CAL LAB

THE INTERNATIONAL JOURNAL OF METROLOGY

Temperature Calibrations, Part 1

Project of an Automated Multiple Decade Ratios Precision Divider for Generation of Low DC Voltages

Selecting a Calibration Management Software System in a Regulated Environment

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VOLUME 28, NUMBER 1

FEATURES

DEPARTMENTS

ON THE COVER: GR Metrology helps manufacturing across the US Midwest rise up in 2021 with complete measurement equipment management.

CALENDAR

UPCOMING CONFERENCES & MEETINGS

The following event dates and delivery methods are subject to change. Visit the event URL provided for the latest information.

May 3-6, 2021 SMSI. Virtual Event. Held in conjunction with SENSOR+TEST, Sensor and Measurement Science International will be a hybrid face-to-face and virtual event. The SMSI brings scientists and researchers from all concerned scientific fields together to secure the success of these ideas in the future. https://www.smsi-conference.com/

May 4-6, 2021 SENSOR+TEST. Virtual Event. From 4 to 6 May 2021 experts will be meeting again for an in-depth exchange on the worldwide most important industrial fair for sensor and measuring technology. www.sensor-test.com

May 17-21, 2021 IEEE I2MTC. Virtual Event. The IEEE I2MTC – International Instrumentation and Measurement Technology Conference – is the flagship conference of the IEEE Instrumentation and Measurement Society and is dedicated to advances in measurement methodologies, measurement systems, instrumentation and sensors in all areas of science and technology. These features make I2MTC a unique event and one of the most important conferences in the field of instrumentation and measurement. https://i2mtc2021.ieee-ims.org/

May 25-27, 2020 IEEE SGSMA. Virtual Event. The Second IEEE International Conference on Smart Grid Synchronized Measurement and Analytics provides a leading forum for disseminating the latest research in Synchronized Measurements and Analytics. The theme of the conference will be focused particularly on synchronized sampling and synchrophasors. http://www.sgsma2021.org/

Jun 6-11, 2021 IMS2021. Atlanta, GA. You are cordially invited join us in Atlanta, 6-11 June 2021 at the intersection of communications, aerospace, automotive, IoT and other emerging technologies to learn the latest developments in MHz-to-THz theory, techniques, devices, systems and applications at the International Microwave Symposium (IMS). IMS2021 is the centerpiece of Microwave Week 2021 comprised of three conferences including the RFIC Symposium (www.rfic-ieee.org) and the ARFTG Conference (www.arftg.org). https://ims-ieee.org/ims2021

Jun 7-9, 2021 IEEE MetroInd4.0&IoT. Virtual Event. The International Workshop on Metrology for Industry 4.0 & IoT aims to discuss the contributions both of the metrology for the development of Industry 4.0 and IoT and the new opportunities offered by Industry 4.0 and IoT for the development of new measurement methods and apparatus. MetroInd4.0&IoT aims to gather people who work in developing instrumentation and measurement methods for Industry 4.0 and IoT. http://www.metroind40iot.org/

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EDITOR'S DESK

New Pants

I heard through the calibration grapevine that laboratories are starting to open up to vendors! This means travel. This means I have to figure out what to do with my hair and buy new pants. I know I am not alone, unless you've been in the lab every week last year. I've been glad to hear many of our customers and advertisers who handle instrumentation have been busy!

Sadly, most of the live meetings and conferences for 2021 still have to go completely online or cancel altogether. We all had optimism that the show would go on, but realistically, not all could. We plan on attending NCSLI in Orlando, Florida this August and MSC in Anaheim, California in November. The organizers expect much smaller crowds than usual, but it seems appropriate given the circumstances.

We have another great paper, by the folks at INRIM in Turin, Italy, originally presented at CIM 2019 in Paris—this year in Lyon, France. "Project of an Automated Multiple Decade Ratios Precision Divider for Generation of Low DC Voltage" seeks to increase resolution of uncertainties for calibration of instruments with ultra-low values, such as nanovoltmeters.

INRIM's electrical paper is followed by Walter Nowocin's detailed account for "Selecting a Calibration Management Software System in a Regulated Environment." Now with IndySoft, Mr. Nowocin was a Calibration Manager at Medtronic for many years, during which he took part in selecting and implementing a new software system. His article is extremely helpful for those looking to upgrade or evaluate a new software system since it was written with the perspective of a customer.

But first, Ryan Egbert and Joseph Rindone of Sine Calibration School start us off with a new Metrology 101 series beginning with "Temperature Calibrations, Part 1." Regular readers will notice our Metrology 101 feature has been spotty over the years. So, we're very glad Sine Calibration School has chosen us to help promote their badge credentialing program for calibration technicians—and *potentially future* technicians—wanting to expand their work knowledge. Employers should take note of online training for their technicians as a great way to invest in their workforce; it's a win-win for employees and employers!

While 2020 was pockmarked with rancor, 2021 seems a bit more single focused on looking forward, gearing up to a pile of work ahead, or perhaps pivoting. It's only the first day of spring and I feel like stockpiling acorns like a squirrel, gearing up for the unknown, but I'm optimistic and that feels about right. Spring has sprung and we all have a lot of work to do.

Happy Measuring,

Sita P. Schwartz
Editor

Jun 21-24, 2021 NEWRAD. Virtual Event. The 14th International Conference on New Developments and Applications in Optical Radiometry Conference covers all aspects of optical radiation measurements and a wide range of topics will be presented, including Earth remote sensing observations and Quantum optics technologies. https://www.nist.gov/news-events/events/2021/06/14th-international-conference-new-developments-and-applications-optical

Jun 23-25, 2021 IEEE MetroAerospace. Virtual Event. The 8th International Workshop on Metrology for AeroSpace aims to gather people who work in developing instrumentation and measurement methods for aerospace. http://www.metroaerospace.org/

Aug 1-4, 2021 A2LA Tech Forum. Hybrid Event - Chantilly, VA. A2LA is committed to providing a dynamically educational experience to help you navigate the waters of accreditation. The A2LA Tech Forum has grown to become one of the largest, multidiscipline events in the accreditation industry, attracting attendees from over 12 different industries. https://www.a2la.org/tech-forum-2021

Aug 21-26, 2021 NCSL International Workshop & Symposium. Orlando, FL. NCSL International provides the best opportunities for the world's measurement science professionals to network and exchange information, to promote measurement education and skill development and to develop a means to resolve measurement challenges. https://www.ncsli.org

Aug 30-Sep 3, 2021 The XXIII IMEKO World Congress. Virtual Event. For all people working in metrology and measurement science coming either from academia or industry, from scientists to engineers, from mathematicians to chemists and physicists, from instrumentation designers to measuring techniques developers, to exchange and share information. http://www.imeko2021.org/

Sep 7-9, 2021 CIM. Lyon, France. The 20th International Metrology Congress is a showcase for industrial applications, advances in R&D and prospects dedicated to measurements, analysis and testing processes. https://www.cim2021.com/

Sep 29-Oct 1, 2021 IEEE AMPS. Cagliari, Italy. The 11th International Workshop on Applied Measurements for Power Systems deals with all the aspects related to measurement applications in current power systems and in future Smart Grids and has the main goal of encouraging discussion on these topics among experts coming from academia, industry and utilities. https://conferences.ieee.org/conferences_events/conferences/conferencedetails/50177

CALENDAR

SEMINARS & WEBINARS: Dimensional

May 12-13, 2021 Gage Calibration & Repair. Dallas, TX. IICT Enterprises. 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. https://www.calibrationtraining.com/schedule

May 26-27, 2021 Dimensional Measurement. Port Melbourne, VIC. Australia NMI. This two-day course (9 am to 5 pm) presents a comprehensive overview of the fundamental principles in dimensional metrology and geometric dimensioning and tolerancing. https://shop.measurement.gov.au/collections/physical-metrology-training

Jun 9-10, 2021 Gage Calibration & Repair. Las Vegas, NV. IICT Enterprises. 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. https://www.calibrationtraining.com/schedule

Jul 12-13, 2021 Gage Calibration & Repair. Hartford, CT. IICT Enterprises. 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. https://www.calibrationtraining.com/schedule

Jul 15-16, 2021 Gage Calibration & Repair. Akron, OH. IICT Enterprises. 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. https://www.calibrationtraining.com/schedule

Aug 12-13, 2021 Gage Calibration & Repair. Bloomington, MN. IICT Enterprises. 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. https://www.calibrationtraining.com/schedule

Sep 8-9, 2021 Gage Calibration & Repair. Las Vegas, NV. IICT Enterprises. 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. https://www.calibrationtraining.com/schedule

SEMINARS & WEBINARS: Electrical

Jun 21-24, 2021 MET-101 Basic Hands-On Metrology. Everett, Washington. Fluke Calibration. A four-day "how to" course that introduces basic measurement concepts, basic electronics related to measurement instruments and math used in calibration. https://us.flukecal.com/training

Sep 20-23, 2021 MET-301 Advanced Hands-On Metrology. Everett, WA. Fluke Calibration. A four-day course on advanced measurement concepts and math used in upper echelon calibration labs and primary standard labs. https://us.flukecal.com/training

SEMINARS & WEBINARS: General

Aug 9-13, 2021 Fundamentals of Metrology. Gaithersburg, MD. The 5-day Fundamentals of Metrology seminar introduces participants to the concepts of measurement systems, units, 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

Aug 16-20, 2021 Fundamentals of Metrology. Gaithersburg, MD. The 5-day Fundamentals of Metrology seminar introduces participants to the concepts of measurement systems, units, 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

Sep 13-17, 2021 Fundamentals of Metrology. Gaithersburg, MD. The 5-day Fundamentals of Metrology seminar introduces participants to the concepts of measurement systems, units, 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 & WEBINARS: Industry Standards

Apr 26-30, 2021 Lead Assessor Intensive Training (ISO/IEC

17025 or ISO/IEC 17020). Washington, DC. ANAB has redesigned its Lead Assessor Intensive Training course to an exercise-based approach to better support and develop the competencies required of a lead assessor. The course was developed in response to the recent change of focus on competence within laboratory-related accreditation standards. https://anab.ansi.org/public-course-schedule

Apr 28-30, 2021 Internal Auditing to ISO/IEC 17025:2017 (en Espanol). Vivir en linea. ANAB. Attendees will learn how to coordinate a quality management system audit to ISO/IEC 17025:2017 and collect audit evidence and document observations, including techniques for effective questioning and listening. https://anab.ansi.org/public-course-schedule

May 17-19, 2021 Internal Auditing to ISO/IEC 17025:2017. Live Online. ANAB. Attendees will learn how to coordinate a quality management system audit to ISO/IEC 17025:2017 and collect audit evidence and document observations, including techniques for effective questioning and listening. https://anab.ansi.org/public-course-schedule

May 17-20, 2021 Forensic ISO/IEC 17025:2017 Internal Auditor. Cary, NC. ANAB. This course provides a detailed review of ISO/IEC 17025:2017 and the related ANAB accreditation requirements for forensic service providers (AR 3125) as well as a review of ISO 19011, Guidelines for Auditing Management Systems. https://anab.ansi.org/training/public-course-schedule

May 19-20, 2021 Understanding ISO/IEC 17025 for Testing and Calibration Labs. Webinar. IAS. Course objective is to learn about ISO/IEC 17025 from one of its original authors. To learn its Principles and what it requires of laboratory staff. https://www.iasonline.org/training/

Jun 28-Jul 2, 2021 Forensic ISO/IEC 17025:2017 Internal Auditor. Live Online. ANAB. This course provides a detailed review of ISO/IEC 17025:2017 and the related ANAB accreditation requirements for forensic service providers (AR 3125) as well as a review of ISO 19011, Guidelines for Auditing Management Systems. https://anab.ansi.org/training/public-course-schedule

August 9-11, 2021 Internal Auditing to ISO/IEC 17025:2017. Live Online. ANAB. Attendees will learn how to coordinate a quality management system audit to ISO/IEC 17025:2017 and collect audit evidence and document observations, including techniques for effective questioning and listening. https://anab.ansi.org/public-course-schedule

