibration certificate is already being further developed: a digital twin could contain even more data and software and would thus enable the measurement process to be simulated. Physical weights already have such digital twins which have been successfully tested. This "digital weight" contains both information from calibrations and estimations concerning the expected behaviour of the weight under certain ambient conditions.

#### Contact

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#### Scientific publication

S. Hackel, F. Härtig, J. Hornig, T. Wiedenhöfer: The digital calibration certificate. PTB-Mitteilungen 127 (4), 75–81 (2017)

Source: https://www.ptb.de/cms/en/ presseaktuelles/journals-magazines/ptbnews.html

## A2LA Announces Acquisition of WorkPlace Training

August 27, 2018, Frederick, MD and Wayzata, MN – A2LA and WorkPlace Training (WPT) today announced A2LA's acquisition of WorkPlace Training. The addition of WPT's robust e-learning modules will complement A2LA's wide-reaching instructor-led classroom training offerings. E-learning modules offered by WPT include tutorials, practice, assessments and record keeping on topics such as measurement, calibration and ISO/IEC 17025.

"Partnering with A2LA gives us a unique opportunity to bring our calibration and metrology training to an even broader audience as a part of their world-class accreditation and training portfolio," said Paul Hanssen, Founder of WorkPlace



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## INDUSTRY AND RESEARCH NEWS



Training. "We are excited to fortify our already long-term relationship with A2LA and deliver our expertise to reach even more technicians and engineers."

"A2LA is dedicated to improving measurement results that impact safety around the world, which is supported by effective training for measurement and quality assurance professionals. WorkPlace Training's reputation for providing measurement-focused e-learning training makes this a natural expansion of our training and accreditation services offerings," stated Lonnie Spires, A2LA President/CEO. "Our customers have increasingly requested A2LA to provide its world-leading training in e-learning format and we are making that a reality with the acquisition."

"The addition of WorkPlace Training completes a full spectrum of training offerings and delivery, from international standards to measurements and from instructorled to e-learning, to bolster laboratory conformance, competence, and confidence," expressed Tim Osborne, Senior Director of Training Services. "The values, vision and mission that WPT embraced for 30 years parallels those of A2LA which results in an immediate win for the customer."

WPT was founded in 1989, with the purpose of delivering a

comprehensive, relevant and current measurement science training curriculum. Since their founding, WPT has provided training for thousands of learners around the world.

#### About A2LA

As the largest U.S.-based multidiscipline accreditation body, A2LA offers an established infrastructure engineered with over 35 years of ISO standards development and use. A2LA accreditation programs are based on internationally-accepted criteria for competence. For over two decades, A2LA has also maintained a world-class training program, providing a large spectrum of courses designed to help organizations understand how to conform to international standards. Find more information at www.A2LA.org.



# Calculating the Frequency Response of an Oscilloscope from a Transition Duration Measurement

Donald Larson Entegra Corporation

## Introduction

Many digital oscilloscopes have the capability of acquiring, displaying, and storing a digitized representation (the waveform) of an electrical signal. This digitization creates data, the waveform samples, that have discrete amplitude values and are obtained at discrete instants. The storing of the waveform gives the metrologist the ability to perform several useful calculations on the waveform using software embedded in the digital oscilloscope and/or a personal computer. Calculations to determine transition duration (risetime or falltime) and amplitude are the most used. Since the waveform is a digitized replica of the signal, additional information about the oscilloscope performance characteristics may be calculated, along with the associated measurement uncertainties, without requiring any additional measurements. Transition duration measurements were examined by author Jerry L. Eldred [1]; his treatment will be expanded here to include frequency response and bandwidth measurements.



Figure 1. Tektronix CSA 8000 with 80E02 sampler and Entegra Corporation Model 1150.

## **Frequency Response and Bandwidth**

The frequency response of an oscilloscope is the response of the oscilloscope to sinusoidal inputs, as a function of frequency. The 3 dB attenuation bandwidth,  $f_{-3dB}$ , or just bandwidth, is a key performance specification of an oscilloscope, so much so that the bandwidth is printed on the front panel of every modern oscilloscope. The bandwidth is defined as the lowest signal frequency whose waveform amplitude is 3 dB less than the actual input signal amplitude.

## Bandwidth from Transition Duration - Rule of Thumb Method

A simple "rule of thumb" calculation has been used for many years to estimate  $f_{-3dB}$  from the transition duration. The equation is:

$$f_{-3dB} = 0.35/\tau$$
 Eq. 1

where  $\tau$  is the 10 % to 90 % transition duration (the reference levels are given as a percentage of amplitude). This equation is derived by assuming a frequency response waveform with a Gaussian roll-off. Although a Gaussian waveform is noncausal, this relationship gave a reasonable estimate until the advent of digital oscilloscopes, which have different frequency response roll-offs. The major oscilloscope manufacturers each advocate using a different number in place of the "0.35" [2]. For example, Tektronix advocates using "0.45" and Keysight Technology "0.50."

Though useful as a crude "Rule of Thumb" estimator, Equation 1 is too inaccurate to be used in metrology, so, a more rigorous method is the subject of this article.

## Common Bandwidth Measurement Method

Some metrologists calibrate oscilloscopes using two single frequencies to verify the oscilloscope's bandwidth. They do this because they can use a multi-product calibrator as follows. A reference, low frequency sinewave is applied to the oscilloscope input channel (a 50 kHz sinewave for example). The amplitude of the acquired waveform is assumed to be the same as the calibrated amplitude of the input signal and is recorded. A second sinewave with the same calibrated amplitude as the reference frequency but at the same frequency as the oscilloscope bandwidth is next applied to the input of the oscilloscope. The amplitude displayed by the oscilloscope is again measured. If the measured amplitude of this second, high frequency sinewave is equal to or greater than 70.7 % of the reference frequency amplitude, the oscilloscope bandwidth specification is considered met.

