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Quality Manual of Digital Voltmeter and Current to Voltage Converter Calibrations

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2. Definition

2.1. Introduction

This quality manual describes the principle and the operation of the equipment used for digital voltmeter (DVM) and current to voltage converter (CVC) calibrations. Calibrated devices are Hewlett Packard/Agilent multimeters and current to voltage converters, manufactured either by Stanford Research Systems or Vinculum/Lab Kinetics. Calibrated quantities are DC current and DC voltage for DVM's and gain for CVC's.

2.2. Object and field of application

Calibrator: Secondary transfer standard calibrated with the electrical primary standards, used for calibrating digital voltmeters and current to voltage converters.

Digital Voltmeter: Multimeter used for electrical measurements. This quality manual describes the calibration of DC voltage and current ranges of Hewlett Packard (HP)/Agilent 3458A and 34401A multimeters.

Current to Voltage Converter: Transimpedance amplifier with adjustable gain that is used to convert low currents to voltage. This quality manual describes the calibration of gain of Stanford Research Systems SR570 and Vinculum/Lab Kinetics SP042 current to voltage converters.

2.3. Features

Calibration setup includes the following features:

- a) Fully automated DC current calibration for HP 3458A and 34401A multimeters
- b) Fully automated DC voltage calibration for HP 3458A and 34401A multimeters
- c) Semi-automated gain calibration for Stanford Research Systems SR570 and Lab Kinetics SP042 current to voltage converters
- d) Automated measurement data processing

3. Equipment

1. Keithley model 263 calibrator
2. Two coaxial cables labelled “Keithley 263 calibrator”
3. BNC-to-banana adapter
4. Coaxial cable with BNC male connectors or Lemo connectors for CVC calibrations
5. Hewlett Packard 3458A multimeter for CVC calibrations
6. Measurement computer with LabView 8.5 or newer installed with the extensions package needed for exporting data to MS Excel.
7. The decimal pointer needs to be dot “.” when running the LabView program. If the Keithley calibrator gives a bus error “berr”, the decimal pointer needs to be changed in the system or in the LabView options.
8. LabView software for calibration, newest versions can be found at \\metrology\webpages\quality\electrical
9. GPIB interface card for the computer (preferably NI GPIB-USB-HS)
10. One GPIB cable

4. Measurement traceability

The calibrations are traceable via the Keithley model 263 calibrator to **VTT MIKES** group of electrical quantities. The calibrator is calibrated at **VTT MIKES** with 2-year interval. Full calibration including current and voltage is performed. The Hewlett Packard 3458A multimeter for CVC calibrations needs traceability as well, and should be calibrated prior to CVC calibrations.

5. Calibration and measurement procedures including validation methods

5.1. Scale realization

5.1.1. Introduction

Keithley Model 263 Source/Calibrator is calibrated against reference standards at the Centre for Metrology (**VTT MIKES**). Scale realization is based on primary standards.

Calibrated source/calibrator stores the scale realization. It can be used for voltage, current and resistance calibrations. Calibrator should be stored and used in constant temperature and during calibration ambient temperature should be static and no significant electromagnetic interference should be present.

With this device, DC voltage can be calibrated over the range of 100 mV to 10 V, DC current 1 pA to 10 mA and resistance 1 k Ω to 1 G Ω .

5.1.2. Multimeter

In addition to the calibrator, a multimeter is needed for CVC calibrations. An HP 3458A, which has been recently calibrated, should be used. A unit with low uncertainties in 1 VDC range should be chosen to ensure high quality calibrations.

5.2. Calibration of HP 3458A multimeter

Measurement

- Calibrator and the multimeter to be calibrated must be turned on 4 hours before the measurement begins.
- After 4-hour warm-up time, perform the auto calibration procedure on the multimeter.
- Connect the output of the calibrator to the voltage input of the multimeter using coaxial cable and BNC-banana-adaptor.
- Start HPcal_new_v2.vi LabView-software, and select multimeter type (HP 3458A) and quantity to be measured (voltage). When program starts, warm-up timer starts counting. Timer is for reference purpose only. Measurements are started by pressing GO-button.
- Observe the results at the beginning of measurement to make sure that every-thing works.
- In the end of the voltage measurements, offset voltages are measured. At this point software asks you to disconnect calibrator and short input pins. Press OK after doing so.
- Next connect the coaxial cable to the current terminals and run software for current measurements.

