Using Reference Multimeters for Precision Measurements

Advanced techniques for improved confidence in metrology

Teleconference:
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Conference Code: 1010759559

Welcome and Thanks!

Greetings from –

Fluke Corporation
Everett, Washington, USA

We are very pleased to bring you this presentation on replacing analog null detector meters with digital multimeters in voltage reference intercomparisons

This presentation is based on Fluke's extensive experience with:

- **Calibration Instruments**
- **Standards Lab Metrology**
- **Our experience and understanding of the problems faced when making such measurements**

Thanks for your time, we hope you find it both valuable and useful.

Presented by

Fluke's Precision Measurement
Business Unit

and Jack Somppi
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Fluke Precision Measurement Web Seminar Series

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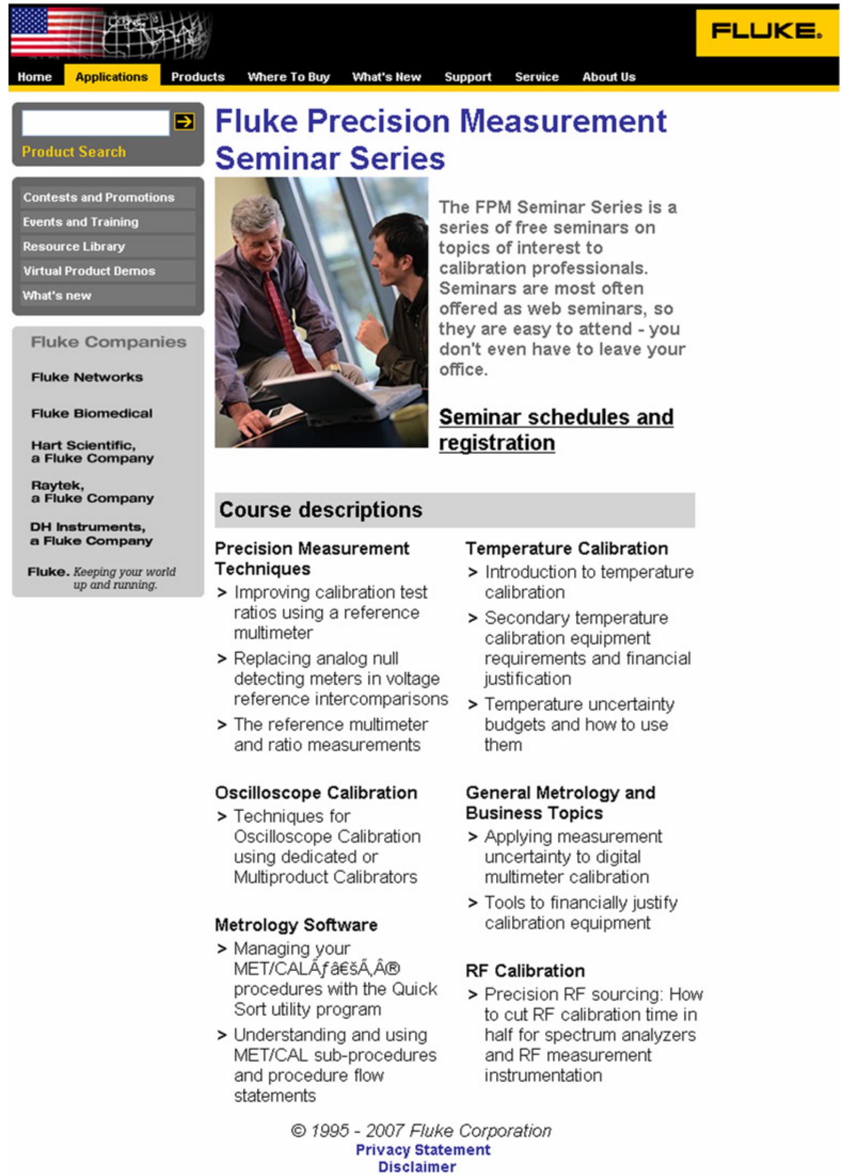
Our Seminar Topics Include:

- Precision Measurement Techniques
- Oscilloscope Calibration
- General Metrology
- Temperature Calibration
- Metrology Software
- RF Calibration

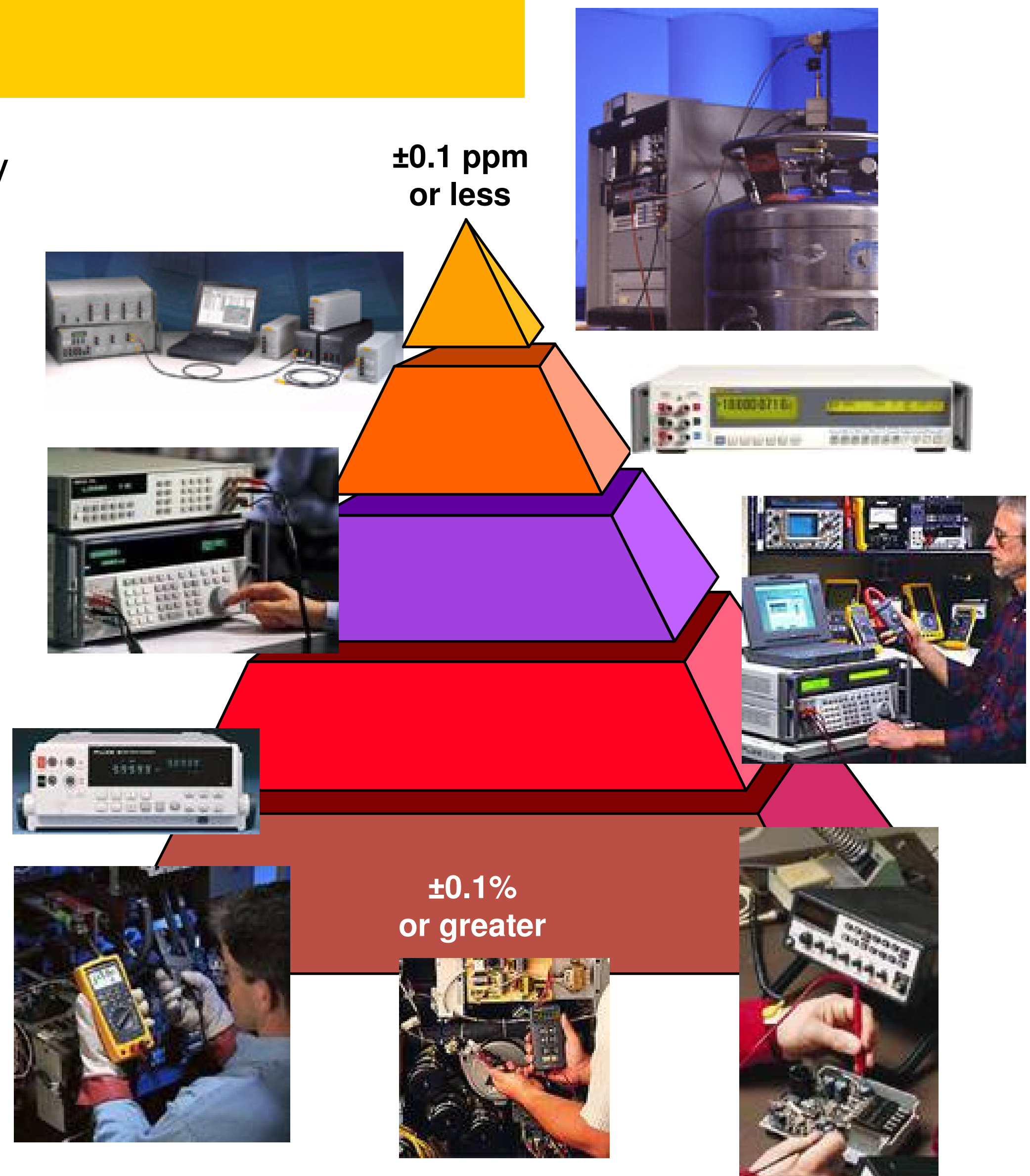


Web seminar etiquette

- Choice of Audio – VOIP or Teleconference
  - VOIP receives audio only while teleconference is two way sound
- Don’t mute your phone if you have background music enabled
- Use Q&A or chat to send me questions or request clarification
- There will be an opportunity throughout the discussion to pause and ask questions.
- You can view the material using either full screen or multi window methods

Introduction –
Precision electrical metrology

- DC/low frequency ac electrical metrology can span more than five decades of uncertainties between the requirements of basic industrial testing to the highest level measurements done in primary standard's laboratories.
- Irregardless of the uncertainty, all labs require proper metrology techniques to support SI unit traceability.
- A reference multimeter can assist in a variety of tasks to support SI unit traceability.