While this procedure does work for many tests, it may not always be correct. What if the oscilloscope's frequency response has developed a dip at a frequency that is less than  $f_{-3dB}$ ? This condition would not be discovered using the method just described. Even if multiple measurements were made at different input frequencies (the "swept frequency" method), as is done if the frequency response is being measured, unless the input frequency is increased in small enough increments, any dips in the frequency response may not be found. For example, if the frequency response of a 500 MHz bandwidth oscilloscope contains a dip at 435 MHz, this may not be discovered if the frequency increments are 25 MHz or even 10 MHz.

As will be explained in the next section, time domain measurements may provide the oscilloscope's frequency response with a fine frequency resolution from a single measurement.

## The Fourier Transform – From Time to Frequency and Back

Some digital oscilloscopes include embedded software, the Discrete Fourier Transform (DFT), that will calculate the frequency spectrum of the acquired waveform. LabView, Matlab, and other software packages also include the DFT. The Fourier Transform describes the relationship between a time-domain representation of a signal and its frequency-domain representation (or spectrum). If you are not familiar with the Fourier Transform, there are several good texts on the subject [3].

Data that is a function of time (i.e. voltage vs. time or current vs. time) is called time-domain data. Similarly, data that is a function of frequency is termed frequencydomain data. The Fourier Transform converts timedomain data into frequency-domain data and the Inverse Fourier Transform converts frequency-domain data into time-domain data. The Fourier Transform assumes that the duration of the time-domain data, the waveform epoch, is an integer number of cycles of a repetitive signal. This means that the first sample and the last sample of the waveform must have the same amplitude.

An important property of the Fourier Transform is that the duration of the waveform (its epoch) will determine the frequency resolution,  $\Delta f$ , of the frequency-domain data (the spectrum). The longer the waveform epoch, the smaller will be  $\Delta f$ . The Fourier Transform provides a complex (real and imaginary) spectrum that can be converted to a magnitude and phase spectra. We will only consider the magnitude here.

## Step-like Waveform vs. Impulse-like Waveform

A step-like waveform has an upper and lower state whereas an impulse-like waveform has only one state (and is the derivative of a corresponding step-like waveform). There are various advantages and disadvantages to using either an impulse-like waveform or step-like waveform when determining the impulse response or frequency response of an oscilloscope.

For many years, metrologists in the national metrology institutes preferred to use step-like waveforms from calibrated pulse generators, this was primarily for two reasons. The first is that waveform averaging can be used to reduce signal noise without impacting the amplitude, even in the presence of jitter. After averaging, the amplitude of a step-like waveform can be more accurately computed, this is done using a histogram or other method [4]. Once the amplitude is determined, the 10 % and 90 % reference levels can be found, the 10 % and 90 % reference level instants determined, and the transition duration calculated.

This option is difficult for an impulse-like waveform, signal averaging in the presence of jitter will reduce the amplitude and as a consequence, the transition duration will increase. Therefore, other methods such as a peak detection method must be employed. One method is to fit a parabola to the peak of the impulse [4].

The second reason that a step-like waveform is preferred over an impulse-like waveform is the impact of oscilloscopes with different bandwidths on the measured waveform amplitude. For an impulse-like waveform, both the amplitude and transition duration are dependent on the oscilloscope bandwidth. In fact, an impulse can be too fast with too little energy in the frequencies within the oscilloscope bandwidth. If the oscilloscope bandwidth is too low, the impulse amplitude may be so small as to be undetectable. In this case, another longer, calibrated impulse generator must be used. This does not happen with a calibrated step-like pulse generator. The amplitude of the step-like waveform remains constant for oscilloscopes with different bandwidths.

Of course, the measured transition duration from either a calibrated impulse-like or calibrated step-like pulse generator will be longer when measured with an oscilloscope with lower bandwidth, but only one calibrated step-like pulse generator is required for a wide range of oscilloscope bandwidths. It is important to note that the impulse response is the derivative of the step response function. It is also important to note that all transition duration values mentioned herein use 10 % to 90 % amplitude values.

## Fourier Transform of Step Response

As previously mentioned, the Fourier Transform requires that the amplitudes of the first and last samples be identical. A step-like waveform does not meet this requirement unless an integer multiple of complete cycles are acquired. Since the number of samples and the time

resolution are limited by the oscilloscope hardware, obtaining a full cycle of the step-like waveform while having a sufficient number of samples in the transition region may not be possible. Over the years, many different ways of dealing with the discontinuity in amplitude between the first and last waveform samples have been proposed [5]. An intuitively simple method is the Nahman-Gans Extension. The acquired step-like waveform is extended by inverting a replica of the steplike waveform and offsetting its level by adding to this replica the value of the sum of the amplitudes of the first and last samples, and then appending this inverted and offset waveform to the original waveform. The resulting waveform has twice as many samples as the original but the first and last samples have identical amplitudes. Since only the measured data is used, no new waveform features or additional frequency content are introduced. However, a step-like waveform with a duration of N/2, where N is the total number of samples, is created because of the noise in the first and last samples, and this will introduce an error in the spectrum that is proportional to the waveform noise. The primary draw-back to this method is that Nis doubled so all the numerical processing takes twice as long to compute. Also, because of this unique process, all even harmonics in the spectrum are zero.

Another effective method of dealing with this problem is to convert the step-like waveform to an impulse-like waveform by taking the first difference of the waveform data. No new frequency structure results from this calculation. However, because of noise in the waveform, the values of the first and last waveform samples in the difference waveform may not be equal. This discontinuity will still introduce a small error in the frequency response spectrum because of assumed cyclic convolution in the DFT.

We recommend using a step-like waveform, determine the pulse parameters of amplitude and transition duration, form an impulse-like waveform using the first difference method, and calculate the Fourier Transform to determine the frequency response and  $f_{-3dB}$  of the oscilloscope. These computations presume that the oscilloscope bandwidth to be 10 times less than that of the pulses input into the oscilloscope. If this is not the case, additional considerations are necessary, which is discussed in the next section.

