

Report No. 1180

Digital Multimeter

Proficiency Testing Program

Round Five

May 2020

ACKNOWLEDGMENTS

PTA wishes to gratefully acknowledge the technical assistance that was provided for this program by Dr T Zhang, National Measurement Institute, Australia. This assistance included preparation and input into the design of the program, technical advice, calibration of the digital multimeter and discussion in the final report.

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PO Box 7507, Silverwater NSW 2128, Australia

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1. Foreword

This report summarises the results of an interlaboratory comparison on digital multimeter calibration by laboratories. This program is accredited to ISO/IEC 17043:2010 "*Conformity assessment - General requirements for proficiency testing*" by International Accreditation New Zealand (IANZ).

Proficiency Testing Australia (PTA) conducted the program from July 2018 to April 2020. The Program Coordinator was Dr M Li. The Technical Adviser was Dr T Zhang, National Measurement Institute, Australia. This report was authorised by Mrs K Cividin, PTA Quality Manager. The aim of the program was to assess laboratories' ability to competently perform the prescribed analyses.

2. Program Features and Design

Each laboratory was randomly allocated a unique code number for the program to ensure confidentiality of results. Reference to each laboratory in this report is by code number only.

Laboratories were provided with the "Instructions to Participants" and "Results Sheets" (refer Appendix C).

Participants were provided with one Keysight Model 34465A digital multimeter.

Eight laboratories from Australia, Hong Kong, Qatar and Sweden participated in the program, and all the laboratories submitted results for inclusion in the final report..

Results as reported by participants for each testing point along with corresponding summary statistics are presented in Appendix A for each laboratory.

3. Reporting by Participants

Laboratories were asked to report their test results on a proforma "Results Sheet" (refer Appendix C). The participating laboratories were asked to report uncertainties at 95% confidence levels.

4. Reference Values

The reference values for the digital multimeter are the average of the 'before' and 'after' values, which were carried out by the National Measurement Institute, Australia (NMI) at the beginning and end of the program. Note that the 'before' values are the calibration values taken before the circulation schedule for the

program. The 'after' values are the calibration values taken after the circulation schedule was completed.

The following calculations are used to determine the reference:

$$1. \text{ REF} = \frac{1}{2} (\text{REF}_1 + \text{REF}_2)$$

$$2. \text{ U}_{\text{REF}} = \frac{1}{2} (\text{U}_{\text{REF1}} + \text{U}_{\text{REF2}})$$

5. Summary of Results

A summary of the results returned by the participating laboratories, compared to the reference values, is presented in Appendix A.

In accordance with international practice, measurement performance has been assessed on the basis of an E_n ratio for each measurement. The E_n ratios are calculated using a standard statistical technique for comparing values and are derived from the following expression:

$$E_n = \frac{\text{Lab} - \text{Ref}}{\sqrt{(\text{U}_{\text{Lab}})^2 + (\text{U}_{\text{Ref}})^2}}$$

where *Lab* is the laboratory correction result, *Ref* is the correction result measured by NMI, U_{Lab} is the laboratory's reported uncertainty of measurement at a 95% confidence level, and U_{Ref} is the uncertainty associated with the *Ref* at a 95% confidence level.

Interpretation of corrections: The actual value (nominal value) is equal to the sum of the digital multimeter reading and the correction.

For example, if the digital multimeter displays +10.000 00 V and the correction is - 0.000 04 V, the actual voltage is +10.000 000 V + (- 0.000 04 V) = + 9.999 96 V.

6. PTA and Technical Adviser's Comments

Most of the results reported were in agreement with each other and with the reference values. The DC Current measurements were very consistent with no outliers reported. The DC Voltage measurements highlighted eight outliers from LAB 3 (1 outlier), LAB 5 (1 outlier), LAB 8A (5 outliers) and LAB 8B (1 outlier). The AC Current measurements identified one outlier from LAB 1B. The AC Voltage measurements produced seven outliers from LAB 1A (1 outlier), LAB 1B (1 outlier), LAB 5 (3 outliers) and LAB 8A (2 outliers). The resistance measurements had four outliers from LAB 2 (1 outlier), LAB 3 (1 outlier), LAB 8A (1 outlier) and LAB 8B (1 outlier).

There were, however, a few outliers with large E_n values. Some may be due to small uncertainty values estimated by the participants, although most of these seemed to be caused by measurement errors.

Most of the uncertainties were realistic and conservative. Some uncertainty values varied significantly from one laboratory to another, especially for resistance measurements.

Possible sources of error could be range setting, inaccurate reference, temperature variations, operator measurement or recording errors etc.