Traceability requires proficiency in both precision measurement and precision sourcing

- Some tests require either only sourcing standards (such as calibrating meters) or only measurement standards (such as calibrating sources)
- Some tests require simultaneous use of measurement and sourcing standards (such as current shunt calibration or certain resistance calibrations)
- Laboratory measurement assurance programs use both precision measurement devices and precision sources to cross-check a standard's instrumentation between formal calibrations.
- Certain accuracy enhancement techniques use simultaneous sourcing and measurement to improve test uncertainties.

Lab capabilities are strongest when there are similar measurement and sourcing capabilities.

A reference multimeter is optimized for precision metrology

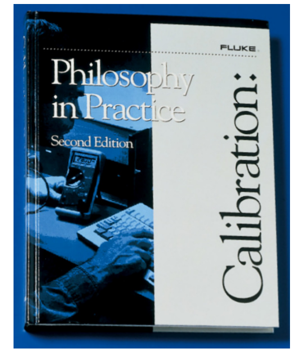
How is a reference multimeter different from a common multimeter?

- 8½ digits of measurement resolution
  - Highly linear a/d converter with 120 million to 200 million counts
  - High useable sensitivity (for example – resolves 1 nV out of 100 mV)
  - Range points set at 1.2 to 1.9 times the decade points to maximize over ranging benefits and decade point measurement accuracy
- Very good long and short term stability:
  - ±0.5 to ±1 ppm in 24 hours
  - ±3 to ±6 ppm in 1 year
- Designed with advanced ratio measurement capabilities to support the best uncertainties and best measurement practices
- Reduce measurement errors with voltage and ohms guarding

Reference multimeters are alternatives to many traditional precision instruments

- Null detectors
- Nanovoltmeters
- Kelvin-Varley dividers
- Resistance bridges
- Micro-ohmmeter
- Precision thermometers
- Electrometers/pico-ammeters
- External shunts
- Ammeters
- AC/DC transfer standards
- Multifunction transfer standards

For more information -



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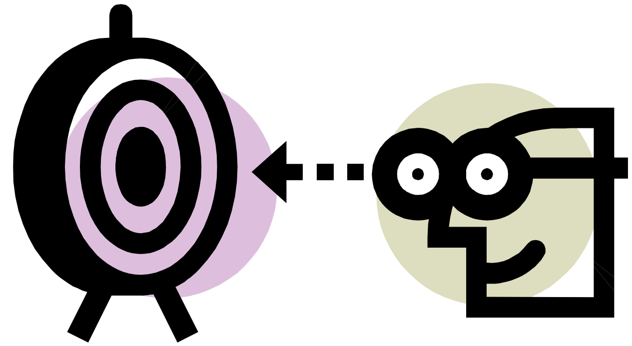
Replacing Analog Null Detecting Meters in Voltage Reference Intercomparisons

The DMM’s role as an modern digital
“null detector”

Objectives & Benefits

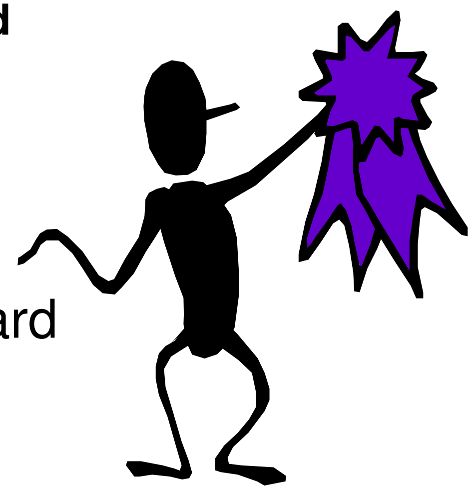


Objective of this session-

- Study
  - **How a digital multimeter, versus the older/obsolete analog null detectors, can be used to compare and calibrate 10 volt reference standards**
  - **Investigate the measurement techniques required for good metrology.**

Benefits

- Understand and implement modern and automatable measurement techniques to improve reference standard metrology in you labs.



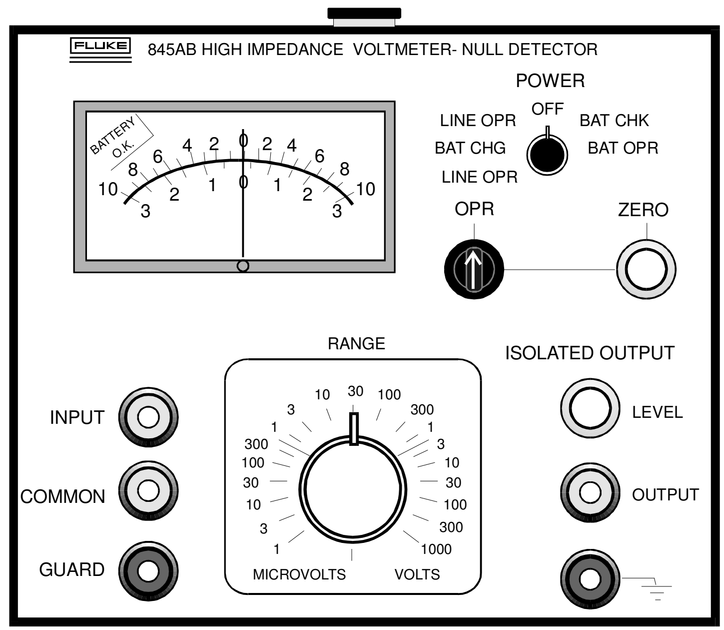
Session Overview

Topics Covered in this session

- The analog null detector and comparing voltage standards
- Reference comparisons using a DMM
- Best measurement practices
- Measurement details
- Working with multiple standards
- Digital meters vs. analog null detectors

The Analog Null Detector

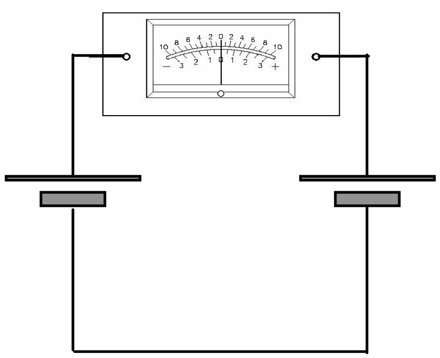
- The null detector instrument was commonly used to measure small differences in different dc voltages
- It is often used to intercompare similar voltage references for tracking changes
- A similar application is using a null detector to certify one standard against another known standard or set of standards.