## **Convolution Effects**

There is another effect that must be considered to obtain accurate measurement results and that is convolution. When a signal generator output is measured using any waveform recorder like an oscilloscope, the result is a convolution of the finite impulse responses of the two instruments. Suppose that the output of a step-like pulse generator with a short transition duration and wide bandwidth,  $f_{g'}$  is used to determine the step response and 3 dB analog bandwidth,  $f_{s'}$  of a fast-response (highspeed) oscilloscope. The acquired waveform is described as a mathematical convolution of the pulse output from the pulse generator and the impulse response of the oscilloscope. The -3 dB analog bandwidth of the acquired waveform,  $f_{gg'}$  may be approximated by using a Gaussian approximation of  $f_{g'}$   $f_{s'}$  and  $f_{sg}$  and the "root sum of squares" (RSS) method to relate the oscilloscope bandwidth  $f_s$  and the pulse generator bandwidth  $f_{g}$ :

$$\frac{1}{f_{sg}} = \sqrt{\left(\frac{1}{f_s}\right)^2 + \left(\frac{1}{f_g}\right)^2}$$
 Eq. 2

A numerical example is helpful to illustrate the magnitude of the effect of convolution. Suppose that  $f_s = 2$  GHz and that  $f_g = 2$  GHz, the result of Equation 2 is  $f_{sg} = 1.414$  GHz. That is, the acquired waveform has less bandwidth than 2 GHz even though the bandwidth of both the oscilloscope and pulse generator is 2 GHz. Deconvolution of the pulse waveform from the acquired waveform must be used in this case to get an accurate estimate of the bandwidth of the oscilloscope or a calibrated pulse generator producing pulses with faster transition duration must be found. For example, if  $f_g = 12$  GHz (like an Entegra Model 1012 High Speed Reference Pulse Generator), the effects of convolution, estimated by Equation 2 would be greatly reduced; instead of  $f_{sg} = 1.414$  GHz, it would be 1.973 GHz or less than 1.4 % error (Eq. 3).

$$\frac{1}{f_{sg}} = \sqrt{\left(\frac{1}{2}\right)^2 + \left(\frac{1}{12}\right)^2}$$
 Eq. 3

If pulses with even shorter transition duration were used, like those provided by an Entegra Model 1120, with  $f_g$ =18 GHz, the result is  $f_{sg}$ =1.988 GHz or about 0.6 % error. Figure 1 (page 20) depicts a Tektronix CSA8000 with a 80E02 sampling head (12.5 GHz bandwidth) measuring the output of an Entegra Corporation Model 1150 (50 GHz bandwidth). There is a 1.85 mm to 3.5 mm adapter between the pulse generator output and the sampling head input. If a coaxial cable, connector adapters, or terminations are used to connect the pulse generator to the oscilloscope, the effects of their bandwidths must also be included by inserting additional terms inside the square root in Equation 2. Please note that Equation 2 may also be used with transition durations by replacing 1/*f* terms with  $\tau$  (transition duration) terms.

#### **Uncertainty Analysis**

The uncertainty analysis for step-like and impulselike waveform parameters is covered by IEC 62754:2017 "Computation of waveform parameter uncertainties" [6] and in "Pulse parameter uncertainty analysis" [7]. One component of the uncertainty in the bandwidth may be determined by using the expanded uncertainty,  $u_{\tau}$ , of  $\tau$  to represent a set of step-like waveforms that have a range of transition durations equal to  $\tau - u_{\tau}$  to  $\tau + u_{\tau}$ , where these step-like waveforms are generated numerically. The DFT of each waveform in this set is then calculated, a bandwidth for each spectrum obtained, and the standard deviation of the resultant set of bandwidths is used as the primary contributor to the uncertainty.

Four different pulse generators and four different sampling oscilloscopes and samplers were used to examine the variation in  $f_{sg}$  as the transition durations were varied. The initial waveforms were acquired and then a set of waveforms were created from each of them by adjusting the sampling intervals to obtain the desired variation in  $\tau$ . The waveform epoch was altered by this process as well, which, as mentioned previously, affects the frequency interval or resolution,  $\Delta f$ .

Figure 2 (on the following page) depicts the five initial waveforms and the results are presented in Table 1. The percent variation in  $f_{sg}$  very closely followed the percent variation in  $\tau$ . All acquired waveforms used a 2 ns epoch. The number of samples in the waveform for the Tektronix 067-1338-00 #2 was 1000, for the Tektronix 067-1338-00 #1 and Fluke 9500B-9550 was 1024, and for the Entegra 1150 was 4096. The same Entegra Corporation Model 1150 Reference Pulse Generator was used to generate both waveforms depicted in Figure 2, only the sampling oscilloscopes acquiring the waveforms were different.

The Agilent 86118A has a  $f_s \approx 70$  GHz and the Agilent 83484A has a  $f_s \approx 50$  GHz. In Table 1, the differences in transition duration and bandwidth are noted.

We also examined the change in  $f_{sg}$  as the transition occurrence instant changed position in the waveform epoch. In Figure 2, all of the transition occurrence instants are at 400 ps or 20 % of the epoch. There was only a very small change (less than 0.06 ps) when the transition occurrence instant was delayed or advanced up to 15 % (100 ps to 550 ps from the first sample of the waveform). Consequently, this effect can be neglected. Once  $u_{\tau}$  is determined, its contribution to the measurement uncertainty,  $f_{sg'}$  expressed as a percentage, can be determined. These percentages were observed to be approximately the same.

As previously mentioned, the duration of the time domain waveform, i.e. the waveform epoch, determines the frequency resolution,  $\Delta f$  of the frequency response calculated using the Fourier Transform. This discrete  $\Delta f$  is another contributor to the uncertainty in the frequency response and bandwidth. The effect of  $\Delta f$  on the uncertainty is handled similarly to how the time resolution affects the uncertainty in the transition duration

## **METROLOGY 101**



Figure 2. Waveforms acquired using four different pulse generators and four samplers (volts vs. seconds).

[7]. Since the probability of finding the -3 dB point on the frequency response is uniformly distributed across the interval  $f_{-3dB} - \Delta f \operatorname{to} f_{-3dB} + \Delta f$ , the measurement uncertainty is 0.577  $\Delta f$ .