SEMINARS & WEBINARS: Mass

Sep 20-30, 2021 Advanced Mass Seminar. NIST Gaithersburg Campus, MD. 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

Oct 18-29 Mass Metrology Seminar. NIST Gaithersburg Campus, MD. The Mass Metrology Seminar is a two-week, "hands-on" seminar. It incorporates approximately 30 percent lectures and 70 percent demonstrations and laboratory work in which the participant performs measurements by applying procedures and equations discussed in the classroom. The seminar focuses on the comprehension and application of the procedures, the equations, and calculations involved. https://www.nist.gov/pml/weights-and-measures/about-owm/calendar-events

SEMINARS & WEBINARS: Measurement Uncertainty

Apr 26-27, 2021 Understanding Measurement Uncertainty (en Espanol). Vivir en Linea. ANAB. Attendees of the two-day Fundamentals Measurement Uncertainty training course will learn a practical approach to measurement uncertainty applications, based on fundamental practices. https://anab.ansi.org/public-course-schedule

May 20, 2021 Basic Uncertainty Concepts. Webinar. NIST. 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) and includes some simple calculations. https://www.nist.gov/news-events/events/2021/05/5710-basic-uncertainty-concepts

May 20-21, 2021 Understanding Measurement Uncertainty. Live Online. ANAB. Attendees of the two-day Fundamentals Measurement Uncertainty training course will learn a practical approach to measurement uncertainty applications, based on fundamental practices. https://anab.ansi.org/public-course-schedule

Jun 9-10, 2021 Uncertainty of Measurement for Labs. Webinar. IAS. The training includes case studies and discussions, with application of statistical components in practical examples that are frequently encountered by testing laboratories. https://www.iasonline.org/training/

Aug 11-13, 2021 MET-302 Introduction to Measurement Uncertainty. Everett, WA. Fluke Calibration. A three-day "how to" course that introduces and demonstrates measurement uncertainty concepts and techniques. https://us.flukecal.com/training

Aug 12-13, 2021 Understanding Measurement Uncertainty. Live Online. ANAB. Attendees of the two-day Fundamentals Measurement Uncertainty training course will learn a practical approach to measurement uncertainty applications, based on fundamental practices. https://anab.ansi.org/public-course-schedule

SEMINARS & WEBINARS: Pressure

Apr 19-23, 2021 Advanced Piston Gauge Metrology. Phoenix, Arizona. Fluke Calibration. A five-day course focusing on the theory, use and calibration of piston gauges and deadweight testers. https://us.flukecal.com/training

Jun 23-24, 2021 Pressure Measurement. Port Mebourne, VIC. Australia NMI. This two-day course (9 am to 5 pm each day) covers essential knowledge of the calibration and use of a wide range of pressure measuring instruments, their principles of operation and potential sources of error — it incorporates extensive hands-on practical exercises. https://shop.measurement.gov.au/collections/physical-metrology-training

Sep 20-24, 2021 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 & WEBINARS: RF & Microwave

Jun 29-Jul 1, 2021 VNA Tools Training Course. Bern-Wabern, Switzerland. Federal Institute of Metrology METAS. VNA Tools is free software developed by METAS for measurements with the Vector Network Analyzer (VNA). The software facilitates the tasks of evaluating measurement uncertainty in compliance with the ISO-GUM and vindicating metrological traceability. The software is available for download at www.metas.ch/vnatools. The three day course provides a practical and hands-on lesson with this superior and versatile software. https://www.metas.ch/metas/en/home/dl/kurse---seminare.html

Sep 7-9, 2021 VNA Tools Training Course. Bern-Wabern, Switzerland. Federal Institute of Metrology METAS. VNA Tools is free software developed by METAS for measurements with the Vector Network Analyzer (VNA). The software facilitates the tasks of evaluating measurement uncertainty in compliance with the ISO-GUM and vindicating metrological traceability. The software is available for download at www.metas.ch/vnatools. The three day course provides a practical and hands-on lesson with this superior and versatile software. https://www.metas.ch/metas/en/home/dl/kurse---seminare.html

Sep 21-23, 2021 VNA Tools Training Course. Beaverton, OR. Federal Institute of Metrology METAS. VNA Tools is free software developed by METAS for measurements with the Vector Network Analyzer (VNA). The software facilitates the tasks of evaluating measurement uncertainty in compliance with the ISO-GUM and vindicating metrological traceability. The software is available for download at www.metas.ch/vnatools. The three day course provides a practical and hands-on lesson with this superior and versatile software. https://www.metas.ch/metas/en/home/dl/kurse---seminare.html

SEMINARS & WEBINARS: Software

Apr 26-30, 2021 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. http://us.flukecal.com/training

May 3-7, 2021 TWB 1031 MET/CAL® Procedure Development Web-Based Training. Fluke Calibration. A five-day (2-hour sessions), instructor-led web-based training, course on creating procedures with the latest version of MET/CAL. http://us.flukecal.com/training

May 10-14, 2021 MC-207 Advanced MET/CAL® Procedure Writing. Everett, Washington. Fluke Calibration. A five-day course for advanced users of MET/CAL calibration software. http://us.flukecal.com/training

Jun 7-11, 2021 MC-205 MET/TEAM® Asset Management. Everett, Washington. Fluke Calibration. A five-day course on the use of MET/TEAM software to manage and report on your assets in the calibration metrology lab. http://us.flukecal.com/training

Jul 12-16, 2021 Basic MET/CAL® Procedure Writing. Everett, WA. Fluke Calibration. In this five-day Basic MET/CAL Procedure Writing course, you will learn to configure MET/CAL software to create, edit, and maintain calibration solutions, projects and procedures. http://us.flukecal.com/training

Jul 19-23, 2021 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. http://us.flukecal.com/training

Aug 30-Sep 2, 2021 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. http://us.flukecal.com/training

Sep 20-24, 2021 MC-207 Advanced MET/CAL® Procedure Writing. Everett, Washington. Fluke Calibration. A five-day course for advanced users of MET/CAL calibration software. http://us.flukecal.com/training

SEMINARS & WEBINARS: Temperature & Humidity

Apr 15-16, 2021 Infrared Calibration. American Fork, Utah. Fluke Calibration. A two-day course on the basics of infrared temperature metrology to help begin or sustain an infrared temperature calibration program. https://us.flukecal.com/training

May 10, 2021 Temperature Measurement and Calibration (with optional practical day). Teddington, UK. NPL. This is a 2-3 day course, covering the range –200 °C to 3000 °C, the course will concentrate on those methods of measurement which are of greatest technological and industrial importance. https://training.npl.co.uk/course/temperature-measurement-and-calibration-with-optional-practical-day/

May 13, 2021 Humidity Measurement and Calibration. Teddington, UK. NPL. This is a 2 day course covering dew point, relative humidity and other humidity quantities, the course will concentrate on methods of measurement which are of greatest technological relevance to attendees. https://training.npl.co.uk/course/humidity-measurement-and-calibration/

Sep 13-17, 2021 Advanced Topics in Temperature Metrology. American Fork, UT. A three-day course for those who need to get into the details of temperature metrology. This course is for experienced calibration technicians, metrologists, engineers, and technical experts working in primary and secondary-level temperature calibration laboratories who would like to validate, refresh, or expand their understanding of advanced topics in temperature metrology. https://us.flukecal.com/training

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A Better Way to Measure Acceleration

March 08, 2021, NIST News —You're going at the speed limit down a two-lane road when a car barrels out of a driveway on your right. You slam on the brakes, and within a fraction of a second of the impact an airbag inflates, saving you from serious injury or even death.

The airbag deploys thanks to an accelerometer — a sensor that detects sudden changes in velocity. Accelerometers keep rockets and airplanes on the correct flight path, provide navigation for self-driving cars, and rotate images so that they stay right-side up on cellphones and tablets, among other essential tasks.

Addressing the increasing demand to accurately measure acceleration in smaller navigation systems and other devices, researchers at the National Institute of Standards and Technology (NIST) have developed an accelerometer a mere millimeter thick that uses laser light instead of mechanical strain to produce a signal.

Although a few other accelerometers also rely on light, the design of the NIST instrument makes the measuring process more straightforward, providing higher accuracy. It also operates over a greater range of frequencies and has been more rigorously tested than similar devices.

Not only is the NIST device, known as an optomechanical accelerometer, much more precise than the best commercial accelerometers, it does not need to undergo the time-consuming process of periodic calibrations. In fact, because the instrument uses laser light of a known frequency to measure acceleration, it may ultimately serve as a portable reference standard to calibrate other accelerometers now on the market, making them more accurate.

The accelerometer also has the potential to improve inertial navigation in such critical systems as military aircraft, satellites and submarines, especially when a GPS signal is not available. NIST researchers Jason Gorman, Thomas LeBrun, David Long and their colleagues describe their work in the journal Optica.

The study is part of NIST on a Chip, a program that brings the institute's cutting-edge measurement-science technology and expertise directly to users in commerce, medicine, defense and academia.

Accelerometers, including the new NIST device, record changes in velocity by tracking the position of a freely moving mass, dubbed the "proof mass," relative to a fixed reference point inside the device. The distance between the proof mass and the reference point only changes if the accelerometer slows down, speeds up or switches direction. The same is true if you're a passenger in a car. If the car is either at rest or moving at constant velocity, the distance between you and the dashboard stays the same. But if the car suddenly brakes, you're thrown forward and the distance between you and the dashboard decreases.

The motion of the proof mass creates a detectable signal. The accelerometer developed by NIST researchers relies on infrared light to measure the change in distance between two highly reflective surfaces that bookend a small region of empty space. The proof mass, which is suspended by flexible beams one-fifth the width of a human hair so that it can move freely, supports one of the mirrored surfaces. The other reflecting surface, which serves as the accelerometer's fixed reference point, consists of an immovable microfabricated concave mirror.

Together, the two reflecting surfaces and the empty space between them form a cavity in which infrared light of just the right wavelength can resonate, or bounce back and forth, between the mirrors, building in intensity. That wavelength is determined by the distance between the two mirrors, much as the pitch of a plucked guitar depends on the distance between the instrument's fret and bridge. If the proof mass moves in response to acceleration, changing the separation between the mirrors, the resonant wavelength also changes.

To track the changes in the cavity's resonant wavelength with high sensitivity, a stable single-frequency laser is locked to the cavity. As described in a recent publication in Optics Letters, the researchers have also employed an optical frequency comb — a device that can be used as a ruler to measure the wavelength of light — to measure the cavity length with high accuracy. The markings of the ruler (the teeth of the comb) can be thought of as a series of lasers with equally spaced wavelengths. When the proof mass moves during a period of acceleration, either shortening or lengthening the cavity, the intensity of the reflected light changes as the wavelengths associated with the comb's teeth move in and out of resonance with the cavity.

Accurately converting the displacement of the proof mass into an acceleration is a critical step that has been problematic in most existing optomechanical accelerometers. However, the team's new design ensures that the dynamic relationship between the displacement of the proof mass and the acceleration is simple and easy to model through first principles of physics. In short, the proof mass and supporting beams are designed so that they behave like a simple spring, or harmonic oscillator, that vibrates at a single frequency in the operating range of the accelerometer.

This simple dynamic response enabled the scientists to achieve low measurement uncertainty over a wide range of acceleration frequencies — 1 kilohertz to 20 kilohertz — without ever having to calibrate the device. This feature is unique because all commercial accelerometers have to be calibrated, which is time-consuming and expensive. Since the publication of their study in Optica, the researchers have made several improvements that should decrease their device's uncertainty to nearly 1%.

Capable of sensing displacements of the proof mass that are less than one hundred-thousandth the diameter of a hydrogen atom, the optomechanical accelerometer detects accelerations as tiny as 32 billionths of a g, where g is the acceleration due to Earth's gravity. That's a higher sensitivity than all accelerometers now on the market with similar size and bandwidth.

With further improvements, the NIST optomechanical accelerometer could be used as a portable, high-accuracy reference device to calibrate other accelerometers without having to bring them into a laboratory.