Laboratory codes 4, 6 and 7 did not report any outliers. Laboratory codes 1A and 2 each had one outlier. Laboratory codes 3 and 8B each had two outliers. Laboratory code 1B had 3 outliers, laboratory code 5 reported 4 outliers, and laboratory code 8A reported 8 outliers.

The interlaboratory comparison results may provide evidence to support the level of competency that the participating laboratories can achieve in digital multimeter measurements.

It is recommended that values of $|E_n| \geq 1.0$, and any other results considered unsatisfactory are investigated and that corrective actions be taken by the laboratories concerned. There are results where the LAB-REF value is larger than the U_{LAB} value, even though the $|E_n|$ value is less than one. For each of these cases, it is recommended that the laboratory check the results and take corrective action as necessary.

7. Reference

- [1] *Guide to Proficiency Testing Australia*, 2019 (This document can be found on the PTA website, www.pta.asn.au)

APPENDIX A

Summary of Reported Results

SUMMARY OF REPORTED RESULTS

DIGITAL MULTIMETER ROUND FIVE

| DC VOLTAGE | | | | | | | | | | | | | |
|--------------|----------------|-------------|------------------|----------|----------------|-------------|------------------|----------|----------------|------------|------------------|----------|----------------|
| RANGE (V) | NOMINAL (V) | LAB 1A (µV) | | | | LAB 1B (µV) | | | | LAB 5 (µV) | | | |
| | | CORR. | U _{LAB} | LAB-REF | E _n | CORR. | U _{LAB} | LAB-REF | E _n | CORR. | U _{LAB} | LAB-REF | E _n |
| 0.1 | 0 | 0.4 | 1.0 | 0.40 | 0.28 | 0.6 | 1.0 | 0.59 | 0.41 | 0.0 | 0.0 | 0.00 | 0.00 |
| 0.1 | 0.1 | -0.2 | 2.0 | -1.05 | -0.43 | 0.8 | 1.9 | -0.08 | -0.03 | 1.32 | 1.2 | 0.47 | 0.25 |
| 0.1 | -0.1 | 0.8 | 2.0 | 0.75 | 0.31 | 1.5 | 2.0 | 1.50 | 0.62 | -1.15 | 1.2 | -1.20 | -0.64 |
| 1 | 1 | 5 | 10 | -2.50 | -0.17 | 5 | 10 | -2.50 | -0.17 | 2.3 | 6 | -5.17 | -0.43 |
| 1 | -1 | -5 | 10 | -3.09 | -0.21 | -4 | 10 | -2.20 | -0.15 | -0.8 | 6 | 0.67 | 0.06 |
| 10 | 5 | 14 | 50 | -11.40 | -0.16 | 14 | 50 | -11.00 | -0.16 | 20 | 21 | -5.00 | -0.09 |
| 10 | 10 | 50 | 100 | -4.70 | -0.03 | 42 | 100 | -13.39 | -0.09 | 60 | 38 | 5.00 | 0.05 |
| 10 | -5 | -14 | 50 | -34.40 | -0.49 | -10 | 50 | -30.00 | -0.42 | -20 | 21 | -40.00 | -0.74 |
| 10 | -10 | -41 | 100 | -81.10 | -0.57 | -27 | 100 | -66.80 | -0.47 | -42 | 38 | -81.67 | -0.76 |
| 100 | 100 | 84 | 1000 | -66.11 | -0.06 | 91 | 1000 | -59.00 | -0.06 | -850 | 540 | -1000.00 | -1.53 |
| 100 | -100 | 161 | 1000 | -39.00 | -0.04 | 13 | 1000 | -186.80 | -0.18 | 850 | 540 | 650.00 | 1.00 |
| 1000 | 100 | 34 | 1000 | 34.00 | 0.01 | 991 | 1000 | 991.00 | 0.27 | 0 | 540 | 0.00 | 0.00 |
| 1000 | 1000 | 3095 | 22271 | 1095.00 | 0.04 | 8020 | 21067 | 6020.00 | 0.24 | -1833 | 6900 | -3833.33 | -0.24 |
| 1000 | -1000 | -2145 | 22270 | -1645.00 | -0.06 | -5270 | 22270 | -4770.00 | -0.18 | 2833 | 6900 | 3333.33 | 0.21 |