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- When offset values for current scale are measured, calibrator must be disconnected. Terminals of the multimeter are not shorted. Follow the instructions on the screen.

Correction

- LabView-software saves the results in the Excel-sheet.
- Update the blue cells with calibrator's corrected data, if necessary.
- Corrections are calculated automatically, results are shown in the yellow cells. Copy the contents of the yellow cells to the measurement report.

5.3. Calibration of HP 34401A / Agilent 34410A / Keysight 34461A DMM

- Same instructions apply as for HP 3458A multimeter.

Remarks

- Select the correct multimeter type in the LabView software.
- Instead of auto calibration procedure, a self-test procedure is performed.

5.4. Calibration of Stanford SR570 CVC

Measurement

- 4-hour warm-up time is needed.
- CVC is not computer controlled.
- After warm-up time, connect coaxial cable to the input of the CVC.
- Connect output of the CVC to the voltage input terminals of the HP 3458A multimeter using BNC cable and BNC-banana adaptor.
- Open the LabView-library CurrentToVoltage_Calib.llb and start the program CurrentVoltage_Converter_Calib.vi, select the correct device and observe the voltage readings at the beginning to make sure that the results are feasible. If the measured voltage is clearly out of range, calibration software will hold until correct readings are present.
- Set the gain manually after each measurement round according to the instructions given by the software.
- Measurement are done using following filter settings: low pass 0 dB, low pass 6 dB and low pass 12 dB.
- The calibration procedure is done twice, so that operation modes "LOW DRIFT" and "LOW NOISE" of the SR570 are calibrated separately.

Correction

- Copy the measured data to the Excel-sheet Stan_cal.xls to the appropriate cells.
 - Update the cells with calibrator's corrected data, if necessary.
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- Corrections are calculated automatically, results are shown in the green cells. Copy the contents of the green cells to the measurement report.

5.5. Calibration of Vinculum/Lab Kinetics SP042 CVC / MRI CVC / MRI CVC-B

- Open the LabView-library CurrentToVoltage_Calib.llb and start the program CurrentVoltage_Converter_Calib.vi.
- Some devices need cables with Lemo-connectors.
- Follow the same procedures as with Stanford SR570. Apply the on-screen instructions.

Remarks

- The filter bandwidth knob (low-pass frequency) should be turned to 10 Hz position in the measurements. **Note Vinculum and MRI CVCs make use of the filter only when the post-amp is used.**
- Only preamp value -1 should be measured for all gain settings. Linearity of the preamp is measured separately using gain 10^5 .
- MRI CVCs with an input bias option (MRI CVC-B) are calibrated both with and without the bias voltage.

5.6. Calibration of Femto DDPCA-S / DLPCA-300

- Open the LabView-library CurrentToVoltage_Calib.llb and start the program CurrentVoltage_Converter_DDPCA-S.vi. Select the correct device before running the measurement.
- Follow the same procedures as with Stanford SR570. Apply the on-screen instructions.
- The amplifier is calibrated without biasing and with the internal bias voltage applied. Before the measurement, the bias is measured for the input of the amplifier using multimeter and set to 5 V.
- The full bandwidth setting is used in all the measurements.

5.7. Calibration of Femto DLPCA-200

- Open the LabView-library CurrentToVoltage_Calib.llb and start the program CurrentVoltage_Converter_DDPCA-S.vi. Select the correct device before running the measurement.
- The amplifier is calibrated without biasing and with the internal bias voltage applied. Before the measurement, the bias is measured for the input of the amplifier using multimeter and set to 5 V.
- The amplifier is set to DC-mode.

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- The second amplification stage is set to low.
 - The full bandwidth setting is used in all the measurements.