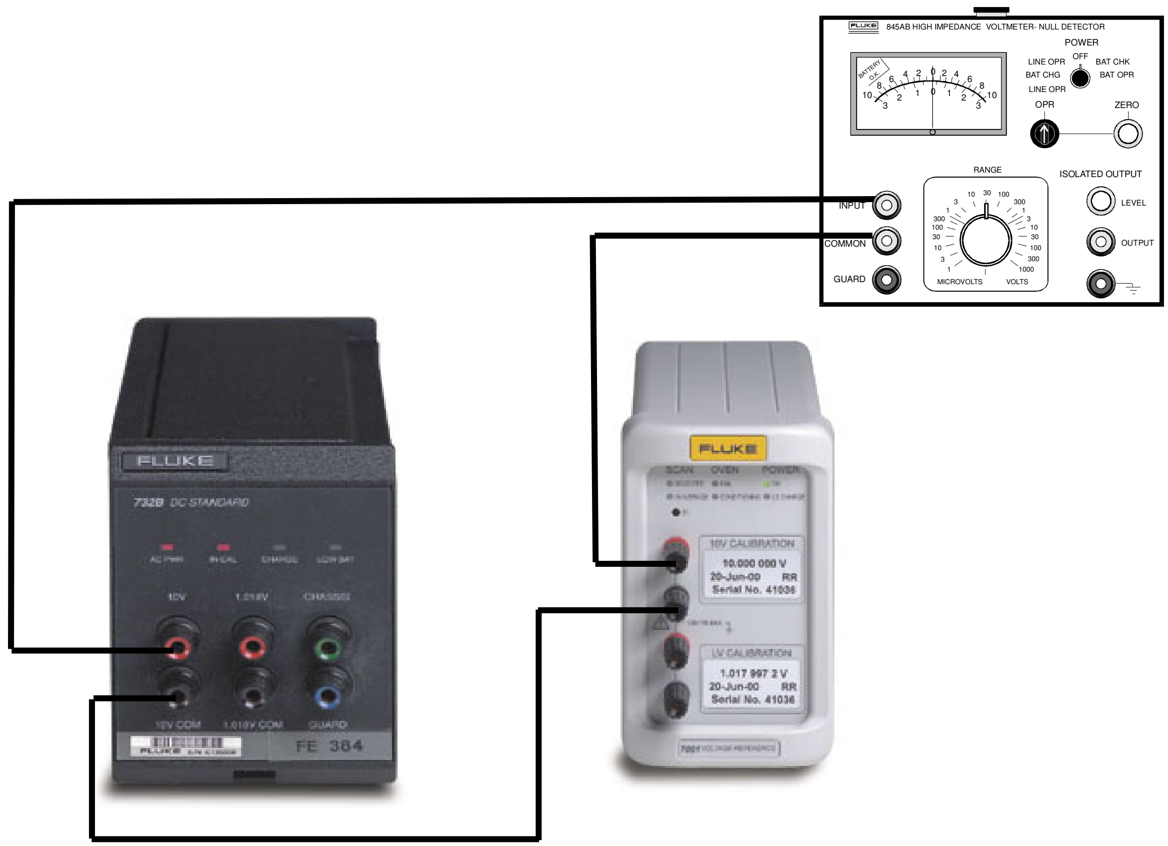
Fluke's 845AB Null Detector

Reference Comparisons Using a Null Detector

Null detector



Comparing two similar voltages by measuring the voltage difference between one 10 V standard and another 10 V standard



Today’s Situation

- Few analog null detectors continue to be made, so there is limited availability of such instruments.
- Existing Fluke 845 Series instruments are no longer serviceable.
- Often, precision DMMs can be used in many null detector applications.

Let’s examine this application more closely, using dmm techniques.

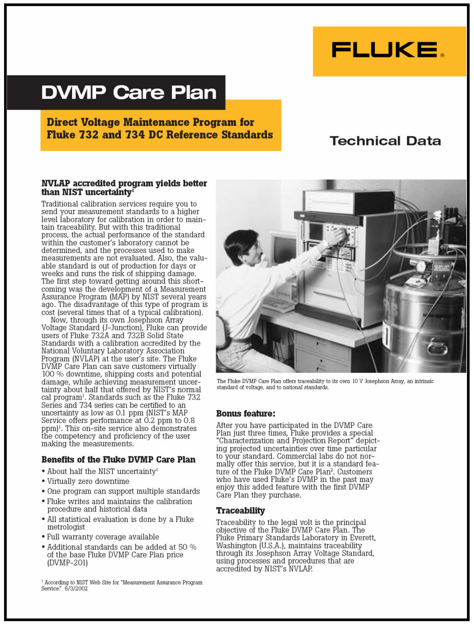
An Example-
Comparing Voltage Standards

Reference is the 732B's 10 V output which is certified at +10.000 123 0 V

UUT is the 7001 Reference's 10 V output

Similar Voltage Reference Measurement Applications

- Fluke's Direct Voltage Maintenance Program Care Plan
  - Measure your standard in your lab, and Fluke can certify the measurement.
  - Compares your standard to a Fluke owned and certified standard.
  - Accredited certificates to ±0.1 ppm uncertainty
  - Available as: 732B-200 and 732B-201 services
- Self-maintain and track your own 10 volt references.



FLUKE

DVMP Care Plan

Direct Voltage Maintenance Program for Fluke 732 and 734 DC Reference Standards

Technical Data

NVLAP accredited program yields better than NIST uncertainty[1]

Traditional calibration services require you to send your measurement standards to a higher level laboratory for calibration in order to maintain traceability. But with this traditional process, the actual performance of the standard within the customer's laboratory cannot be determined, and the processes used to make measurements are not evaluated. Also, the valuable standard is out of production for days or weeks and runs the risk of shipping damage. The first step toward getting around this shortcoming was the development of a Measurement Assurance Program (MAP) by NIST several years ago. The disadvantage of this type of program is cost (several times that of a typical calibration).

Now, through its own Josephson Array Voltage Standard (J-Junction), Fluke can provide users of Fluke 732A and 732B Solid State Standards with a calibration accredited by the National Voluntary Laboratory Association Program (NVLAP) at the user's site. The Fluke DVMP Care Plan can save customers virtually 100 % downtime, shipping costs and potential damage, while achieving measurement uncertainty about half that offered by NIST's normal cal program[1]. Standards such as the Fluke 732 Series and 734 series can be certified to an uncertainty as low as 0.1 ppm (NIST's MAP Service offers performance at 0.2 ppm to 0.8 ppm)[1]. This on-site service also demonstrates the competency and proficiency of the user making the measurements.

Benefits of the Fluke DVMP Care Plan

- About half the NIST uncertainty[1]
- Virtually zero downtime
- One program can support multiple standards
- Fluke writes and maintains the calibration procedure and historical data
- All statistical evaluation is done by a Fluke metrologist
- Full warranty coverage available
- Additional standards can be added at 50 % of the base Fluke DVMP Care Plan price (DVMP-201)

[1] According to NIST Web Site for "Measurement Assurance Program Service." 6/3/2002

The Fluke DVMP Care Plan offers traceability to its own 10 V Josephson Array, an intrinsic standard of voltage, and to national standards.

Bonus feature:

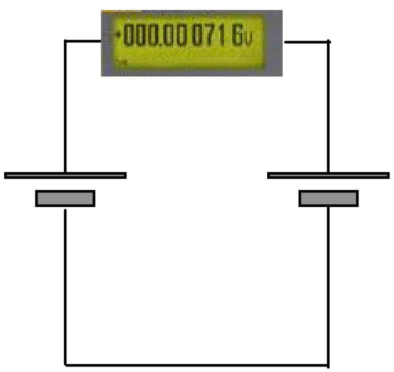
After you have participated in the DVMP Care Plan just three times, Fluke provides a special "Characterization and Projection Report" depicting projected uncertainties over time particular to your standard. Commercial labs do not normally offer this service, but it is a standard feature of the Fluke DVMP Care Plan[2]. Customers who have used Fluke's DVMP in the past may enjoy this added feature with the first DVMP Care Plan they purchase.

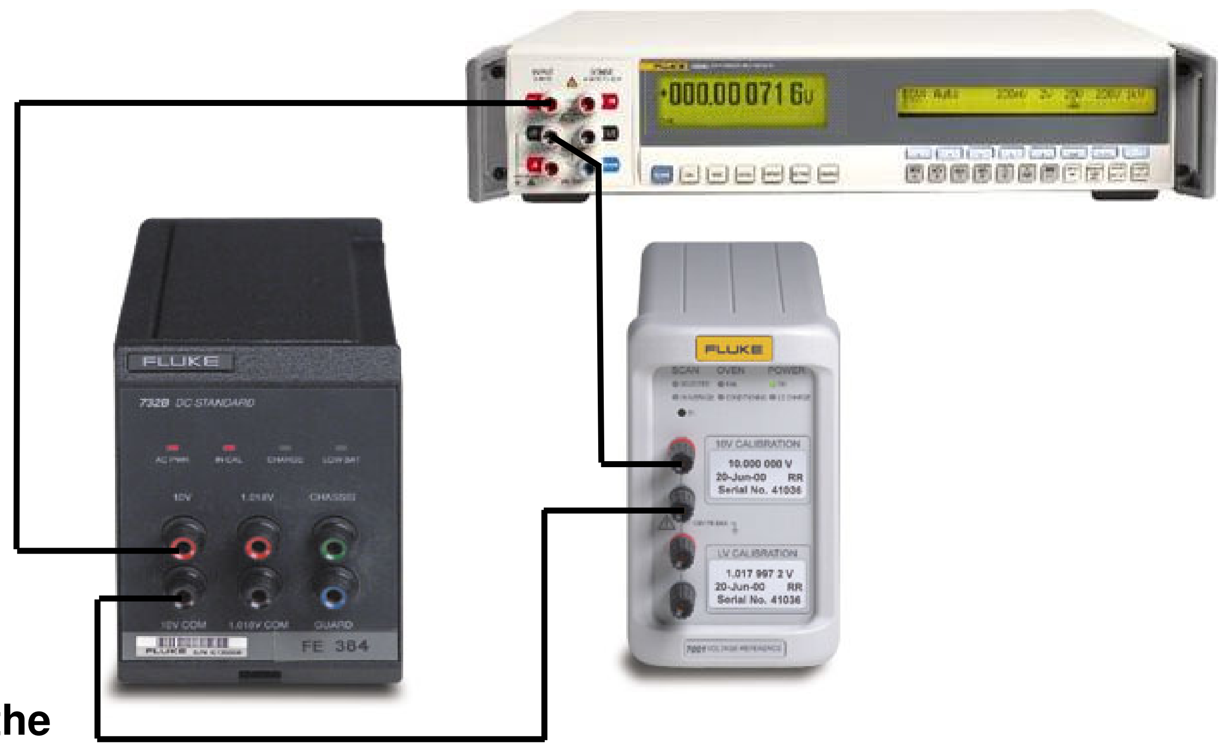
Traceability

Traceability to the legal volt is the principal objective of the Fluke DVMP Care Plan. The Fluke Primary Standards Laboratory in Everett, Washington (U.S.A.), maintains traceability through its Josephson Array Voltage Standard, using processes and procedures that are accredited by NIST's NVLAP.

