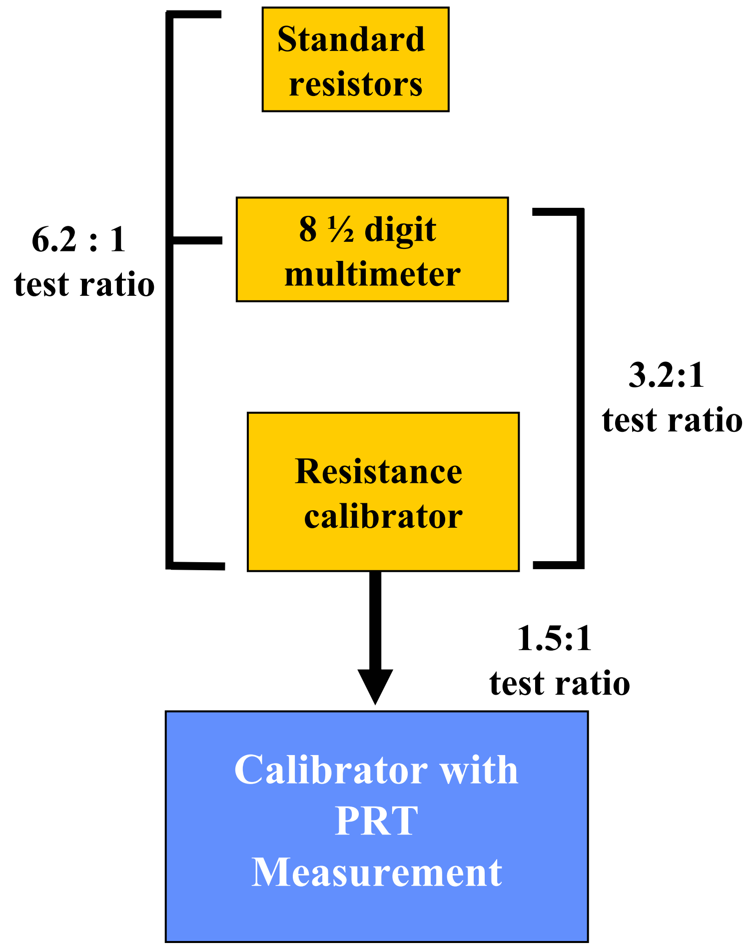
Improving Test Ratios Using Reference Multimeters

Boosting the working accuracy of precision sources

Session Topics

Case study: Calibrating a calibrator with PRT measurement capabilities (a limited resistance measurement function)

- Begin with a resistance calibrator.
    - Calibrator resistance sourcing provides a lower than desired 1.5:1 test ratio
- Enhance the calibrator with an 8½ digit multimeter.
    - Measurement disciplining of the calibrator's resistance output for a 3.2:1 test ratio
- Enhance TUR further by comparison with standard resistors.
    - Characterization of the calibrator resistance output by ratios with standard resistors for a 6.2:1 test ratio



Problem Statement

- Accepted levels of test uncertainty ratios (TURs) and test specification ratios (TSRs) have been set to various levels by different quality and calibration standards, such as 10:1 or 4:1 or 3:1.
- These levels are set as acceptable limits for calibration pass or fail decisions.
  - This minimizes the risk of incorrect decisions on marginal units under test (UUTs)
- However, there will always be instrument test requirements whose TURs are less than the required levels.
  - Calibration instruments will always have test requirements where the test requirement is for better uncertainty than the instrument capabilities alone.
  - In these cases, special metrology engineering work is done to design an acceptable test technique with appropriate levels of uncertainty.

A Case Study of Improving a TUR from 1.5:1 to 6.2:1

Using a multi-product calibrator to calibrate a high performance resistance measuring instrument

The calibrator:
Fluke 5520A MPC

The UUT:
PRT measurement on a Fluke 525A Temperature Calibrator

Details of the Challenge

- Fluke 525A Temperature Calibrator has precision SPRT measurement capability that must be calibrated.
- The available calibrator is a 5520A Multi-Product Calibrator.
- Calibration points of 400 ohms and 4 kohms are required.
- 525A has specification of ±40 ppm for 400 ohms and 4 kohms measurement.
- 5520A has specification of ± 27 ppm at 400 ohms and 4 kohms.
- A test uncertainty ratio (TUR) of 1.5:1 (or 40ppm/27ppm) is not acceptable.

What enhancements can be made to improve the TSR between the calibrating standard of the 5520A and the measurement accuracy of the 525A?

Method 1: Traditional Accuracy Enhancement

Assist with a DMM because it has better resistance specs than the 5520A.

- Measure the 5520A calibrator with the precision DMM.
- Note the reading correction and then quickly make measurement of the same parameter with UUT.
- Uncertainty is based on a combination of the meter reading and calibrator stability.