5.8. Calibration of Keithley 6485 Picoammeter

- The measurement rate of the device is set to slow (5 PLCs) and device averaging is set to 100 samples.
- At each current measurement range, a current corresponding to $\pm 50\%$ of the range is measured. The current offsets are also measured. i.e.
- The current readings are recorded manually from the display of the picoammeter.

5.9. Adjustment of HP 3458A

In case drifting is observed, reading of the HP 3458A can be adjusted. Calibrator is connected to the input terminals of the multimeter and DC voltage or resistance is applied. Adjustment is performed by applying CAL-command.

CAL-command is typically secured. In this case SECURE-command must be applied before CAL-command. Format is SECURE old_code,new_code, the default old code is 3458. New code should be set to 0, when security feature is disabled.

Refer to the 3458A Service Manual for more specific instructions. The manual is located in Metrology server in the same folder with other electrical QM documents.

In the calibration certificate, both the results before and after the adjustment are reported.

6. Handling of calibration items

Items to be calibrated should be switched on 4 hours before calibrations.

7. Uncertainty budgets

Measured uncertainties must be compared with the ones of the previous calibration. If there is significant variation, the cause should be examined. Possible causes are, among others, equipment malfunction, faulty cables, electromagnetic interference or insufficient warm up time. If considered necessary, measurements must be redone.

Most significant contributor to the uncertainty of the multimeter and the CVC is the noise of the device itself. With multimeters, the effect of the noise is lowered by measuring each voltage 10 times. Integration time (number of power line cycles) is $NPLC = 100$ for both types of meters. A low-pass filter is used with both types of CVC's to help reducing the noise in the measurements.

8. Accommodation and environmental conditions

Measurements are preferably done in a temperature controlled laboratory room, such as room 1567 at TUAS building. Alternatively, if the device to be calibrated is a permanent or a semi-permanent part of a measurement setup, the calibration can be performed on-site.

During the measurements, temperature and humidity near the devices is monitored and the values should be written to the measurement report. All kind of interference should be minimized when choosing the location for the measurements.

9. Field calibrations

No field calibrations are carried out.

10. Control data

The measurement data coming from the calibrations and development of the equipment is archived. The data of the measurements is archived in Aalto file server, in the folder:

\\work.org.aalto.fi\T405\MIKES-Aalto\Calibrations\REPORTS\

by the person who performs the measurements. Data is stored in an Excel-file which has the same file name as the measurement report.

Raw data (txt-files) is stored in the measurement computer. All measurement data is also backed up by the measurer (Timo Dönsberg) to his or her personal folder located at

\\work.org.aalto.fi\T405\MIKES-Aalto\Users

Manually taken measurement data is stored in a measurements notebook.

11. Certificates

Calibrations are done for internal use only. Therefore, no official calibration certificates are written. Instead, a template called “Measurement report” or “Mittauspöytäkirja” in Finnish should be used. The certificate numbers are of form INT XYZ, where XYZ is a consecutive number, starting from 001. Internal calibrations are listed in file Cal_INT.xls (\\work.org.aalto.fi\T405\MIKES-Aalto\Calibrations\).

The calibration date and the number of the calibration certificate should be written on the “Kalibroitu”-sticker and the sticker should be placed on a visible place on the calibrated device. The lion logo (“Kansallinen mittanormaalilaboratorio”) should be cut off.

12. Intercomparisons

13. Publications

Manuals relevant to calibrations can be found in

\\work.org.aalto.fi\T405\MIKES-Aalto\Quality\Electrical\Manuals

1. A User's Guide to Agilent 3458A Front Panel Operation
2. Agilent Technologies 3458A Multimeter Calibration Manual
3. Agilent Technologies 3458A Multimeter User's Guide
4. HP 34401A Multimeter User's Guide
5. Agilent 34410A Multimeter User's Guide
6. Keysight 34461A Multimeter User's Guide
7. Keithley Model 263 Calibrator/source Instruction Manual
8. Lab kinetics, Vinculum, HANDBOOK FOR PICOAMMETER TYPE SP042-03
9. Stanford MODEL SR570 Low-Noise Current Preamplifier