| AC VOLTAGE | | | | | | | | | | | | | |
|----------------|---------------|-------------|------------------|---------|----------------|-------------|------------------|---------|----------------|------------|------------------|---------|----------------|
| NOMINAL (V) | FREQ (kHz) | LAB 1A (mV) | | | | LAB 1B (mV) | | | | LAB 5 (mV) | | | |
| | | CORR. | U _{LAB} | LAB-REF | E _n | CORR. | U _{LAB} | LAB-REF | E _n | CORR. | U _{LAB} | LAB-REF | E _n |
| 0.01 | 1 | 0.0010 | 0.0020 | -0.002 | -0.25 | 0.0013 | 0.0020 | -0.002 | -0.22 | 0.002 | 0.005 | -0.001 | -0.12 |
| 0.1 | 1 | -0.002 | 0.020 | -0.042 | -1.71 | -0.003 | 0.020 | -0.04 | -1.76 | 0.012 | 0.015 | -0.03 | -1.33 |
| 1 | 0.057 | 0.006 | 0.060 | -0.03 | -0.23 | 0.012 | 0.060 | -0.02 | -0.18 | 0.024 | 0.053 | -0.01 | -0.09 |
| 1 | 1 | 0.004 | 0.060 | -0.02 | -0.16 | 0.002 | 0.060 | -0.02 | -0.18 | 0.012 | 0.053 | -0.01 | -0.11 |
| 1 | 50 | -0.30 | 0.20 | -0.01 | -0.04 | -0.35 | 0.200 | -0.06 | -0.20 | -0.411 | 0.085 | -0.12 | -0.55 |
| 10 | 0.057 | 0.09 | 0.60 | -0.26 | -0.20 | 0.22 | 0.60 | -0.13 | -0.10 | 0.03 | 0.50 | -0.32 | -0.26 |
| 10 | 1 | 0.01 | 0.60 | -0.09 | -0.07 | 0.03 | 0.60 | -0.07 | -0.05 | -0.17 | 0.50 | -0.27 | -0.22 |
| 10 | 50 | -2.8 | 2.0 | 0.08 | 0.03 | -3.31 | 2.00 | -0.46 | -0.16 | -4.19 | 0.85 | -1.34 | -0.60 |
| 100 | 0.057 | -1.5 | 6.0 | -5.49 | -0.41 | 2.6 | 6.0 | -1.37 | -0.10 | 5.3 | 5.8 | 1.27 | 0.10 |
| 100 | 1 | -1.2 | 6.0 | -4.72 | -0.35 | 2.3 | 6.0 | -1.17 | -0.09 | 4.7 | 5.8 | 1.18 | 0.09 |
| 100 | 50 | -37 | 20 | -1.02 | -0.04 | -34.3 | 20.0 | 1.17 | 0.04 | -43.3 | 9.0 | -7.83 | -0.34 |
| 750 | 0.057 | 45 | 38 | -64.88 | -0.42 | 131 | 38 | 21.74 | 0.14 | -65 | 56 | -174.50 | -1.09 |
| 750 | 1 | 9 | 38 | -105.98 | -0.69 | 136 | 38 | 20.55 | 0.13 | -113 | 56 | -228.17 | -1.42 |

Notes: 1. Reference Laboratory: National Measurement Institute (NMI), Australia. Ref No: RN182242 & RN200026.

2. Uncertainties of measurement are at a 95% confidence level.

3.
$$E_n = \frac{\text{LAB} - \text{REF}}{\sqrt{(U_{\text{LAB}})^2 + (U_{\text{REF}})^2}}$$
 Values of $|E_n| \geq 1.0$ require investigation.

4. En ratios are based on laboratory's reported uncertainties and calibration data from NMI.

5. Confidentiality: Refer to the *Guide to Proficiency Testing, Australia (2019)*.

SUMMARY OF REPORTED RESULTS

DIGITAL MULTIMETER ROUND FIVE

DC CURRENT

| RANGE (A) | NOMINAL (A) | LAB 1A (µA) | | | | LAB 1B (µA) | | | | LAB 5 (µA) | | | |
|--------------|----------------|-------------|------------------|---------|----------------|-------------|------------------|---------|----------------|------------|------------------|---------|----------------|
| | | CORR. | U _{LAB} | LAB-REF | E _n | CORR. | U _{LAB} | LAB-REF | E _n | CORR. | U _{LAB} | LAB-REF | E _n |
| 0.01 | 0.01 | -0.14 | 0.30 | 0.14 | 0.11 | -0.2 | 0.3 | 0.08 | 0.07 | -0.40 | 0.40 | -0.12 | -0.10 |
| 0.1 | 0.1 | -3.1 | 2.1 | -0.002 | -0.0002 | -4 | 10 | -0.69 | -0.05 | -3.7 | 5.2 | -0.57 | -0.05 |
| 3 | 1 | -351 | 100 | -41.20 | -0.07 | -269 | 132 | 41.00 | 0.07 | -275 | 92 | 34.50 | 0.06 |