Paper 1: F. Zhou, Y. Bao, R. Madugani, D.A. Long, J.J. Gorman and Thomas W. LeBrun. Broadband thermomechanically limited sensing with an optomechanical accelerometer. Optica. Published March 8, 2021. DOI: 10.1364/OPTICA.413117

Paper 2: D.A. Long, B.J. Reschovsky, F. Zhou, Y. Bao, T.W. LeBrun and J.J. Gorman. Electro-optic frequency combs for rapid interrogation in cavity optomechanics. Optics Letters. Published Jan. 29, 2021. DOI: 10.1364/OL.405299

Source: *https://www.nist.gov/news-events/news/2021/03/better-way-measure-acceleration*

Driving Manufacturing Technological Change in the Region

15 Dec 2020, Coventry University Research News – The University of Nottingham, Loughborough University and Coventry University in the UK have recently launched the Midlands Centre for Data-Driven Metrology (MCDDM)—https://www.mcddm.ac.uk/.

The new centre aims to support and develop the region's manufacturing businesses by helping them to adopt digital manufacturing technologies and strategies (part of the so-called "Industry 4.0") in their operations.

Industry 4.0 encompasses the application of digital technologies into advanced manufacturing that will allow manufacturers to improve their processes by becoming more cost efficient, sustainable and agile with consequent improvements in productivity. This creates increased dependency on generating and managing multiple streams of data within these processes. The understanding and application of embedded metrology (the science of measurement) is essential for users to trust this data and be able to use it to make vital business decisions.

MCDDM is funded by the Research England Development Fund and will support small to medium enterprises (SMEs) as well as larger manufacturing-based businesses in the Midlands.

The university's Institute for Future Transport and Cities (IFTC) will work with MCDDM as it has a well-established metrology group, which includes an impressive range of equipment, capabilities and a team of experts. Moreover, thanks to this extensive metrology knowledge bank, the University has developed its own training material and currently runs the UK's only Foundation Degree in Metrology.

The MCDDM will offer manufacturing businesses training and opportunities to have hands-on exposure to facilities, university knowledge and expertise with a view to establishing good practice in a practical environment

This development aligns with IFTC's longer term plans to expand its industrial engagement and develop more university – business relationships such as those already in place with Unipart Manufacturing, FEV and HORIBA MIRA.

We are delighted to be a founding member of the MCDDM and we look forward to working collaboratively with our new partners to support the region's manufacturing organizations by harnessing our collective expertise in metrology for greater industry impact.

Source: *https://www.coventry.ac.uk/research/about-us/research-news/2020/driving-manufacturing-technological-change/*

CAL-TOONS by Ted Green teddytoons@icloud.com

METROLOGY 101

Temperature Calibrations, Part 1

Ryan Egbert and Joseph Rindone
Sine Calibration School

The following article is part one of a four-part Metrology 101 series focusing on temperature. The written content provided here is also intended to be combined with demonstration videos that we will provide through our school, Sine Calibration School. If you follow this series and complete the training online, you will be awarded our temperature badge credential for free! But, for this to happen, you must complete all of the content provided this year and complete the final quiz in our school in December 2021. Register today at www.sinecalibration.com, you will see a link at the top of the screen. More information will be provided along the way, but let's not waste anymore space here in this article.

Introduction

In this first article of the course, it is best to establish the purpose of this training and its intended audience. At Sine Calibration School we teach the beginning principles and foundational knowledge of calibration for technicians that are either brand new to the field, or ones that never had the opportunity to have a formal education in calibration and metrology. If you are a "seasoned" metrologist, this could be a refresher course for you, but you may not learn much new information.

With that being said, please also understand that we will not be covering everything there is to know about temperature calibrations. This is the basics, the beginning of your journey to learning temperature calibrations.

In this course we want you to come away with the following basic principles relating to the calibration of basic temperature reading devices:

1. **Identify the key temperature points of the Kelvin and Celsius scales.**
2. **Identify the characteristics of thermocouples, resistance temperature detectors (RTDs), and thermistors.**
3. **Identify the key calibration considerations when performing calibrations on thermocouples, RTDs, and thermistors.**
4. **Identify the characteristics of temperature sources and considerations for sourcing temperature.**

There will be more covered throughout this training, but those are the "big picture" ideas that we want you to come away with. To start things off we want to discuss a little bit about the importance and history of temperature.

Why is Temperature Important?

Temperature is a crucial factor considered in many aspects of modern science, technology, and life. One does not have to look far to find how critical temperature is in our lives, just think of the low tolerance our bodies have to the drift of our own internal temperature. In manufacturing, temperature reading devices provide the key measurements of production processes. For example, the temperature sensors of an autoclave used for sterilization of surgical products at a medical manufacturer. An incorrect or invalid calibration of those sensors could place lives in danger from pathogens not being killed. Or perhaps a plastic molding machine that creates the many toys and components we enjoy daily. Incorrect temperatures in these situations can make the plastics not flow correctly, creating a defective product, or the product to be too soft or too brittle. Lastly, consider the importance of monitoring temperature in daily applications like cooking, or monitoring the temperature of the engine in your car.

History of Temperature Scales

Alright so you get it, temperature is important. Understand though, that civilization did not always have a good way of interpreting the changes in the temperature around us. For thousands of years, temperature had been on the back burner so to say. It was not until a few centuries ago, in the 1700s, that it came into focus as being a very impactful variable in our world. A few important scientists in history developed techniques to understand, interpret and scale thermometers. These individuals effectively created, or influenced, our modern temperature scales. This is important in developing a methodology for calibrating a temperature reading device. We require a reliable way to achieve specific temperature points, but more importantly it requires a scale in which someone is able to read the current temperature. Enter: Daniel Gabriel Fahrenheit and Anders Celsius.

The Fahrenheit and Celsius (Centigrade) Scales

Fahrenheit and Celsius either created, or greatly influenced, the temperature scales that the general public are most familiar with today (and of course the scales are named after). Fahrenheit was first, developing his scale in 1724 and the Celsius scale that we know today being proposed in 1743. There are and were other temperature scales over time, but here we are only talking about the most commonly used in the industry.

Celsius was originally called Centigrade, from the Latin word "centum", which means 100, and "gradus", which means steps. When originally developed it was "upside-down" from our scale of today, with the boiling point at 0 °C and freezing being 100 °C [1] . The switch to the current scale is what changed in 1743.

Let us examine these two scales by looking at the similarities and the differences between them. The Fahrenheit scale was developed and based upon the freezing and boiling points of water. In this scale, water freezes at 32 °F and boils at 212 °F, with the pressure reference for the measurement being sea level. Likewise, since 1743, the Celsius scale was also based on the freezing and boiling points of water, but the freezing point in this scale is 0 °C and the boiling point at 100 °C. Which makes more sense to you, the reader?

Both of these scales were developed using glass thermometers filled with mercury. It is interesting to note, however, that Fahrenheit actually invented the mercury-in-glass thermometer and the Fahrenheit scale. On the other hand, the Centigrade scale was renamed in honor of Anders Celsius only back in 1948.

The Temperature SI Unit - The Kelvin

Fahrenheit and Celsius are acceptable scales and are widely used today in the modern world. However, they are not the perfect solution for all applications. One issue with both is that the scales utilize negative numbers for temperatures below a zero point. This can be problematic in some scientific and mathematical applications. An influential scientist saw this issue and proposed a solution, that scientist was William Thompson, otherwise known as Lord Kelvin.

William Thompson was a physicist and engineer from Belfast, who in 1848, wrote a paper On an Absolute Thermometric Scale which touched upon the need for a scale that had a null point (zero) that was absolute zero [2]. Absolute zero is the temperature at which there is no molecular movement.

It was in 1954 that Resolution 3 of the 10th General Conference on Weights and Measures gave the Kelvin scale its modern definition. At that point in time the defining point of the scale was at the Triple Point of Water (TPW). We will discuss the triple point of water a little later in this article, but this definition would become the International System of Units (SI unit) for temperature: The Kelvin, or K.

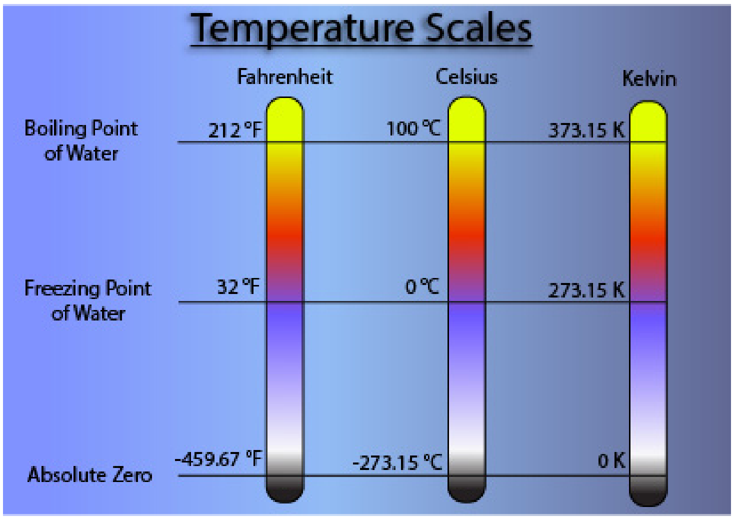
Kelvin and Celsius

Up to this point we have talked about both Celsius and Fahrenheit, but this is where the focus will shift to the Celsius and Kelvin scales.

When looking at those two scales, Celsius and Kelvin, there are a few things that are important for us to know. For one, Celsius and Kelvin are used together so often because they share the same magnitude. What exactly does that mean? Having the same magnitude means that when you increase the temperature by 1 K, it is the same as increasing the temperature by 1 °C. The difference between them being their scale, with 0 K being equal to -273.15 °C, also known as absolute zero [3].

This also brings forward the point on the proper way we express temperatures in Kelvin. Notice we do not use the degree (°) symbol, instead using the number followed by a space and then K.

Previously, we mentioned some of the definitions of the temperature scales, the definition for the Kelvin scale from 1954 until 2019, was the triple point of water. The triple point of a substance is the combined temperature and pressure at which the three phases of matter being gas, liquid, and solid of that substance coexist at the same time and in the same place, in thermodynamic equilibrium [3].



The Triple Point of Water

Many substances have triple points including metals. In water, this occurs at precisely 0.01 °C, or 273.16 K. Many of you that are new to this concept may have a hard time envisioning how this actually happens. That is where our first video demo comes in, we will show you the process. Please note, there are many different standard triple point cells out there from different manufacturers, but they all are

working off of the same principles. It is important to have direct training on the triple point cell that you have in your particular lab if you have one.

Over time scientists found the need to get away from physical artifacts defining SI units because of the observation of drift in those artifacts. Even though the TPW is not necessarily an artifact, scientists found the need to make all SI definable directly by defining constants [4].

This meant that the triple point of water would no longer be our definition of the Kelvin. On 16 November 2018, a new definition of the Kelvin was adopted, in the form of a fixed value of the Boltzmann constant and was officially changed on 20 May 2019. Even though this has changed, it did not change the impressive measurement uncertainty that this method carries, with many commercial TPW cells having uncertainties better than ± 0.0005 °C. You will see as we go forward with different types of temperature sensors and their associated accuracies, that this is incredibly accurate for a temperature reading. With triple point cells not being a common standard in many labs at this point, we also wanted to talk about and show you the proper way to create an ice point reference bath.

Ice Point Reference Bath

An alternative to the TPW cell is an ice point reference bath. In comparison to a TPW cell, a properly made ice bath has an expected temperature of 0.000 °C with a worse, yet still impressive uncertainty of 0.01 °C. NIST has even found that if done properly, the ice bath can have uncertainties as good as 0.002 °C [5]. This is still more accurate than all but the most precise temperature sensing devices and can be an especially useful field standard. This will be demonstrated in our second video for this article. In that video we demonstrate the steps to creating a proper ice bath, per the instructions set forward from NIST. An ice bath has the positive side of being very mobile, where a triple point cell can be fragile and difficult to achieve the point outside of a lab environment.

