2023
APRIL
MAY
JUNE

How to Calibrate Thermometry Bridges: Ensuring Accurate Temperature Measurements

A Better Way to MET/CAL® With a Twist of Object-Oriented Programming

PRECISION CURRENT INSTRUMENTATION AND CURRENT CALIBRATION

DANISENSE HIGH PRECISION CURRENT TRANSDUCERS

± 50A to ± 10000A DC/AC precision fluxgate current transducers for power measurement, battery test systems, high-stability power supplies, and current calibrations.

- Current Ranges 50A ... > 10000A
- Linearity Error down to 2 ppm
- Very high absolute amplitude and phase accuracy from dc to over 1kHz
- Low signal output noise
- Low fluxgate switching noise on the pimary

HIGH CURRENT CALIBRATION SERVICES

Your ability to deliver accurate and reliable measurements depends on the stability of your equipment, and your equipment depends on the accuracy and quality of its calibration.

With over 25 years of calibration experience, GMW offers AC and DC NIST Traceable and/or **ISO/IEC 17025:2005 Accredited*** current calibration services for Current Transducers at our San Carlos, CA location and On-Site for minimal disruption of daily operations.

Transducers manufacturers calibrated by GMW include, but not limited to, Danisense, LEM, GE, ABB, Danfysik, Hitec, AEMC, VAC, PEM, Yokogawa.

* See gmw.com/current-calibration for Scope of Accreditation

GMW*Associates*

WWW.GMW.COM | INSTRUMENTATION FOR ELECTRIC CURRENT AND MAGNETIC FIELD MEASUREMENT

FEATURES

DEPARTMENTS

ON THE COVER: Opto-Cal Metrologist, Bob Myers, using a REL, Inc. LED UV-A inspection lamp (https://www.relinc.com) coupled with a Hamamatsu S2281 silicon photodiode standard to perform an ISO/IEC-17025:2017 accredited calibration of a Gould-Bass DLM-1000 ultraviolet sensor at Opto-Cal's laboratory (https://www.optocal.com/), located in San Diego, CA. LED-based UV inspection lamps have revolutionized onsite NDT applications, providing a more compact inspection tool with stability in the UV-A far superior to its predecessors. Digital photograph shot by Evan Jameson.

CALENDAR

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

Aug 28-31, 2023 | IEEE AUTOTESTCON. National Harbor, MD. AUTOTESTCON is the world's premier conference that brings together the military/aerospace automatic test industry and government/military acquirers and users to share new technologies, discuss innovative applications, and exhibit products and services. https://2023.autotestcon.com/

Sep 7-11, 2023 International Scientific Symposium Metrology and Metrology Assurance (MMA). Sozopol, Bulgaria (Hybrid event). The XXXIII Symposium "METROLOGY AND METROLOGY ASSURANCE 2023" is a part of "Science Days of TU-Sofia" and it is organized by the Technical University of Sofia - Department "Electrical Measurements", Department "Precision Engineering and Measurement Instruments" and the Bulgarion Section of IEEE and with the attendance of Bulgarian Institute of Metrology, Union of the Metrologists in Bulgaria, Bulgarian Academical Association of Metrology and Kozloduy Nuclear Power Plant. The ISS "MMA 2023" will provide insights to the latest achievements in metrology and metrology assurance. https://metrology-bg.org/en/home/

Sep 20-21, 2023 | IMEKO TC4 International Symposium. Pordenone, Italy. 26th IMEKO TC4 International Symposium and 24th International Workshop on ADC and DAC Modelling and Testing (IWADC) in Pordenone, Italy. For the first time this International Symposium will be organized in parallel to the industry-driven World Magnetic Conference at the trade show COILTECH Italy. https://conferences.imeko.org/event/3/

Sep 21-22, 2023 IMEKO TC10 Conference. Delft, The Netherlands. The International Measurement Confederation IMEKO, Technical Committee 10 on Measurement for Diagnostics, Optimization and Control (https://www.imeko.org/index.php/tc10-homepage) kindly invites you to attend the 19th IMEKO TC10 Conference:

EDITOR'S DESK

The Whole Experience

Recently, I was made aware of the change of definition to the word "metrology." *The International Vocabulary of Metrology* (VIM) now defines it as the "science of measurement *and its application*."[1] This is just a tiny example of what I would not have known if I didn't volunteer with NCSL International and heard it during a meeting. In fact, this addition to the definition helps my elevator pitch whenever someone asks me about the weather.

This past July in Orlando, Florida, during the NCSLI International's Workshop & Symposium Conference Opening Session, President Georgette Macdonald championed the metrology conference experience and how we can get the most out of it. She referred to the conference program which had a full page devoted to "Getting the Most from Your Conference Investment." One suggestion I thought most valuable, but not always obvious was:

> Start with an end in mind. Based upon a review of the Conference content, outline the objectives that you will accomplish as a result of attending the Conference. Get support from your management and determine if they have any specific objectives as well.

If you think about it, it's also solid advice outside the context of a conference!

In this issue, David Southworth of Isothermal Technology introduces the reader to calibration of resistance bridges, in "How to Calibrate Thermometry Bridges: Ensuring Accurate Temperature Measurements."

Then moving on to the world of automation, our publisher/programmer extraordinaire demonstrates how to interchange calibrators using object-oriented programming design patterns in Fluke MET/CAL®.

Finally, Dan Wiswell continues his craft in storytelling, by capturing those early years of discovery as we attempted to measure electricity, long before we built the infrastructure we all now take for granted.

Our intention is to cover the various experiences of metrology in each issue, from current events to historical relevance. I hope you'll discover new ways you can experience metrology at work and elsewhere, wherever that may be.

Happy Measuring,

Sita Schwartz, Editor

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1   https://jcgm.bipm.org/vim/en/2.2.html

"MACRO meets NANO in Measurement for Diagnostics, Optimization and Control" to be held in Delft, The Netherlands. https://conferences.imeko.org/event/7/

Sep 27-29, 2023 International Workshop on Applied Measurements for Power Systems (AMPS). Bern, Switzerland. IEEE AMPS 2023 deals with all the aspects related to measurement applications in new power systems and networks (Smart Grids) and has the main goal of encouraging discussion on these topics among experts coming from academia, industry and utilities. https://amps2023.ieee-ims.org/

Nov 6-8, 2023 International Workshop on Metrology for Agriculture and Forestry (MetroAgriFor). Pisa, Italy. Since the first edition, MetroAgriFor intends to create an active and stimulating forum where academics, researchers and industry experts in the field of measurement and data processing techniques for Agriculture, Forestry and Food can meet and share new advances and research results. https://www.metroagrifor.org/

SEMINARS & WEBINARS: Dimensional

Aug 1-2, 2023 Precision Gage Calibration & Repair Training. Virtual. IICT Calibration & Metrology Training. This online, 2-day precision gage and repair training offers specialized training in calibration and repair for the individual who has some knowledge of basic Metrology. https://calibrationtraining.com/

Aug 8-9, 2023 Precision Gage Calibration & Repair Training. Bloomington, MN. IICT Calibration & Metrology Training. This in-person, 2-day precision gage and repair training offers specialized training in calibration and repair for the individual who has some knowledge of basic Metrology. https://calibrationtraining.com/

Aug 15-16, 2023 Dimensional Measurement Tools Basics Class. Minneapolis, MN. QC Training. QC Training Services' Dimensional Measurement Tools – Basics class is an introduction to some of the most common gages used on the shop floor. The purpose is to provide practical instruction on the different tools available and their

proper use to build workers' skill and knowledge. https://qctraininginc.com/class-calendar/

Aug 15-17, 2023 Gage Calibration Methods Class. Cincinnati, OH. QC Training. This 3-day hands-on workshop offers specialized training in calibration and repair for the individual who has some knowledge of basic Metrology. Attendees will be equipped with the knowledge to meet current and future calibration needs, be prepared to save the company money on calibrations, and grow professionally. https://qctraininginc.com/class-calendar/

Aug 15-17, 2023 Dimensional Gage Calibration. Aurora, IL. Mitutoyo America's Gage Calibration course is a unique, active, educational experience designed specifically for those who plan and perform calibrations of dimensional measuring tools, gages, and instruments. https://www.mitutoyo.com/training-education/classroom/

Aug 17-18, 2023 Precision Gage Calibration & Repair Training. Las Vegas, NV. IICT Calibration & Metrology Training. This in-person, 2-day precision gage and repair training offers specialized training in calibration and repair for the individual who has some knowledge of basic Metrology. https://calibrationtraining.com/

Aug 21-22, 2023 Precision Gage Calibration & Repair Training. Oklahoma City, OK. IICT Calibration & Metrology Training. This in-person, 2-day precision gage and repair training offers specialized training in calibration and repair for the individual who has some knowledge of basic Metrology. https://calibrationtraining.com/

Sep 12-14, 2023 Dimensional Gage Calibration. Aurora, IL. Mitutoyo America's Gage Calibration course is a unique, active, educational experience designed specifically for those who plan and perform calibrations of dimensional measuring tools, gages, and instruments. https://www.mitutoyo.com/training-education/classroom/

Sep 14-15, 2023 Precision Gage Calibration & Repair Training. Hartford, CT. IICT Calibration & Metrology Training. This in-person, 2-day precision gage and repair training offers specialized training in calibration and

repair for the individual who has some knowledge of basic Metrology. https://calibrationtraining.com/

Sep 18-19, 2023 Precision Gage Calibration & Repair Training. Cleveland, OH. IICT Calibration & Metrology Training. This in-person, 2-day precision gage and repair training offers specialized training in calibration and repair for the individual who has some knowledge of basic Metrology. https://calibrationtraining.com/

Sep 19-21, 2023 Gage Calibration Methods Class. Cincinnati, OH. QC Training. This 3-day hands-on workshop offers specialized training in calibration and repair for the individual who has some knowledge of basic Metrology. Attendees will be equipped with the knowledge to meet current and future calibration needs, be prepared to save the company money on calibrations, and grow professionally. https://qctraininginc.com/class-calendar/

Sep 21-22, 2023 Precision Gage Calibration & Repair Training. Indianapolis, IN. IICT Calibration & Metrology Training. This in-person, 2-day precision gage and repair training offers specialized training in calibration and repair for the individual who has some knowledge of basic Metrology. https://calibrationtraining.com/

Oct 12-13, 2023 Precision Gage Calibration & Repair Training. Des Moines, IA. IICT Calibration & Metrology Training. This in-person, 2-day precision gage and repair training offers specialized training in calibration and repair for the individual who has some knowledge of basic Metrology. https://calibrationtraining.com/

Oct 17-19, 2023 Gage Calibration Methods Class. Cincinnati, OH. QC Training. This 3-day hands-on workshop offers specialized training in calibration and repair for the individual who has some knowledge of basic Metrology. Attendees will be equipped with the knowledge to meet current and future calibration needs, be prepared to save the company money on calibrations, and grow professionally. https://qctraininginc.com/class-calendar/

Oct 24-25, 2023 Precision Gage Calibration & Repair Training. Virtual. IICT Calibration & Metrology Training. This 2-day, online precision gage and repair training offers specialized training in calibration and repair for the individual who has some knowledge of basic Metrology. https://calibrationtraining.com/

Nov 7-9, 2023 Gage Calibration Methods Class. Cincinnati, OH. QC Training. This 3-day hands-on workshop offers specialized training in calibration and repair for the individual who has some knowledge of basic Metrology. Attendees will be equipped with the knowledge to meet current and future calibration needs, be prepared

to save the company money on calibrations, and grow professionally. https://qctraininginc.com/class-calendar/

Nov 8-9, 2023 Precision Gage Calibration & Repair Training. Madison, WI. IICT Calibration & Metrology Training. This in-person, 2-day precision gage and repair training offers specialized training in calibration and repair for the individual who has some knowledge of basic Metrology. https://calibrationtraining.com/

Nov 15-16, 2023 Precision Gage Calibration & Repair Training. Virtual. IICT Calibration & Metrology Training. This 2-day, online precision gage and repair training offers specialized training in calibration and repair for the individual who has some knowledge of basic Metrology. https://calibrationtraining.com/

Dec 5-6, 2023 Precision Gage Calibration & Repair Training. Bloomington, MN. IICT Calibration & Metrology Training. This in-person, 2-day precision gage and repair training offers specialized training in calibration and repair for the individual who has some knowledge of basic Metrology. https://calibrationtraining.com/

Dec 12-13, 2023 Precision Gage Calibration & Repair Training. Virtual. IICT Calibration & Metrology Training. This 2-day online precision gage and repair training offers specialized training in calibration and repair for the individual who has some knowledge of basic Metrology. https://calibrationtraining.com/

SEMINARS & WEBINARS: Education

Aug 17, 2023 Metric System Education Resources. Adobe Connect Pro. NIST. This 1.5 hour session will explore NIST Metric Program education publications and other resources that can be downloaded and freely reproduced by teachers, parents, and students. These resources are helpful to students as they become familiar with metric units, develop measurement quantity reference points, and learn more about SI basics. https://www.nist.gov/pml/owm/training

SEMINARS & WEBINARS: Electrical

Sep 25-28, 2023 Advanced Hands-On Metrology. Everett, WA. Fluke Calibration. This course introduces the student to advanced measurement concepts and math used in standards laboratories. https://us.flukecal.com/training