AC CURRENT

| RANGE (A) | NOMINAL (A) | LAB 1A (µA) | | | | LAB 1B (µA) | | | | LAB 5 (µA) | | | |
|--------------|----------------|-------------|------------------|---------|----------------|-------------|------------------|---------|----------------|------------|------------------|---------|----------------|
| | | CORR. | U _{LAB} | LAB-REF | E _n | CORR. | U _{LAB} | LAB-REF | E _n | CORR. | U _{LAB} | LAB-REF | E _n |
| 1 | 0.01@57Hz | -8 | 3 | -5 | -0.41 | -7.6 | 2.5 | -4.57 | -0.36 | 7 | 2 | 10.30 | 0.82 |
| 1 | 0.01@1kHz | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | 6 | 2 | 8.25 | 0.65 |
| 1 | 0.1@400Hz | 11 | 25 | 7 | 0.149 | 18 | 25 | 13.59 | 0.28 | -37 | 15 | -41.25 | -0.92 |
| 1 | 0.1@1kHz | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | -29 | 15 | -35.78 | -0.79 |
| 3 | 1@57Hz | -196 | 482 | -278 | -0.57 | -310 | 250 | -393.00 | -1.49 | -25 | 295 | -107.33 | -0.35 |
| 3 | 1@400Hz | -271 | 483 | -320 | -0.65 | -238 | 250 | -287.50 | -1.09 | -26 | 295 | -76.00 | -0.25 |
| 3 | 1@1kHz | n/a | n/a | n/a | n/a | 291 | 705 | 291.00 | 0.41 | -15 | 295 | -62.17 | -0.20 |

RESISTANCE

| NOMINAL (Ω) | LAB 1A (Ω) | | | | LAB 1B (Ω) | | | | LAB 5 (Ω) | | | |
|----------------|------------|------------------|---------|----------------|------------|------------------|---------|----------------|-----------|------------------|---------|----------------|
| | CORR. | U _{LAB} | LAB-REF | E _n | CORR. | U _{LAB} | LAB-REF | E _n | CORR. | U _{LAB} | LAB-REF | E _n |
| 100 | -0.00052 | 0.00070 | 0.0002 | 0.07 | 0.0001 | 0.0017 | 0.0009 | 0.23 | -0.0010 | 0.0010 | -0.0003 | -0.07 |
| 100 000 | -0.34 | 0.70 | 0.56 | 0.28 | 0.0 | 1.0 | 0.90 | 0.42 | -1.4 | 1.1 | -0.53 | -0.24 |
| 10 000 000 | -587 | 751 | -797.00 | -0.72 | -463 | 751 | -673.00 | -0.61 | -83 | 400 | -293 | -0.32 |

Notes: 1. Reference Laboratory: National Measurement Institute (NMI), Australia. Ref No: RN182242 & RN200026.

2. Uncertainties of measurement are at a 95% confidence level.

3.
$$E_n = \frac{\text{LAB - REF}}{\sqrt{(U_{\text{LAB}}^2 + U_{\text{REF}}^2)}}$$

Values of $|E_n| \geq 1.0$ require investigation.