Reference Comparisons Using a DMM

DMM's displayed value





The DMM replaces the null detector to measure the difference.

Applying the DMM's Specs

- Key attributes for intercomparing voltage standards
  - Good resolution (1 nV)
  - Short term stability (0.5 ppm in 200 mV or 0.1 µV)
  - High input impedance ($>10^{10}$ Ohm for up to 20 V)
  - Excellent CMRR (140 dB at DC)
  - Measurement isolation ($>10^{10}$ Ohms lo to ground)
  - Low noise (typically < 50 nV)
- Overall measurement considerations
  - Use absolute specifications.
  - The measured difference value (from near zero to tens or hundreds of microvolts) is accurate to within ± 0.1 µV .
  - The certified uncertainty on the reference standard is larger –- often ± 1 µV to ± 3 µV – the dominant factor in the measurement uncertainty.

DC Voltage

DC Voltage

Range	Full Scale	Uncertainty Relative to Cal Stds ± (ppm Reading + ppm Range) 24 hour TCal ±1 °C	90 day TCal ±1 °C	365 day TCal ±1 °C	Absolute Uncertainties 365 day TCal ±1 °C	365 day TCal ±5 °C
95 % Confidence Level						
200 mV	199.999 999	0.7 + 0.5	1.4 + 0.5	2.7 + 0.5	4.5 + 0.5	5.0 + 0.5
2 V	1.999 999 99	0.5 + 0.2	1.4 + 0.2	2.7 + 0.2	3.0 + 0.2	3.5 + 0.2
20 V	19.999 999 9	0.5 + 0.2	1.4 + 0.2	2.7 + 0.2	3.0 + 0.2	3.5 + 0.2
200 V	199.999 999	1.0 + 0.2	2.6 + 0.2	4.0 + 0.2	4.5 + 0.2	5.5 + 0.2
1000 V	1050.000 00	1.0 + 0.5	2.6 + 0.5	4.0 + 0.5	4.5 + 0.5	5.5 + 0.5
99 % Confidence Level						
200 mV	199.999 999	0.8 + 0.6	2.0 + 0.6	3.5 + 0.6	6.0 + 0.6	6.5 + 0.6
2 V	1.999 999 99	0.6 + 0.25	1.8 + 0.25	3.5 + 0.25	4.0 + 0.25	4.5 + 0.25
20 V	19.999 999 9	0.6 + 0.25	1.8 + 0.25	3.5 + 0.25	4.0 + 0.25	4.5 + 0.25
200 V	199.999 999	1.2 + 0.25	3.5 + 0.25	5.2 + 0.25	6.0 + 0.25	7.0 + 0.25
1000 V	1050.000 00	1.2 + 0.6	3.5 + 0.6	5.2 + 0.6	6.0 + 0.6	7.0 + 0.6

DC Voltage (Secondary Specifications)

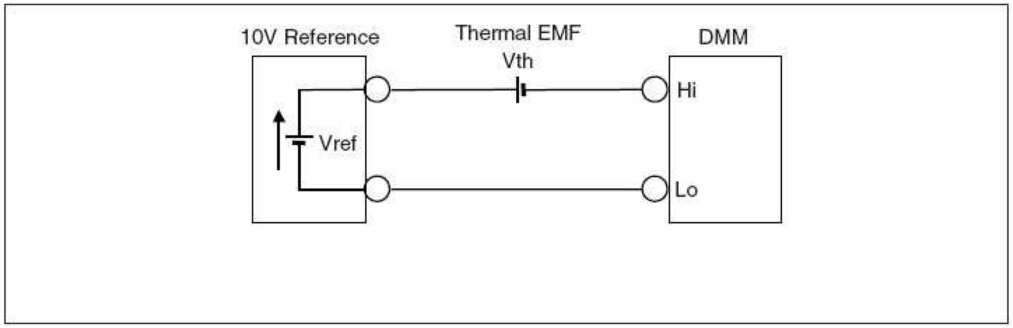
Range	Transfer Uncertainty 20 mins ±1 °C ± (ppm Reading+ ppm Range)	Temperature Coefficient ± ppm Reading/°C 15 °C - 30 °C	5 °C - 15 °C 30 °C - 40 °C
200 mV	0.4 + 0.3	0.4	0.6
2 V	0.12 + 0.1	0.3	0.5
20 V	0.12 + 0.1	0.3	0.5
200 V	0.4 + 0.1	0.7	1.0
1000 V	0.4 + 0.3	0.7	1.0

Type	Multi-slope, multi-cycle A-D Converter
CMRR (1 KΩ unbalance)	140 dB at DC and 1 - 60 Hz
NMRR	
Filter Out	60 dB at 50/60 Hz ±0.09 %
Filter In	110 dB at 50/60 Hz ±0.09 %
Protection (All ranges)	1 kV rms
Input Impedance	
200 mV to 20 V Ranges	> 10 GΩ
200 V & 1000 V Ranges	10.1 MΩ ± 1 %
Max Input Current	50 pA
Ratio Accuracy	
Range to Range	±(Net Front Input Accuracy + Net Rear Input Accuracy)
Within Range	Apply 24 hour or 20 minute Transfer Uncertainty specifications
Settling Time (to 10 ppm step size)	
Filter Out	< 50 ms
Filter In	< 1 s

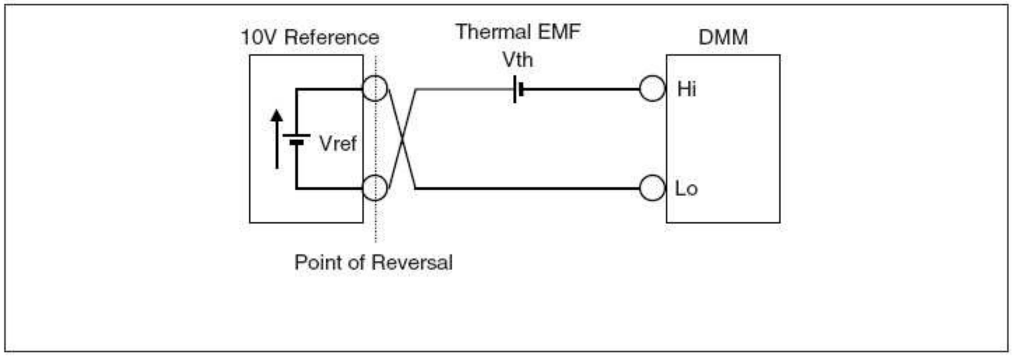
Best Measurement Practices (1)

- Eliminate errors due to various offset effects by making repeated measurements and reversing the test leads.
- A simple reversal technique on a single reference used to correct for thermal emf errors is shown.

  V_{Ref} =(+ Forward – Reverse)/2
- More thorough lead reversal methods can correct for other errors, including voltage offsets, common mode signal errors, etc.
- In practice, Fluke switches at both the DMM terminals (forward and reverse) and at the UUT (positive and negative polarity), with several measurements taken in each configuration.