Oct 30-Nov 2, 2023 Basic Hands-On Metrology. Everett, WA. Fluke Calibration. This Metrology 101 basic metrology training course introduces the student to basic measurement concepts, basic electronics related to measurement instruments and math used in calibration. https://us.flukecal.com/training
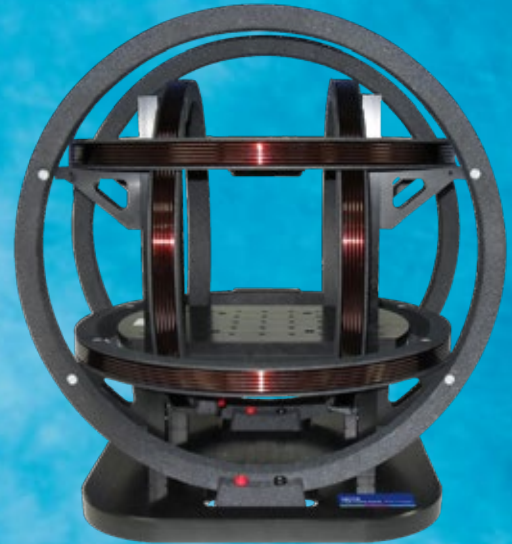
SEMINARS & WEBINARS: Flow

Sep 19-21, 2023 Flow Measurement and Calibration Seminar (in English). Neufahrn, Germany. TrigasFI. Measuring principles of flow meters for liquids and gases. Accuracy, performance, calibration techniques and procedures. Featuring networking event with Lunch hosted at the Munich Oktoberfest. https://www.trigasfi.de/en/training-and-seminars/

Sep 19-22, 2023 Gas Flow Calibration Using molbloc/molbox. Phoenix, AZ. Fluke Calibration. Gas Flow Calibration Using molbloc/molbox is a four day training course in the operation and maintenance of a Fluke Calibration molbloc/molbox system. https://us.flukecal.com/training

SEMINARS & WEBINARS: General

Aug 7-11, 2023 Fundamentals of Metrology. Gaithersburg, MD. The 5-day Fundamentals of Metrology seminar is an intensive course that introduces participants to the concepts of measurement systems, units, good laboratory practices, data integrity, measurement uncertainty, measurement assurance, traceability, basic statistics and how they fit into a laboratory Quality Management System. https://www.nist.gov/pml/owm/training

Aug 22-23, 2023 Measurement System Analysis. Minneapolis, MN. QC Training. In our Measurement Systems Analysis training, attendees will discover the amounts and types of variations that exist in measurement systems, to ensure that product acceptance or process control decisions are based on "good data." Students will learn how to conduct studies to evaluate variability due to bias, repeatability, reproducibility, stability, and linearity. https://qctraininginc.com/class-calendar/

Sep 1, 2023 Calibration and Measurement Fundamentals. Online. National Measurement Institute, Australia. This course covers general metrological terms, definitions and explains practical concept applications involved in calibration and measurements. The course is recommended for technical officers and laboratory technicians working in all

industry sectors who are involved in making measurements and calibration process. https://shop.measurement.gov.au/collections/physical-metrology-training

Oct 16-20, 2023 Fundamentals of Metrology. Gaithersburg, MD. NIST. The 5-day Fundamentals of Metrology seminar is an intensive course that introduces participants to the concepts of measurement systems, units, good laboratory practices, data integrity, measurement uncertainty, measurement assurance, traceability, basic statistics and how they fit into a laboratory Quality Management System. https://www.nist.gov/news-events/events/2023/10/5873-fundamentals-metrology

Dec 1, 2023 Calibration and Measurement Fundamentals. Online. National Measurement Institute, Australia. This course covers general metrological terms, definitions and explains practical concept applications involved in calibration and measurements. The course is recommended for technical officers and laboratory technicians working in all industry sectors who are involved in making measurements and calibration process. https://shop.measurement.gov.au/collections/physical-metrology-training

SEMINARS & WEBINARS: Industry Standards

Sep 12-13, 2023 Laboratories: Understanding the Requirements and Concepts of ISO/IEC 17025:2017. Live Online. ANAB. This introductory course is specifically designed for those individuals who want to understand the requirements of ISO/IEC 17025:2017 and how those requirements apply to laboratories. https://anab.ansi.org/training

Sep 12-14, 2023 Internal Auditing to ISO/IEC 17025:2017 (Non-Forensic). Live Online. ANAB. ISO/IEC 17025 training course prepares the internal auditor to clearly understand technical issues relating to an audit. Attendees of Auditing to ISO/IEC 17025 training course 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/training

Sep 13-14, 2023 Understanding ISO/IEC 17025 for Testing and Calibration Labs. Scheduled online for M-East India and South Asia. This 2-day Training Course examines structural components of the standard. Quality system and technical requirements are grouped in a manner that makes them clear and understandable. https://www.iasonline.org/training/ias-training-schedule/

Oct 3-4, 2023 Understanding ISO/IEC 17025 for Testing and Calibration Labs. Scheduled online for the Americas. This 2-day Training Course examines structural components of the standard. Quality system and technical requirements are grouped in a manner that makes them clear and understandable. https://www.iasonline.org/training/ias-training-schedule/

Oct 11-12, 2023 Internal Auditing for all Standards. Scheduled online for M-East India and South Asia. IAS. This 2-day Training Course examines auditing principles and techniques and facilitates the practice of required internal audit skills. It is based on internationally-recognized approaches to conducting conformant internal audits. The techniques learned by participants promote the involvement of all types of staff as auditors and auditees. https://www.iasonline.org/training/ias-training-schedule/

Nov 1-2, 2023 Internal Auditing for all Standards. Scheduled online for the Americas. IAS. This 2-day Training Course examines auditing principles and techniques and facilitates the practice of required internal audit skills. It is based on internationally-recognized approaches to conducting conformant internal audits. https://www.iasonline.org/training/ias-training-schedule/

Nov 14-15, 2023 Understanding ISO/IEC 17025:2017 for Testing and Calibration Laboratories. Online. A2LA Workplace Training. This course is a comprehensive review of the philosophies and requirements of ISO/IEC 17025:2017. The participant will gain an understanding of conformity assessment using the risks and opportunities-based approach. https://www.a2lawpt.org/events

Nov 16-17, 2023 Auditing Your Laboratory to ISO/IEC 17025:2017. Online. A2LA Workplace Training. This ISO/IEC 17025 auditor training course will introduce participants to ISO/IEC 19011, the guideline for auditing management systems as applied to ISO/IEC 17025:2017. The participant will learn about auditing principles and develop skills for performing higher-value internal audits. https://www.a2lawpt.org/events

Dec 4-7, 2023 Understanding ISO/IEC 17025:2017 for Testing and Calibration Laboratories. Online. A2LA WorkPlace Training. This course is a comprehensive review of the philosophies and requirements of ISO/IEC 17025:2017. The participant will gain an understanding of conformity assessment using the risks and opportunities-based approach. https://www.a2lawpt.org/events

Dec 5-6, 2023 Laboratories: Understanding the Requirements and Concepts of ISO/IEC 17025:2017. Online. ANAB. This introductory course is specifically designed for those individuals who want to understand the requirements of ISO/IEC 17025:2017 and how those requirements apply to laboratories. https://anab.ansi.org/training

Dec 5-6, 2023 Understanding ISO/IEC 17025 for Testing and Calibration Labs. Online. IAS. This 2-day Training Course examines structural components of the standard. See the published syllabus. Quality system and technical requirements are grouped in a manner that makes them clear and understandable. https://www.iasonline.org/training/ias-training-schedule/

Dec 11-14, 2023 Auditing Your Laboratory to ISO/IEC 17025:2017. Online. A2LA Workplace Training. This ISO/IEC 17025 auditor training course will introduce participants to ISO/IEC 19011, the guideline for auditing management systems as applied to ISO/IEC 17025:2017. The participant will learn about auditing principles and develop skills for performing higher-value internal audits. https://www.a2lawpt.org/events

SEMINARS & WEBINARS: Mass

Oct 23-Nov 3, 2023 Mass Metrology Seminar. Gaithersburg, 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. https://www.nist.gov/pml/owm/training

SEMINARS & WEBINARS: Measurement Uncertainty

Aug 7-9, 2023 Introduction to Measurement Uncertainty. Everett, WA. Fluke Calibration. This course will teach you how to develop uncertainty budgets and how to understand the necessary calibration processes and techniques to obtain repeatable results. https://us.flukecal.com/training

Aug 9, 2023 Measurement, Uncertainty and Calibration Workshop. Lower Hutt, NZ. Measurement Standards Laboratory of New Zealand. This course gives a broad high-level overview of measurement and calibration principles, and calculation of uncertainty. https://www.measurement.govt.nz/training/

Fluke 5560A High Performance Multi-Product Calibrator

The broadest electrical workload coverage and highest accuracy

Calibrate meters that measure AC/DC volts, current resistance, capacitance, and inductance all with the same calibrator. Featuring 30 A continuous current output with extended AC/DC measurement ranges and a 4:1 test TUR for the most popular 6.5-digit multimeters, this new class of multi-product calibrators can calibrate the most demanding workloads.

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Calibration

Learn more
us.flukecal.com/5560A

Aug 22&24, 2023 Introduction to Estimating Measurement Uncertainty. Online Delivery. Australian NMI. This course will give you a clear step-by-step approach to uncertainty estimation with practical examples; you will learn techniques covering the whole process from identifying the sources of uncertainty in your measurements right through to completing the uncertainty budget. https://shop.measurement.gov.au/collections/physical-metrology-training

Aug 23, 2023 Measurement, Uncertainty and Calibration Workshop. Auckland, NZ. Measurement Standards Laboratory of New Zealand. This course gives a broad high-level overview of measurement and calibration principles, and calculation of uncertainty. https://www.measurement.govt.nz/training/

Aug 28-29, 2023 Measurement Uncertainty Budgets Class. Milwaukee, WI. QC Training. This workshop presents a combination of lecture and classroom exercises to demonstrate the principles of measurement uncertainty analysis. https://qctraininginc.com/class-calendar/

Sep 7-8, 2023 Measurement Uncertainty Budgets Class. Minneapolis, MN. QC Training. This workshop presents a combination of lecture and classroom exercises to demonstrate the principles of measurement uncertainty analysis. https://qctraininginc.com/class-calendar/

Sep 13-14, 2023 Measurement Confidence: Fundamentals. Online. ANAB. This Measurement Confidence course introduces the foundational concepts of measurement traceability, measurement assurance and measurement uncertainty as well as provides a detailed review of applicable requirements from ISO/IEC 17025 and ISO/IEC 17020. https://anab.ansi.org/training

Sep 14, 2023 Basic Uncertainty Concepts. 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/2023/09/5872-basic-uncertainty-concepts

Sep 26-28, 2023 Measurement Uncertainty: Practical Applications. Live Online. ANAB. This course reviews the basic concepts and accreditation requirements associated with measurement traceability, measurement assurance, and measurement uncertainty as well as their interrelationships. https://anab.ansi.org/training

Dec 4, 2023 Introduction to Measurement Uncertainty. Online. A2LA WorkPlaceTraining. This course is a suitable introduction for both calibration and testing laboratory participants, focusing on the concepts and mathematics of the measurement uncertainty evaluation process. The participant will gain an understanding of the statistical techniques required to estimate measurement uncertainty, and will practice those skills to create basic uncertainty budgets. https://www.a2lawpt.org/events

Dec 4-5, 2023 Measurement Confidence: Fundamentals. Online. ANAB. This Measurement Confidence course introduces the foundational concepts of measurement traceability, measurement assurance and measurement uncertainty as well as provides a detailed review of applicable requirements from ISO/IEC 17025 and ISO/IEC 17020. https://anab.ansi.org/training

Dec 13-15, 2023 Measurement Uncertainty: Practical Applications. Live Online. ANAB. This course reviews the basic concepts and accreditation requirements associated with measurement traceability, measurement assurance, and measurement uncertainty as well as their interrelationships. https://anab.ansi.org/training

SEMINARS & WEBINARS:
Photometry & Radiometry

Aug 7, 2023 Spectrophotometer Calibration Workshop. Lower Hutt, NZ. Measurement Standards Laboratory of New Zealand. This course covers the calibration of benchtop spectrophotometers, including wavelength accuracy, photometric accuracy and stray light characterisation. It is highly interactive and includes hands-on sessions to develop practical skills. https://www.measurement.govt.nz/training/

CALENDAR

SEMINARS & WEBINARS: Pressure

Aug 8, 2023 Pressure Calibration Workshop. Lower Hutt, NZ. Measurement Standards Laboratory of New Zealand. This workshop is a practical one-day session dealing with all aspects of pressure gauge and transducer calibration. https://www.measurement.govt.nz/training/

Aug 14-18, 2023 Principles of Pressure Calibration Web-Based Training. Fluke Calibration. This is a short form of the regular five-day in-person Principles of Pressure Calibration class. It is modified to be an instructor-led online class and without the hands-on exercises. It is structured for two hours per day for one week. https://us.flukecal.com/training

Aug 22, 2023 Pressure Calibration Workshop. Auckland, NZ. Measurement Standards Laboratory of New Zealand. This workshop is a practical one-day session dealing with all aspects of pressure gauge and transducer calibration. https://www.measurement.govt.nz/training/

Oct 2-6, 2023 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). https://us.flukecal.com/training

Oct 16-20, 2023 Advanced Piston Gauge Metrology. Phoenix, AZ. Fluke Calibration. Focus is on the theory, use and calibration of piston gauges and dead weight testers. https://us.flukecal.com/training

SEMINARS & WEBINARS: Software

Aug 14-18, 2023 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. https://us.flukecal.com/training

Sep 11-15, 2023 Advanced MET/CAL® Procedure Writing. Everett, WA. Fluke Calibration. A five-day procedure writing course for advanced users of MET/CAL® calibrations software. https://us.flukecal.com/training

Oct 2-6, 2023 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. https://us.flukecal.com/training

Oct 9-13, 2023 MET/CAL® Procedure Development Web-Based Training. Fluke Calibration. Learn to create procedures with the latest version of MET/CAL, without leaving your office. This web seminar is offered to MET/CAL users who need assistance writing procedures but have a limited travel budget. https://us.flukecal.com/training

Oct 16-20, 2023 MET/TEAM® Asset Management. Everett, WA. Fluke Calibration. This five-day course presents a comprehensive overview of how to use MET/TEAM® Test Equipment and Asset Management Software in an Internet browser to develop your asset management system. https://us.flukecal.com/training

Nov 7-9, 2023 VNA Tools Training Course. Berne-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

Nov 13-17, 2023 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. https://us.flukecal.com/training

Nov 13-17, 2023 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. https://us.flukecal.com/training

SEMINARS & WEBINARS: Temperature & Humidity

Aug 7, 2023 Infrared Radiation Thermometry Workshop. Lower Hutt, NZ. Measurement Standards Laboratory of New Zealand. This is a practical course covering problems with the use and calibration of infrared radiation thermometers, including reflections, absorption, emissivity, and instrumental effects. https://www.measurement.govt.nz/training/

Aug 10, 2023 Temperature Measurement and Calibration Workshop. Lower Hutt, NZ. Measurement Standards

Calibrating Sanitary Sensors Just Got Simpler!