4. E_n ratios are based on laboratory's reported uncertainties and calibration data from NMI.

5. Confidentiality: Refer to the *Guide to Proficiency Testing, Australia (2019)*.

SUMMARY OF REPORTED RESULTS

DIGITAL MULTIMETER ROUND FIVE

| DC VOLTAGE | | | | | | | | | | | | | |
|--------------|----------------|------------|------------------|----------|----------------|-------------|------------------|-----------|----------------|-------------|------------------|----------|----------------|
| RANGE (V) | NOMINAL (V) | LAB 7 (µV) | | | | LAB 8A (µV) | | | | LAB 8B (µV) | | | |
| | | CORR. | U _{LAB} | LAB-REF | E _n | CORR. | U _{LAB} | LAB-REF | E _n | CORR. | U _{LAB} | LAB-REF | E _n |
| 0.1 | 0 | 0.4 | 13.2 | 0.40 | 0.03 | 7.16 | 6.0 | 7.16 | 1.18 | n/a | n/a | n/a | n/a |
| 0.1 | 0.1 | 2.5 | 16.4 | 1.65 | 0.10 | 7.60 | 18.0 | 6.75 | 0.37 | n/a | n/a | n/a | n/a |
| 0.1 | -0.1 | -0.9 | 17.3 | -0.95 | -0.05 | 19.4 | 22.0 | 19.35 | 0.88 | n/a | n/a | n/a | n/a |
| 1 | 1 | 5 | 73 | -2.50 | -0.03 | 64 | 210 | 56.50 | 0.27 | n/a | n/a | n/a | n/a |
| 1 | -1 | -2 | 68 | -0.50 | -0.01 | 72 | 50 | 73.50 | 1.44 | n/a | n/a | n/a | n/a |
| 10 | 5 | 0 | 420 | -25.00 | -0.06 | 300 | 700 | 275.00 | 0.39 | n/a | n/a | n/a | n/a |
| 10 | 10 | 0 | 670 | -55.00 | -0.08 | 620 | 3900 | 565.00 | 0.14 | n/a | n/a | n/a | n/a |
| 10 | -5 | 0 | 500 | -20.00 | -0.04 | 360 | 300 | 340.00 | 1.12 | n/a | n/a | n/a | n/a |
| 10 | -10 | 20 | 730 | -20.00 | -0.03 | 700 | 600 | 660.00 | 1.09 | n/a | n/a | n/a | n/a |
| 100 | 100 | 1100 | 7100 | 950.00 | 0.13 | 11400 | 12000 | 11250.00 | 0.94 | 2000 | 12000 | 1850.00 | 0.15 |
| 100 | -100 | -800 | 7100 | -1000.00 | -0.14 | 10800 | 13000 | 10600.00 | 0.82 | -4000 | 13000 | -4200.00 | -0.32 |
| 1000 | 100 | 2000 | 7000 | 2000.00 | 0.26 | 4000 | 40000 | 4000.00 | 0.10 | 20000 | 4000 | 20000.00 | 3.76 |
| 1000 | 1000 | 14000 | 65000 | 12000.00 | 0.18 | 132000 | 100000 | 130000.00 | 1.29 | 20000 | 100000 | 18000.00 | 0.18 |
| 1000 | -1000 | -9000 | 66000 | -8500.00 | -0.13 | 116000 | 100000 | 116500.00 | 1.15 | 30000 | 100000 | 30500.00 | 0.30 |

| AC VOLTAGE | | | | | | | | | | | | | |
|----------------|---------------|------------|------------------|---------|----------------|-------------|------------------|---------|----------------|-------------|------------------|---------|----------------|
| NOMINAL (V) | FREQ (kHz) | LAB 7 (mV) | | | | LAB 8A (mV) | | | | LAB 8B (mV) | | | |
| | | CORR. | U _{LAB} | LAB-REF | E _n | CORR. | U _{LAB} | LAB-REF | E _n | CORR. | U _{LAB} | LAB-REF | E _n |
| 0.01 | 1 | 0.001 | 0.041 | -0.002 | -0.05 | 0.006 | 0.129 | 0.003 | 0.03 | n/a | n/a | n/a | n/a |
| 0.1 | 1 | 0.005 | 0.083 | -0.04 | -0.42 | 0.066 | 0.175 | 0.03 | 0.15 | n/a | n/a | n/a | n/a |
| 1 | 0.057 | 0.126 | 0.504 | 0.09 | 0.18 | 0.108 | 24.39 | 0.07 | 0.00 | n/a | n/a | n/a | n/a |
| 1 | 1 | 0.106 | 0.478 | 0.08 | 0.17 | 0.138 | 24.39 | 0.11 | 0.00 | n/a | n/a | n/a | n/a |
| 1 | 50 | -0.196 | 1.962 | 0.09 | 0.05 | 1.742 | 3.9 | 2.03 | 0.52 | n/a | n/a | n/a | n/a |
| 10 | 0.057 | 1.29 | 5.70 | 0.94 | 0.16 | 1.02 | 25 | 0.67 | 0.03 | n/a | n/a | n/a | n/a |
| 10 | 1 | 1.82 | 6.75 | 1.72 | 0.25 | 1.56 | 25 | 1.46 | 0.06 | n/a | n/a | n/a | n/a |
| 10 | 50 | -0.93 | 27.81 | 1.92 | 0.07 | 15.12 | 62.3 | 17.97 | 0.29 | n/a | n/a | n/a | n/a |
| 100 | 0.057 | 11.0 | 72.0 | 7.00 | 0.10 | 19.2 | 99 | 15.20 | 0.15 | 28 | 99 | 24.00 | 0.24 |
| 100 | 1 | 17.6 | 74.2 | 14.10 | 0.19 | 528.8 | 99 | 525.30 | 5.27 | 20 | 99 | 16.50 | 0.17 |
| 750 | 0.057 | 173 | 535 | 63.50 | 0.11 | 62 | 1160 | -47.50 | -0.04 | 250 | 1160 | 140.50 | 0.12 |
| 750 | 1 | 133 | 535 | 18.00 | 0.03 | 4016 | 840 | 3901.00 | 4.57 | 140 | 840 | 25.00 | 0.03 |