Another contribution to the uncertainty is the waveform epoch not being an integer number of signal cycles. Using the Nahman-Gans, First Difference, or other method to address this situation may still result in a small difference in the amplitude between the first and last samples in the waveform. This will effectively introduce an additional ideal step-like (square-wave) waveform to the measured signal and, thus, to its spectrum. This additional squarewave spectrum is more noticeable in the lower-frequency parts of the spectrum as this is where it has the greatest power. This effect is particularly noticeable on the acquired waveform when using an impulse-like signal as the input to the oscilloscope. Rarely are the values of the first and last samples equal for an impulse-like signal unless a full cycle is acquired. However, even in this case, noise will affect the equality. The situation when the values of the first and last samples are unequal is treated as an error and the waveform is corrected for this error before calculating the Fourier Transform. Due to noise, measurement uncertainties are associated with this error correction.

There may be other measurement uncertainty contributors to the transition duration and thus the frequency response that you may decide to include. For example, if the temperature in your lab is not very stable, both the oscilloscope step response and pulse generator output may vary [8].

In keeping with NIST and the GUM recommendations [9], the various uncertainty components examined above are combined using the RSS formula similar to Equation 2 above to yield the combined uncertainty. The expanded uncertainty is then calculated by multiplying the combined uncertainty by a coverage factor, usually 2 for a 95 % level of confidence. The expanded uncertainty is the value usually reported to your customer.

## **METROLOGY 101**

Pulse Generator	Sampler (f <sub>s</sub> )	Transition Duration $(\tau)$	Bandwidth $(f_{sg})$	% Change in τ	% Change in $f_{sg}$
Tektronix 067-1338-00 #1	Agilent 86118A (70 GHz)	12.56 ps	23.05 GHz	±2.5%	+2.43 % to -2.56%
Tektronix 067-1338-00 #2	Tektronix 80E01 (50 GHz)	15.06 ps	21.46 GHz	±2.5%	+2.42 % to -2.56%
Entegra 1150 #1	Agilent 86118A (70 GHz)	9.50 ps	49.42 GHz	±2.5%	+2.43 % to -2.57%
Entegra 1150 #1	Agilent 83484A (50 GHz)	11.33 ps	48.83 GHz	±2.5%	+2.44 % to -2.56%
Fluke 9500B- 9550	Tektronix SD32 (50 GHz)	28.36 ps	10.60 GHz	±2.5%	+2.45 % to -2.55%

Table 1. Variation in Transition Duration and Resulting Variation in Bandwidth

## Summary

The frequency response and bandwidth of the oscilloscope under test may be calibrated by using a steplike waveform from a calibrated step-like pulse generator. The waveform's time and amplitude parameters, such as transition duration, pulse duration, amplitude, noise, and aberrations, can be measured using the internal software of the oscilloscope or external software. The step-like waveform is converted to an impulse-like waveform using a method like the Nahman-Gans extension method or the first difference method. The Discrete Fourier Transform is then used to calculate the spectrum of the impulse-like waveform and the 3 dB attenuation bandwidth is determined from the frequency response. The uncertainty of the transition duration is found and converted to a percentage which is assumed to be the same percentage uncertainty for the bandwidth. This percentage is changed to a frequency and combined with other contributors to the measurement uncertainty of the bandwidth and reported.

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Donald R. Larson worked at NIST for almost 38 years where he started the fast optical detector calibration service in 1995 and was responsible for calibrating fast pulse generators and oscilloscopes from 1998 to 2006. In 2008, he founded Entegra Corporation which manufactures reference pulse generators with  $f_{-3dB}$  up to 50 GHz. For more information, please visit http://www.entegra-corp.com, email sales@entegra-corp.com, or call 240-672-7645.

# In Focus: Colorado Engineering Experiment Station (CEESI)

## Sita Schwartz Editor

The Colorado Engineering Experiment Station, Inc. (CEESI), a subsidiary of Western Energy Support & Technology, Inc. (WEST), provides accredited NIST traceable calibration for numerous types of flow meters for customers around the world in the energy and aerospace industries. With roots going back to the University of Colorado in Boulder, they also engineer flow testing systems, participate in inter-laboratory comparisons, and sponsor training and flow measurement events.



## What's in Nunn?

I first knew about Colorado Engineering Experiment Station, Inc. (CEESI) from Cal Lab Magazine's previous editor, Carol Singer, who published their events and workshops in the magazine's calendar section. I came across their incredibly large, online library (www. measurementlibrary.com) hosted by CEESI and the Pipeline Research Council International (PRCI). They've managed to organize and upload thousands of papers from more than a dozen contributors from the flow measurement community, mostly from the hydrocarbon energy industry. So, this was all I knew about them, until I went to visit. I should have done my homework ahead of time as I was completely overwhelmed!

CEESI is located in Nunn, Colorado—about 1½ to 2 hours

north of the Denver Metro Area or 35 minutes south of Cheyenne, Wyoming—seemingly in the middle of nowhere. There's rolling prairie, small herds of pronghorn, and lots of barb wire fencing. The testing stations and buildings of this facility are spread out over 27 acres with a lovely, wide view of the high plains. These open spaces emphasize how big and blue the sky is out here at 5,000 feet in elevation.

With more than 40 employees, much of their staff is comprised of senior flow measurement technicians and engineers. CEESI employees author many of the technical papers that end up in the Measurement Library and also serve as instructors for flow measurement training courses. This aspect of R&D and learning has its roots from the very beginning. Besides the cool aspect of large-scale and highaccuracy calibration and engineering, CEESI is also defined by its unique history.



Figure 1. Outside the missile bay, originally built for an Atlas E Missile, now used for flow meter testing.

## History

The Engineering Experiment Station began as a program, run by the College of Engineering at the University of Colorado (CU) in Boulder from 1951 to 1965 "for research, development, and testing of small rocket nozzles. In addition, the Station became the sole location for testing gas turbine meters as the military began to use these meters [1]." The program produced flow measurement systems and allowed researchers to participate in the development of high pressure gas flow standards and critical flow venturis.

The site in Nunn was originally one of 27 testing sites for the Atlas E nuclear missiles. It was assigned to the 566th Strategic Missile Squadron of F. E. Warren AFB in Cheyenne, Wyoming [2]. The facility served as a surplus missile silo for two short years, becoming obsolete when the Air Force shifted from liquid to solid fueled propulsion. The military was motivated to unload the sites for repurposing and the underground facilities have since been used for



Figure 2. View from the loft of the missile bay.