Sanitary Sensors found in the pharmaceutical and food industries have traditionally been some of the most challenging sensors to calibrate, as they must be perfectly placed in the uniform zone of the calibrator. The new JOFRA RTC-168 Reference Temperature Calibrator provides a solution with a new well design, redesigned sensor basket, and a temperature equalizer that combine to create an extended uniformity zone resulting in improved, highly accurate liquid calibrations

■ Patented DLC (Dynamic Load Compensation) system for perfect temperature uniformity in the insert.

■ Redesigned liquid basket vertically extends the temperature uniformity zone.

■ Industry first reverse airflow system protects the sensor under test from excess heat.

■ Special sanitary sensor insert supports small sensing cables.

■ Intuitive, fast, and user-friendly navigation.

■ USB connector for communication.

■ High profile design and well-known, long lasting JOFRA quality.

All-In-One Solution

The RTC-168 is more than just a wet bath calibrator. With its revolutionary removable liquid container you can switch from wet to dry calibration in just minutes, with temperature ranges from -30° to 165°C in both wet and dry configurations.

The JOFRA RTC-168

www.ametekcalibration.com

Laboratory of New Zealand. This course covers the use, care, and calibration of liquid-in-glass, platinum resistance, thermocouple, and radiation thermometers. https://www.measurement.govt.nz/training/

Aug 11, 2023 Humidity and Moisture Calibration Workshop. Lower Hutt, NZ. Measurement Standards Laboratory of New Zealand. This practical one-day course will introduce you to humidity generation, calibration, and measurement, along with the conceptual framework for understanding the various limitations in humidity measurements. https://www.measurement.govt.nz/training/

Aug 22-24, 2023 Temperature Measurement. Lindfield NSW. NMI Australia. This three-day course (9 am to 5 pm) covers the measurement of temperature and the calibration of temperature measuring instruments. It incorporates extensive hands-on practical exercises. https://shop.measurement.gov.au/collections/physical-metrology-training

Aug 24, 2023 Temperature Measurement and Calibration Workshop. Auckland, NZ. Measurement Standards

Laboratory of New Zealand. This course covers the use, care, and calibration of liquid-in-glass, platinum resistance, thermocouple, and radiation thermometers. https://www.measurement.govt.nz/training/

Aug 25, 2023 Humidity and Moisture Calibration Workshop. Auckland, NZ. Measurement Standards Laboratory of New Zealand. This practical one-day course will introduce you to humidity generation, calibration, and measurement, along with the conceptual framework for understanding the various limitations in humidity measurements. https://www.measurement.govt.nz/training/

Aug 25, 2023 Infrared Radiation Thermometry Workshop. Auckland, NZ. Measurement Standards Laboratory of New Zealand. This is a practical course covering problems with the use and calibration of infrared radiation thermometers, including reflections, absorption, emissivity, and instrumental effects. https://www.measurement.govt.nz/training/

Sep 11-13, 2023 Advanced Topics in Temperature Metrology. American Fork, UT. Fluke Calibration. 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

Oct 16-18, 2023 Practical Temperature Calibration. American Fork, UT. Fluke Calibration. A three-day course loaded with valuable principles and hands-on training designed to help calibration technicians and engineers get a solid base of temperature calibration fundamentals. https://us.flukecal.com/training

SEMINARS & WEBINARS: Vibration

Nov 7-9, 2023 Fundamentals of Random Vibration and Shock Testing. Newark, CA. This three-day Training in Fundamentals of Random Vibration and Shock Testing covers all the information required to plan, perform, and interpret the results of all types of dynamic testing. Some

of the additional areas covered are fixture design, field data measurement and interpretation, evolution of test standards and HALT/HASS processes. https://equipment-reliability.com/open-courses/

SEMINARS & WEBINARS: Weight

Aug 22, 2023 Balances and Weighing Workshop. Auckland, NZ. Measurement Standards Laboratory of New Zealand. This course provides training to assist laboratory personnel demonstrate quality assurance in their measurements. https://www.measurement.govt.nz/training/

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

Domestic Gas Meters Suitable for Hydrogen

Measurements are within all maximum permissible errors

PTBnews 2.2023 — As part of preparations for pilot projects in which private households will be supplied with hydrogen via the normal natural gas grid, PTB investigated whether the devices currently used for natural gas metering would also be suitable for hydrogen. The results show that all maximum permissible errors are complied with.

In order to ensure sufficient energy supplies and to reduce carbon dioxide emissions, the use of hydrogen, which would include injecting it into the natural gas grid, is becoming more and more important. The question that arises here is whether the meters widely used in private households are suitable for correctly measuring hydrogen-methane mixtures and pure hydrogen according to legal regulations.

To prepare for the transition to hydrogen in the public gas supply system, the *Deutscher Verein des Gas und Wasserfaches* (DVGW, the German Technical and Scientific Association for Gas and Water) is testing the injection of up to 20 % hydrogen (H_2) into suitable grids as part of a research project. Here, it is economically relevant whether the diaphragm gas meters currently in place can continue to be used. This is only possible if they remain within the maximum permissible errors, i.e., if they can measure with sufficient accuracy. The domestic gas pressure regulator valves connected upstream of the diaphragm gas meters also have to work reliably under changing flow rates and gas mixtures.

PTB has tested a total of six new diaphragm gas meters with two domestic gas pressure regulator valves (each from a different manufacturer) in various combinations as regards measurement errors and control accuracy at flow rates ranging from 40 l/h to 10 m^3/h. As diaphragm gas meters are calibrated with air during the manufacturing process, the meters under test were also calibrated with air, nitrogen and pure methane, the main component of natural gas.

The results show that the maximum permissible errors of the diaphragm gas meters over the entire flow rate range of ± 1.5 % in the upper and ± 3 % in the lower range (as per EN 1359) are complied with when the meters are supplied either with pure hydrogen or with a 20 % or 30 % (mole fraction) blend of hydrogen in methane. No systematic differences were observed here. The meters can continue to be adjusted with air during the manufacturing process. The control characteristics of domestic gas pressure regulator valves are also independent of the gas type over the entire flow rate range. The results and experience gained will be taken into account in a follow-up project that will include similar tests being conducted on industrial meters that have been installed in the grid for at least one calibration interv

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Project website: Investigation of the behavior of domestic supply meters in connection with domestic gas pressure regulator valves when blending H_2 in other gases (DVGW research project G 202010): https://www.dvgw.de/themen/forschung-und-innovation/forschungsprojekte/dvgw-forschungsprojekt-h2-messrichtigkeit

Source: https://www.ptb.de/cms/en/presseaktuelles/journals-magazines/ptb-news.html
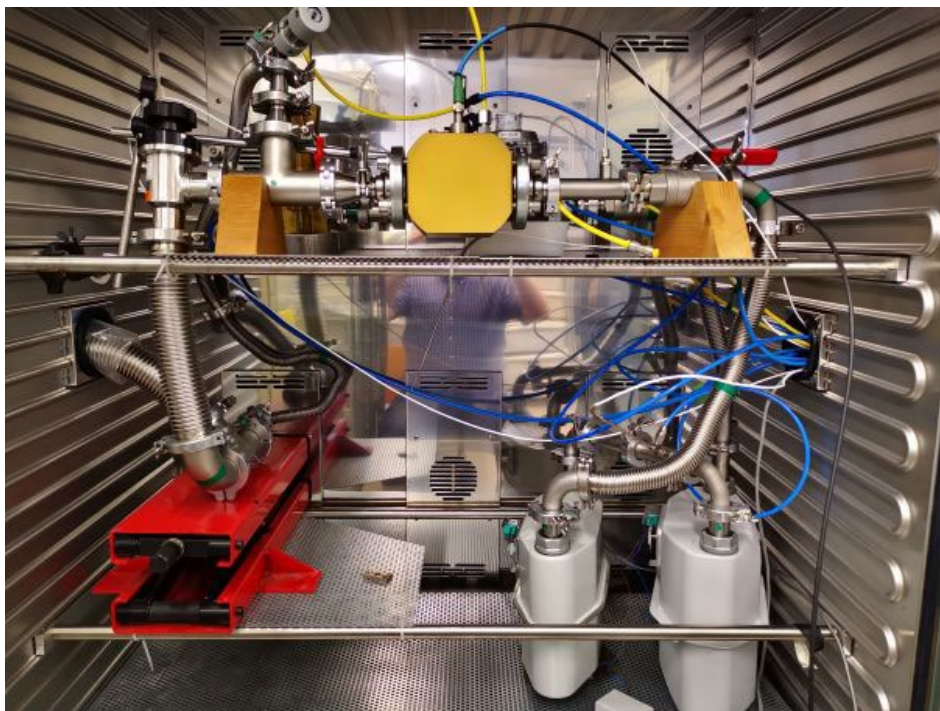
Test setup for determining the measurement errors of diaphragm gas meters and the control accuracy of domestic gas pressure regulator valves with various gases and gas mixtures. Credit: PTB

NAAF Formed to Support Regional and Global Conformity Assessment

Fri Jun 09 2023 — The North American Accreditation Forum (NAAF) has been established by accreditation bodies in North America to provide a platform for accreditation bodies, industry associations and companies to promote the exchange of knowledge, ideas, and views on conformity assessment and accreditation in support of the principles of the WTO and USMCA. As a nonprofit organization, the mission of NAAF is to "…promote confidence in accreditation in support of global free and fair trade."

The founding members of NAAF include Accreditation Canada Diagnostics, AIHA Laboratory Accreditation Programs, American Association for Laboratory Accreditation (A2LA), ANSI National Accreditation Board (ANAB), Canadian Association for Laboratory Accreditation (CALA), entidad mexicana de acreditación (ema), International Accreditation Service (IAS), National Voluntary Laboratory Accreditation Program (NVLAP), Perry Johnson Laboratory Accreditation (PJLA), Standards Council of Canada (SCC), and United Accreditation Foundation (UAF). The accreditation body members of NAAF provide accreditation for testing laboratories, calibration laboratories, inspection agencies and certification bodies, among others.

The founding members of NAAF are signatories to international arrangements such as the International Laboratory Accreditation Cooperation (ILAC) and/or International Accreditation Forum (IAF), as well as signatories to the Asia Pacific Accreditation Cooperation (APAC) and/or the IAAC (Inter-American Accreditation Cooperation) - organizations whose purpose is to reduce technical barriers between countries through mutual recognition of accreditation bodies results based on peer reviews conducted by other signatory members. In addition to supporting the reduction of barriers and mutual recognition of accreditation bodies, NAAF will promote open and competitive conformity assessment activities worldwide among accreditation bodies, providing customers and conformity assessment bodies with choice and access to competent accreditation services facilitating domestic and international trade. NAAF will work to facilitate global fair trade as described in the WTO (World Trade Organization) and United States-Mexico-Canada Agreement (USMCA)

CAL-TOONS by Ted Green   teddytoons@icloud.com

CARL'S SECRET FOR RESURRECTING TEST EQUIPMENT? AN I.V. OF LIQUID SMOKE.

principles. Today, June 9, 2023, is World Accreditation Day and the theme "Accreditation: Supporting the Future of Global Trade" illustrates how standards, regulations, metrology and accredited conformity assessment create the quality infrastructure needed for global trade as supported by NAAF's mission and objectives. For more information about NAAF, visit www.na-af.org.

Source: https://www.na-af.org/news

New CCL-CCTF Application Programming Interface Prototype Web Service is Now Available

The BIPM Time Department launched a new prototype service on 19 June 2023. The list of recommended values of standard frequencies for applications, including the practical realization and secondary representations of the definition of the metre and of the second, have become machine-readable. Previously, the mises en pratique for the metre and the second were accessible from the BIPM website exclusively as PDF files.

The Consultative Committee communities in length (CCL) and time and frequency (CCTF) expressed the need to access data in a machine-readable format.[1] The BIPM Time Department consequently initiated a digital transformation project to automate the data retrieval process by means of a dedicated database and Application Programming Interface (API). The first phase of the project consists of the provision of data in XML format, including: values and uncertainties of the standard frequencies approved for the mise en pratique, authority approval, date of approval, and requirements to achieve specified uncertainty levels.

The current version of the CCL-CCTF API web service (https://webtai.bipm.org/api/ccl-cctf/v1.0/index.html) is a prototype intended for thorough testing, and user feedback is highly encouraged.

The BIPM Time Department acknowledges the support of Dr Andrew Lewis (NPL) and Dr Andrew Lancaster (NPL) for having kindly provided the XML scheme.