- Notes:**
1. Reference Laboratory: National Measurement Institute (NMI), Australia. Ref No: RN182242 & RN200026.
 2. Uncertainties of measurement are at a 95% confidence level.
 3.
$$E_n = \frac{\text{LAB} - \text{REF}}{\sqrt{U_{\text{LAB}}^2 + U_{\text{REF}}^2}}$$
 Values of $|E_n| \geq 1.0$ require investigation.
 4. En ratios are based on laboratory's reported uncertainties and calibration data from NMI.
 5. Confidentiality: Refer to the *Guide to Proficiency Testing, Australia (2019)*.

SUMMARY OF REPORTED RESULTS

DIGITAL MULTIMETER ROUND FIVE

DC CURRENT

| RANGE (A) | NOMINAL (A) | LAB 7 (µA) | | | | LAB 8A (µA) | | | | LAB 8B (µA) | | | |
|--------------|----------------|------------|------------------|---------|----------------|-------------|------------------|---------|----------------|-------------|------------------|---------|----------------|
| | | CORR. | U _{LAB} | LAB-REF | E _n | CORR. | U _{LAB} | LAB-REF | E _n | CORR. | U _{LAB} | LAB-REF | E _n |
| 0.01 | 0.01 | -0.72 | 1.44 | -0.44 | -0.23 | 1.38 | 4 | 1.66 | 0.40 | 0.33 | 4 | 0.61 | 0.15 |
| 0.1 | 0.1 | -8.4 | 18.0 | -5.30 | -0.26 | 0.8 | 36 | 3.90 | 0.10 | 10.8 | 35.35 | 13.90 | 0.38 |
| 3 | 1 | -377 | 456 | -67.00 | -0.09 | 0.484 | 2920 | 310.48 | 0.10 | 285 | 2920 | 595.00 | 0.20 |

AC CURRENT

| RANGE (A) | NOMINAL (A) | LAB 7 (µA) | | | | LAB 8A (µA) | | | | LAB 8B (µA) | | | |
|--------------|----------------|------------|------------------|---------|----------------|-------------|------------------|---------|----------------|-------------|------------------|---------|----------------|
| | | CORR. | U _{LAB} | LAB-REF | E _n | CORR. | U _{LAB} | LAB-REF | E _n | CORR. | U _{LAB} | LAB-REF | E _n |
| 1 | 0.01@57Hz | -4 | 14 | -1.00 | -0.05 | 7.66 | 491 | 10.66 | 0.02 | 1.2 | 491 | 4.20 | 0.01 |
| 1 | 0.01@1kHz | -5 | 14 | -3.00 | -0.16 | 10.28 | 491 | 12.28 | 0.03 | 0.9 | 491 | 2.90 | 0.01 |
| 1 | 0.1@400Hz | 17 | 174 | 13.00 | 0.07 | 24 | 498.5 | 20.00 | 0.04 | 6 | 498.5 | 2.00 | 0.004 |
| 1 | 0.1@1kHz | 13 | 174 | 6.50 | 0.04 | 197.8 | 498.5 | 191.30 | 0.38 | 14 | 498.5 | 7.50 | 0.01 |
| 3 | 1@57Hz | -41 | 1835 | -123.50 | -0.07 | 702 | 4520 | 619.50 | 0.14 | 150 | 4520 | 67.50 | 0.01 |
| 3 | 1@400Hz | -1 | 1835 | -50.50 | -0.03 | 2136 | 4520 | 2086.50 | 0.46 | 50 | 4520 | 0.50 | 0.0001 |
| 3 | 1@1kHz | -51.0 | 1835.00 | -98.00 | -0.05 | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a |

RESISTANCE

| NOMINAL (Ω) | LAB 7 (Ω) | | | | LAB 8A (Ω) | | | | LAB 8B (Ω) | | | |
|----------------|-----------|------------------|---------|----------------|------------|------------------|---------|----------------|------------|------------------|---------|----------------|
| | CORR. | U _{LAB} | LAB-REF | E _n | CORR. | U _{LAB} | LAB-REF | E _n | CORR. | U _{LAB} | LAB-REF | E _n |
| 100 | -0.0044 | 0.0290 | -0.004 | -0.13 | 0.0334 | 0.008 | 0.03 | 3.95 | 0.102 | 0.008 | 0.10 | 11.90 |
| 100 000 | 1.1 | 20.4 | 2.00 | 0.10 | 0.56 | 4.58 | 1.46 | 0.30 | 2.0 | 4.58 | 2.90 | 0.59 |
| 10 000 000 | -740 | 9440 | -950.00 | -0.10 | 1867 | 12300 | 1657.00 | 0.13 | 1500 | 12300 | 1290 | 0.10 |

Notes: 1. Reference Laboratory: National Measurement Institute (NMI), Australia. Ref No: RN182242 & RN200026.