Figure 3. Porter calibration lab for small, low flow meters.

homes, document storage, machine shops, etc. But the underground tunnels and staging areas also had great potential for flow testing. So, in 1966, Dr. Tom Arnberg helped to separate the Engineering Experiment Station from CU and move it to the decommissioned missile site. The non-profit also went through a name change to Colorado Engineering Experiment Station, Inc. (CEESI).

"During the late 1960's and early 1970's, the facility became home to two new high pressure primary flow standards, identified as 'Primary A' [volumetric] and 'Primary B' [gravimetric], which are still in use today. [1]" In 1986, CEESI changed hands when it was purchased by Walt Seidl and Steve Caldwell, both of whom had been quite involved with the company already. Incorporated as a for-profit, commercial calibration facility, CEESI has since expanded and grown. Where there was just an underground missile bunker and tunnels, there are now numerous test areas, storage tanks, and buildings spread out over the facility.

## Capabilities

CEESI is a NIST traceable, primary and secondary flow meter calibration facility and one of the largest in North America, serving customers around the world. They can engineer tests that utilize a wide variety of gases and fluids, including replicating multiphase conditions found in oil and gas production. Most of the meters are calibrated in a test area known as the "Mechanical and Electrical" room by the Air Force crew. Located nearby are the primary flow standards and metrology lab for pressure, temperature, viscosity and density calibrations. The original "Missile Bay" is now used to calibrate larger meters operating at higher flowrates, while the largest meters are calibrated in an outdoor test area.

The largest test area is the Wet Gas/Multiphase facility. From the second floor of the Wet Gas Building, an oversized picture window looks out over an expansive, rectangular shaped gas loop. Rich Schoonover, who was recently appointed President of Corporate Operations, explained the operations cost of keeping the flow of gas running through the loop runs at \$10,000 a month.

Together with the Northern Plains Natural Gas Company and several flow meter vendors, a high flow natural gas calibration facility was completed in Garner, Iowa in 1999. This facility fulfills a need for ultrasonic meter calibrations traceable to standards in the United States. For those not familiar with pressure and flow measurement (like me), ultrasonic meters are vital to the natural gas industry by being able to measure the velocity of flow through a pipe.



Figure 4. The entrance (building J) to a bunker used to safely monitor and control tests at the adjacent high flow, outdoor air test stand.

The ultrasonic waves can transmit the frequency at which it travels along with the flow.

Additional buildings at the Colorado facility house additional test areas, but the latest edition is an impressively large Liquid Hydrocarbon Flow Calibration Facility. With two provers, a set of master meters, and four different fluids, the facility operates over a broad range of flowrates and viscosities. An outstanding feature is the control system that maintains temperature to within 0.2 F° during calibration.

A Cryogenic Flow Calibration Facility was also recently brought online in Colorado. This system, owned by the National Institute of Standards and Technology (NIST) in Boulder and operated by CEESI,



Figure 5. Technicians working on the loop.



Figure 6. Latest installation: Liquid Hydrocarbon Flow calibration facility.

"is a pumped continuous system allowing for thermal equilibrium and continuous operation without liquid [nitrogen] loss [3]." CEESI worked closely with NIST in order to meet operational criteria and match data from the rebuilt system to historical data [4]. CEESI.com has a lot of great photos of the cryogenic lab in action, so I encourage

anyone interested in this type of extreme temperature measurement to check out their website. In fact, CEESI's website is a goldmine of information—the more you look, the more you find about their facility and flow calibration.

## **Corporate Info**

CEESI has undergone further changes in recent years. Besides the addition of the Cryogenic and Liquid Hydrocarbon Flow calibration facilities, CEESI has seen a change of hands at the management level. Rich Schoonover was appointed President of Corporate Operations in November of 2017. Rich joins a company with over 50 years of leadership within the flow calibration industry. At its locations in Nunn, Colorado, and Garner, Iowa, CEESI performs NIST-traceable primary and secondary calibrations on numerous types of meters and valves, using a wide range of flow rates, pressures, temperatures, and test gases.



Figure 7. Shot of the flow software interface from the control room.

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Many thanks to Jason Tator for his time and patience, to Tom Kegel for his help editing, and Rich Schooner for his hospitality.

## **CEESI Snapshot**

- Locations: Nunn, Colorado and Garner, Iowa, USA
- **1951** Established as the Engineering Experiment Station by the University of Colorado
- **1986** Incorporated as an independent, commercial facility
- Founding members: Walt Seidl and Steve Caldwell
- Number of employees: 40+
- Parent Company: Western Energy Support & Technology, Inc. (WEST)
- **Calibration services:** Flow meters, including: critical flow venturis/sonic nozzles, ultrasonic flowmeters, orifice meters, differential meters, and turbine meters.
- Accreditation: NVLAP
- Sponsored events and training: International Symposium on Fluid Flow Measurement (ISFFM), North American Fluid Flow Measurement Council, Ultrasonic Meter Seminar



## Keysight Technologies Infiniium UXR-Series Oscilloscopes

SANTA ROSA, Calif., September 18, 2018 – Keysight Technologies, Inc. (NYSE: KEYS), a leading technology company that helps enterprises, service providers, and governments accelerate innovation to connect and secure the world, announced the new Infiniium UXR-Series of oscilloscopes, with models ranging from 13 to 110 GHz of true analog bandwidth, offering industry leading signal integrity, and investment protection that meets the needs of technology advancements today and tomorrow.

Keysight's new Infiniium UXR-Series enables high-speed serial and optical designers, focused on current and next generation technologies, to quickly create comprehensive designs with higher margins, thereby reducing time to market of their innovation. Superior performance levels, combined with a wide selection of bandwidth choices, make the Infiniium UXR-series the ideal solution for engineers and designers working with any generation of DDR, USB, PCIe or other serial technologies, as well as PAM4, 5G, radar, satellite communications, and optical designs.