Source: BIPM News, https://www.bipm.org/en/-/2023-06-20-ccl-cctf-api.

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1   "A Digital Framework for Realising the SI—A Proposal or the Metre," https://iopscience.iop.org/article/10.1088/1681-7575/ac7fce

How to Calibrate Thermometry Bridges: Ensuring Accurate Temperature Measurements

David Southworth

Isothermal Technology Ltd.

Introduction

Thermometry bridges play a crucial role in temperature measurement, particularly when it comes to the interpolation of the Standard Platinum Resistance Thermometer (SPRT) specified by the ITS-90. However, to achieve precise and reliable results, it is essential to calibrate these bridges accurately. In this article, we will explore the history of bridge calibration, common methods used for verification, and introduce a solution known as the Resistance Bridge Calibrator (RBC) developed by Rod White at MSL New Zealand [1].

The Linearity Check: A Simple Starting Point

One straightforward method for checking the accuracy of a resistance bridge involves measuring two resistors separately and then measuring them in series. Ideally, the series measurement should equal the sum of the individual measurements. This linearity check provides an initial assessment of the bridge's performance and its ability to deliver accurate readings.

Complement Checks: Assessing Reciprocity

Another convenient way to evaluate a bridge is through complement or reciprocal checks. By connecting a resistor to the "reference side" of the bridge (Rs) and another resistor to the unknown side (Rx), one can compare the two reciprocal ratios. If properly calibrated, the product of these ratios should be unity, indicating accurate bridge performance.

Verifying Performance over the Entire Range: The Challenge

While linearity and complement checks are valuable tools, they are not sufficient for verifying bridge performance over a wide measurement range. Standard resistors with the necessary tolerance and stability are limited in availability, making it challenging to cover the entire operating range. Also, assuming that the bridge meets specifications from limited tests at a limited number of points can be risky.

Introducing the Resistance Bridge Calibrator (RBC): A Solution to Overcome the Limitations of Traditional Calibration Methods

Rod White developed the Resistance Bridge Calibrator (RBC). This innovative device utilizes a network of four base resistors that can be switched in various series parallel combinations, allowing for the realization of 35 distinct four-terminal resistances.
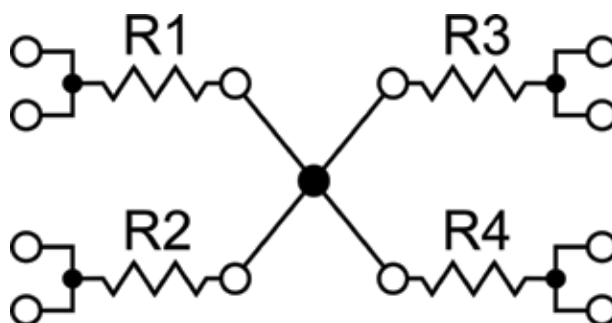
Figure 1. The Four Base Resistors
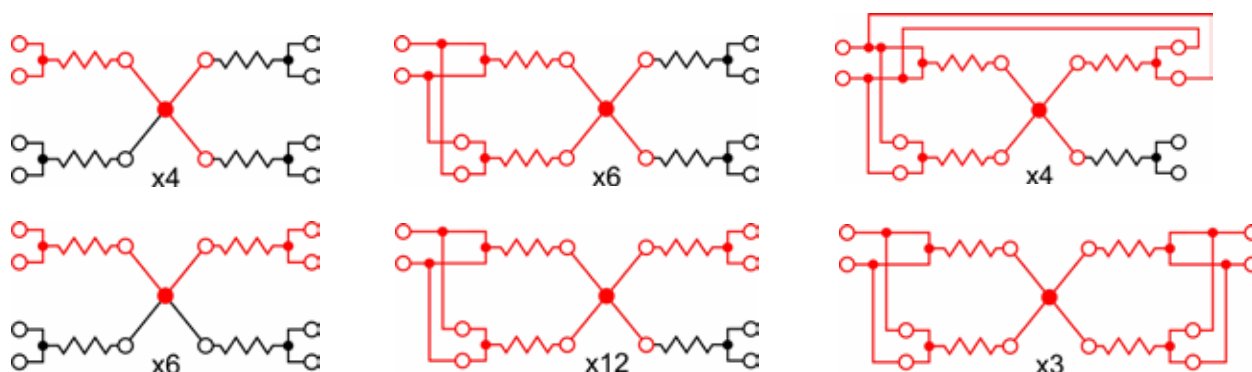
Figure 2. The 35 available connections from parallel series connections

In order to ensure the current divides in proportion to the conductance of the resistors and the potentials are averaged correctly, it is necessary to use both current and potential sharing resistors.

Tremendous care is needed at the common zero-ohm point; even small variations in the PCB material can limit the performance. The principle is simple, but the implementation is demanding.

Up to 70 Ratio Values

When combined with a single reference resistor and reciprocal measurements, a total of 70 ratios can be generated to measure bridge performance across the entire operating range.

A Sample Test Report

The software allows the desired ratio values to be selected. Here we are using 34 ratio values, no complements (Figure 4).

As well as automatically gathering the readings and calculating the fitted values and residuals, we can plot the bridge linearity (Figure 5).

The uncertainty can be calculated and a certificate printed.

Standard deviation of residuals: 1.033×10^{-8}

Standard uncertainty in the corrected readings: 1.033×10^{-8}

Number of fitted parameters: 4

Number of readings: 34

Number of degrees of freedom: 30

Expanded uncertainty in the corrected readings at the 95 % level of confidence: 2.110×10^{-8}

Coverage factor: 2.04

History and Development of the RBC

Initially, the RBC underwent rigorous testing on 38 different resistance bridges, including both AC and DC types. The results revealed that one in five of the tested bridges were faulty, indicating the need for a reliable calibration solution. The concept of the RBC, with its four base resistors and versatile connections, proved to be a simple yet effective approach.

Figure 3.

Figure 4.

Temperature Control: Minimizing Uncertainty

The RBC's uncertainty is primarily influenced by the temperature coefficients of the resistors and ambient temperature variations. The resistors used in the RBC are carefully selected, offering temperature coefficients within ±0.3 ppm/°C at temperatures ranging from 20 °C to 23 °C. To maintain accuracy, it is recommended to operate the RBC in a laboratory
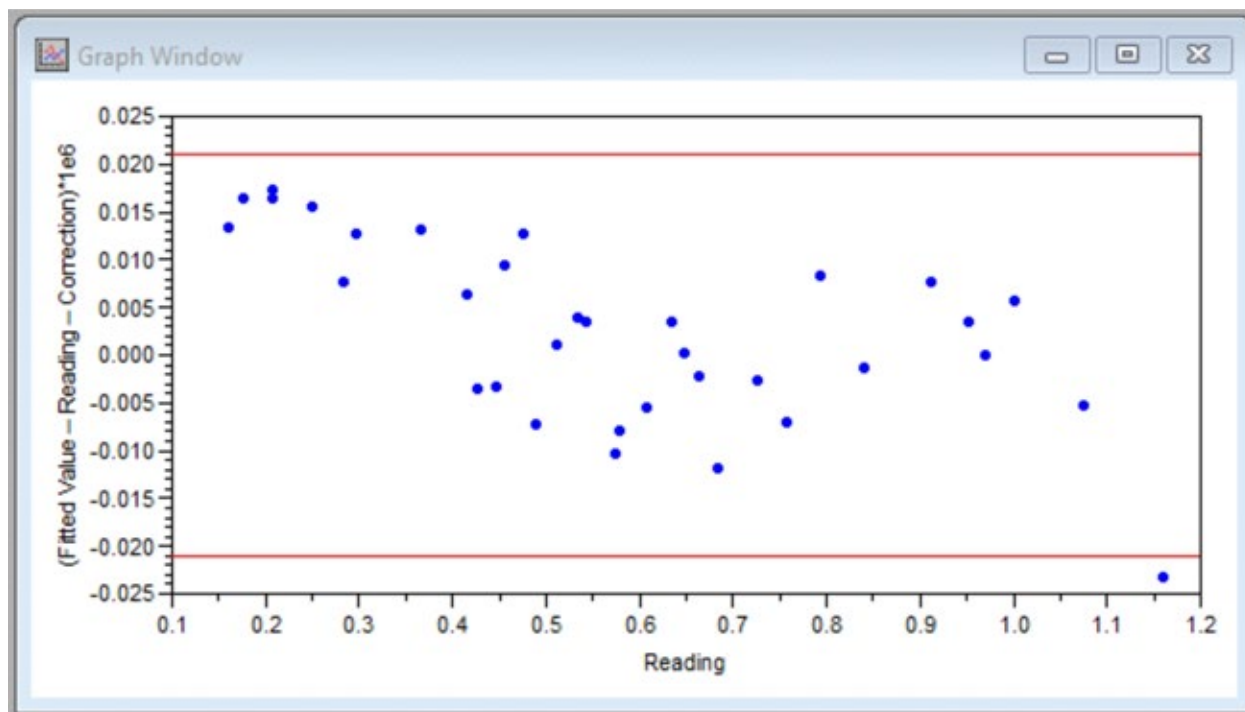
Figure 5.

with precise temperature control, minimizing variations and ensuring optimal performance within the practical limits.

Further Development

The Automatic Resistance Bridge Calibrator builds upon the success of the manual RBC, leading to an improved version introduced as the RBCA. This automated model offers several benefits, including the ability to be placed into a temperature-controlled oil or air bath, effectively overcoming the temperature coefficient limitation. With enhanced internal circuitry, the Automatic Resistance Bridge achieves an impressive accuracy of 0.01 ppm (at 100 Ω). Additionally, automated operation eliminates the need for manual data capture and entry, streamlining the calibration process.

Results and Future Applications

The performance of resistance bridges, including the RBC, has been subject to comprehensive analysis. Researchers, such as Jon Pearce et al. at NPL, have published papers characterizing the performance of AC and DC resistance bridges [2].

References

[1] White D.R., A Method for Calibrating Resistance Bridges. Proceedings TEMPMEKO 1996, 129-134.

[2] Pearce, J.V., Gray, J. & Veltcheva, R.I. Characterisation of a Selection of AC and DC Resistance Bridges for Standard Platinum Resistance Thermometry. *Int J Thermophys* 37, 109 (2016). https://doi.org/10.1007/s10765-016-2113-6

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A Better Way to MET/CAL®
With a Twist of Object-Oriented Programming

Michael L. Schwartz

Cal Lab Solutions, Inc.

Fluke MET/CAL® is a great tool for automation, but it is dated. Over the last 40 years, how we write, support, and maintain software has changed dramatically! We have moved from a single-core 8086 microprocessor to ultra-powerful multi-core 64-bit computers. And though much of MET/CAL's core technology is dated, that doesn't mean we, as programmers, can't apply better software development techniques to write better automation.

One of the best software techniques to use in MET/CAL comes from Object Oriented Programming (OOP). Though these techniques work best in OOP-based languages, they can be applied to script-based languages like MET/CAL. In this paper, we will use OOP design patterns, creating a pseudo-driver for the Meatest 9010.

Then we will show the flexibility of the OOP Abstract Factory Pattern and how it allows us to interchange calibrators like the Fluke 5500A, 5520A, 5522A, 5540A, 5550A, 5560A, 5700A, 5720A, 5730A with the Meatest 9010, with no changes to the UUT Test Procedure.

1. Introduction

Many users have hardware that is not supported by their current version of MET/CAL. If you have a 9.x Version or lower, there is no support for the new 5540A, 5550A, or 5560A. And if you have a Meatest or Transmille calibrator, there is no MET/CAL support for their hardware.

This paper will show you how to create a pseudo-driver in MET/CAL to support your lab's new hardware in your current version of MET/CAL and how to structure the rest of your procedure to support flexible standards.

We will detail creating a MET/CAL procedure to calibrate AC voltage on a Keysight 34450A using a Meatest 9010. The full procedure will be available for free, along with the 9010 drivers, from the Cal Lab Solutions procedure store: https://store.CalLabSolutions.com.

2. Design Patterns

Elements of Reusable Object-Oriented Software (1994) is a software engineering book describing software design patterns. The book was written by Erich Gamma, Richard Helm, Ralph Johnson, and John Vlissides, with a foreword by Grady Booch. The book contains chapters describing 23 classic software design patterns, including examples: https://en.wikipedia.org/wiki/Design_Patterns.

The book as a whole is a great read, and the patterns in the book cover many of the problems software developers are faced with on a daily basis. In this paper, we are not going to cover all 23 design patterns. Instead, we are going to focus on Abstract Class Factory and how we implemented it in MET/CAL.

2.1 Abstract Class Factory

The Abstract Class Factory is a design that provides a way to create families of like objects without imposing their concrete class by encapsulating a group of individual factories that have a common theme without specifying their concrete class; meaning, we want to create and communicate with the object's abstraction instead of the object specifically.

In metrology terms, we want to talk to a family of reference standards that can Source AC Voltage instead of a specific standard like a Fluke 5520A or Meatest 9010. When the procedure needs an AC voltage reference standard, the abstract class factory will provide one.

In MET/CAL, this is a conceptual change moving away from the FSC-based instrument-specific commands like:

```
5520    3.5V        1kH     SI S 2W
  or
5720    3.5V        1kH      S 2W
```

To an abstract representation defining the abstract requirements: "Volts= 3.5, Frequency= 1e3."

Where the Voltage and Frequency values are passed to a pseudo-driver, that converts the abstract requirements to instrument-specific commands.

3. Development Standards

To pull all of this together, we have to talk about the Cal Lab Solutions MET/CAL development standards. We have been using this development standard, with minor changes, for more than 20 years now. It has stood the test of time, and it allows us to support customers who want to use the new Fluke 8588A DMM in their MET/CAL version 7.11.