Instrument Uncertainties to Consider

Resistance

Resistance [1] [2] [3] [9]

Range	Full Scale	Mode [10]	Uncertainty Relative to Cal Stds			Absolute Uncertainties	
			± (ppm Reading + ppm Range) [4]				
			24 hour TCal ±1 °C	90 day TCal ±1 °C	365 day TCal ±1 °C	365 day TCal ±1 °C	365 day TCal ±5 °C
99% Confidence Level							
2 Ω	1.999 999 99	Normal	6.0 + 2.5	10 + 2.5	12 + 2.5	19 + 2.5	22 + 2.5
20 Ω	19.999 999 9	Normal	3.0 + 0.9	5.5 + 0.9	8.5 + 0.9	11.5 + 0.9	12.0 + 0.9
200 Ω	199.999 999	Normal	1.8 + 0.3	5.0 + 0.3	8.5 + 0.3	9.5 + 0.3	10 + 0.3
2 kΩ	1.999 999 99	Normal	1.2 + 0.3	4.5 + 0.3	8.5 + 0.3	9.5 + 0.3	10 + 0.3
20 kΩ	19.999 999 9	Normal	1.2 + 0.3	4.5 + 0.3	8.5 + 0.3	9.5 + 0.3	10 + 0.3
200 kΩ	199.999 999	Normal	1.2 + 0.3	4.5 + 0.3	8.5 + 0.3	9.5 + 0.3	10 + 0.3
2 MΩ	1.999 999 99	Normal	2.5 + 0.6	5.0 + 0.6	8.5 + 0.6	10.5 + 0.6	12 + 0.6
20 MΩ	19.999 999 9	Normal	4.5 + 6.0	7.5 + 6.0	12 + 6.0	20 + 6.0	25 + 6.0
200 MΩ	199.999 999	Normal	25 + 60	30 + 60	35 + 60	75 + 60	150 + 60
2 GΩ	1.999 999 99	Normal	325 + 600	450 + 600	650 + 600	675 + 600	1810 + 600

- 8508A resistance measurement:
  - 1 Year, 99 % confidence, Tcal ±5 ºC absolute spec
  - ±10 ppm of reading + 0.3 ppm of range equals
  - At 4 kΩ equals 11.5 ppm of uncertainty
- Short term stability of 5520A
  - Not normally specified
  - Evaluated for this case

How the 5520A Short Term Stability Was Evaluated

- 5520A output set at 4 kohms
- Measurements made for three minutes
- Repeated 10 times, including operate-to-standby-to-operate transitions
- Standard deviation (σ) determined
- Measurement uncertainty
  - "Type A"
  - 2.58 x σ for 99 % confidence
- 2.58 * 1.94 = 5 ppm

Error Analysis

- DMM ohms readout gives 11.5 ppm
- Short term stability of the calibrator was measured to be 5 ppm
- Combine the errors using an RSS method results in 12.5 ppm
- This improved TUR is:
  - (40ppm/12.5ppm) = <u>3.2:1</u>
  - a definite improvement over 1.5:1
- But other methods can improve this still more.

- Use the better stability of the calibrator (vs. the DMM resistance spec) as the basis for still more improvement.
- Characterize the calibrator’s resistance in a ratio compared with standard resistors.
- Use a precision DMM to make a precision ratio of the calibrator to the standard resistors.
- The excellent uncertainty of the DMM’s ratio measurement, along with the better uncertainty of the standard resistors, are a better alternative than simple resistance measurement by the DMM.

Front “A” channel

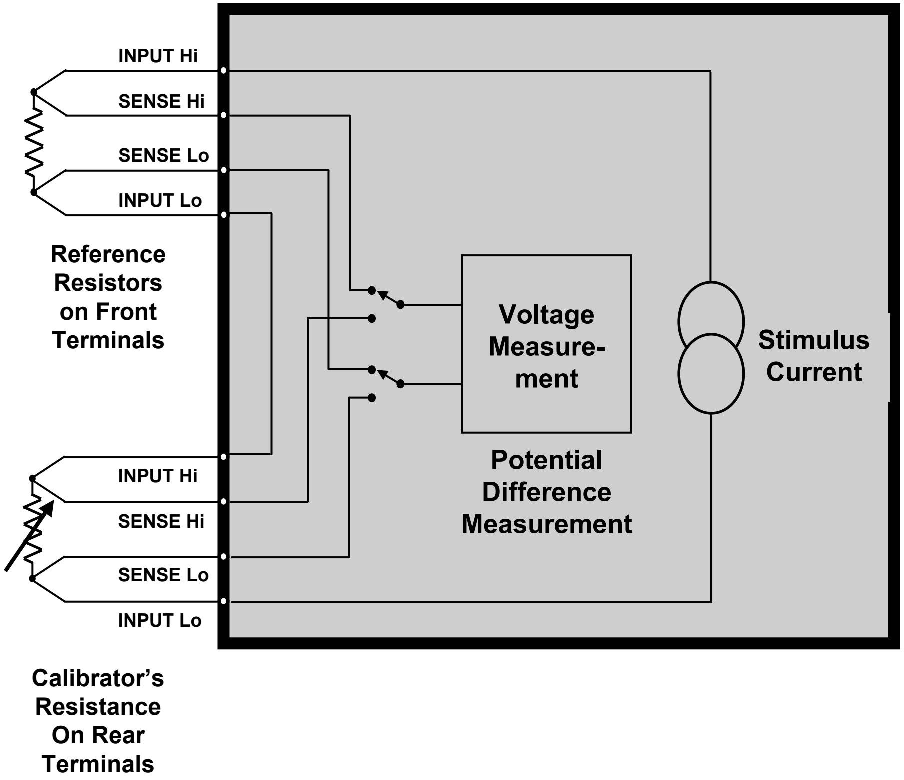
Rear “B” channel

Ratio “A” to “B”