Forward Measurement

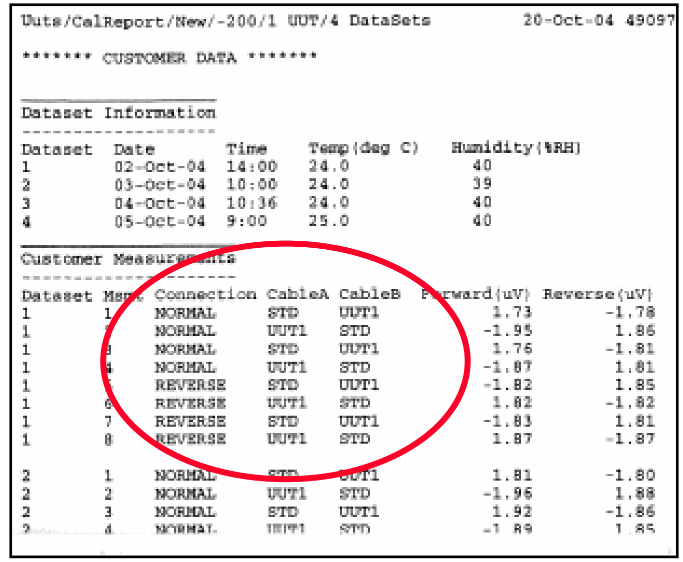


Reverse Measurement

Best Measurement Practices (2)

Improve measurement uncertainty by statistically averaging measurements to eliminate random errors.

- The measured value is the **average** of the multiple repeated measurements
- Measurement uncertainty is based on the **standard deviation** of the values
- In practice, the Fluke Voltage Maintenance Program makes three or more sets of multiple measurements.
- Each set of measurements consists of a combination of four different lead configurations - Forward/reverse and positive/negative polarity measurements -- sequenced through twice (provides eight measurements per set).



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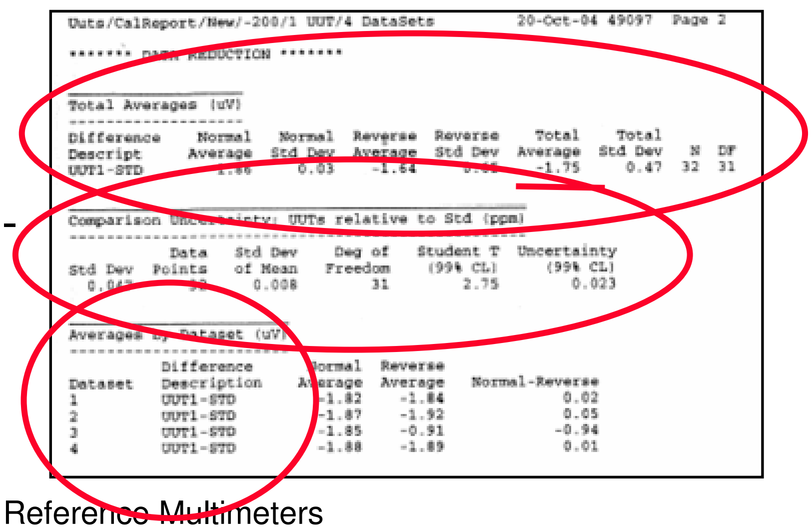
******* CUSTOMER DATA *******

Dataset Information

Dataset	Date	Time	Temp(deg C)	Humidity(%RH)
1	02-Oct-04	14:00	24.0	40
2	03-Oct-04	10:00	24.0	39
3	04-Oct-04	10:36	24.0	40
4	05-Oct-04	9:00	25.0	40

Customer Measurements

Dataset	Meas	Connection	CableA	CableB	Forward(uV)	Reverse(uV)
1	1	NORMAL	STD	UUT1	1.73	-1.78
1	2	NORMAL	UUT1	STD	-1.95	1.86
1	3	NORMAL	STD	UUT1	1.76	-1.81
1	4	NORMAL	UUT1	STD	-1.87	1.81
1	5	REVERSE	STD	UUT1	-1.82	1.85
1	6	REVERSE	UUT1	STD	1.82	-1.82
1	7	REVERSE	STD	UUT1	-1.83	1.81
1	8	REVERSE	UUT1	STD	1.87	-1.87
2	1	NORMAL	STD	UUT1	1.81	-1.80
2	2	NORMAL	UUT1	STD	-1.96	1.88
2	3	NORMAL	STD	UUT1	1.92	-1.86
2	4	NORMAL	UUT1	STD	-1.89	1.85



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******* DATA REDUCTION *******

Total Averages (uV)

Difference Descript	Normal Average	Normal Std Dev	Reverse Average	Reverse Std Dev	Total Average	Total Std Dev	N	DF
UUT1-STD	[illegible]	0.03	-1.64	[illegible]	-1.75	0.47	32	31

Comparison Uncertainty: UUTs relative to Std (ppm)

Std Dev	Data Points	Std Dev of Mean	Deg of Freedom	Student T (99% CL)	Uncertainty (99% CL)
[illegible]	[illegible]	0.008	31	2.75	0.023

Averages by Dataset (uV)

Dataset	Difference Description	Normal Average	Reverse Average	Normal-Reverse
1	UUT1-STD	-1.82	-1.84	0.02
2	UUT1-STD	-1.87	-1.92	0.05
3	UUT1-STD	-1.85	-0.91	-0.94
4	UUT1-STD	-1.88	-1.89	0.01

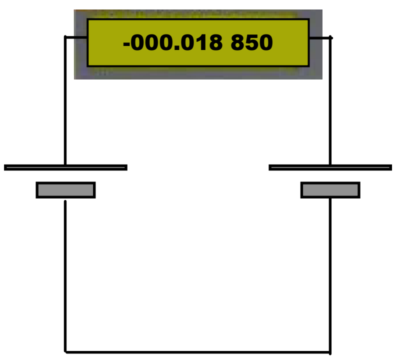
Best Measurement Practices (3)

- Zero the DMM before the measurements are performed.
  - Use a zero ohm shorting bar with *__small__* thermal mass.
- Use low thermal emf leads for test connections.
  - Crimp copper sleeves or lugs on copper wires.
  - Use low thermal solder (Cadmium-Tin).
  - Clean connections and remove oxides (0.2 uV vs. 1000 uV!).
  - If non-oxidized, clean copper isn't practical, then use gold-flashed copper terminals on the cables.

8508A Shorting Bars

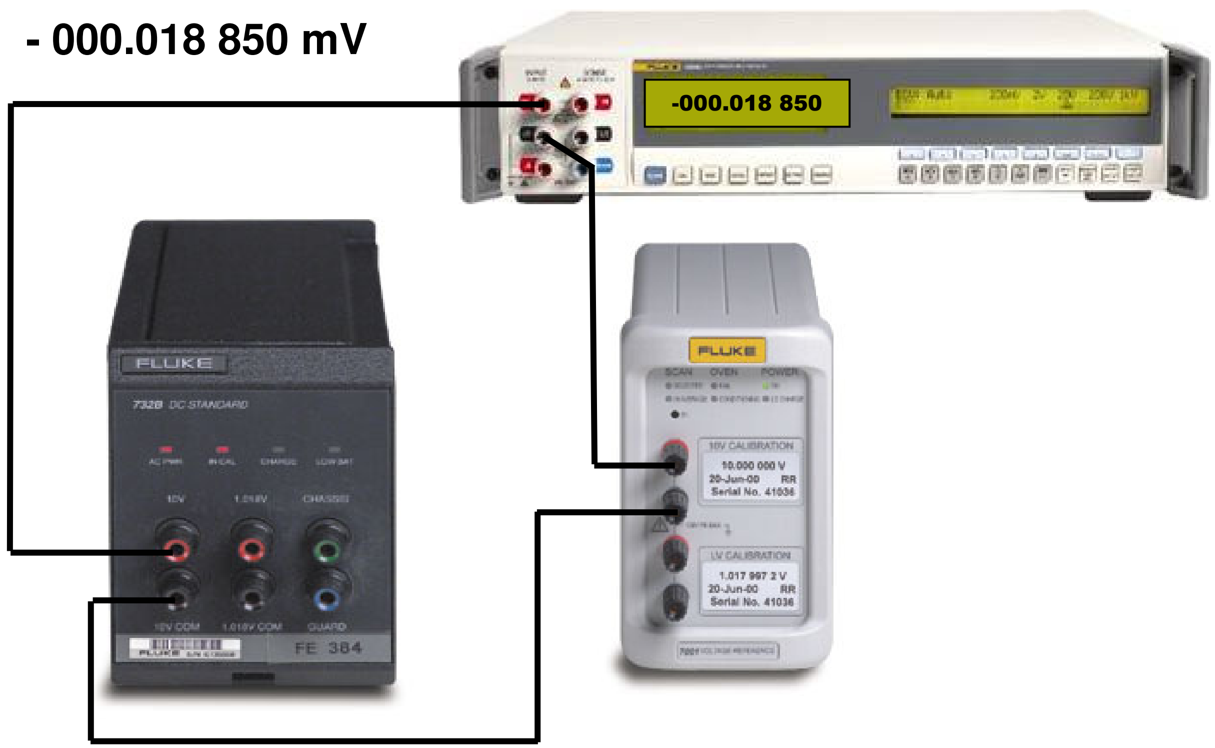
Measurement Details: a Simplified Configuration