3.1 Main Procedure

Every MET/CAL procedure needs a Main procedure. This is the starting point for the automation. The Main procedure provides two major operations:

1. Controls Order of Procedure execution

2. Controls Order of Printed results

Below is a short sample of a Main Procedure.

```
================================================================================
INSTRUMENT:          Agilent 34450A : Digital Multimeter (Ver)
DATE:                2023-05-30 10:59:08
AUTHOR:              Cal Lab Solutions
REVISION:            $Revision: $
ADJUSTMENT THRESHOLD: 80%
NUMBER OF TESTS:     17
NUMBER OF LINES:     361
================================================================================
STEP     FSC    RANGE NOMINAL          TOLERANCE     MOD1        MOD2 3  4 CON
  1.001  ASK-   R     N                P                              F       W
  1.002  ASK+                                         X                 L  T


# Setup the Station
  1.003  HEAD          * SETTING THINGS UP *
  1.004  MATH          S[30]="PreCal.Steps"
  1.005  CALL          Agilent 34450A Sub Config

# Rest the UUT
  1.006  MATH          S[30]="Reset"
  1.007  CALL          Agilent 34450A Sub Tools
………….
# Setup the Station
  2.021  HEAD          * Configuring Station *
  2.022  MATH          S[30]="Station.Setup"
  2.023  CALL          Agilent 34450A Sub Config

# SelfTest
  2.024  JMPL          SelfTest
  2.025  LABEL         SelfTest_Done
…………..
```

```
#==================== * End to End Sequencer * =======================
  2.032  JMPL          Start_sequencer
  2.033  EVAL    Copyright Cal Lab Solutions  All rights reserved.
  3.001  LABEL         Start_sequencer


  3.002  JMPL          ZeroOffsetVerificationFront1Year
  3.003  LABEL         ZeroOffsetVerificationFront1Year_done
  3.004  JMPL          DCVoltsGainVerification
  3.005  LABEL         DCVoltsGainVerification_done
  3.006  JMPL          ACVoltsVerification
  3.007  LABEL         ACVoltsVerification_done
  3.008  JMPL          CapacitanceVerification
  3.009  LABEL         CapacitanceVerification_done
  3.010  JMPL          OhmsGainVerification
  3.011  LABEL         OhmsGainVerification_done
  3.012  JMPL          DCCurrentGainVerification
  3.013  LABEL         DCCurrentGainVerification_done
  3.014  JMPL          ACCurrentVerification
  3.015  LABEL         ACCurrentVerification_done
  3.016  JMPL          FreqGainVerification
  3.017  LABEL         FreqGainVerification_done
  3.018  JMPL          Verification_Complete
  3.019  EVAL    Copyright Cal Lab Solutions  All rights reserved.
………………..


#====================================================================
  5.001  LABEL         SelfTest
  5.002  HEAD          { * INTERNAL SELF TEST * }
  5.003  TARGET


  5.004  IF            Find(S[25],"None",1)==0
  5.005  DISP          Disconnect all front Panel Connections.
  5.006  MATH          S[25]= "None"
  5.007  ENDIF


  5.008  MATH          S[30]="Reset"
  5.009  CALL          Agilent 34450A Sub Tools


  5.010  IEEE          *TST?[i]
  5.011  EVAL    -e (MEM==0):Internal Self-Test
  6.001  JMPL          Verification_Aborted                      (MEM!=0)
  6.002  JMPL          SelfTest_Done
  6.003  EVAL    Copyright Cal Lab Solutions  All rights reserved.


#====================================================================
  7.001  LABEL         ZeroOffsetVerificationFront1Year
  7.002  RSLT          =
  7.003  HEAD          { * ZERO OFFSET VERIFICATION FRONT 1 YEAR  * }
  7.004  HEAD          * ZERO OFFSET VERIFICATION FRONT 1 YEAR  *
  7.005  IF            Find(S[23],"Skip_ZeroOffsetVerificationFront1Year",1)==0
  7.006  MATH          S[24]="ZeroOffsetVerificationFront1Year,"
  7.007  CALL          Agilent 34450A Sub Test Points
  7.008  ELSE
```

```
  7.009  RSLT           = Skipped
  7.010  ENDIF
  7.011  JMPL           TestSelectionMode (L[30]==1)
  7.012  JMPL           ZeroOffsetVerificationFront1Year_done
  7.013  EVAL   Copyright Cal Lab Solutions All rights reserved.
#=====================================================================
  8.001  LABEL          DCVoltsGainVerification
  8.002  RSLT           =
  8.003  HEAD           { * DC VOLTS GAIN VERIFICATION  * }
  8.004  HEAD           * DC VOLTS GAIN VERIFICATION  *
  8.005  IF             Find(S[23],"Skip_DCVoltsGainVerification",1)==0
  8.006  MATH           S[24]="DCVoltsGainVerification,"
  8.007  CALL           Agilent 34450A Sub Test Points
  8.008  ELSE
  8.009  RSLT           = Skipped
  8.010  ENDIF
  8.011  JMPL           TestSelectionMode (L[30]==1)
  8.012  JMPL           DCVoltsGainVerification_done
  8.013  EVAL   Copyright Cal Lab Solutions All rights reserved.


…………..
#=====================================================================
 12.001  LABEL          ACVoltsVerification
 12.002  RSLT           =
 12.003  HEAD           { * AC VOLTS VERIFICATION  * }
 12.004  HEAD           * AC VOLTS VERIFICATION  *
 12.005  IF             Find(S[23],"Skip_ACVoltsVerification",1)==0
 12.006  MATH           S[24]="ACVoltsVerification,"
 12.007  CALL           Agilent 34450A Sub Test Points
 12.008  ELSE
 12.009  RSLT           = Skipped
 12.010  ENDIF
 12.011  JMPL           TestSelectionMode (L[30]==1)
 12.012  JMPL           ACVoltsVerification_done
 12.013  EVAL   Copyright Cal Lab Solutions All rights reserved.
……………
#=====================================================================
 15.005  LABEL          Verification_Complete
 15.006  HEAD           [7]{V E R I F I C A T I O N   C O M P L E T E !}[d999]
 15.007  HEAD           [d499]
 15.008  HEAD           [7]V E R I F I C A T I O N   C O M P L E T E ![d999]
 15.009  HEAD           [d499]
 15.010  HEAD           [7]V E R I F I C A T I O N   C O M P L E T E ![d999]
 15.011  HEAD           [d499]
 15.012  HEAD           {Thank you for Choosing Cal Lab Solutions!}

 15.013  END
========================================================================
INSTRUMENT:            Agilent 34450A Sub Test Points
DATE:                  2023-05-30 12:13:53
AUTHOR:                Cal Lab Solutions
REVISION:              $Revision: $
ADJUSTMENT THRESHOLD:  80%
NUMBER OF TESTS:       106
NUMBER OF LINES:       1870
```

3.2 Sample Code Main

Notice in the Main sample code that the Main calls the Test Points Sub on lines 7.007, 8.007, 12.007 CALL Agilent 34450A Sub Test Points. All of these calls are the same name, and none of them list any specific standards.

3.3 Sub Test Points

The test points' sub is focused on the Pass/Fail operation of the automated calibration procedure. Here we set up the test requirements, UUT setup requirements, and the test points' pass-fail limits.

Notice there are no commands sent to the UUT nor the reference standards used in the calibration procedure.

Notice on line 54.004, it calls the Test Routine Sub with an init command. This is a pre-run call for the whole test group. Here is where any special operations are called before the test group can be run.

Then at every test point, we set the @Volts, @Frequency, and @Range per the written procedure. Additionally, we use the TSET command to set the UUT's resolution with the UUT_Res keyword and set U3 set to 0, but there is where we can add repeatability from a repeatability study.

```
===========================================================================
 STEP     FSC     RANGE  NOMINAL         TOLERANCE      MOD1        MOD2  3  4 CON
 1.001    MATH           L[1]=Find(S[24],"ZeroOffsetVer",1)==1
 1.002    JMPL           ZeroOffsetVerificationFront1Year              (L[1]==1)
 1.003    MATH           L[1]=Find(S[24],"DCVoltsGainVer",1)==1
 1.004    JMPL           DCVoltsGainVerification                       (L[1]==1)
 1.005    MATH           L[1]=Find(S[24],"DCCurrentGainVer",1)==1
 1.006    JMPL           DCCurrentGainVerification                     (L[1]==1)
 1.007    MATH           L[1]=Find(S[24],"OhmsGainVer",1)==1
 1.008    JMPL           OhmsGainVerification                          (L[1]==1)
 1.009    MATH           L[1]=Find(S[24],"FreqGainVer",1)==1
 1.010    JMPL           FreqGainVerification                          (L[1]==1)
 1.011    MATH           L[1]=Find(S[24],"ACVoltsVer",1)==1
 1.012    JMPL           ACVoltsVerification                           (L[1]==1)

..........
#==========================================================================
 54.001   MATH           S[25]="Check Connections"
 54.002   LABEL          ACVoltsVerification
 54.003   MATH           S[26]="ReConfig"

# Perform Any Pre-Calibration Steps
 54.004   CALL           Agilent 34450A Sub Test Routines-Init

#----------------------------
 54.005   MATH           @Nominal=100*1e-3
 54.006   MATH           @Volts=100E-3
 54.007   MATH           @Frequency=20
 54.008   MATH           @Range=100E-3
 54.009   TSET           UUT_Res = 0.001E-3
 54.010   IF             Find(S[23],"EnableRepeatability",1)>0
 54.011   TSET           U3 = 0
 54.012   ENDIF
 54.013   CALL           Agilent 34450A Sub Test Routines-Conf
 54.014   MATH           L[9]=Fld(S[31],2,"Unc=")/1e-3
 54.015   ACC            100mV           L9U
 54.016   IF             1==0
 54.017   TARGET         -m
```

```
 54.018  CALL          Agilent 34450A Sub Test Routines-Meas
 54.019  ENDIF
 54.020  MATH          MEM=Fld(S[31],2,"Value=")/1e-3
 54.021  MEMCX  100    mV              1.01U          20Hz
#----------------------------
 55.001  MATH          @Nominal=100*1e-3
 55.002  MATH          @Volts=100E-3
 55.003  MATH          @Frequency=45
 55.004  MATH          @Range=100E-3
 55.005  TSET          UUT_Res = 0.001E-3
 55.006  IF            Find(S[23],"EnableRepeatability",1)>0
 55.007  TSET          U3 = 0
 55.008  ENDIF
 55.009  CALL          Agilent 34450A Sub Test Routines-Conf
 55.010  MATH          L[9]=Fld(S[31],2,"Unc=")/1e-3
 55.011  ACC           100mV           L9U
 55.012  IF            1==0
 55.013  TARGET        -m
 55.014  CALL          Agilent 34450A Sub Test Routines-Meas
 55.015  ENDIF
 55.016  MATH          MEM=Fld(S[31],2,"Value=")/1e-3
 55.017  MEMCX  100    mV              0.3U           45Hz
#----------------------------
 56.001  MATH          @Nominal=100*1e-3
 56.002  MATH          @Volts=100E-3
 56.003  MATH          @Frequency=1e3
 56.004  MATH          @Range=100E-3
 56.005  TSET          UUT_Res = 0.001E-3
 56.006  IF            Find(S[23],"EnableRepeatability",1)>0
 56.007  TSET          U3 = 0
 56.008  ENDIF
 56.009  CALL          Agilent 34450A Sub Test Routines-Conf
 56.010  MATH          L[9]=Fld(S[31],2,"Unc=")/1e-3
 56.011  ACC           100mV           L9U
 56.012  IF            1==0
 56.013  TARGET        -m
 56.014  CALL          Agilent 34450A Sub Test Routines-Meas
 56.015  ENDIF
 56.016  MATH          MEM=Fld(S[31],2,"Value=")/1e-3
 56.017  MEMCX  100    mV              0.3U           1kHz
……..
#----------------------------
 79.001  MATH          @Nominal=750*1
 79.002  MATH          @Volts=750
 79.003  MATH          @Frequency=10e3
 79.004  MATH          @Range=750
 79.005  TSET          UUT_Res = 0.001
 79.006  IF            Find(S[23],"EnableRepeatability",1)>0
 79.007  TSET          U3 = 0
 79.008  ENDIF
 79.009  CALL          Agilent 34450A Sub Test Routines-Conf
 79.010  MATH          L[9]=Fld(S[31],2,"Unc=")/1
 79.011  ACC           750V            L9U
 79.012  IF            1==0
 79.013  TARGET        -m
```

```
 79.014  CALL            Agilent 34450A Sub Test Routines-Meas
 79.015  ENDIF
 79.016  MATH            MEM=Fld(S[31],2,"Value=")/1
 79.017  MEMCX   750     V               1.25U         10kHz


# Power Down / Return To Safe Mode
 80.001  CALL            Agilent 34450A Sub Test Routines-Done
 80.002  END


========================================================================
INSTRUMENT:            Agilent 34450A Sub Test Routines-Init
INSTRUMENT:            Agilent 34450A Sub Test Routines-Conf
INSTRUMENT:            Agilent 34450A Sub Test Routines-Meas
INSTRUMENT:            Agilent 34450A Sub Test Routines-Done
DATE:                  2023-05-30 15:38:34
AUTHOR:                Cal Lab Solutions
```

The Test Points Sub is set up to call the Test Routines Sub four times. First, with the -Init at the beginning, then at each test point, it will call the -Conf and -Meas. The -Conf call will set up the reference standard and UUT for the test, while the -Meas will make the measurement. You will notice the -Meas is listed just below the TARGET Function Select Code (FSC), allowing it to be called multiple times for multiple measurements with statistics turned on. And finally, at the end of all the test points, the -Done is called, turning off all the outputs and leaving the station in a safe state.