Setup for Ratio Style Characterization

- Additional equipment required:
  - 10 kohm reference resistor
  - 1 kohm reference resistor
- Ohms ratio of approximately 2.5:1
  - 10 kohm to 4 kohms
  - 1 kohm to 400 ohms
- 5520A is actually adjusted to output exactly 400 ohms and 4 kohms.
- Use a DMM test current similar to the UUT's test current.

8508A in Ohms Ratio Mode



- If the 1 kohm standard resistor is certified to be 999.977 ohms, then the displayed ratio would need to be 2.4999425
 (as 999.977/400.000)
- Adjust the 5520A output to reach the target 8508A measured ratio of 2.4999425.
- Let’s assume for this example that the 5520A has an error of +15ppm.
- Then the 5520A setting of 399.9940 ohms gives the desired ratio
- This 5520A setting of 399.9940 ohms is established as the true 400 ohm setting used to calibrate the 525A test point.

Desired ratio “A/B”
2.4999425

Front “A” channel
999.977 ohms

Rear “B” channel
adjusted to
399.9940 ohms

Calibrate the UUT

Characterized 399.9940 ohms

Characterized Ωs

Verified/adjusted to be 400.000 ohms

- Apply the characterized values of exactly 400 ohms (as determined by ratio) and 4 kohms to the resistance measurement function of the UUT.
- Verify and/or adjust the UUT's performance at these points.

Resistance Ratio Uncertainty

- Consider the 4 kΩ test.
- Use 20 kΩ range transfer spec
  - ±0.2 ppm of reading + 0.15 ppm of range
- DMM transfer measurement of 10 kΩ standard resistor is 0.5 ppm.
- DMM transfer measurement of 4 kΩ on 5520A is 0.95 ppm.
- RSS combination of both measurement uncertainties is *1.1 ppm* of ratio.

Resistance - Normal Mode (Secondary Specifications) [1] [2] [3] [14]

Range	Measurement Current	Transfer Uncertainty 20 mins ±1 °C ± (ppm Reading + ppm Range)	Temperature Coefficient ± ppm Reading/°C 15 °C - 30 °C	Temperature Coefficient ± ppm Reading/°C 5 °C - 15 °C 30 °C - 40 °C
2 Ω	100 mA	2.0 + 2.0	1.5	2.5
20 Ω	10 mA	0.8 + 0.7	0.6	1.0
200 Ω	10 mA	0.2 + 0.15	0.5	0.8
2 kΩ	1 mA	0.2 + 0.15	0.5	0.8
20 kΩ	100 µA	0.2 + 0.15	0.5	0.8
200 kΩ	100 µA	0.2 + 0.15	0.5	0.8
2 MΩ	10 µA	0.5 + 0.5	0.6	1.0
20 MΩ	1 µA	2.5 + 5	2	3
200 MΩ	100 nA	15 + 50	20	30
2 GΩ	10 nA	200 + 500	200	300

Error Analysis

- 742A 10k has 4 ppm specification.
- 8508A ratio specification of 1.1 ppm
- 5520A short term stability of 5 ppm
- Combined errors (RSS) = 6.5 ppm
- TUR = (40 ppm / 6.5 ppm) or 6.2:1
- Almost a two times improvement over traditional accuracy enhancement!
- The final TUR is very acceptable for such a test.

Accuracy Enhancement Summary

There are several ways a high performance meter can improve a calibrator's performance.

- Calibrator disciplining through direct measurement of the output improves it up to the limit of the DMM spec plus calibrator stability.
- A better technique is to take advantage of several low uncertainty measurement elements together using:
    - The excellent stability of the calibrator
    - The low uncertainty of the standard resistor
    - The low uncertainty of the same range ratio measurement of the DMM.

The Value of Accuracy Enhancement

- Inadequate measurement accuracy ratios is a common situation in many labs. This can have a costly impact on test quality when incorrect “pass” decisions are made.
- A precision reference multimeter is a versatile cal lab tool that can effectively improve accuracy ratios in metrology applications where an existing precision source’s specifications fall short of the required uncertainties.
- The costs of higher accuracy sources and standards are often significantly large when merely improving existing sourcing uncertainties compared to the versatility that precision measurement offers as an addition to precision sourcing.

Questions?

8508A in ohms ratio mode