A properly created ice point reference can be used as an intrinsic standard for a 0.0 °C measurement. The need for this often comes in situations where a probe may not fit properly into another calibration heat source, like a dry well (which we will cover in this course).

Another possible use for an ice bath is to use it to verify the 0.0 °C reference point for a standard probe that you are using. The devil here is in the details though, something as simple as not having your ice to water ratio correct in your ice bath can give large errors of whole degrees. Pay very close attention to the considerations in building a good ice bath.

This brings us to the conclusion of the first temperature lesson, focusing on the background information we need you to know before we get into the fun stuff – learning about temperature reading devices and actually calibrating them. As you proceed into the videos please keep in mind that we are very responsive to questions and welcome them. If you need any assistance during this course please contact us at support@sinecalibration.com.

References

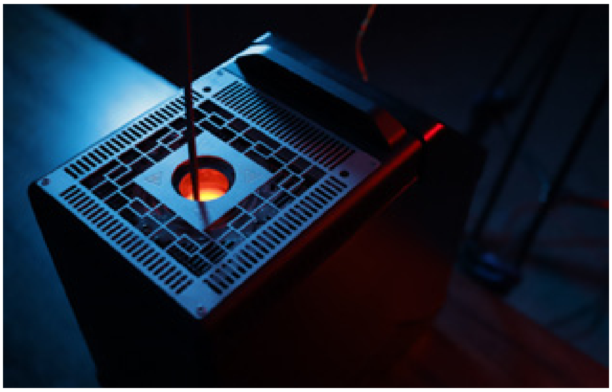
[1] Karwatka, D. (2017). Gabriel Fahrenheit and Anders Celsius and Their Temperature Scales. *Tech Directions*, 77(4), 10–11.

[2] Elihu, T. (1916). William Thomson, Lord Kelvin (1824-1907). *Proceedings of the American Academy of Arts and Sciences*, 51(14), 896–899.

[3] Renneboog, R. M. (2014) Triple Point, *Chemistry: Properties of Matter*, p. 1

[4] Fischer, J. (2016). Low uncertainty Boltzmann constant determinations and the kelvin redefinition. *Philosophical Transactions: Mathematical, Physical and Engineering Sciences*, 374(2064), 1–14. DOI: 10.1098/rsta.2015.0038

[5] Mangum, B. W. (1995). *Reproducibility of the Temperature of the Ice Point in Routine Measurements.* NIST Technical Note 1411.



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Project of an Automated Multiple Decade Ratios Precision Divider for Generation of Low DC Voltages

Flavio Galliana[1], Roberto Cerri, Davide Corona
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At the National Institute of Metrological Research (INRIM) an automatable precision DC voltage fixed-ratios divider allows the division ratios of DC Voltages from 10:1 to 10^7:1. It can be quickly calibrated when necessary and involved in traceability transfer. Its resistors are selected bulk metal foil ones connected in series in four terminal configuration whose values are 90 kΩ, 9 kΩ, 900 Ω, 90 Ω, 9 Ω, 0.9 Ω, 90 mΩ and 10 mΩ. The main advantage of this divider is that it can be automatically calibrated with a calibrator and a digital multimeter. Its calibration starts from a 10 V value. It takes advantage of the DMM linearity, in particular in the 10 V range that allows improving its calibration uncertainty. After calibration, it can be used to divide DC Voltages lower than 10 V. Preliminary evaluation of its calibration uncertainties and mid-term stabilities (a week) span respectively from 1.4×10^{-6} to 6.0×10^{-4} and from 2.4×10^{-7} to 4.5×10^{-4} for ratios from 10:1 to 10^7:1. This divider could be involved in the calibration of nanovoltmeters in a typical range from 10 V down to 100 nV.

1. Introduction

Today, the traceability from the DC Voltage standard to low and ultra-low values is still a challenge due to the needs in research, nanotechnology and medical frameworks. National and high level secondary laboratories have used for calibration of digital multi-meters (DMMs) and multifunction calibrators (MFCs) commercial high precision manually operating DC voltage dividers [1, 2] or a recently developed automated fixed ratios divider [3]. In addition, research on DC Voltage divider has been wide. Effective guarded dividers were developed for high accuracy DC voltage applications [4, 5] also for high voltages [6–10]. Problems arise for lower voltages. The widespread instrument to measure low DC Voltages is the nanovoltmeter. Modern nanovoltmeters are highly sophisticated and accurate instruments often involved in precise and highly advanced measurement applications. Unfortunately, many of them are not calibrated and used trusting in their manufacturer specifications. At high level, National Measurement Institutes (NMIs) nanovoltmeters are calibrated vs. the Josephson Voltage Standards (JVS) changing the microwave frequency [11, 12]. Nevertheless, this choice is expensive and time consuming. NMIs and Laboratories without the JVS need alternative solutions. Interesting and valid solutions with easily available instruments are proposed in [13, 14]. At National Institute of Metrological Research (INRIM) an automatable multiple decade ratios precision divider has been built which is currently being automated.

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2. The INRIM DC Voltage Divider

This divider is made with 90 kΩ, 9 kΩ, 900 Ω, 90 Ω, 9 Ω, 0.9 Ω, 90 mΩ and 10 mΩ resistors connected in four terminal configuration. The advantage of this divider lies in its easy and quick calibration when necessary with a calibrated DC Voltage calibrator and a particular DMM, widespread in National Measurement Institutes (NMIs) and in electrical calibration laboratories as [15]. Once the divider is calibrated it can be involved in a measurement setup, with a DC Voltage reference standard or a calibrated MFC, for the generation of low DC Voltages and calibration of nanovoltmeters mainly in the range from 100 nV to 10 V. Its scheme is shown in Figure 1.

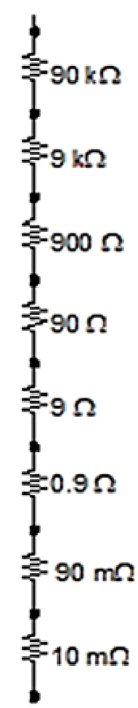

Figure 1. Scheme of the INRIM divider for generation of DC Voltage low values.

The divider has been made with high nominal power resistors with respect to the applied power during the divider calibration of ratios calibration. The ratio between these two powers has been kept as high as possible to neglect the effects of the power coefficients. It has been made with selected Vishay low temperature coefficient (TCR) resistors and with

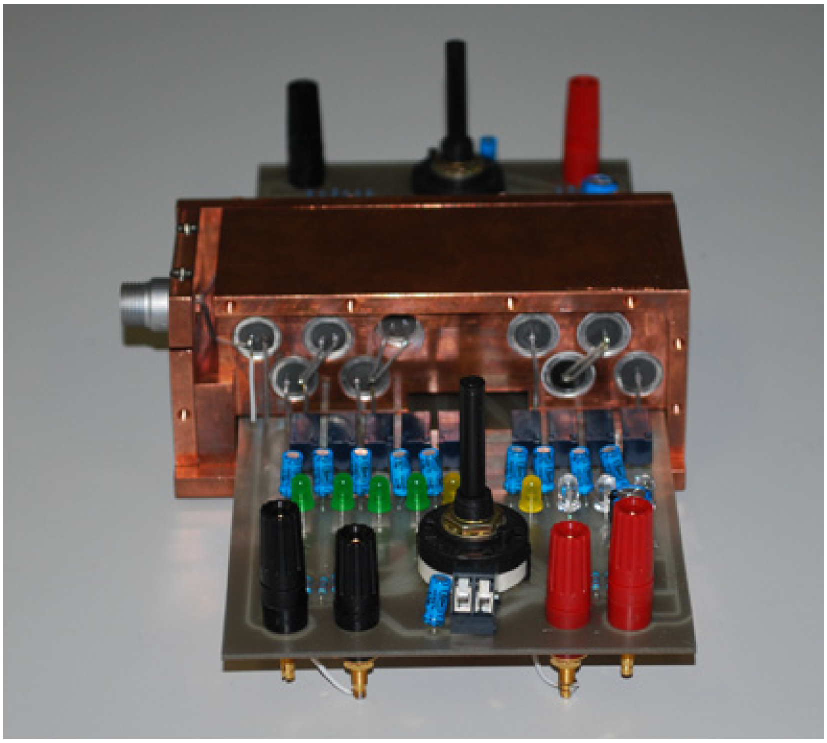

Figure 2. Photo of the INRIM divider in which the copper box housing the resistors can be seen.

satisfactory short-term stability. The bistable relays have a very low contact resistance (few mΩ) being equipped with silver/gold contacts with thermo-electromotive forces (emfs) on closing contacts extremely small ≅ 40 nV.

To reduce noises due to self-heating or to electrical noise due to their excitation and maintenance voltages, taking advantage of their bistable feature, their activation is made by coupling their coils in alternating regime sending them only a single pulse. Therefore, no voltage is present during the measurement on the excitation coils of the relays.

The printed circuit, in vetronite, has been built with a micro milling technique for ultra-high insulation between the tracks. The coppered surfaces have double thickness than the standard. Resistors have been inserted in holes of a copper box to minimize electrical and thermal noises.

Relays connections have been made very short to minimize parasitic resistances. The coils and the control circuits are supplied by a 5 V DC Voltage avoiding the noise due to mains. The condition of the relays, that currently is carried out with switches, is constantly monitored by switching on LED diodes, activated by auxiliary contacts, allowing to detect a possible incorrect operation. Solderings have been carried out with tin and specific flux for low emfs.

2.1 Building Details

In Figure 2, a photo of the developed prototype shows its characteristics. The resistors of the resistive divider, to avoid immunity to electrical and thermal noises, have been inserted in a milled copper box. The connections of the relays to the resistors are very short to reduce the parasitic resistance of the connections by bringing them as close as possible to the copper box to improve also the thermal anchoring.

The resistors are placed in the box cavities by means of a thin layer of thermally conductive paste.

It can be noted in Figure 3 a series of additional components wired on the welding side of the printed circuit have been added to allow a four-wire connection.

3. Calibration of the INRIM DC Voltage Divider

It is possible to calibrate the divider when necessary updating the values its division ratios. A quick calibration can be made with the setup of Figure 4. This setup involves the DMM [15], characterized in linearity on its 10 V range according to the suggestion of

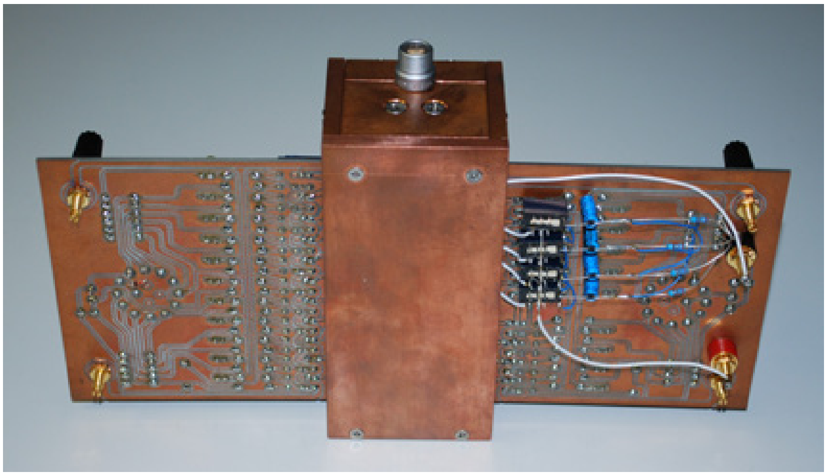

Figure 3. Photo of the connections of the resistors of the INRIM divider, allowing their connection in four terminal configuration.