DMM's displayed value



The DMM replaces the null detector to measure the difference

- 000.018 850 mV



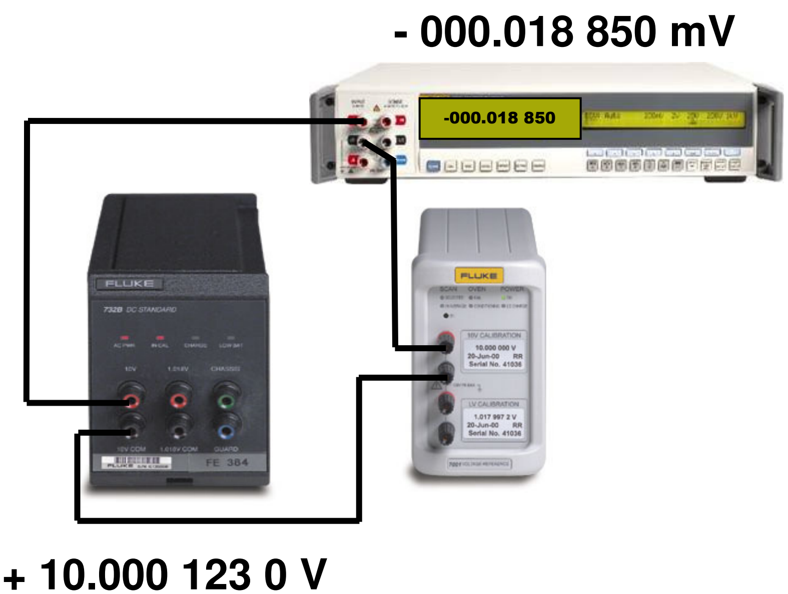
+10.000 123 0 V

Determining the UUT Value

- In this example, the DMM measurements on the difference was determined to be: **- 000.018 850 mV**
- This value is subtracted from the 732B certified value of 10.000 123 0 V:

  The UUT value equals

  10.000 123 0 V minus - 0.000 018 850 V
- The UUT is calculated to be: **+10.000 141 9 V**



Simplified Error Analysis (1) –The Reference Standard Traceability

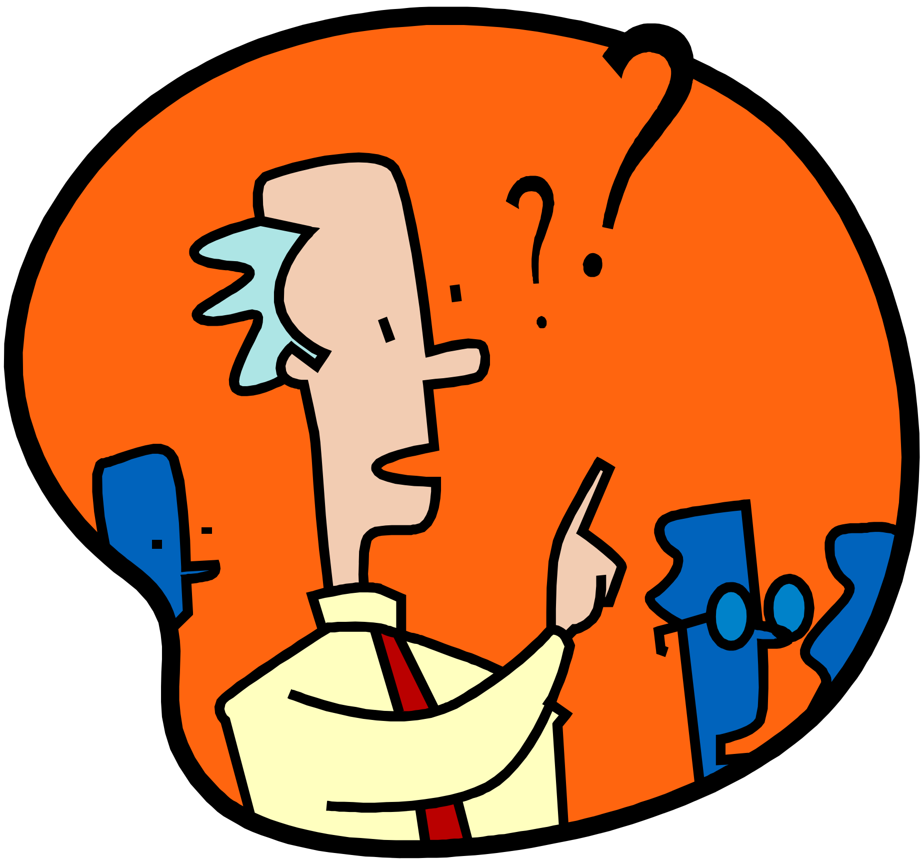
- **Traceable uncertainties for the calibrating standard are a combination of the initial calibration uncertainty plus its stability**
- **Stability depends both upon the number of references instruments combined to form the reference value and the time between periodic recertifications. Here are several alternatives to consider:**
  - A single reference has a stability of ±0.7 ppm (or ±7 μV) per 90 days and ±1.6 ppm (or ±16 μV) per year. This is combined with the initial calibration uncertainty of about ±0.1 ppm.
  - Maintaining a group of four references to obtain an average reference value improves the stability to ±1.2 ppm/year.
  - Four references, certified every 90 days, with historical data, improve the stability to a certified value that is predictable to ±0.2 ppm/year
- **Another alternative is importing traceability using a service to provide a well know, traceable and characterized standard**
  - Traceability of ±0.1 ppm (or ±1 μV) from a standard supplied by Fluke's with the DVMP Care Program

Simplified Error Analysis (2) – Adding the Measurement Uncertainty

- The DMM measurement process
  - ±0.1 µV taken from the 1-year absolute specification
- The combined RSS of errors is dominated by the reference uncertainties that range between ±1 µV to ±16 µV
  - The dmm measurement uncertainties are on the order of ±.1 µV or less and are inconsequential.
- As an example, if the calibration was performed using traceability with a Fluke 732B-200 reference standard supplied through Fluke's DVMP Care Plan, then the UUT is certified to be:

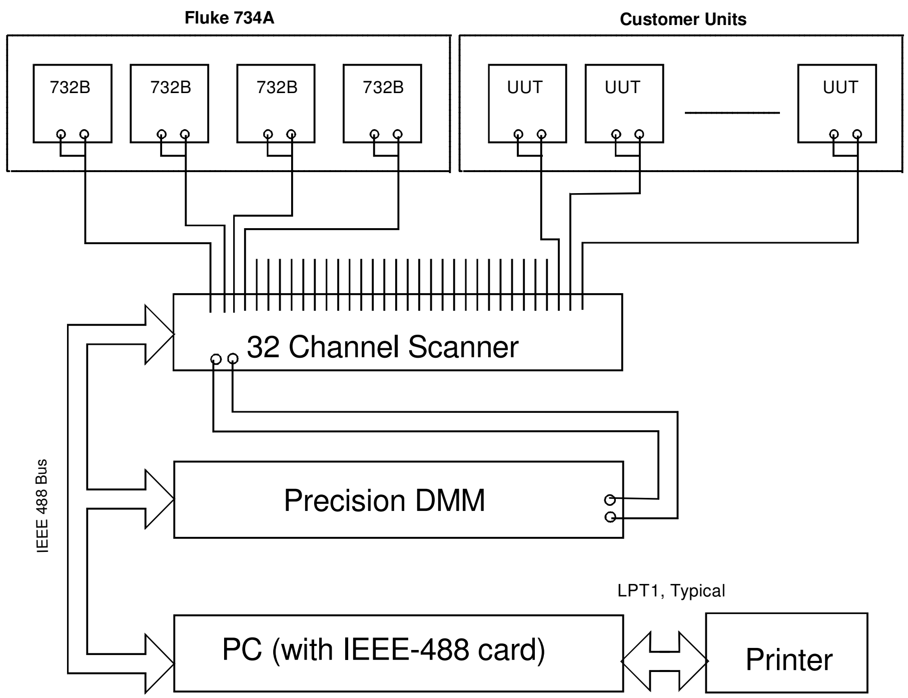
+10.000 141 9 V ±1 µV

Questions?