3.4 Sub Test Routines

The Test Routines Sub is where most of the action takes place. Its job is to carry out the test settings based on the test process. For a DMM calibration, that process is usually resetting the calibrator and then the UUT. Set up the UUT to take the measurement, set up the calibrator, and turn the output on. Then make a measurement. Return the Output of the calibrator, its uncertainty, and the measurement of the DMM back to the Test Points Sub.

```
REVISION:              $Revision: $
ADJUSTMENT THRESHOLD:  80%
NUMBER OF TESTS:       10
NUMBER OF LINES:       559
========================================================================
 STEP    FSC    RANGE NOMINAL          TOLERANCE    MOD1      MOD2  3  4 CON
 1.001   MATH         L[1]=Find(S[24],"ZeroOffsetVer",1)==1
 1.002   JMPL         ZeroOffsetVerificationFront1Year            (L[1]==1)
 1.003   MATH         L[1]=Find(S[24],"DCVoltsGainVer",1)==1
 1.004   JMPL         DCVoltsGainVerification                     (L[1]==1)
 1.005   MATH         L[1]=Find(S[24],"DCCurrentGainVer",1)==1
 1.006   JMPL         DCCurrentGainVerification                   (L[1]==1)
 1.007   MATH         L[1]=Find(S[24],"OhmsGainVer",1)==1
 1.008   JMPL         OhmsGainVerification                        (L[1]==1)
 1.009   MATH         L[1]=Find(S[24],"FreqGainVer",1)==1
 1.010   JMPL         FreqGainVerification                        (L[1]==1)
 1.011   MATH         L[1]=Find(S[24],"ACVoltsVer",1)==1
 1.012   JMPL         ACVoltsVerification                         (L[1]==1)
..........
#=======================================================================
 8.001   LABEL        ACVoltsVerification
 8.002   JMPL         ACVoltsVerification_Init PSub("-Init")
```

```
  8.003  JMPL          ACVoltsVerification_Conf PSub("-Conf")
  8.004  JMPL          ACVoltsVerification_Meas PSub("-Meas")
  8.005  JMPL          ACVoltsVerification_Done PSub("-Done")


  8.006  DISP          Error Calling Sub.
  8.007  END


# Init ================================
  8.008  LABEL         ACVoltsVerification_Init
# Perform Any Pre Test Group Operations
  8.009  END


# Configure ============================
  8.010  LABEL         ACVoltsVerification_Conf
  8.011  MATH          S[31]=""


  8.012  MATH          S[30]="Check Connection"
  8.013  CALL          Agilent 34450A Sub Config


# Configure to Testing
  8.014  IF            Find(S[26],"ACVoltsVerification",1)==0


# Reset & Configure Measurement Device
  8.015  MATH          S[30]="Reset"
  8.016  CALL          Agilent 34450A Sub Tools


# Reset & Configure Source
  8.017  MATH          S[30]="Source.Volts.AC Reset"
  8.018  CALL          Agilent 34450A Sub Config


  8.019  MATH          S[26]="ACVoltsVerification"
  8.020  ENDIF


# Setup Measurement Device
  8.021  MATH          S[30]="Setup"
  8.022  CALL          Agilent 34450A Sub Tools


# Setup Source
  8.023  MATH          S[30]="Source.Volts.AC "
  8.024  MATH          S[30]=S[30]&"Volts= "&@Volts
  8.025  MATH          S[30]=S[30]&"Frequency= "&@Frequency
  8.026  CALL          Agilent 34450A Sub Config


# Measure ==============================
  8.027  LABEL         ACVoltsVerification_Meas


# Measure the Value
  8.028  MATH          S[30]="Measure"
  8.029  CALL          Agilent 34450A Sub Tools


  8.030  END
```

```
# Done =============================
  8.031  LABEL          ACVoltsVerification_Done


# Turn All Sources Off
  8.032  MATH           S[30]="Source.Volts.AC Reset"
  8.033  CALL           Agilent 34450A Sub Config


  8.034  END
………..


=============================================================================
INSTRUMENT:           Agilent 34450A Sub Tools
DATE:                 2023-05-30 16:15:35
AUTHOR:               Cal Lab Solutions
REVISION:             $Revision: $
ADJUSTMENT THRESHOLD: 80%
NUMBER OF TESTS:      4
NUMBER OF LINES:      91
```

When the Test Routine Sub is called, it immediately jumps down to the section of code on line 8.001 for the AC Volts Verification test routine. Under the -Init call (Line 8.008), it does nothing because there is nothing to do pre-calibration for a DMM. However, under the -Conf call (Line 8.010), the first step is to "Check Connections." Notice the code does not give the user a connection message but instead calls a "Check Connections" operation; that is because connections are managed using a State Machine Design Pattern, another design pattern. We can cover this in more detail later.

Next, in the -Init section of the Test Routine Sub, we Reset the UUT and Calibrator if they haven't been reset for the AC Volts test on Lines 8.0014 to 8.020. The Test Routines Sub doesn't do the work; instead, it loads S[30] with a command and passes the work to another sub-procedure (Lines 8.016 & 8.018).

Now on line 8.021, the procedure sets S[30], the command variable, and calls the UUT Sub Tools on line 8.022. On lines 8.023 to 8.025, S[30] is set with the output requirements for the calibrator. On line 8.026, we call the Sub Config procedure to set up the calibrator. Notice, there is nothing specific about the calibrator, we have only defined the output requirements so far in the Test Routines Sub.

On line 8.028, we set S[30] to "Measure" and call the Sub Tools Procedure on line 8.029 where the sub will make the measurement. We finish it all up in the -Done section, where line 8.032 S[30] contains the "Reset Command" and line 8.033 calls the sub to do the work.

3.5 Sub Tools

The tools sub is where we house most of the commands sent to the UUT throughout the procedure. If there is a typo or the command is wrong, we can simply change it in one place.

```
=============================================================================
 STEP    FSC    RANGE NOMINAL        TOLERANCE       MOD1       MOD2  3  4 CON
  1.001  JMPL         Reset          (Find(S[30],"Reset",1)>0)
  1.002  JMPL         Setup          (Find(S[30],"Setup",1)>0)
  1.003  JMPL         Measure        (Find(S[30],"Measure",1)>0)
………..
#============================================================================
  2.001  LABEL        Reset
  2.002  VISA         *RST
  2.003  VISA         *OPC?[i!]
# Add Code to Reset the UUT Here.
```

```
  2.004  END
  2.005  EVAL    Copyright Cal Lab Solutions All rights reserved.


#===========================================================================
  3.001  LABEL         Setup
............
#=============================
  3.017  IF            Find(S[24],"ACVoltsVer",1)==0
  3.018  VISA          CONF:VOLT:AC [V @Range]
  3.019  END
  3.020  ENDIF

..............
#===========================================================================
  4.001  LABEL         Measure
  4.002  VISA          READ?[i!]
  4.003  VISA          READ?[i]
  4.004  MATH          S[31]="Value= " & MEM & S[31]
  4.005  END
  4.006  EVAL    Copyright Cal Lab Solutions All rights reserved.


===========================================================================
```

We could add some IEEE or VISA commands for the UUT in the Test Routines Sub, but then we couldn't share the code. For example, on lines 4.001 to 4.004 where we take a measurement, these lines of code are used for all the UUT measurement operations. Remember, the goal is to write less code.

3.6 CLS Programming Standards

This is one of the key parts of the Cal Lab Solutions programming standards. None of the UUT Specific code is mixed with the standard-specific code. You will notice all of the procedures above had Agilent 34450A in them–Agilent 34450A Sub Test Points, Agilent 34450A Sub Test Routines, and Agilent 34450A Sub Tools–yet, none of them had any mention of the standards that will be used.

NOTE: From the Main Procedure, through the Sub Test Points, Sub Test Routines, and Sub Tools, we have yet to make any calls, connection messages, or code specific to the Reference Standards that will be used in this procedure. This is more than 80% of the code for the Agilent 34450A procedure, and everything so far has been generic and built around the object model of a calibrator, not any specific hardware.

3.7 Sub Config

Here is where the magic happens. This is where the link between the UUT Specific Code gets linked to the Reference Standards and their associated drivers. This is where we have implemented the concept of an Abstract Class Factory. Even though in a scripting language like MET/CAL, we can't create objects at run time; we can still use the pattern to create\link the specific (or concrete) calibrator driver we need at compile time.

Two things to note here: First, on line 9.007, when the Sub Config is called with "Check Connection," the IF statement causes it to check its current connection stored in S[25]. If the current connection is not "9010.2W<--->UUT.2W," it gives the user a connection message. This is how a State Machine design pattern works. Its function is to move the UUT connection through a series of connection states.

Next, the specific (or concrete) call to the 9010 Source Volts AC driver is made on line 9.013. These are the two links needed between the UUT-specific code and the Reference Standard-Specific code, and it is all done in one single file.

3.8 CLSD-Source.Volts.AC

This is the abstract name for all the drivers that are able to source Volts AC. It is the "Abstract" part of the Abstract Factory Pattern. CLSD-Source.Volts.AC (9010 Hi\Lo) makes it a concrete (or specific) abstract class implementation.

```
INSTRUMENT:           Agilent 34450A Sub Config
DATE:                 2023-05-30 17:50:45
AUTHOR:               Cal Lab Solutions
REVISION:             $Revision: $
ADJUSTMENT THRESHOLD: 80%
NUMBER OF TESTS:      11
NUMBER OF LINES:      314
============================================================================
 STEP    FSC    RANGE NOMINAL          TOLERANCE    MOD1       MOD2  3  4 CON
 1.001   JMPL         PreCal.Steps          (Find(S[30],"PreCal.Steps",1))
 1.002   JMPL         Station.Setup         (Find(S[30],"Station. Setup",1))


 1.003   MATH         L[1]=Find(S[24],"ZeroOffsetFront1Year",1)==1
 1.004   JMPL         ZeroOffsetFront1Year                         (L[1]==1)
 1.005   MATH         L[1]=Find(S[24],"DCVoltsGainVer",1)==1
 1.006   JMPL         DCVoltsGainVer                               (L[1]==1)
 1.007   MATH         L[1]=Find(S[24],"DCCurrentGainVer",1)==1
 1.008   JMPL         DCCurrentGainVer                             (L[1]==1)
 1.009   MATH         L[1]=Find(S[24],"OhmsGainVer",1)==1
 1.010   JMPL         OhmsGainVerification                         (L[1]==1)
 1.011   MATH         L[1]=Find(S[24],"FreqGainVer",1)==1
 1.012   JMPL         FreqGainVerification                         (L[1]==1)
 1.013   MATH         L[1]=Find(S[24],"ACVoltsVer",1)==1
 1.014   JMPL         ACVoltsVerification                          (L[1]==1)
..............
#===========================================================================
 9.001   LABEL        ACVoltsVerification
 9.002   JMPL         ACVoltsVerification_Conn     Find(S[30],"Connect",1)>0
 9.003   JMPL         ACVoltsVerification_Source   Find(S[30],"Source",1)>0


 9.004   DISP         Error Calling Sub
 9.005   END


#=======================================
 9.006   LABEL        ACVoltsVerification_Conn
 9.007   IF           Find(S[25],"9010.2W<--->UUT.2W",1)==0
 9.008   DISP         Connect the Meatest 9010 Hi\Lo Output to the
 9.008   DISP         UUT Hi\Lo Input (Front).
 9.009   MATH         S[25]= "9010.2W<--->UUT.2W"
 9.010   ENDIF
 9.011   END


#=======================================
 9.012   LABEL        ACVoltsVerification_Source
 9.013   CALL         CLSD-Source.Volts.AC                    (9010 Hi\Lo)
 9.014   END



============================================================================
```

Below is the generic command "Source.Volts.AC Volts= 3.5 Frequency= 1e3" which gets error checked and then converted into commands the Meatest 9010 is able to understand. Here also, the Type-B uncertainties are looked up, then passed back to the Sub Test Points.