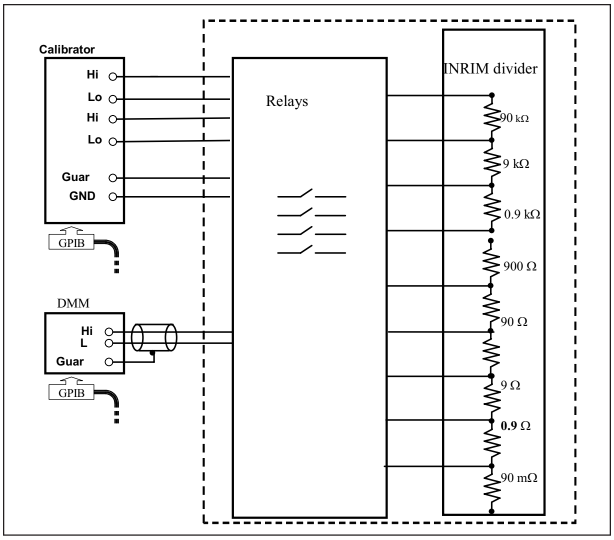

Figure 4. Measurement setup for the quick calibration of the divider.

[16, 17] and a J. Fluke 5700A calibrator [18] as high stability DC voltage generator. The measurement process, for each section, consists in measuring the input voltage to a section of the divider and alternatively the output voltage ten times lower. A DC Voltage from a high stability DC Voltage calibrator is applied to a resistor, while the DMM measures this voltage. Then, leaving unchanged the supplying point and the voltage value, the DMM measures the voltage on the one-decade lower value resistor without changing the DMM range. Applying in cascade this strategy from the first section to the last one, it is possible to obtain the ratios from 10:1 to 10^7:1.

For example, considering the section with an input resistance of 10 kΩ, the 10 V (LV_H) voltage is applied to it and measured with the DMM on the 10 V range. Then, leaving unchanged the point of application of the 10 V, the DMM will read the output on 900 Ω corresponding (taking into account the resistors from 900 Ω to ground) at 1 kΩ (1 V always on the 10 V range). The ratio between the input on 10 kΩ and the output on 900 Ω will therefore be evaluable. The same procedure is repeated at −10 V to lower the emfs' effects. The procedure can include, before the polarities reversal and before each section change, the evaluation of the zeroes to be eventually added to the following DMM readings. The unknown ratio values are given, meaning the values at both polarities from the following relation:

$$R = \frac{L_H}{L_L} \qquad (1)$$

Where R ≅ 10 is the ratio, L_H is the supplying voltage while L_L is the voltage on the lower decade resistor. Those voltages are the mean voltage readings by the DMM. In Table 1, the involved resistors, voltages and DMM readings for each divider section, are listed.

To take into account all the input quantities in the uncertainty budget for the quick calibration of the divider, Equation 1 can be re-written as:

$$R = \frac{L_H \varepsilon_{linH} \varepsilon_G \varepsilon_{emfH}}{L_L \varepsilon_{linL} \varepsilon_{emfL}} \cdot \varepsilon_{load} \qquad (2)$$

where
ε_{linH} and ε_{linL} are the DMM linearity specifications at 10 V and 1 V;
ε_{iemf0} and ε_{lemfL} are the emfs when the DMM measures 10 V and 1 V; and
ε_G ε_{Vc} and ε_{load} are respectively the corrections due to the stability of calibrator to the voltage coefficient of the divider and to the load effect at the DMM input.

Section	Cumulative ratio	Resistor to apply V_H	Resistor to measure L_L	L_H (V)	L_L (V)	DMM range
1	10:1	90 kΩ	10 kΩ	10	1	10
2	10^2:1	9 kΩ	1 kΩ	10	1	10
3	10^3:1	900 Ω	100 Ω	1	0.1	1
4	10^4:1	90 Ω	1Ω	1	0.1	1
5	10^5:1	9 Ω	1 Ω	0.1	10^{-2}	0.1
6	10^6:1	9 Ω[2]	90 mΩ	10^{-2}	10^{-3}	0.1
7	10^7:1	9 Ω[3]	10 mΩ	10^{-3}	10^{-4}	0.1

Table 1. Resistors, voltages and DMM ranges for the quick calibration of the INRIM divider.

2 V_H is applied on the 9 Ω resistor to avoid excessive load on the calibrator, but L_H is measured on the 900 mΩ resistor.
3 V_H is applied on the 9 Ω resistor to avoid excessive load on the calibrator, but L_H is measured on the 90 mΩ resistor.

Uncertainty component	type	1 δ (×10^{-7})
DMM noise of L_H	A	0.3
DMM noise of L_L[4]	A	0.1
ε_{linH}	B	0.6
ε_{linL}	B	3.2
ε_G	B	2.3
ε_{eVc}	B	0.0
ε_{emfH}	B	0.1
ε_{emfL}	B	1.2
ε_{load}	B	5.8 [5]
RSS		7.1

Table 2. Standard uncertainties of the quick calibration of the first section of the INRIM divider.

3.1 Uncertainties of the Quick Calibration Method of the Divider

Let's consider the example of the previous paragraph where on an input resistance of 10 kΩ is supplied a DC Voltage of 10 V. Taking advantage of the DMM linearity specifications on the 10 V range, it is possible to consider these instead of the much larger accuracy specifications. In Table 2, the standard uncertainties budgets of the quick calibration of this section is given.

In these first characterization measurements, the divider has been used in a semi-automated way, selecting the desired ratios by means of a rotary selector. In Table 3, the standard uncertainties of each section and the standard uncertainty of the cumulative ratios are reported. These ratios are obtained multiplying the 10:1 ratios of each section.

The uncertainties of the cumulative ratios are evaluated taking into account a partial correlation ($r = 1.6\times10^{-4}$) in the evaluation of the cumulative ratios. r was evaluated according to [19].

4. Discussion

In addition to the described work, an analysis of the short-time stability of the divider ratios has been made. In fact, as it can be quickly calibrated when necessary and involved in traceability transfer, as its involvement in a measurement setup for calibration of nanovoltmeters. Table 4 shows the preliminary values of the short-time (a week) stability of the divider ratios.

These values have to be confirmed in successive evaluations of the divider and inserted in the divider use uncertainties [20], along with its calibration uncertainties. Use uncertainties are those with which it can be used when involved in calibration of other instrumentation though the divider is realized to be quickly calibrated when necessary to be used shortly after. In Figure 5 (on the following page), the mid-term stability of the 10:1 ratio is shown.

4 This measurement is also made on the 10 V range of the DMM.

5 This component has been evaluated considering the input impedance of a specific DMM. The input impedance of the available DMMs model [15] were accurately measured and the item with the higher impedance (about $8.6\times10^{11}\Omega$) was enrolled in the measurement setup.

Section	u (×10^{-6})	Cumulative Ratios	u (×10^{-6})	U (×10^{-6})
1	0.7	10:1	0.7	1.4
2	0.4	10^2:1	0.9	1.7
3	1.5	10^3:1	1.7	3.4
4	1.5	10^4:1	2.3	4.6
5	6.8	10^5:1	7.0	14
6	30.5	10^6:1	32.5	63
7	296	10^7:1	296	592

Table 3. Uncertainties of the quick calibration of each section and of the cumulative ratios of the INRIM divider.

5. Conclusion

From the preliminary results, the performance of the divider is satisfactory. Next work will be the full automation of the divider and the further verification of its measurement noises in the calibration and of its short-term stabilities. Consequently, the calibration uncertainties could be re-evaluate as well as its short-time use uncertainties can be evaluated. Latest results will be soon published on a top metrology journal. These results include the divider automation, the evaluation of the divider: short and mid-term drift, temperature dependence, calibration and use uncertainties for all the ratios. In addition, the description of a solution to minimize the DMM load effect and the emf effect of the relays will be given.

Ratios	Stability (×10^{-6})
10:1	0.3
10^2:1	0.3
10^3:1	0.7
10^4:1	0.8
10^5:1	6.6
10^6:1	47.6
10^7:1	446

Table 4. Short-time stability of the divider ratios.

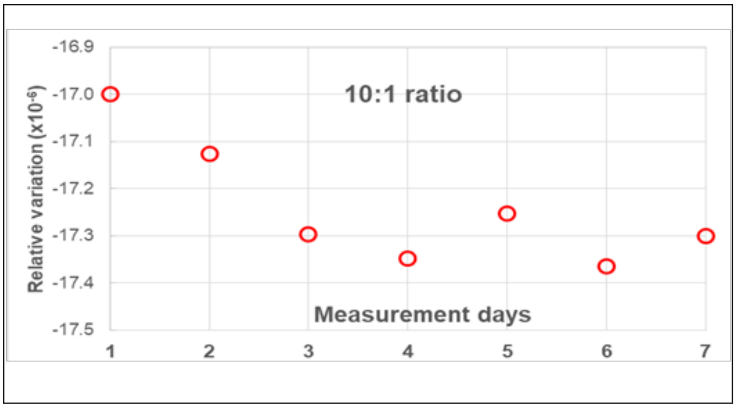

Figure 5. Mid-term stability of the 10:1 ratio.

References

[1] Fluke Corporation, *752A Reference Divider Instruction Manual*, Rev. 1, (1984).

[2] Fluke Corporation, *720A Kelvin Varley Voltage Divider Instruction Manual*, Rev. 2, (1974).

[3] F.Galliana, P.P. Capra R. Cerri, M. Lanzillotti, "Automated precision DC voltage fixed ratios divider," *Measurement* 122, pp. 291-296, (2018).

[4] Y. Sakamoto, T. Endo, H. Shao, S. Matsuzawa, "Automated DC voltage divider to calibrate voltages up to 1 kV," *Prec. El. Measur. Conf. (CPEM)*, pp. 363-364, (2000).

[5] Tadashi Endo, Y. Sakamoto, T. Sakuraba, Y. Murayama, H. Yoshida, A. Odawara, "Automated voltage divider to calibrate a 10-V output of Zener voltage standard," *IEEE Trans. Instrum. Meas.* Vol 40 (2), pp. 333- 336, (1991).

[6] H. Hirayama, M. Kobayashi, K. Murakami, T. Kato, "10-kV High-Accuracy DC Voltage Divider," *IEEE Trans. Instrum. Meas.* 23 (4) pp. 314- 317, (1974).

[7] Yi Li, Miyuru K. Ediriweera, F. S. Emms, A. Lohrasby, "Development of Precision DC High-Voltage Dividers," *IEEE Trans. Instrum. Meas.* 60 (7), pp. 2211-2216 (2011).

[8] R.B.D. Knight; P. Martin, "A high voltage divider having an uncertainty of 5 p.p.m. at 100 kV," *IEEE Trans. Instrum. Meas.* 42 (2), pp. 568-570, (1993).

[9] N. Dragounova, "Precision high-voltage dc dividers and their calibration," *IEEE Trans. Instrum. Meas.* 54 (5), pp. 1911-1915, (2005).

[10] A. Merev, Ö. Kalenderli, "The construction of a DC high voltage precision divider," *Journal of Electrostatics* 67 (5) pp. 741-745, (2009).

[11] D. Georgakopoulos, S. Grady, I. Budovsky, S. Grady, "Quantum Calibration System for Digital Voltmeters at Voltages from 10 nV to 1 kV," *IEEE Trans. Instrum. Meas.* 62 (6), pp. 1581-1586, (2013).

[12] H. E van den Brom, E.t Houtzager, G. Rietveld, R.van Bemmelen and O. Chevtchenko, "Voltage linearity measurements using a binary Josephson system," *Meas. Sci.Tech*, 18, (11), (2007).

[13] M. Early, L. Christian, T. B. Lawson, "Building-up the DC voltage scale for sources and meters," *29th Prec. El. Measur. Conf. (CPEM)*, pp. 138-139, (2014).

[14] D. Aviles, E. Navarrete, "DC Voltage Traceability to Microvolt and Nanovolt Levels," *31st Prec. El. Measur. Conf. (CPEM)*, pp. 138-139, DOI: 10.1109/CPEM.2018.8501104, (2018).

[15] Agilent Technologies, *3458A Multimeter - User's Guide*, rev. B.01, (2001).

[16] A. Sosso, R. Cerri, "Calibration of multimeters as voltage ratio standards," *Prec. El. Measur. Conf. (CPEM)*, pp. 375-376, (2000).

[17] J. I. Giem, "Sub-ppm linearity testing of a DMM using a Josephson Junction array," *IEEE Trans. Instrum. Meas.*, 40 (2), 329-332, (1991).