"Today's electronic and communications systems have become more complex requiring next generation test and measurement," said Jessy Cavazos, Industry Director, Test & Measurement, Frost & Sullivan. "Keysight's deep heritage and extensive expertise in test and measurement is clearly reflected in the new UXR series of oscilloscopes, which deliver next generation innovations to address the rapidly evolving measurement and compliance needs in the high-speed digital, terabit and optical research, 5G, RF, and aerospace and defense markets."

Keysight's new Infiniium UXR-Series delivers a low noise floor and high vertical resolution to ensure measurements are not impacted by oscilloscope noise and signals are represented accurately. As a result, eye diagrams are significantly more open, and true margins and performance can be determined.

Keysight Infiniium UXR-Series 13 to 110 GHz oscilloscope models enable designers to accelerate time to market of their innovation, with:

• 10-bit vertical resolution and industry leading signal integrity for superior effective number of bits (ENOB), leading to faster compliance testing with higher margins;



- sampling rates of 256 GSa/s per channel on 40 to 110 GHz models and 128 GSa/s per channel on 13 to 33 GHz models, creating accurate reconstruction of high-speed signals;
- up to four full-bandwidth channels with less than 35 fs (rms) of inter-channel intrinsic jitter providing accurate timing and skew measurements;
- an optional full factory grade self-calibration module which ensures ongoing measurement accuracy while reducing the need to take the unit out of service,
- a chipset based on a Keysight-proprietary Indium Phosphide (InP) process that enables exceptionally wide bandwidth and extremely low noise floor.

Keysight also announced two additional solutions that, when paired with the company's Infiniium UXR-Series oscilloscopes, offer a full end-to-end solution from stimulus to analysis for PAM4 and 400G, 600G, as well as terabit coherent optical interconnect designs. These solutions include:

- N4391B Optical Modulation Analyzer (OMA) –a compact, realtime oscilloscope-based OMA designed specifically for complex optical data transmission and terabit measurement challenges.
- M8194A 120 GSa/s arbitrary waveform generator (AWG) -Keysight's fastest AWG delivers a new level of stimulus performance for generating challenging formats such as 64 GBaud 64QAM (quadrature amplitude modulation) and other wideband modulation schemes.

"High-speed serial and optical technologies are continually pushing speed and performance boundaries as the development of terabit and 5th generation serial technologies accelerate," said Dave Cipriani, Keysight Vice President, Digital and Photonics Center of Excellence. "The expanded UXR oscilloscope series, the UXR-based OMA, and Keysight's fastest AWG, collectively offer high-speed designers an unprecedented end-to-end solution to rapidly advance their technology development today, while providing investment protection into the future."

#### **Additional Information**

- More information about the Keysight Infiniium UXR Series realtime oscilloscopes is available at www.keysight.com/find/UXR.
- More information about the Keysight N4391B OMA is available at www.keysight.com/find/oma\_backgrounder.
- More information about the Keysight M8194A AWG is available at www.keysight.com/find/awg\_backgrounder.

## Mitutoyo America Offers Free Online Video Training

AURORA, IL – October 2, 2018 – Mitutoyo America Corporation is now providing free online video training in dimensional metrology with the opportunity to earn certified credentials to demonstrate competency. Available credentials include both theory, through online tests, and performance, involving hands-on demonstration of skills.

The online training and certified credentials are available through the Mitutoyo Institute of Metrology, the educational department of Mitutoyo America, which provides courses and on-demand resources across a wide variety of measurement related topics, including basic inspection techniques, principles of dimensional metrology, calibration methods and GD&T.

Material from Mitutoyo's calibration course is used in the



first online videos, which together create a standards-based course entitled "General Calibration Concepts, Micrometers and Calipers." The training material combines concepts from the available American National Standards in dimensional metrology with best calibration practices at Mitutoyo America. Metrology professionals can now access all the calibration training videos through the Mitutoyo America website or Mitutoyo America YouTube Channel.

To supplement the free online training, and to provide an opportunity to demonstrate learning and competency, the first two certified credentials are now available in dimensional calibration. The Level 1 theory credential is a single online test that covers the material from the online video course, including general calibration concepts, overview of dimensional calibration elements, and the calibration of micrometers and calipers. A test can be taken for a nominal fee of \$75.00.

The Level 2 performance credential involves performing the calibrations of micrometers and calipers within expected levels of accuracy. The Level 2 performance test is available at locations throughout the U.S. for a nominal fee of \$250.00.

For those already experienced in dimensional calibration methods, it is possible to take the tests at any time. Mitutoyo America recognizes that many organizations, looking to meet quality system requirements and the demands of auditors, are seeking cost effective means to demonstrate the competency of their experienced calibration personnel. Credentials can therefore be earned by anyone passing the tests and there is no requirement to watch the training videos or attend any Mitutoyo educational course prior to the test. The Mitutoyo Institute of Metrology will continue to offer traditional classroom courses , as well. For those attending the Gage Calibration course, the opportunity to take the tests and earn Level 1 and Level 2 credentials will be available at no additional cost. For more information, visit www.mitutoyo. com/education.

#### Asterion<sup>®</sup> Programmable Power Platform DC 1.7–5 kW Series

SAN DIEGO, October 4, 2018 - AMETEK Programmable

high-performance DC power supplies with either fixed or autoranging output.

Like the Asterion AC family, the Sorensen Asterion DC Series sets a new standard for power density. All units are just 1U (44.45mm/1.75in) high, so rack space requirements are minimal. Asterion DC Series supplies offer rated output voltages in 40 V and 60 V for 1.7 kW, 3.4 kW and 5.0 kW power levels.

The new DC series features two types of product lines: fixed range and autoranging. The fixed range supplies are economical, traditional rectangular wave output power supplies with all the enhanced operation advantages standard with the Asterion platform. The autoranging supplies feature expanded current and voltage range at the full output power level, enabling the ability to satisfy a wider testing need without requiring the purchase of additional models.

The intuitive front panel touchscreen interface and multilanguage display ensure exceptional ease of use. An auto-paralleling capability supports operating multiple units in parallel to increase the total output power level.