It may seem like a lot of code to write… but remember, you only write it once! Then you can reuse the driver sub in multiple MET/CAL procedures any time you need an AC Voltage source.

```
INSTRUMENT:            CLSD-Source.Volts.AC                    (9010 Hi\Lo)
DATE:                  2022-01-18 19:17:54
AUTHOR:                Cal Lab Solutions
REVISION:              $Revision: 14 $
ADJUSTMENT THRESHOLD:  70%
NUMBER OF TESTS:       1
NUMBER OF LINES:       210
CONFIGURATION:         Meatest 9010
============================================================================
 STEP    FSC    RANGE NOMINAL        TOLERANCE     MOD1        MOD2  3  4 CON
  1.001  JMPL         ConnectionName      (Find(S[30], "Name?",1)>0)
  1.002  JMPL         Setup               (Find(S[30], "Setup",1)>0)
  1.003  JMPL         Setup               (Find(S[30], "PreCal",1)>0)
  1.004  JMPL         Reset               (Find(S[30], "Reset",1)>0)
  1.005  JMPL         OutputOff           (Find(S[30], "OutputOff",1)>0)
  1.006  JMPL         Source.Volts.AC     (Find(S[30], "Source.Volts.AC",1)>0)


  1.007  DISP         Error Calling Sub..  Unknown Command
  1.008  MATH         MEM=9.9e39
  1.009  END


……….. 


#============================================================================
  1.015  LABEL        Reset
  1.016  IEEE         [@9010]*CLS
  1.017  IEEE         [@9010]*RST
  1.018  IEEE         [@9010]*OPC?[SRQ 0][i!][SRQ 0]
  1.019  END
#============================================================================
  1.020  LABEL        OutputOff
  1.021  IEEE         [@9010]*CLS
  1.022  IEEE         [@9010]OUTP OFF
  1.023  IEEE         [@9010]*OPC?[SRQ 0][i!][SRQ 0]
  1.024  END
#============================================================================
  1.025  LABEL        Source.Volts.AC
# Get the Voltage
  1.026  MATH         L[1]=Fld(S[30],2,"Volts=")
  1.027  MATH         L[2]=Fld(S[30],2,"Frequency=")


# Error Check the Values
  1.028  IF           Abs(L[1]>1050)
  1.029  DISP         Error [L1] Volts is Out of the
  1.029  DISP         Meatest 9010's Range
  1.030  END
  1.031  ENDIF
```

```
1.032  IF           (abs(L[1])>2) && (L[2]>100e3)
1.033  DISP         Error: Unsupported Frequency [L2]Hz
1.033  DISP         > 2 V Ranges
1.034  END
1.035  ELSEIF       (abs(L[1])>=20) && (L[2]>100e3)
1.036  DISP         Error: Unsupported Frequency [L2]Hz
1.036  DISP         > 20 V Ranges
1.037  END
1.038  ELSEIF       (abs(L[1])>280) && (L[2]>30e3)
1.039  DISP         Error: Unsupported Frequency [L2]Hz
1.039  DISP         > 280 V Ranges
1.040  END
1.041  ELSEIF       (L[2]<15)
1.042  DISP         Error: Unsupported Frequency [L2]Hz
1.043  END
1.044  ELSEIF       (L[2]>300e3)
1.045  DISP         Error: Unsupported Frequency [L2]Hz
1.046  END
1.047  ENDIF


# Setup The Standard
1.048  IEEE         [@9010]*CLS
1.049  IEEE         [@9010]OUTP OFF
1.050  IEEE         [@9010]:SOUR:VOLT:AC:FREQ 1000
1.051  IEEE         [@9010]:SOUR:VOLT:AC:AMPL [L1]
1.052  IEEE         [@9010]:SOUR:VOLT:AC:FREQ [L2]
1.053  IEEE         [@9010]OUTP ON[D1999]
1.054  IEEE         [@9010]*OPC?[SRQ 0][i!][SRQ 0]


# Calculate the Uncertainties
1.055  IF           (L[1]<=20e-3) && (L[2]>100e3)
1.056  MATH         L[11]= 50000e-6 * L[1] + 900e-6
1.057  ELSEIF       (L[1]<=20e-3) && (L[2]>30e3)
1.058  MATH         L[11]= 10000e-6 * L[1] + 100e-6
1.059  ELSEIF       (L[1]<=20e-3) && (L[2]>10e3)
1.060  MATH         L[11]= 2000e-6 * L[1] + 40e-6
1.061  ELSEIF       (L[1]<=20e-3) && (L[2]>15)
1.062  MATH         L[11]= 2000e-6 * L[1] + 30e-6


1.063  ELSEIF       (L[1]<=200e-3) && (L[2]>100e3)
1.064  MATH         L[11]= 5000e-6 * L[1] + 1e-3
1.065  ELSEIF       (L[1]<=200e-3) && (L[2]>30e3)
1.066  MATH         L[11]= 3000e-6 * L[1] + 300e-6
1.067  ELSEIF       (L[1]<=200e-3) && (L[2]>10e3)
1.068  MATH         L[11]= 1500e-6 * L[1] + 120e-6
1.069  ELSEIF       (L[1]<=200e-3) && (L[2]>15)
1.070  MATH         L[11]= 1000e-6 * L[1] + 80e-6


1.071  ELSEIF       (L[1]<=2) && (L[2]>100e3)
1.072  MATH         L[11]= 5000e-6 * L[1] + 1e-3
1.073  ELSEIF       (L[1]<=2) && (L[2]>30e3)
1.074  MATH         L[11]= 2000e-6 * L[1] + 1e-3
```

```
  1.075  ELSEIF       (L[1]<=2) && (L[2]>10e3)
  1.076  MATH         L[11]= 500e-6 * L[1] + 300e-6
  1.077  ELSEIF       (L[1]<=2) && (L[2]>15)
  1.078  MATH         L[11]= 250e-6 * L[1] + 120e-6


  1.079  ELSEIF       (L[1]<=20) && (L[2]>30e3)
  1.080  MATH         L[11]= 2000e-6 * L[1] + 10e-3
  1.081  ELSEIF       (L[1]<=20) && (L[2]>10e3)
  1.082  MATH         L[11]= 500e-6 * L[1] + 1.5e-3
  1.083  ELSEIF       (L[1]<=20) && (L[2]>15)
  1.084  MATH         L[11]= 250e-6 * L[1] + 700e-6


  1.085  ELSEIF       (L[1]<=100) && (L[2]>10e3)
  1.086  MATH         L[11]= 500e-6 * L[1] + 15e-3
  1.087  ELSEIF       (L[1]<=100) && (L[2]>15)
  1.088  MATH         L[11]= 270e-6 * L[1] + 5e-3


  1.089  ELSEIF       (L[1]<=280) && (L[2]>10e3)
  1.090  MATH         L[11]= 500e-6 * L[1] + 50e-3
  1.091  ELSEIF       (L[1]<=280) && (L[2]>15)
  1.092  MATH         L[11]= 300e-6 * L[1] + 12e-3


  1.093  ELSE
  1.094  MATH         L[11]= 420e-6 * L[1] + 85e-3


  1.095  ENDIF


  1.096  MATH         S[31]=       " Value= " & L[1]
  1.097  MATH         S[31]=S[31]& " Unc= " & L[11]
  1.098  MATH         S[31]=S[31]& " Volts.AC= " & L[1]
  1.099  MATH         S[31]=S[31]& " Volts.AC.Unc= " &L[11]

# Expanded Uncertainties
#-------------------------------
# Standard Resolution
  1.100  IF           L[1]<= 20e-3
  1.101  MATH         L[31]=1e-8
  1.102  ELSEIF       L[1]<= 200e-3
  1.103  MATH         L[31]=1e-7
  1.104  ELSEIF       L[1]<= 2
  1.105  MATH         L[31]=1e-6
  1.106  ELSEIF       L[1]<= 20
  1.107  MATH         L[31]=1e-5
  1.108  ELSEIF       L[1]<= 100
  1.109  MATH         L[31]=1e-4
  1.110  ELSEIF       L[1]<= 280
  1.111  MATH         L[31]=1e-4
  1.112  ELSE
  1.113  MATH         L[11]=1e-3
  1.114  ENDIF
  1.115  MATH         L[31]=L[31]/2/Sqrt(3)
  1.116  TSET         U7 = [L31]
# Standard Traceability (Assuming 4 to 1 or Better)
```

```
1.117   MATH            L[32]=L[11]*.25
1.118   TSET            U5 = [L32]

1.119   END
```

4. Conclusion

We have created a huge library of interchangeable source and measure sub-procedures over the years. There are 40 interchangeable Volts.AC Drivers, covering everything from function generators to Fluke 9500s. Using this driver model, we can even call the new Fluke 5560As in MET/CAL 7 or older.

It is a little bit of work, and it may seem to be overkill for writing a simple calibration procedure when compared to using an instrument-specific FSC in MET/CAL, but running the numbers, this method of software development takes less time with you having just one UUT that you need to support with two different reference standards. And, the time savings is reduced exponentially as the number of reference standards increases.

This is how we at Cal Lab Solutions developed our library of MET/CAL Procedures. One change in a sub-procedure fixes the error in several procedures, making the library easier to support. Less broken code equals more devices getting calibrated. It is clearly "A Better Way to MET/CAL."

Michael L. Schwartz (mschwartz@callabsolutions.com), CEO, Cal Lab Solutions, Inc., Aurora, Colorado, https://www.callabsolutions.com.

The En-Lightened Movement

Dan Wiswell
Cal-Tek Company, Inc.

As we all know, many years ago there was a time when there were no electrical testing instruments. I often think of how difficult it must have been for the pioneers of the electrical industry to perform their experiments without even the most basic kinds of instrumentation. It must have been like finding your way in a dark room. Just like blacksmiths, they had to create their own tools. They did so to solve age-old mysteries that we now take for granted. Imagine living in a time when Volta invented the battery, Ampere had just defined our understanding of electrical currents, and Georg Ohm saw how it all fit together.

Remember, these events all took place at a time when there was no electrical infrastructure anywhere on the planet. The electrification of the world was still decades away. When the Leyden jar was invented in 1745 it became international news. We've all heard the stories of Benjamin Franklin and his kite with a key attached to its string. Ben Franklin's experiment allegedly occurred seven years after the Leyden jar showed up. As a young person, what that story said to me was that back then, there must have been a lot of those kinds of experiments going on. The contributions of each philosopher-turned-scientist caused others to advance their own work. Hans Orsted's experiments with magnetism brought the concept of the solenoid into the mind of Andre-Marie Ampere, which set the stage for the introduction of the telegraph. The first commercial telegraph was the Cooke and Wheatstone telegraph invented in 1837. The following year, the Morse system was invented by Samuel Morse. The Morse system eventually became the standard for international communication.

Very few things in the history of science have focused the attentions of so many people as did the telegraph. Bringing the telegraph from the laboratory into everyday use created an entirely new industry, which required a new set of skills from all the contributors that turned it into a reality. New hardware needed to be developed to manufacture a practical and easy to use utility.

Insulators and wire mounting hardware evolved as the distribution system grew. Wire manufacturing companies struggled to meet the needs of this newly deployed creation. Instruments were designed to aid in the manufacturing and after-market servicing of this new field called telegraphy. An entire host of electrical instruments, called bridges, were developed and named by and for their creators. Names like Thompson, Wheatstone, Kelvin, Varley, and Kohlrausch all became attached to the devices that they created. Most of them were designed for measuring wire resistance and for finding faults in electrical circuits. All of them relied upon a singular device to make them work. That device was called the galvanometer.

The galvanometer can be considered as the Archaeopteryx of modern display technology. It was the first instrument designed to measure small amounts of electrical current. By unifying electricity, magnetism, and optics, the creation of devices like the mirror galvanometer became possible. The first device designed for this purpose was invented by Johann Christian Poggendorff in 1826. In 1858, an improved version of the mirror galvanometer was

Example of a Thompson's mirror galvanometer. Credit: Science Museum London. Source: Wikimedia Commons, licensed under the Creative Commons Attributions-Share Alike 2.0 Generic license: https://en.m.wikipedia.org/wiki/File:Thomsons_mirror_galvanometer,_1858._(9663806048).jpg.

invented by William Thomson, who became Lord Kelvin in his later years. An example of Thomson's mirror galvanometer is depicted on the previous page.

Thomson designed his galvanometer to test the first successful trans-Atlantic telegraph cable that was laid down in 1858. The previous year there was a failed attempt at bridging the Atlantic with a submerged telegraph cable, and Thomson had been involved with that project. When that failed attempt occurred, Thomson immediately set out to develop an instrument that was sensitive enough to detect the weak signals of the testing apparatus used during the testing of the cable.

Before we move forward, just stop and think for a moment. If the Morse telegraphic system was invented in 1838, it was only twenty years later that we successfully spanned the Atlantic with an electrical communication network. This foundational work paved the way for the construction of our electrical power infrastructure that began to develop in the 1880s. By the time the various Edison companies began supplying power to customers, we already had an understanding of the things that can go wrong with a distributed electrical system. As the telegraphic system was created to rely on battery power, it makes perfect sense that the original Edison concept of an electrical power circuit was based on a direct current system. This must have given weight to his argument and case against the use of the alternating current system that Westinghouse was advocating. The fact that our electric grid runs on AC power proves that no one, not even Thomas Edison, can stand in the way of progress for very long.

From the very beginning of electrical testing, it was discovered that the more sensitive the galvanometer used in creating a bridge circuit, the more accurate the test results would be when locating electrical faults. Mirror galvanometers were extremely sensitive by design. In them, a beam of focused light is deflected by its mirror and projected onto a scale. This had the effect of creating a long, mass-less pointer. The longer the beam, the greater the amplified signal. The Thomson mirror galvanometer was capable of detecting extremely small electrical testing signals in submerged trans-Atlantic telegraph cables.

Prior to the advent of more sophisticated testing instruments, telegraph systems were tested with batteries, galvanometers, and resistance coils. People tend to design new things based on, or to replace something that they are familiar with—take the horseless carriage for example. That is why the first portable DC power supplies were called "battery eliminators." These devices helped define the values of voltage, current, and resistance in an electrical circuit. The instrument depicted below is an example of a resistance coil box that was used in those days in conjunction with batteries and galvanometers.

A resistance coil box from the author's private collection. Credit: D. Wiswell

Advances in the understanding of electrical circuits that were defined with the aid of galvanometers began to take hold in other areas of study within the scientific community. Many of these occurred in the field of medicine. The first electrocardiogram was recorded in 1887 using what was called an electrometer. However, the first truly quantifiable test results in this field were obtained by what came to be known as a string galvanometer. In fact, the first courses in electricity that universities offered to students were part of the medical curriculum. This was due to the experiments of Luigi Galvani with static electricity, and the way in which he observed that it caused frog legs to react when stimulated by an electric current. It's not surprising that the first galvanometers were named after Luigi Galvani and his experiments. Pictured on the following page is another early example of a mirror galvanometer designed for laboratory use.

This Leeds and Northrup mirror galvanometer has an old-style, open-architectural design that allows us to see its components. In the picture on the bottom left, notice the horseshoe magnet that is bridged by the meter movement. Light from the bulb at the bottom of the picture is focused through a lens and reflected off the mirror of the movement before it is redirected onto the reticle on the viewing glass in front of the instrument. These galvanometers have always reminded me of Isaac Newton's reflecting telescopes.