[18] Fluke Corporation, *5700A/5720A Series II Multi-function Calibrator Service Manual*, Rev. 1, 3/02, (June 1996).

[19] F.Galliana, M. Lanzillotti, "Accurate comparison between INRIM and a secondary calibration laboratory using a top-class multifunction electrical calibrator," *Measurement* 103, pp. 353-360, (2017).

[20] W. Bich, F. Pennecchi, "On the In-Use Uncertainty of an Instrument," *Advanced Mathematical & Computational Tools in Metrology*, World Scientific, pp. 159-169, (2004).

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Selecting a Calibration Management Software System in a Regulated Environment

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IndySoft Corporation

Selecting a Calibration Management Software System is a critical process for a calibration laboratory, especially in a biomedical regulated environment. However, there are few examples or documents that explain this process from a user's perspective. The objective of this paper is to explain the selection process, provide examples of the documentation used, and to pass along lessons that were learned. The following topics will be discussed: Selection Process Overview, Identify Key Business Representatives, Develop Business Requirements, Identify Vendors, Send Business Requirements to Vendors, Convert Requirements to a Scoring Matrix, Select Vendors for the Demonstration Phase, Evaluate Vendor Demonstration Software, Client Surveys, Vendor Financial Health, and Selection of Vendor of Choice.

Background

As Microsoft kept updating their Windows Operating System with less compatibility with DOS, it became increasingly clear that we were at risk in continuing to use our custom-designed Calibration Management Software System written in Paradox DOS.

In early 2002, we decided to begin our selection process to identify a Calibration Management Software System. An important decision was made to focus on an "off-the-shelf" vendor solution. We did this for two main reasons: (1) decrease risk to losing internal database developers, and (2) lower support cost and decrease time to implement the latest software enhancements to maximize user efficiency and effectiveness.

Additionally, we needed to be thorough in our selection process to ensure that the new software system would stand up to regulatory inspection as our medical device manufacturing company operated in a government regulated industry.

Our selection process was successful in selecting a final vendor that best met our requirements. Because of the rigorous selection process, we were able to achieve a unanimous decision from a global team of decision makers. This robust selection process helped select a software system that is still being used 17 years after implementation.

This paper is intended to explain the selection process, provide examples of the documentation that was used, and to pass along lessons that were learned.

Assumptions

As with any demonstrated process, future success and failure is dependent upon understanding the process limitations and the project constraints. We have identified several assumptions for you to consider when using this process as a template example:

- Understand your own requirements—completely; never substitute good research with a quick easy fix. You will be disappointed in the results.
- We did not develop this selection process from scratch; we incorporated ideas, examples, and recommendations from others. This paper will give credit to those sources.
- Our process was not fixed, but dynamic. We made changes along the way. Your process also needs to have that flexibility.
- Our selection process tried to involve as many people as possible. Stakeholders are in many areas of the business: customers, employees, supporting departments (IT, Finance, etc.) peers, upper management, etc. Your success will be proportional to how many stakeholders you involve.
- The process is time dependent. If we performed this selection process today, the process would incorporate the lessons learned and any ideas gleaned from new research.

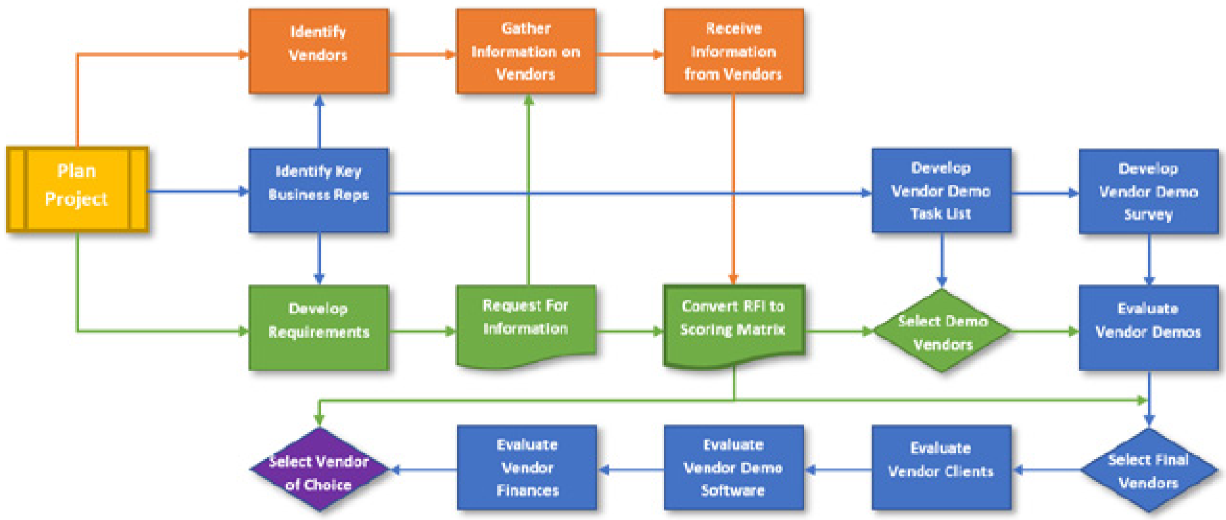

Figure 1. Selection Process.

The Selection Process

The process we used is illustrated in Figure 1. Three main work flows were started together: (1) Identify Key Business Representatives, (2) Develop Business Requirements, and (3) Identify Vendors (Suppliers).

Identify Key Business Representatives

Our selection process wanted to involve as many different businesses in our company as possible to help identify a solution that would best meet everyone's needs. This was a grass-roots effort; a bottom to top process. We wanted to identify one representative from each business that would be responsible for the integrity of the software database, the adherence to regulatory requirements, the impact to business clients, and the effectiveness of the final solution. In most cases, the Key Business Representative was the business calibration manager.

The Key Business Representative's responsibility was to gather their organizational needs and be responsible to communicate to their business stakeholders. The Project Leader (myself) communicated with the Key Business Representatives and they in turn communicated with their stakeholders. We tried to maximize involvement while simplifying decision-making.

Lessons Learned: This arrangement worked very well, especially for the Project Leader to stay on track to the project milestones [1]. The main risk is that the Key Business Representatives will not fully engage with all of their stakeholders.

Develop Business Requirements

Developing business requirements *is the most important aspect* of selecting a calibration management software tool. The earlier you identify these the better. Requirements ensure that you have a standard benchmark. This is important to the Project Leader, to the Key Business Representatives, and to the vendors. Your chance for success will be determined by how comprehensive and accurate your requirements are.

We grouped the 140 plus individual business requirements into 11 categories: regulatory, work flow, management functions, database administrator functions, logistical functions, external systems interface, implementation, technical, vendor, price, and quality [2]. This list has been recently updated and will be a valuable resource for new software implementation projects.

The Key Business Representatives identified the majority of these requirements; however, I want to give credit to two groups that greatly assisted in this effort. One was our own internal IT organization. They had an IT Project Template web site that listed the IT Software Technical Requirements which we used to comprise the main part of our technical requirements section. This ensured that we were standardized to the expectations of our IT support group; e.g. an Oracle database management system. Gary Jennings of Northrop Grumman Corporation also gave us great assistance by sharing his Requirements document [3]. Gary's generosity was invaluable in laying the solid groundwork for our Business Requirements document. Quality Digest article [4] was also used as a general resource for gathering ideas for the requirements list as well as NCSLI Recommended Practice 6 [5].

Lessons Learned: All of the hours invested in developing the business requirements was time well spent. This document turned out to be the key to the success of our selection process.

Identify Vendors

We used various sources to arrive at a vendor list:

- We asked the Key Business Representatives to recommend vendors and their software.
- Quality Digest and other magazines typically publish an Annual Issue listing Equipment, Instruments, and Software tools.
- Attending the annual NCSLI Symposium and Workshop. The annual Measurement Science Conference would be another valuable source of information.

Attending the NCSLI Symposium was especially beneficial. Over 120 vendors were in attendance with seven vendors demonstrating calibration management software. I was able to speak directly to the vendors, observe software demonstrations, receive brochures, and ask questions about technical specifications. As a side benefit, Gary Jennings of Northrup Grumman Corporation was in attendance and this is where our small talk led to us receiving a copy of his requirements document. Serendipity.

At this point we were not evaluating vendors, but gathering a list of potential software systems. We ended up with a list of eleven vendors and their software systems.

Lessons Learned: Even though our list of eleven vendors was a good representation of available calibration management software systems, in hindsight we should have tried to compile a larger list. During the rest of the selection process, we had vendors drop out for various reasons resulting in less quality software to evaluate.

With the selection process underway on three main workflows, we started the active phase of the project.

Send Business Requirements to Vendors

We converted the Business Requirements List to a Request for Information (RFI) document that was sent to each of the eleven vendors [6]. Included in the RFI was background on the selection process, instructions on how to answer the questions, and how and when to return the RFI to be considered for this project. A two-week deadline was emphasized. The project leader initially screened all returned RFIs to ensure that the responses were clear and complete. When necessary, the project leader returned RFIs for additional information. Completed RFIs were given to all Key Business Representatives.

We had to convince one vendor to submit an RFI even though they thought they would not be competitive. That vendor did make it to the next selection phase. Another vendor chose not to respond and could not be convinced otherwise.

Lessons Learned: As you can imagine, once the vendors received our RFI they became very excited about the project and wanted to ask a lot of questions and make requests outside of the instructions in the RFI. As the Project Leader, I just referred them back to the RFI package which included all of the information they needed in this phase of the selection process. This was the best way to remain fair to all vendors and to keep the project on track. Staying firm on the two-week deadline also helped. We had one vendor that never responded and we should have made a better effort to find out why. It turned out that our point of contact had left the company.

	A	B	C	D	E	F	I	L	O	R	U	X	AA	AD
1	STRONG: 3 OK : 2 WEAK : 1		NEEDED: 3 DESIRED: 2 NICE : 1			VENDOR 1	VENDOR 2	VENDOR 3	VENDOR 4	VENDOR 5	VENDOR 6	VENDOR 7	VENDOR 8	VENDOR 9
2	VALUE		WEIGHT		WEIGHT	VALUE	VALUE	VALUE	VALUE	VALUE	VALUE	VALUE	VALUE	VALUE
3	4.1 REGULATORY REQUIREMENTS													
4	1. Is your system compliant to ANSI/ISO/IEC				3	3	1	3	3	1	3	3	3	3
5	17025 2000? If not, describe the gaps and your													
6	corrective action plan.													
7														
8	2. Is your system compliant to Food and Drug				3	3	1	2	3	1	3	3	2	3
9	Administration Quality System Regulation 21													
10	CFR Part 820 Medical Devices; Current Good													
11	Manufacturing Practice; Final Rule? If not,													
12	describe the gaps & your corrective action plan.													
13														
14	3. Is your system compliant to FDA Title 21				3	3	1	1	2	1	3	3	3	3
15	Code of Federal Regulations? (21 CFR Part 11)													
16	Electronic Records; Electronic Signatures;													
17	March 2000? If not, describe the gaps & your													
18	corrective action plan.													
19														
20	4. How do you support the validation of your softw				2	3	1	3	3	2	3	3	3	3
21														
22	5. How will you support future revisions of regulato				2	3	1	3	3	2	3	3	3	3
23	documents?													
24														
25														
26	6. How do you support assistance to your				2	2	2	3	3	2	3	3	3	3
27	customers regarding audit findings due to													
28	system software gaps?													
29														
30	7. What is your method for handling customer				1	3	3	3	3	3	3	3	3	3
31	recommendations for software system improve-													
32	ments or enhancements?													
33														
34	8. How does your system handle data validation?				3	3	1	3	2	2	3	3	3	3
35														
36	9. How does your system handle audit trails and				3	3	1	3	2	2	3	2	3	3
37	activity logs of all data changes?													

Figure 2. Scoring Matrix in Excel.