2. Uncertainties of measurement are at a 95% confidence level.

3.

$$E_n = \frac{\text{LAB - REF}}{\sqrt{(U_{\text{LAB}}^2 + U_{\text{REF}}^2)}}$$

Values of $|E_n| \geq 1.0$ require investigation.

4. E_n ratios are based on laboratory's reported uncertainties and calibration data from NMI.

5. Confidentiality: Refer to the *Guide to Proficiency Testing, Australia (2019)*.

SUMMARY OF REPORTED RESULTS

DIGITAL MULTIMETER ROUND FIVE

| DC VOLTAGE | | | | | | | | | | | | | | | | | |
|--------------|----------------|------------|------------------|----------|----------------|------------|------------------|----------|----------------|------------|------------------|----------|----------------|------------|------------------|----------|----------------|
| RANGE (V) | NOMINAL (V) | LAB 2 (μV) | | | | LAB 3 (μV) | | | | LAB 4 (μV) | | | | LAB 6 (μV) | | | |
| | | CORR. | U _{LAB} | LAB-REF | E _n | CORR. | U _{LAB} | LAB-REF | E _n | CORR. | U _{LAB} | LAB-REF | E _n | CORR. | U _{LAB} | LAB-REF | E _n |
| 0.1 | 0 | 2.7 | 10 | 2.70 | 0.27 | -2.9 | 1.3 | -2.90 | -2.19 | -0.2 | 7 | -0.20 | -0.03 | 1.9 | 4 | 1.90 | 0.47 |
| 0.1 | 0.1 | 3.5 | 20 | 2.65 | 0.13 | 4.6 | 3.8 | 3.75 | 0.96 | 2.51 | 7 | 1.66 | 0.24 | 1 | 7 | 0.15 | 0.02 |
| 0.1 | -0.1 | 0.5 | 20 | 0.45 | 0.02 | 0.57 | 3.8 | 0.52 | 0.13 | -2.19 | 7 | -2.24 | -0.32 | 2.7 | 7 | 2.65 | 0.38 |
| 1 | 1 | 0 | 110 | -3.50 | -0.03 | 11 | 17 | 7.50 | 0.17 | 13.5 | 43 | 10.00 | 0.17 | -1 | 40 | -4.50 | -0.08 |
| 1 | -1 | 0 | 110 | -2.00 | -0.02 | 4 | 17 | 2.00 | 0.05 | -8.1 | 43 | -10.10 | -0.17 | 5 | 40 | 3.00 | 0.05 |
| 10 | 5 | 30 | 510 | 5.00 | 0.01 | 40 | 99 | 15.00 | 0.15 | 61 | 230 | 36.00 | 0.16 | -30 | 179 | -55.00 | -0.31 |
| 10 | 10 | 60 | 1010 | 0.00 | 0.00 | 87 | 177 | 27.00 | 0.15 | 135 | 430 | 75.00 | 0.17 | -70 | 346 | -130.00 | -0.37 |
| 10 | -5 | -30 | 510 | -10.00 | -0.02 | -13 | 101 | 7.00 | 0.07 | -53 | 230 | -33.00 | -0.14 | 30 | 179 | 50.00 | 0.28 |
| 10 | -10 | -50 | 1010 | -5.00 | 0.00 | -43 | 177 | 2.00 | 0.01 | -103 | 430 | -58.00 | -0.13 | 60 | 346 | 105.00 | 0.30 |
| 100 | 100 | -700 | 10010 | -350.00 | -0.03 | -467 | 2392 | -117.00 | -0.03 | 390 | 4700 | 740.00 | 0.14 | 300 | 4622 | 650.00 | 0.12 |
| 100 | -100 | 700 | 10010 | 150.00 | 0.01 | -667 | 2396 | -1217.00 | -0.33 | -190 | 4700 | -740.00 | -0.14 | -300 | 4622 | -850.00 | -0.16 |
| 1000 | 100 | 0 | 10010 | 0.00 | 0.00 | 0 | 2458 | 0.00 | 0.00 | 800 | 4700 | 800.00 | 0.14 | 0 | 8198 | 0.00 | 0.00 |
| 1000 | 1000 | 4000 | 100010 | 2500.00 | 0.02 | 1333 | 23912 | -167.00 | -0.005 | 13300 | 44000 | 11800.00 | 0.23 | -5000 | 47600 | -6500.00 | -0.12 |
| 1000 | -1000 | -3000 | 100010 | -3500.00 | -0.03 | 330 | 23940 | -170.00 | -0.005 | -7800 | 44000 | -8300.00 | -0.16 | 4000 | 47600 | 3500.00 | 0.06 |