The Asterion DC Series is Digital Signal Processor (DSP) controlled and supports multiple programming interfaces. Operators can control the supply from an intuitive front panel touchscreen or remotely via LXI Ethernet, USB and RS-232 standard control interfaces, as well as an optional GPIB control interface for legacy applications.

Function group icons on the touchscreen allow access to the supplies' dashboard, output programming parameters, measurements, sequencing, configuration, control interfaces, applications, and system settings functions.

Operators can select functions and enter parameters either by accessing them directly through the touchscreen or by using the encoder selector button. A dynamic rate change algorithm can adjust the control resolution, which provides precise control over small parameter changes and quick sweeps through an entire range.

Asterion DC Virtual Panels are graphical user interfaces that allow programming, monitoring and controlling of any of the supplies remotely. All operations that can be performed by working directly with the unit's front panel controls also can be performed remotely with these Virtual Panels.

The Asterion DC Series is optimized for use in testing today's complex electronics applications which require lowprofile, lightweight power supplies with high-power density. Applications include military and aerospace electronics test, DC power simulation, commercial manufacturing and process control, R&D, automotive component and battery testing, and a wide range of ATE applications.

For more information on the Asterion DC Series or any of AMETEK's programmable power supplies and programmable loads, contact an authorized AMETEK Programmable Power sales representative by visiting powerandtest.com/sales.

AMETEK Programmable Power also can be contacted directly toll free at 800-733-5427 or 858-450-0085 or at sales. ppd@ametek.com.

Power, the global leader in programmable AC and DC power test solutions, has again expanded its popular Asterion® power supply platform. This time, it's with the addition of a line of programmable,





#### Rohde & Schwarz Introduces the All-New R&S FSW

Munich, September 25, 2018 — The well-established family of R&S FSW high-end signal and spectrum analyzers is used for measurements in various applications, for example in wireless communications device testing for 5G and Wi-Fi, in radar analysis in the automotive and A&D sectors and in satellite system testing. The signal and spectrum analyzers can also be used to characterize RF components such as power amplifiers.

Rohde & Schwarz has further improved the market-leading performance of the R&S FSW family. The new R&S FSW features up to 10 dB lower phase noise compared with the previous models, which is extremely important in applications such as troubleshooting the modulation of 5G signals in the microwave range.

The new R&S FSW analyzers above 26.5 GHz offer an internal analysis bandwidth of 2 GHz. Now users can analyze wideband signals from radar systems or 802.11ad Wi-Fi signals without requiring an external digitizer such as an oscilloscope in the test setup. The R&S FSW can also analyze bandwidths greater than 2 GHz, a feature that may be necessary for automotive radar or 5G applications. When performing measurements with an R&S FSW43 or R&S FSW85, the bandwidth can be extended up to 5 GHz using an R&S RTO2000 oscilloscope.

800 MHz instead of 500 MHz bandwidth is now available for real-time analysis. The new R&S FSW models process the measurement signals twice as fast as before and perform more than two million FFTs per second. They have a 100 % probability of intercept of detecting and accurately measuring signals with a minimum duration of just 0.46 µs. Consequently, all signal details are detected without gaps. This is a crucial feature for transient analysis and when troubleshooting highfrequency applications.

It is very easy to create automated test sequences with the R&S FSW analyzer's embedded SCPI recorder. The user operates the analyzer as usual; the SCPI recorder records the all involved settings and converts them into a script for controlling the analyzer.

The R&S FSW now has a capacitive touch screen and can be operated like a smart phone. The redesigned operating concept and user interface let users take full advantage of this modern operating method.

For more details, go to https://www.rohde-schwarz.com/ product/fsw as well as https://www.rohde-schwarz.com/ highend.

#### The Fluke Calibration 734C DC Reference Standard

Everett, Wash., June 26, 2018 – The new Fluke Calibration 734C DC Reference Standard is the third generation of lab quality voltage reference standards first pioneered by Fluke. It is designed for laboratories that need to maintain traceability to national standards and distribute the volt to production, service, calibration laboratories, or other remote locations. They are the most stable references, only exceeded by a Josephson Junction Array (intrinsic standard for the volt), which is orders of magnitude more difficult and expensive to operate and maintain than a 734C system.

The new 734C adds 1 V and 0.1 V outputs to facilitate DMM calibration eliminating the cost and complexity of adding external dividers. These new outputs were made possible new thin-film resistive networks, which are manufactured in Fluke's own microelectronics fab facility.

The internal wire-wound-based resistors have also been replaced by hermetic thin-film resistive networks, which are less prone to time and temperature induced drift, allowing Fluke to enhance the retrace error adder specifications from 24 hours to 14 days, eliminating the need to return the unit to Fluke to restart in case of lost battery power.

Fluke will also start offering "Select Models" which are two times more stable than the base models at 10 V thanks in large part to the process enhancements to the Zener reference technology pioneered in the popular 732A and 732B.

The 734C consists of four electrically and mechanically independent 732C DC Standards in a rack-width enclosure. Each standard is small and highly portable with 72 hours of battery life that can be extended to more than 210 hours with the optional external battery and charger, making it practical to ship a 732C across town or around the world.

The RoHS-compliant 734C delivers:

- **Independence.** The 734C is the only standard of its type offering complete mechanical and electrical independence of each of its four standards.
- **Portability.** Each 732C Standard is designed for portability. Each is small, light, rugged, and has a long operating battery life.
- **Confidence.** The 732C is based on the proven technology of the Fluke Calibration 732A/B. The 732A was the first standards lab quality electronic reference to gain wide acceptance as a replacement for saturated standard cells.

For more information on the Fluke Calibration 734C DC Reference Standard, visit: https://us.flukecal.com/734C





#### Gigahertz-Optik BN-LH250 Calibration Lamp

September 6, 2018, Amesbury, MA - As the historical 1000W lamp standards are becoming harder to come by, Gigahertz-Optik presents its BN-LH250 250 watt lamp as an alternative to the 1000 watt FEL and DXW type calibration standard lamp.