Convert Requirements to a Scoring Matrix

To make it easier for each Key Business Representative to score the returned RFIs according to their needs, we converted the business requirements to a spreadsheet with a flexible scoring system. Figure 2 includes one page of the spreadsheet to give you an example of this concept. We used the two scores of Value and Weight as the best way to score subjective responses. This is an excellent method for converting subjective responses to a quantitative scoring process.

Each vendor's requirement response was assigned one of three *values*: (1) Exceeds Requirements is *valued* as **Strong** and assigned 3 points, (2) Meets Requirements is *valued* as **OK** and assigned 2 points, and (3) Does Not Meet Requirements is *valued* as **Weak** and assigned 1 point.

Each requirement was additionally assigned one of three *weighted* numbers depending on the importance of the requirement: (a) **Required** requirement is assigned a *weight* of 3 points, (b) **Desired** requirement is assigned a *weight* of 2 points, and (c) **Nice** requirement is assigned a *weight* of 1 point.

Each response was then valued and weighted and added together to arrive at a total Vendor Response Score. We then used this Score in several different phases of our selection process. Refer back to Figure 1.

Lessons Learned: This scoring spreadsheet proved to be an excellent way for each business to decide the importance of each requirement to their needs without delaying the project in needless debate over the scoring of over 140 requirements.

An improvement could be made by identifying a few key requirements as *knockout* requirements to make it easier to eliminate inferior software, e.g. No Multi-server Capability.

Select Vendors for the Demonstration Phase

We decided to select seven vendors (slightly over 50% of the original list) to demonstrate their software to the Key Business Representatives. The scoring matrix was the main criteria used to select the vendors after careful review of the most important (knockout) requirements.

In order to minimize the marketing and sales pitch that is typical in software demonstrations and to standardize scoring, we developed a **Vendor Demonstration Task List**. We sent this task list with an invitation letter to the vendors that were selected to demonstrate their software. We emphasized that we expected the vendors to follow the task list in the allotted time to receive the best evaluation. We gave the vendors 1 hour and 45 minutes to perform these tasks. The task list covered three main areas: workflows, reports, and regulatory, see Figure 3.

We also developed a **Vendor Demonstration Survey** to mirror the task list. The Key Business Representatives used this survey to evaluate the demonstrations using one of three ratings for each task: unsatisfactory, satisfactory, and excellent. See Figure 3 for an example.

After reviewing and scoring the demonstrations, the Key Business Representatives discussed what they

Vendor	Software

Key: (U) Unsatisfactory; (S) Satisfactory; (E) Excellent

Task Requirements	(U)	(S)	(E)	Remarks
WORKFLOW REQUIREMENT				
1. Adding a new piece of equipment to database. (Calibration and Preventative Maintenance Info; linking of external files, bar code capability; "Parent / Child" linking.)	☐	☐	☐	
2. Opening a work order on an existing item due for calibration. (Calibration Procedures; Calibration Standards; Linking to an Automated Calibration Procedure Program.)	☐	☐	☐	
3. Completing the calibration work order. (Multiple Time Entries; Traceability Numbers; History Notes; Out-of-Tolerance data; Humidity/Temperature data; Before and After data; Cal Cert; Cal Label; Forward / Reverse Trace.)	☐	☐	☐	
4. Opening a work order for scheduled preventative maintenance. (Procedure and Required Supplies.)	☐	☐	☐	
5. Completing the work order. (New recall date; add new PM requirement on a different interval; any modification)	☐	☐	☐	
6. Opening a work order for unscheduled maintenance. (Warnings; Flags; Equipment Status; LOTO.)	☐	☐	☐	
7. Completing the work order. (Parts Inventory; Parts Order)	☐	☐	☐	
8. Work Orders in Permanent History.	☐	☐	☐	
9. Open a work order for miscellaneous work.	☐	☐	☐	
10. Remove an item from service. (Different Status Codes.)	☐	☐	☐	
11. Extend or Modify a Calibration or PM Due Date.	☐	☐	☐	
12. Cross-reference of Manufacturer, Model Number, Description, and Calibration / PM Procedures.	☐	☐	☐	
13. Use of Personal Data Assistant, Data Process Controllers, Laptops.	☐	☐	☐	
Task Requirements	(U)	(S)	(E)	**Remarks**
REPORT REQUIREMENTS				
1. Monthly Forecast of Scheduled Work Report.	☐	☐	☐	
2. Overdue for Service Report. Escalation Method.	☐	☐	☐	
3. Past Due Out-of-Tolerance Report.	☐	☐	☐	
4. Monthly Work Summary Report. (Tech hours; parts)	☐	☐	☐	
5. Equipment History Report. (Statistical Data Charts.)	☐	☐	☐	
6. Creating and Incorporating a New Report.	☐	☐	☐	
7. Technician Training Summary Report.	☐	☐	☐	
Task Requirements	(U)	(S)	(E)	**Remarks**
REGULATORY REQUIREMENTS				
1. Compliance to FDA Title 21 CFR Part 11 Electronic Records; Electronic Signatures.	☐	☐	☐	
2. Signature Documents for Auditor Viewing	☐	☐	☐	
3. Audit Trails and Security Levels.	☐	☐	☐	

COMMENTS:

Figure 3. Vendor Demonstration Survey.

Vendor/Software	Client

Key: (U) Unsatisfactory; (S) Satisfactory; (E) Excellent

Task Requirements	(U)	(S)	(E)	Remarks (Use additional sheet if necessary)
SELECTION / IMPLEMENTATION				
1. What software system were you using prior to your current system?	☐	☐	☐	
2. What factors were involved in your selection decision?	☐	☐	☐	
3. How many different systems did you evaluate (which vendors)?	☐	☐	☐	
4. Have you been satisfied with your decision?	☐	☐	☐	
5. Were you satisfied with the conversion of your software?	☐	☐	☐	
6. Were you satisfied with the transfer of your data?	☐	☐	☐	
7. Were you satisfied with the validation process?	☐	☐	☐	
8. Did the vendor meet all of their commitments?	☐	☐	☐	
9. Would you choose this vendor and software again?	☐	☐	☐	
10. What recommendations can you give to us?	☐	☐	☐	
11. Do you feel that you received a good value for the price?	☐	☐	☐	
Task Requirements	(U)	(S)	(E)	**Remarks** (Use additional sheet if necessary)
APPLICATION / USE				
1. How have you implemented the software: single-site, business wide; company wide?	☐	☐	☐	
2. Are you using the software to manage calibration and maintenance?	☐	☐	☐	
3. What areas have you been the most satisfied with?	☐	☐	☐	
4. What areas have you been the least satisfied with?	☐	☐	☐	
5. How long did it take to become comfortable with the software?	☐	☐	☐	
6. How often does the software lockup?	☐	☐	☐	
7. Have you successfully passed a FDA or TUV Audit?	☐	☐	☐	
Task Requirements	(U)	(S)	(E)	**Remarks** (Use additional sheet if necessary)
SUPPORT / TRAINING				
1. Have you been satisfied with follow-on support?	☐	☐	☐	
2. Were you satisfied with the training?	☐	☐	☐	
3. Were you satisfied with the documentation?	☐	☐	☐	
4. Are you satisfied with the vendor's commitment for continuous product improvement?	☐	☐	☐	

COMMENTS:

Figure 4. Vendor Client Survey.

observed and voted to decide the final three vendors for our selection process (again about 50% of the vendors). Each representative was allowed to vote for two vendors out of the seven observed, and the top three vendors with the most votes were notified in writing of their selection to the next phase.

Lessons Learned: As well as we detailed our demonstration task list, the vendors overall did a poor job of following our script. They used too much time in describing their company and other miscellaneous information before performing our task list. As a result, they failed to complete the list and cited a lack of time as a cause. To be fair, we would extend our demonstration time to two hours if we did the process again; however, the task list did a good job of trying to keep the vendors on task to what we needed to see demonstrated. We eliminated a vendor on a lower-scored demo even though they had the highest matrix score. We should have considered giving that vendor another look by either adding them to our final vendor list or having another demo scheduled.

Client Surveys

We asked each vendor to provide a client reference list representing the geographical areas of our Key Business Representatives. We developed a client survey to allow Key Business Representatives to telephone vendor's clients or travel on-site to evaluate software selection and implementation, application and use, and support and training. The survey template ensured that we asked standard questions so different people could telephone or make visits and still have an equitable scoring process. We wanted this survey to essentially answer the question "how happy are you with the vendor's product?" See Figure 4 for an example of our questions and scoring.

Lessons Learned: Certainly, we understand that the vendor is only going to provide a list of clients that are happy with their products. But it still was enlightening what we found out from the "happy" clients. Because we asked for clients located in geographical areas near our Key Business Representatives, we were able to leverage our peers in several on-site visits in an economical manner.

At this point, we were in the final phase of our selection process and the most detailed: evaluate vendor software, interview customers, and investigate vendor financial health.

Evaluate Vendor Demonstration Software

The Key Business Representatives attempted to perform evaluations of the three final vendor's demonstration software. We requested that the vendors provide a **workable** copy of their calibration management software system. We also asked that the software contain a sample database to make it easier to navigate and exercise the software. Two out of three vendors met or exceeded our expectations.

Lessons Learned: This was a true test of whether or not a vendor could prove they had a working copy of software for us to exercise. Asking them to provide a database of existing equipment ensured we had something to work with other than a canned package. We did end up using a sample of our own equipment database information for the two vendors where the software worked, which helped with our evaluation.

These on-site visits were very valuable in seeing the software in actual use.

Vendor Financial Health

An important point to consider is, "how healthy is the vendor's business financially?" You want to know if the company is financially stable and has a history of good finances and what the overall potential business risk is. We have to give credit to Doug Lynde of On Time Support, Inc. for giving us this recommendation. We requested a Dun & Bradstreet Business Information Report ($140) for all three vendors regarding Customer Service, Summary Analysis, Payment Summary, and Corporate and Business Registrations. These reports were shared with each Key Business Representative.

Lessons Learned: The financial reports were very helpful and insightful and well worth the cost. We recommend that this be a must in any selection process even if you are down to evaluating just one vendor.

Selection of Vendor of Choice

After all of the data was gathered on the final three vendors and shared with the Key Business Representatives, the Project Leader initiated a vote by telephone. Each representative was allowed one vote. The vendor with the most votes was going to be the final vendor of choice. Our goal from the beginning, was to have a vendor that everyone would be satisfied with and if necessary, additional project tasks would be performed to ensure this satisfaction. Our telephone vote was unanimous and exceeded our expectations.

Lessons Learned: Our selection process lasted about nine months and actively involved over 10 different company business representatives. To achieve a unanimous decision is a tribute to the detailed selection process and to the active engagement of the Key Business Representatives from beginning to end. We left out one important process—Request for Quote. We should have asked for a Request for Quote as part of the final selection process to be in a better negotiation position with the final vendor, though the final vendor's pricing ended up being very reasonable.

Summary

This selection process was a "grass-roots" effort that ultimately involved 11 different company business units, each with their own requirements and priorities. This process was very effective at including each site's input, but also not getting delayed with endless debate about what is important. The project stayed on track as a result and concluded with a universal decision on the software of choice.

Though this software selection process was for the bio-medical industry and was specific to calibration management software, the process itself can be easily modified to accommodate other regulated industries and for other software purposes.

References

[1] S. Portny, *Project Management for Dummies*, Hoboken, NJ, USA: John Wiley & Sons, Inc. 2000. [4th ed., 2013]
[2] W. Nowocin. "Calibration Software Selection - Business Requirements." IndySoft. http://bit.ly/CalSoftwareBusinessRequirements. (accessed December, 2020 and updated).
[3] G. Jennings, private communication, August, 2002.
[4] D.K. Banerjea, "Gauging Your Software Needs," *Quality Digest*, July 2001.
[5] NCSLI. *Recommended Practice for Calibration Quality Systems for the Healthcare Industries – RP-6*, Boulder, CO, USA: NCSLI, 1999. [4th ed., 2015]
[6] B. Porter-Roth, *Request for Proposal: A Guide to Effective RFP Development*, Boston, MA, USA: Pearson Education, Inc., 2002. [2nd ed., 2005]

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Walter Nowocin was a Calibration Department Manager for Medtronic PLC, the world's largest medical device manufacturer, when this project was implemented.