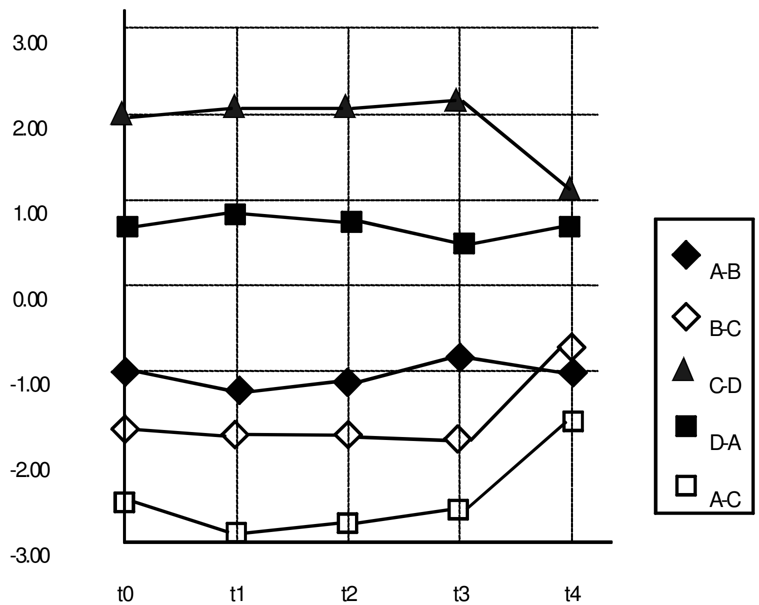
Extending this application – Working with Multiple Standards

- Adding a PC, scanner and software permits automation of standards maintenance.
- Such a system assists in intercomparison, trending and certification work.
- Fluke has used such a system (as shown here) for many years to support both customers and internal requirements.



Fluke's system for intercomparing voltage references

Standards Maintenance Can Provide Control Charted Trends



DATA

	t0	t1	t2	t3	t4
A-B	-1.0	-1.2	-1.1	-0.9	-1.0
B-C	-1.6	-1.7	-1.7	-1.8	-0.7
C-D	+2.0	+2.1	+2.1	+2.2	+1.1
D-A	+0.6	+0.8	+0.7	+0.5	+0.6
A-C	-2.6	-2.9	-2.8	-2.7	-1.7

- Four reference standards can each be intercompared and tracked over time.
- The reference value can be considered as the average of all four reference standards.
- An unusual drift in one reference can easily be detected (as seen in the example with reference C).

Digital Meters versus Analog Null Detectors

	8508A Reference DMM	845AB Analog Null Detector	Comments
Accuracy at null	0.1 µV	0.1 µV	Similar performance
Sensitivity/Range	0.001 µV out of 200 mV	0.02 µV out of 1 µV	DMM measures larger differences with better sensitivity
Input Isolation	10^{+10} Ω (or 10 GΩ)	10^{+12} Ω (or 1000 GΩ)	A battery powered ND has best isolation for critical measurements
Input Resistance	> 10^{+10} Ω (or > 10 G Ω)	10^{+8} Ω but infinite at null	FET inputs vs. chopper amplifier
Bias current	< 50 pA (10 pA Typical)	< 1 pA	Effects measurements with high source resistance, but is often correctable with an offset measurement
Noise	0.05 µV	$0.2\ \mu V_{p\text{-}p}$	DMMs permit averaging of digital values
Automation	YES	NO	

Questions?

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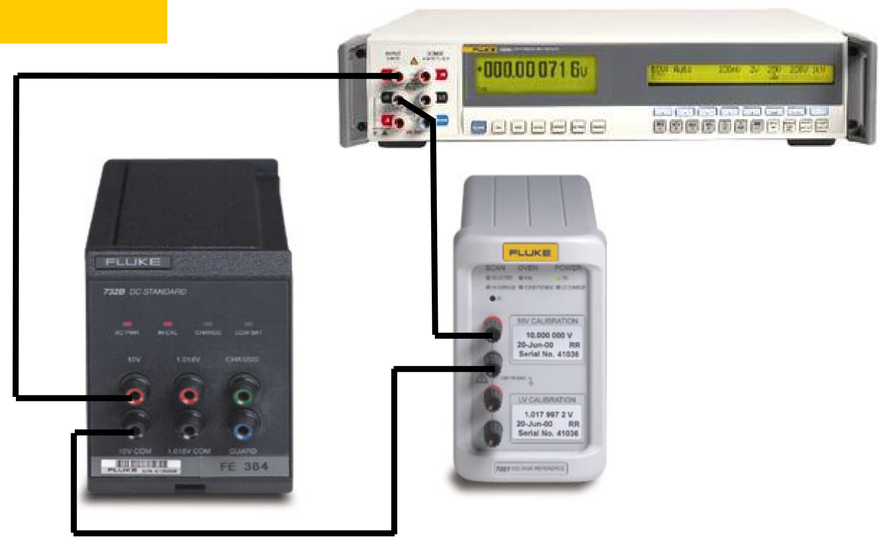
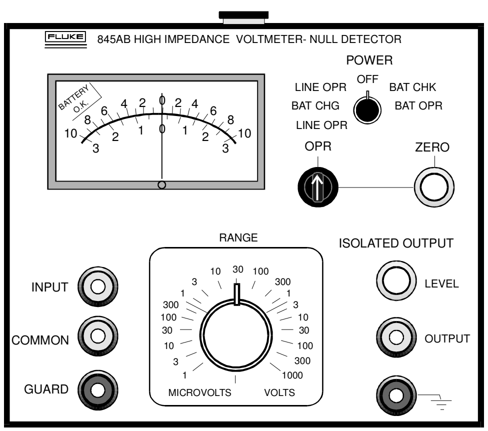
Averages by Dataset (uV)

Dataset	Difference Description	Normal Average	Reverse Average	Normal-Reverse
1	UUT1-STD	-1.82	-1.84	0.02
2	UUT1-STD	-1.87	-1.92	0.05
3	UUT1-STD	-1.85	-0.91	-0.94
4	UUT1-STD	-1.88	-1.89	0.01





DVMP Care Plan

Direct Voltage Maintenance Program for Fluke 732 and 734 DC Reference Standards

Technical Data

NVLAP accredited program yields better than NIST uncertainty[1]

Traditional calibration services require you to send your measurement standards to a higher level laboratory for calibration in order to maintain traceability. But with this traditional process, the actual performance of the standard within the customer's laboratory cannot be determined, and the processes used to make measurements are not evaluated. Also, the valuable standard is out of production for days or weeks and runs the risk of shipping damage. The first step toward getting around this shortcoming was the development of a Measurement Assurance Program (MAP) by NIST several years ago. The disadvantage of this type of program is cost (several times that of a typical calibration).

Now, through its own Josephson Array Voltage Standard (J-Junction), Fluke can provide users of Fluke 732A and 732B Solid State Standards with a calibration accredited by the National Voluntary Laboratory Association Program (NVLAP) at the user's site. The Fluke DVMP Care Plan can save customers virtually 100 % downtime, shipping costs and potential damage, while achieving measurement uncer-

The Fluke DVMP Care Plan offers traceability to its own 10 V Josephson Array, an intrinsic standard of voltage, and to national standards.

Other Null Detector Applications Suitable for DMM Measurements

- In labs with a reference standard and a calibrator, the output drift trends of both instruments can be tracked with regular comparisons of the calibrator’s 10 V output setting versus the 10 Volt Standard.
- Two arms of a Wheatstone Bridge can be balanced with a null detector style measurement.
- Balancing divider resistances (for example the Fluke 752A Reference Divider)
- The outputs of two separate voltage dividers powered by two independent sources can be compared or balanced with a null detector style measurement.
- A modern DMM assists to automate such measurements. Fluke has an example MET/CAL® procedure to compare two 10 volt reference standards.

The Value of Precision Multimeters When Used as Null Detectors

- Traditional analog null detectors are no longer readily available, and existing units cannot be maintained economically.
- Precision multimeters are very versatile, easily automated, and can satisfy most metrology dc/lf ac null measurement applications.
- Coupled with other applications needing precision multimeters, they are the most useful measurement device in an electrical calibration or standard’s lab.