Excellent short-term and long-term stability is achieved due to its highly stable filament. The lamp's quartz envelope is frosted for a more uniform radiation pattern. The BN-LH250 includes a lamp base that fixtures the lamp securely in position with electrical connection made via two laboratory grade sockets. A protective cover with a transparent cross-hair target enables the precise and reproducible alignment / positioning in the calibration set-up.

Each lamp is subjected to a burn-in process prior to its acceptance. Only lamps that meet the strict burn-in criteria are released. This controlled aging process is recorded and confirmed by certificate.

Lamp calibration of spectral irradiance is provided by Gigahertz-Optik's ISO / IEC / EN 17025 accredited calibration laboratory by DAkkS, an ILAC signatory. Alternatively, more cost-effective factory level calibrations are available.

Both accredited and traceable calibrations are available from 250 to 1100nm or 250 to 2500nm.

The LPS-250-BT power supply is available to power and control the BN-LH250. It is a precise frequency modulated, microprocessor controlled power supply for constant current operation of tungsten halogen lamps up to 250W and LEDs in remote control operation with low ripple signal. A current on & off ramp function prevents damage to the lamp filament.

For those customers who require the 1000W lamp standard, Gigahertz-Optik still offers the 1000W FEL and DXW lamp standards as well.

Visit Gigahertz-Optik's website for detailed information on its full range of instrumentation at: gigahertz-optik.com

Press releases for new products and services may be emailed to office@callabmag.com.

#### Morehouse Instrument Company Offers New Portable Calibrating Machines

York, PA – October 19, 2018 – Morehouse Instrument Company has introduced two portable calibrating machines. One of the machines is a 2,000 lbf capacity portable calibrating machine (PCM) which is capable of calibrating various types of load cells, hand-held force gauges, and other force-measuring devices with capacities from 25 lbf through 2,000 lbf while providing stable control to within 0.01 lbf. The PCM solves a safety issue associated with small force measurement below 500 lbf. It eliminates the need for the technician to carry or stack weights which improves safety as those weights are often heavy and can lead to various injuries.

The other machine is a 10,000 lbf capacity portable benchtop calibrating machine (BCM). The benchtop machine allows for calibration of force-measuring equipment with capacities of 100 lbf through 10,000 lbf. It takes up less than a 2 x 2 area and was designed to calibrate a large range of equipment. The system provides a fine control that enables the technician to calibrate several load cells, crane scales, dynamometers, and other force equipment while controlling the force to as little as 0.05 lbf throughout the range.

Both Portable Morehouse Calibrating Machines (PCM & BCM) and were designed with field calibration requirements in mind, and with the goal of providing all necessary force calibration tools in a portable package. These calibrators give the operators accurate and stable force measurements in a robust and low-maintenance design. The system is equipped with several time-saving features that enable a quality force calibration where portability and time are of critical importance.

For more information, email sales@mhforce.com or call 717-843-0081. Visit us online at www.mhforce.com.





## No Faking Automation

Automation has its own quality system automatically built in. When software performs the same test, the same way over and over again, it can't be wrong. There is no fake it till you make it. You can't just put a sticker on it and hope nobody checks. The life of automation is longer than a single calibration. Users can always look at the measurements made by automation and question the results. Especially if something looks wrong or they are getting contradicting manual measurements.

My old boss told me a story of when his company sent him and a colleague to the Fluke MET/CAL<sup>®</sup> programming course. After the training, he was writing one procedure every couple of weeks while his colleague was writing ten or more in a week. The difference was my boss was writing the test process into his code, while

his colleague was banging the code out. You can bang out a lot of procedures in a very short amount of time if all the procedures do is ask "Enter a value," then "Print it," followed by the word "PASS."

Good automation has some very interesting side effects. First and foremost, the automation engineer has to learn the measurement process. I mean really learn it! This is why it is very hard to find good automation engineers. They need to be able to see the test in their heads in order to build the procedure.

After that, the engineer must overcome obstacles. Things like the equipment idiosyncrasies have to be a known quantity for the test process settings and commands of how the equipment behaves. The smallest detail can mess up your measurement

## Michael Schwartz Cal Lab Solutions, Inc.

process, like the input impedance on the 3458A can cause the calibrator to trip. Setting up a calibrator for say 1,000 V, then resetting the 3458A, and putting it into auto range; that trips the calibrator. That breaks the automation!

It is helpful when the manufacturer has a well-defined RESET state of the hardware with all of the default settings. The worst is when a manufacturer allows the end user to configure a custom default state because now the state is largely an unknown. And when the equipment state is unknown, the



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only resolution is to set *every* setting on the instrument.

I hate when I miss something, because if I miss it, it means the customer found it. I really don't like saying "I didn't know that." And after 30 years in this field, there is a lot I still don't know! I have learned to pay attention and listen to the technicians who work with the equipment every day, because in most cases, the technicians know the equipment better than the engineers who designed it. They know all the tricks, quarks and idiosyncrasies of the equipment and measurement process.

The second obstacle for engineers is learning the test process. To code it, the automation engineer has to know the test process inside and out. Often that means cracking the books and learning a new measurement theory. Even if you have detailed step by step instructions, it's difficult to code anything without understanding the measurement process and the metrology behind the test.

The hardest part is when there is no written test procedure (our company charges more for this because we have to first write some sort of test process). If there is no known procedure, or something similar, then the automation needs to be written based on the calibration results from the factory or from the equipment specifications. In

> cases like this, I have found Google and Wikipedia are a great resource. A few months ago, while I was working on the IFR6000s, I was amazed at the level of detail I found on Wikipedia related to aviation guidance systems. It gave me some insight on how landing systems operated and I was fortunate enough to be seated

next to a pilot on my last trip to Detroit, but that is a story for another time.

The thing I find most frustrating is when I am working on an automation project where the customer has been calibrating a device for years manually. I am using the same hardware, the same UUT, but I can't get the test to work. So I ask the tech "What am I doing wrong here?" only to get that dreaded answer of "I don't remember!" Now I have to figure it out, or tell the managers that not only do they not have the hardware to test this correctly, but this test they've been doing manually can't be done with this hardware.

Because automation remembers, it remembers the process every single time. As an automation engineer, we have to figure it out! And, it has to be right, because our name is attached to that calibration. ?

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