Rohde & Schwarz NGU

Munich, February 16, 2021 — The steady extension of the Rohde & Schwarz portfolio of specialty power supplies continues with the first two models in the R&S NGU series of high-precision SMUs. The instruments' innovative current feedback amplifier technology provides both maximum sensitivity and accuracy to reliably measure currents from nA to A in a single sweep. To handle rapidly changing load conditions typical of battery-powered communications devices switching between sleep and transmit modes, the R&S NGU features an optimized control loop load providing a best in class recovery time of under 30 µs with minimum overshoot.

The R&S NGU SMUs include six current ranges from 10 µA with 100 pA resolution, to 10 A with 10 µA resolution. For all ranges, accuracy up to 0.025 % is achieved. Voltage is measured with 10 µV resolution in the 20 V range and 1 µV resolution in the 6 V range. For the typical measurement problem of capacitance at the input to the device under test, the R&S NGU features a variable capacitance mode adjustable in steps from 1 µF to 470 µF, compensating the capacitance, so that the current is displayed as if it was measured directly at the device under test. Devices up to 20 V, 8 A, and 60 W are all supported.

The four-quadrant R&S NGU401 is the specialist for semiconductor testing. It provides source measurements for any equipment requiring source and sink voltages in the range from –20 V to +20 V. In addition to the voltage regulation mode of power supplies, the R&S NGU includes a fast current regulation mode to avoid damaging current-sensitive devices under test, such as LEDs or other semiconductors. An external arbitrary waveform source connector turns the R&S NGU401 into an AC source and makes it possible to simulate glitches or unstable power supplies of up to 1 kHz.

The two-quadrant R&S NGU201 is optimized for battery drain analysis of any battery-powered device, including mobile phones, tablets, and the full range of IoT equipment. Design engineers can use it to simulate real-world battery characteristics. Once the battery model characteristics are defined, they can be re-used whenever required. With its 8 A maximum current, the instrument even supports fast-charge applications.

In addition to the dedicated source measurement features, the R&S NGU series also includes the elaborate features common to all specialty power supplies from Rohde & Schwarz. The market-leading data acquisition rate of 500 ksample per second offered by the FastLog functionality captures voltage and current levels every 2 µs so that even the shortest intermittent glitches are detected. With the optional built-in digital voltmeter, users can check voltages at any point in the device under test as well as the input voltage.

The new R&S NGU201 and R&S NGU401 source measure units are part of the R&S Essentials portfolio, and are now available from Rohde & Schwarz and selected distribution partners. With market introduction, a limited number of the fully equipped special model R&S NGU401COM is on offer at an attractive price.

For more information on the R&S NGU source measure units, visit: https://www.rohde-schwarz.com/product/ngu.html

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Ralston Differential Pressure Transmitter Calibration Kits

Selecting your equipment for calibrating pressure instruments just got a lot simpler

The calibration of differential pressure (DP) transmitters is very important to maintain correct flow data for oil and gas pipelines or anywhere that orifice plates are being used for flow measurement. Pressure transmitters today are quite accurate and often only need zero and span adjustments done during commissioning and periodically to adjust for head corrections, drift and other factors. One of the challenges of calibrating a pressure transmitter is having the correct equipment that can apply the correct pressure without leaks, especially in remote or hard to reach areas. It is also difficult to document the results of a calibration if weather or the environment do not cooperate.

The solution is to make sure to have the correct equipment to perform the calibration. When calibrating a DP transmitter it is necessary to have all the equipment needed such as Ralston Instruments full calibration kits which include a precision digital test gauge, hand pump, hose, adapters and carrying case.

For more information about calibration kits contact Ralston Instruments at ralstoninst.com

Keysight Compact DC Electronic Loads for the Bench

SANTA ROSA, Calif., December 1, 2020 – Keysight Technologies, Inc. (NYSE: KEYS), a leading technology company that helps enterprises, service providers and governments accelerate innovation to connect and secure the world, today announced the Keysight EL30000 Series bench DC electronic loads. These instruments offer a compact bench form factor with a built-in data logger that delivers insights for immediate, real-time decisions, and minimizes the need for additional instruments with an accurate system that measures voltage, current and calculates power.

An electronic load is an instrument designed to test sources by presenting various resistances and measuring the response. Device manufacturers and design engineers use electronic loads to test power devices such as power supplies, batteries, battery modules, solar panels, fuel cells, LED drivers and power converters.

Keysight's bench electronic loads enable customers to test a wide range of power sources, perform both static and dynamic tests to ensure devices can output constant energy, as well as handle a sudden increase or decrease in demand. Multiple ranges allow accurate measurements for small and large devices from zero to 150V. Using the built-in measurement system eliminates the need for an external digital multimeter, shunts and associated wiring.

The new Keysight EL30000 Series electronic load systems enable device manufacturers and design engineers to:

- Measure voltage and current accurately with a fully integrated voltmeter and ammeter that simultaneously measures the device under test (DUT) voltage and current.
- Capture measurements over time with the built-in data logger that continuously logs voltage, current and power to a data file.
- Create, capture and display fast transients with a dynamic load profile and built-in scope mode that digitizes the voltage and current, and shows the results, reducing measurement set up complexity.
- Simplify tests with standard operating modes: constant voltage (CV), constant current (CC), constant resistance (CR) and constant power (CP).
- Connect with USB, LAN (LXI Core) and optional general-purpose interface bus (GPIB) to easily measure, capture and display results.

"Our customers are focused on accelerating their next-generation designs," said Christopher Cain, vice president and general manager of Keysight's Electronic Industrial Products. "Simplifying the testing of batteries and the electronics design at the heart of portable electronics, enables faster time to market and maximum performance."

Keysight's EL30000 Series bench DC electronic loads are available now. Pricing is as follows:

- EL34143A single-input, 150V, 60A, 350W - USD 2,200
- EL34243A dual-input, 150V, 60A, 600W – USD 3,520

Keysight's EL30000 Series includes a 3-year warranty and built-in KeysightCare Technical Support. More information is available at www.keysight.com/us/en/products/dc-electronic-loads.html.

KCC Scientific Frequency and Voltage Converter

By KCC Scientific, Mains reconstruction provides the ultimate power conditioner—and much more.

Denver, Colorado (February 2021) – Electronics innovator KCC Scientific launches the new Mercury 1000 Voltage and Frequency Converter, supporting precision electronic equipment up to 1000 watts. The Mercury family of converters are capable of converting, reconditioning and regulating the local power grid in any country. "The KCC Professional Series precision voltage and frequency converters have selectable output frequency of 50.0000Hz or 60.0000Hz as well as selectable output voltage of 115V or 230V AC," says Ken Reindel, president of KCC Scientific. The compact, lightweight Mercury line incorporates features such as separate EU and US power outlets, power monitor display, and a wide base ideal for component stacking. "The series is ideal for laboratory precision measurement and testing equipment up to 1000 watts. It works equally well in the US, EU, UK, Australia, Japan and other worldwide locations."

KCC Scientific is known for precision power sources, enabling electronic devices from all countries to be powered from any outlet worldwide. "This technology is critical for anyone using equipment with nondomestic power requirements," says Teri Reindel, KCC Scientific executive team member. "Even for domestic equipment, delivering pure sine power isolated from frequency drift and mains power line noise makes a discernable difference in power quality. Because the output is precision, regulated (both voltage and frequency), and isolated, it is immune from today's ever-increasing mains power line aberrations."

About KCC Scientific

KCC Scientific provides voltage and frequency converters capable of powering valued electronic devices up to 1000 watts. Economical, high-precision These KCC clean-power converters are designed to match the voltage, frequency, and wattage requirements of devices to the local mains powerline anywhere in the world. Using these products, an electronic device is powered exactly as it was originally designed to be, with no compromises, regardless of the quality of the local power grid. KCC Scientific converters are precision engineered, conservatively rated and well-protected from overloads. All KCC Scientific products are confidently backed with a two-year warranty.

More information at http://www.kccscientific.com.

TCP/IP & The Mini-Calibration Network

Michael L. Schwartz
Cal Lab Solutions, Inc.

Today, many of the units coming in for calibration don't have a GPIB interface. All they have are a Universal Serial Bus (USB) or a TCP/IP Local Area Network (LAN) interface. When connected to the computer via USB, we discover our IT department has locked us, mere mortals, out of the computer so we can't install the driver for the Unit Under Test (UUT). When connecting the UUT to the LAN, it can't be found because the Media Access Control Address (MAC Address) is not authorized on the network, so the only way left to calibrate the UUT is manually!

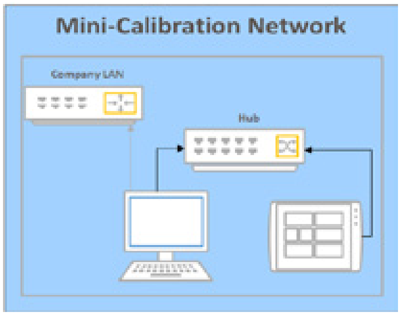
There is a better way! It will require a little cooperation with IT; nothing crazy as giving you administration rights or access to critical systems, just the simple idea of creating a mini-calibration network that allows a workstation to communicate with the UUT and maybe a few other standards.

The idea is simple. Computers are not limited to just one Network Interface Card (NIC); they can actually have multiple NIC cards installed. For example, most laptops have both a hard-wired LAN connection and a wifi connection.

To communicate with a UUT or other hardware using our mini-calibration network, all we need to do is to add another hard-wired NIC card to our workstation. This is easily done with a direct-wired connection or the use of an ethernet hub or switch.

There are only a few steps to setting up a mini-calibration network between the workstation and hardware. First, the IP address can't interfere with the company's main network. Most company LANs are set up using a 10.x.x.x network or a 192.x.x.x network. So when setting up your mini-calibration network, you have to use the IP address range not used by the company's main network.

For example, my company uses the 10.x.x.x, so my mini-calibration network will use a 192.168.1.x set of TCP/IP addresses. This will give me the ability to add up to 253 instruments in my mini-network where x is the unique address of the device. (Not so mini compared to the 32 instrument limit of GPIB.)



I recommend using a USB-NIC card. They are easy to use and you can think of it like a USB-GPIB controller. I also recommend using an ethernet hub to connect between the workstation and the UUTs/other hardware.

When the USB-NIC is connected, the computer windows will automatically set up the device to use Dynamic Host Configuration Protocol DHCP. If you don't have admin rights you may need a little help from IT to change NIC's configuration.

On Windows 10 in the control panel, you can set a specific address by double clicking on the "Network and Sharing Center," then clicking on the change adapter settings. Find the USB-NIC and right-click it and select Properties. You will have to have administrator rights to the workstation. In the popup window find "Internet Protocol Version 4 9TCP/IPv4," then select Properties. This may be different on your computer/operating system, but the concept is the same.

Once you get the to properties window, most likely the "Obtain IP address automatically" will be selected. We need to change that and select "Use the following IP Address." This is where you manually set the workstation's IP address. Once the IP address is selected, the Subnet Mask and Gateway should be enabled for editing.

I set my workstation up as follows: IP address to "192.168.1.254," the Subnet Mask to "255.255.255.0," and leave the Default Gateway blank. It is important to note, because this mini-calibration network is only connected to the workstation, you can set all your workstations up the same way.

Once the workstation is set up, and connected to the hub, now you can set up the UUT. There are 253 addresses ranging from "192.168.1.1" to "192.168.1.253" that can be used for instrument control.

I am going to set my UUT IP Address to "192.168.1.1" and the Subnet Mask to "255.255.255.0." Each UUT will be different and you will have to read the manual for the specifics. Once done, you should be able to communicate with the UUT.

Now you can test your connection using the Command prompt. Open a Windows Command prompt by clicking on the Windows start icon and typing "Command Prompt." When open, type "Ping 192.168.1.1." If everything is working correctly, the UUT should respond and you are ready to calibrate the UUT. In the next issue, I will cover setting up VISA using NI MAX. ❧

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