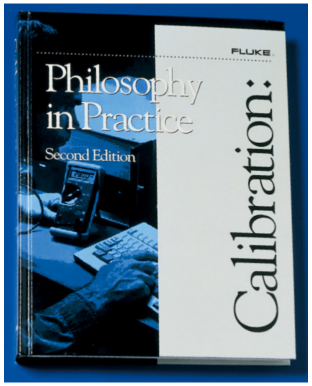
Session Summary

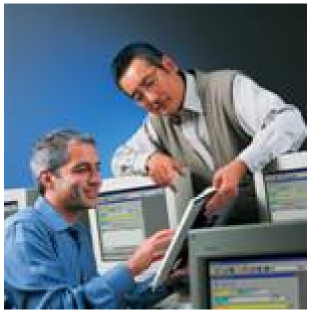
- The analog null detector and comparing voltage standards
- Reference comparisons using a DMM
- Best measurement practices
- Measurement details
- Working with multiple standards
- Digital meters vs. analog null detectors

More Information

- For more information on voltage reference comparison techniques, refer to:
  - Technical material on maintaining 10 voltage references at www.fluke.com, specifically the paper:

    “Maintaining 10 VDC at 0.3 PPM or Better in Your Laboratory”
  - Fluke’s ***Calibration: Philosophy in Practice***, sections on
    - Primary and Secondary Standards
    - Metrology Statistics
  - Material taught in the classes on the **Principles of Metrology**, as well as Fluke’s other web-based training courses
  - Fluke Direct Voltage Maintenance Program Care Plan





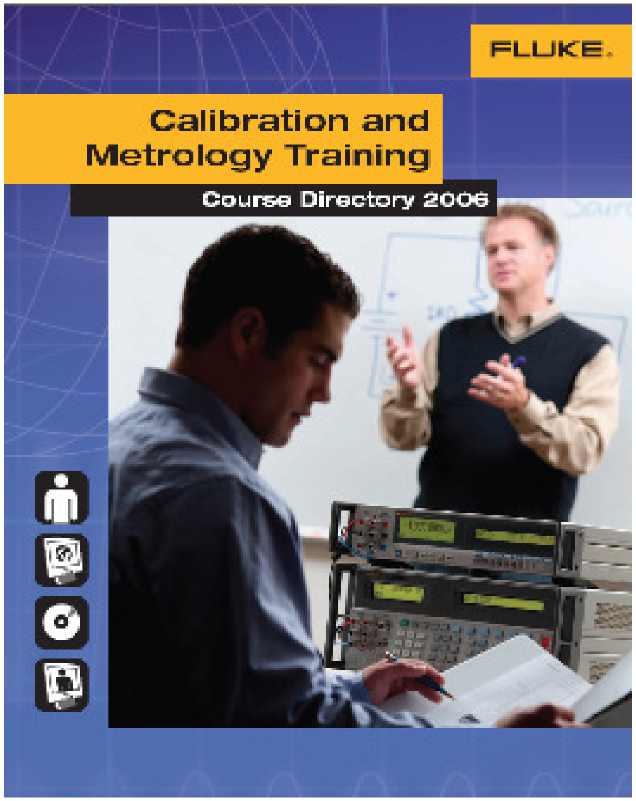
Calibration and metrology training from Fluke

- Fluke calibration and metrology training helps you get the most from your investment in calibration instruments and software
- Multiple ways to learn:
  - **Instructor-led classroom sessions**
  - **Instructor-led web-based courses**
  - **Self-paced web-based training**
  - **Self-paced CD-ROM training**
- Multiple locations
  - **United States and Canada**
  - **Europe**
  - **Singapore**

Members of the MET/SUPPORT Gold and Priority Gold CarePlan support programs receive a 20 % discount off any Fluke calibration training course

Calibration and metrology training

- **Instructor-Led Classroom Training**
  - MET-101 Basic Hands-on Metrology (new in 2007)
  - MET-301 Advanced Hands-on Metrology (new in 2007)
  - Cal Lab Management for the 21st Century
  - Metrology for Cal Lab Personnel (A CCT prep course)
  - MET/CAL Database and Reports
  - MET/CAL Procedure Writing
  - MET/CAL Advanced Programming Techniques
  - On-Site Training
  - Product Specific Training
- **Instructor-Led Web-Based Training**
  - MET/CAL Database Web-Based Training
  - MET/CAL Procedure Development Web-Based Training
- **Self-Paced Web-Based Training**
  - Introduction to Measurement and Calibration
  - Precision Electrical Measurement
  - Measurement Uncertainty
  - AC/DC Calibration and Metrology
  - Metrology for Cal Lab Personnel (A CCT prep course)
- **Self-Paced Training Tools**
  - MET/CAL-CBT7 Computer Based Training
  - MET/CAL-CBT/PW Computer-Based Training (new in 2007)
  - Cal-Book: Philosophy in Practice textbook



More information:
www.fluke.com/2008caltraining

FLUKE

MET-302
Hands-On Metrology Statistics

General Technology Workshops

A powerful three-day "how to" workshop that describes and demonstrates measurement uncertainty concepts and techniques

This three-day course will introduce the student to basic measurement uncertainty concepts in the fields of electrical, temperature, pressure and flow measurements. From the hands-on exercises and examples given in the course, attendees will learn about the uncertainty budgeting process. The course material is based on the GUM "The ISO Guide to the Expression of Uncertainty in Measurement" and ANSI/NCSL Z540.2. The MET-302 course uses simulated and real-world measurements as exercises, giving the student the ability to see the practical application of uncertainty calculations. A discussion is also included on consumer risk (false accepts) and producer risk (false rejects), as referenced in ANSI/NCSL Z540.3, and the effects of Guardbanding.

Who should take this course

This course is designed for engineers, laboratory managers and technicians who need to understand how to develop uncertainty budgets. Attendees of this course will find the information essential to understand necessary calibration processes and techniques for obtaining repeatable results.

Course prerequisites

It is recommended that attendees have a high school education and a basic understanding of math, algebra, physics and science. Some hands-on experience in dc-lf electrical calibration, temperature calibration, pressure and flow calibration is helpful. Formal statistics training is not required.

Course outline

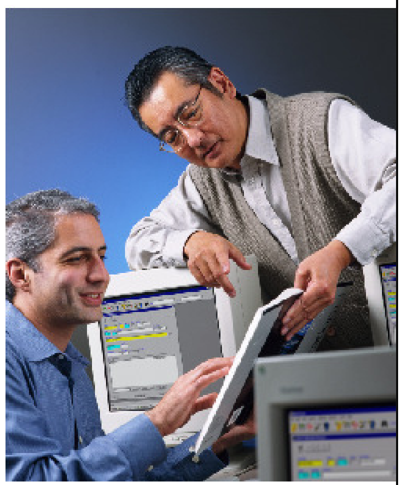
- What is Uncertainty in a Measurement?
- Introduction to Basic Metrology Statistics
- Instrument Specifications
- Statistical Distributions
- Calculating Measurement Uncertainty
- Using the Student's t Distribution and the Welch-Satterthwaite Equation
- Creating a Basic Uncertainty Budget
- Statistical Techniques in Metrology
- Guardbanding and Risk Analysis
- Uncertainty in Temperature Measurement
- Uncertainty in Pressure Measurement
- Uncertainty in Gas Flow Measurement
- Course Exam

Course materials

Each student will receive a course text book, an exercise handbook and a copy of "The Metrology Handbook" by ASQ (American Society for Quality) Measurement Quality Division.

Registration

Register online at www.calibration.fluke.com. Select Events and Training, then Register and Pricing. You will be prompted for your contact information, the course date and location. Press Submit to send your request to the training coordinator for processing. You will receive instructions about how to finalize your registration.



If you have membership in one of Fluke's Gold Plans, inquire about a 20% discount on the course fee.

Course information

Course No. TRC 1302

Course Length: 3 days or approximately 24 hours of class time (This supports a certified calibration technician's requirement for continuing education.)

After completing the course, all attendees will receive a Fluke Certificate of Completion.

FLUKE

NEW

MET-302 Hands-On Metrology Statistics	
Course Number: TRC 1302 3 days / Starts Tuesdays	
March 18-20, 2008	Seattle, WA
June 3-5, 2008	Seattle, WA
August 12-14, 2008	Seattle, WA
October 14-16, 2008	Seattle, WA

More information:
www.fluke.com/2008caltraining

THANK YOU !

For material related to this session, visit our web site:

http://www.fluke.com

For any questions or copies of this presentation:

email inquiries to: jack.somppi@fluke.com