Another significant advance in galvanometric design occurred with the merging of its basic concept and that of the d'Arsonval/Weston meter movement in the late 1880s (pictured below).

A Leeds and Northrup mirror galvanometer. Credit: D. Wiswell

A Rawson Electrical Instruments Model 501 Galvanometer with a modified d'Arsonval meter movement. Credit: D. Wiswell

Clockwise from left to right: Leeds and Northrup Type S Murray/Varley Bridge, Leeds and Northrup Model 4282 Ohmmeter, Honeywell Model 2745 Potentiometer, and Rubicon Instruments Model 1071 Wheatstone Bridge. Credit: D. Wiswell

could resolve measurements with accuracies previously unachievable outside of a laboratory environment.

As the need for electrical measurement began to diversify, so did the design variations of galvanometers for specific applications. Today, these electro-mechanical indicators have become almost universally obsolete. Now, it is much more common to see instruments with graphical displays sporting apps that emulate these instruments that were created in the days of old. It is probably a natural tendency to think of these old instruments by comparing them to their modern equivalents, but I wonder. As Lord Kelvin was standing in a darkened laboratory observing the projected beam of light radiating from his galvanometer as it danced to the cadence of Morse code, did he envision an alternate future? What if his galvanometer had never been considered by d'Arsonval? What would have happened if he had colluded with the likes of Orsted and Maxwell? Maybe they would have created a movement with a mirror suspended in a manipulated magnetic field which could project those holographic images we see in science fiction movies. I remain hopeful and enthusiastic that one day I will see such things pass through my laboratory.

When this occurred, low-cost, high-quality galvanometers became available to the general public and quickly became ubiquitous in the front-panel designs of electrical measuring instruments manufactured by companies around the world. Pictured on this page are a few examples of portable instruments manufactured with galvanometers as an integral part of their front panel designs.

I believe that this was about the time at which electrical and electronic test equipment began to enter the modern era. Before this time, instruments were generally designed to act as building blocks that replicated the three legs of Ohm's Law and its foundational parameters. Galvanometers could be scaled to measure current. With a known current deflection, resistors could be added in series to create volt meters or added in parallel to create higher current ammeters. Batteries supplied the circuit with a VA source.

Prior to the design of the d'Arsonval/Weston based movements, galvanometers were typically stand-alone devices that were paired with other stand-alone components to create the bridge circuits they were used in. These new, smaller galvanometers allowed for the creation of portable test equipment and elegantly designed laboratory standards that

Left: A Brown Instruments Model 1117 Portable Poteniometer (complete with its own thermometer). Right: A Shallcross Model 638-2 Kelvin-Wheatstone Bridge. Credit: D. Wiswell

METTLER TOLEDO Introduces the XPR Multichannel Pipette Calibration Balance

The XPR105MCP is the high-speed solution for ISO 8655-compliant calibration of multichannel pipettes. It has a readability of 10 µg and supports multichannel pipettes with up to 12 channels and nominal volumes from 0.5 – 1000 µL.

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Learn more about the XPR105MCP Calibration Balance by visiting: https://www.mt.com/us/en/home/products/ Laboratory_Weighing_Solutions/analytical-balances/ XPR105MCP.html

About METTLER TOLEDO

METTLER TOLEDO is a leading global manufacturer of precision instruments. The Company is the world's largest manufacturer and marketer of weighing instruments for use in laboratory, industrial and food retailing applications. The Company also holds top-three market positions in several related analytical instruments markets and is a leading provider of automated chemistry systems used in drug and chemical compound discovery and development.

Additional information about METTLER TOLEDO can be found at www.mt.com/lab.

Digital Surf Unveils Mountains® 10, the Most Comprehensive Version to Date

Besançon, France, May 31, 2023 – Digital Surf today announced the release of the tenth major version of the company's renowned Mountains® software analysis platform for surface metrology & microscopy, trusted by 50+ leading instrument manufacturers and 22,000+ users.

Version 10 highlights include:

- A new product family for users of light microscopes, MountainsImage®, providing a complete toolkit for pre-processing and analyzing image data. The new line includes tools for enhancement, measurement, luminance histograms, color inversion, conversion to monochrome, particle analysis including color segmentation, fiber analysis and image contour analysis.
- A new job-specific Lens Analysis module for the study of aspheric optical surfaces and profiles in applications from many industries including imaging systems, sensors and lasers.
- The improvement of features for Automation, key in today's fast-paced industrial and research environments. In particular a new Automation tab now groups together Mountains® productivity functions such as document templates for processing of large batches of measured data, user-defined analysis recipes (known as Minidocs) and customization options allowing customers to work faster.
- CAD compare on Shell data (freeform surfaces): users can now compare measured Shell data with CAD models and access full surface texture analysis on this kind of dataset.

- New product for spectral analysis MountainsSpectral® Analyze for users working with spectra only, including automatic peak detection and fitting and parameter map generation.
- The recently-released Fiber analysis tool has been extended to all product families including those designed for topography analysis.

"In the ever-evolving surface metrology & microscopy industries, Digital Surf remains dedicated to building the best and most up-to-date surface imaging and analysis software" said Christophe Mignot, Digital Surf CEO. "Version 10 is our most comprehensive product release yet, bridging all the remaining gaps between the various datatypes and instrument technologies we cater for: topography analysis, image analysis and spectroscopy analysis. We are very excited to deliver Mountains® 10 to our users and receive their feedback."

See full press release: www.digitalsurf.com/news/press-release-digital-surf-unveils-mountains-10-the-most-comprehensive-version-to-date/

Introducing NEW Ralston LC20 Field Gauge with Bluetooth

The new Bluetooth-equipped Field Gauge LC20 is a reference-grade data logging pressure gauge that gives you the freedom to monitor and log pressure from a safe distance, even in dangerous or difficult-to-reach areas. Use the FieldLab Mobile App to initiate pressure logging and monitor readings remotely from your phone or tablet from up to 30 m (100 ft) away. Control and monitor multiple gauges at the same time, in real time, and easily share pressure data over email, network drives, or text message.

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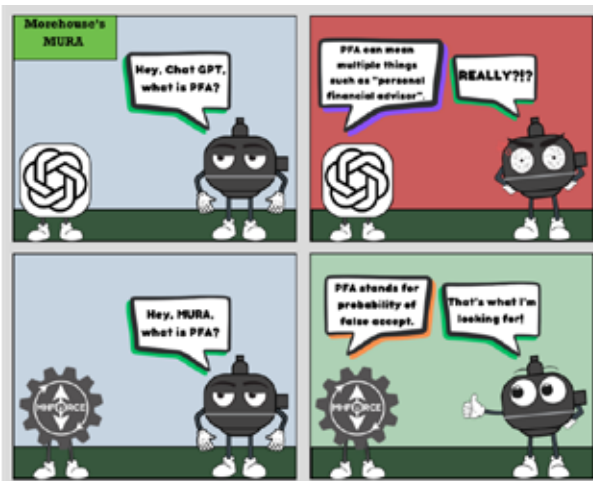
Morehouse is Excited to Announce the NEW MURA Chatbot

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York, Pa, June 8, 2023: Morehouse Instrument Company, Inc. has announced today a new website feature. MURA, which stands for Measurement Uncertainty Resource Assistant, is the fastest and most comprehensive resource for all your force metrological questions. MURA has scanned over 5 million characters from a host of relevant metrological standards, the Morehouse e-book - *Force Calibration for Technicians and Quality Manager* (https://mhforce.com/force-calibration-for-technicians-ebook-2022-edition/), Morehouse webpages, and other highly technical documents.

MURA was designed to help you make better measurements by answering difficult questions quickly without having to wait days or weeks for an expert to get back to you.

MURA is extremely simple to use - all you have to do is ask! Just click on our MURA icon, located at the bottom left corner on our website."

MURA has been carefully developed to be as accurate and precise as possible while still retaining its conversational tone. This means that even if you're unclear on something—or just not sure what you're asking—you'll get a clear response that helps guide you on the right path.

Morehouse Instrument Company: Based in York, PA, Morehouse Instrument Company has been a leading name in the American and international industry-grade equipment manufacturing scene for over a century. Founded in 1920, the company specializes in providing cutting-edge calibration products and services that are intelligently designed to reduce measurement risk. Morehouse Instrument Company is renowned for its industry-leading calibration machines, load cells, load cell accessories, and more. The company has worked for a list of elite clientele worldwide, ranging from NASA to NPL (National Physical Laboratory) to the US Air Force, and more.

Diff Tools & Revision Control

Michael Schwartz
Cal Lab Solutions, Inc.

Most revision control tools come with a diff tool of some kind. And if you develop software and don't use revision control or a diff tool of some kind, I have to say, "WTF?"

A diff tool will show you the difference between two files, usually by highlighting the text that is different. And if you are using a diff tool in conjunction with a revision control system, it will show you the changes to a file over time. This is handy for software developers, especially when you work with a team of developers. It really helps find and fix bugs quickly, especially when one of your fixes breaks the code.

We at Cal Lab Solutions use both GitHub and Source Gear Vault for revision control. GitHub (https://github.com/) is a cloud-based solution now owned by Microsoft. We use it for all of our open-source projects, mostly because it is free for use with open-source software

projects. Plus, it is easy to add new developers and contributors to the projects.

But for Fluke MET/CAL® projects, we like to use Source Gear Vault (https://sourcegear.com/vault/). Unlike most revision control tools, Vault lets you share files between projects. This is handy for MET/CAL procedures because we often use the same files/sub-procedures in different projects. Vault allows us to share the exact same copy of a file in different folders.

In my article, "A Better Way to MET/CAL," I talk about creating drivers for a specific standard and sharing it with several projects. Vault just makes it easy to streamline that process. That is why we use it over other revision control tools, especially for MET/CAL procedures.

And one of the things I like about Vault is the company will let you use its DiffMerge tool for free. This

gives a developer the ability to see the difference between two files and even merge the changes into a file. For a free download, visit: https://sourcegear.com/diffmerge/downloads.html

In this example (Figure 1), you can see the changes required to convert a MET/CAL procedure to run with the Fluke 5522A vs. a Meatest 9010 using our development methodology. As you can see, the differences are highlighted in red, making the change–mostly likely a typo–easier to spot.

In MET/CAL, you will have to create two projects, one for each standard's configuration. But again, you can use the DiffMerge tool to look at the differences between the two project and solution files.

So, if you are tired of going cross-eyed, looking at two files trying to track down the error or see the changes, download Source Gear's DiffMerge tool.
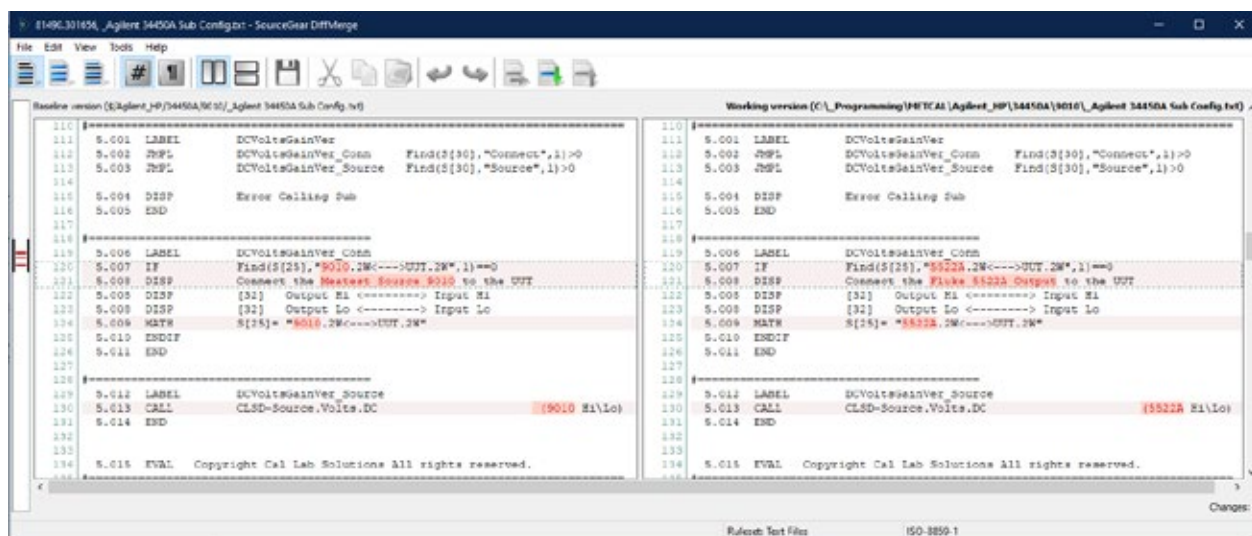

Figure 1. Screenshot of DiffMerge application.

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CALIBRATES DC CURRENT

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- ◦ No power coefficient
- ◦ No temperature coefficient
- ◦ DC and AC Operation
- ◦ Simple easy to use design

	Rating (Amps)	Resistance (Ohms)	Power Rating (Watts)	Time Constant	DC Accuracy	AC Accuracy (± μA / A)	Stability 1 year (± μA / A)	Temperature Coefficient (± μA/A/°C)	Power Coefficient (± μA/A/W)
Typical Shunt	10	0.1	140	> 10 minutes	0.01%	No spec	10	4	4
Typical Shunt	300	0.001	100	> 10 minutes	0.01%	No spec	10	4	4
6311A	10	0	N/A	< 10 seconds	< 0.0005%	< 20	0.05	0	0
6311A	300	0	N/A	< 10 seconds	< 0.0005%	< 20	0.05	0	0

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