| AC VOLTAGE | | | | | | | | | | | | | | | | | |
|----------------|---------------|------------|------------------|---------|----------------|------------|------------------|---------|----------------|------------|------------------|---------|----------------|------------|------------------|---------|----------------|
| NOMINAL (V) | FREQ (kHz) | LAB 2 (mV) | | | | LAB 3 (mV) | | | | LAB 4 (mV) | | | | LAB 6 (mV) | | | |
| | | CORR. | U _{LAB} | LAB-REF | E _n | CORR. | U _{LAB} | LAB-REF | E _n | CORR. | U _{LAB} | LAB-REF | E _n | CORR. | U _{LAB} | LAB-REF | E _n |
| 0.01 | 1 | -0.001 | 0.005 | -0.002 | -0.34 | 0.001 | 0.00884 | -0.0002 | -0.02 | 0.00057 | 0.023 | -0.001 | -0.02 | 0 | 23.5 | -0.001 | 0.00 |
| 0.1 | 1 | 0.006 | 0.05 | -0.005 | -0.10 | 0.015 | 0.0261 | 0.004 | 0.14 | 0.0098 | 0.039 | -0.001 | -0.03 | -0.009 | 62 | -0.02 | -0.0003 |
| 1 | 0.057 | -0.041 | 0.5 | -0.07 | -0.14 | 0.057 | 0.243 | 0.03 | 0.11 | 0.0066 | 0.28 | -0.02 | -0.08 | -0.022 | 0.614 | -0.05 | -0.08 |
| 1 | 1 | -0.015 | 0.5 | -0.03 | -0.06 | 0.054 | 0.243 | 0.04 | 0.15 | -0.0179 | 0.28 | -0.03 | -0.11 | -0.01 | 0.614 | -0.03 | -0.04 |
| 1 | 50 | -0.713 | 0.5 | -0.19 | -0.36 | -0.81 | 0.407 | -0.29 | -0.65 | -0.6595 | 0.82 | -0.14 | -0.17 | 0.602 | 1.8 | 1.12 | 0.62 |
| 10 | 0.057 | -0.52 | 5 | -0.52 | -0.10 | 0.056 | 2.44 | 0.06 | 0.02 | -0.133 | 2.8 | -0.13 | -0.05 | 0.06 | 6.2 | 0.06 | 0.01 |
| 10 | 1 | -0.41 | 5 | -0.21 | -0.04 | 0.3 | 2.44 | 0.50 | 0.20 | 0.255 | 2.8 | 0.46 | 0.16 | 0.26 | 6.2 | 0.46 | 0.07 |
| 10 | 50 | -7.07 | 5 | -1.62 | -0.31 | -5.6 | 4.77 | -0.15 | -0.03 | -5.4 | 8.2 | 0.05 | 0.01 | 6.13 | 18 | 11.58 | 0.64 |
| 100 | 0.057 | -0.4 | 50 | -4.40 | -0.09 | 2.2 | 25 | -1.80 | -0.07 | 3.45 | 41 | -0.55 | -0.01 | -3 | 62 | -7.00 | -0.11 |
| 100 | 1 | 3.5 | 50 | 0.50 | 0.01 | 9.5 | 24.4 | 6.50 | 0.25 | 10.18 | 41 | 7.18 | 0.17 | -2.9 | 62 | -5.90 | -0.09 |
| 100 | 50 | -62.8 | 50 | -5.80 | -0.11 | -82.5 | 288.9 | -25.50 | -0.09 | -61.57 | 100 | -4.57 | -0.05 | 59.9 | 63 | 116.90 | 1.79 |
| 750 | 0.057 | -85 | 375 | 16.50 | 0.04 | -58.6 | 274 | 42.90 | 0.15 | 31.4 | 310 | 132.90 | 0.42 | 88 | 431 | 189.50 | 0.44 |
| 750 | 1 | -84 | 375 | 41.00 | 0.11 | -56 | 273 | 69.00 | 0.25 | -10.5 | 310 | 114.50 | 0.36 | 112 | 432 | 237.00 | 0.54 |

Notes: 1. Reference Laboratory: National Measurement Institute (NMI), Australia. Ref No: RN200025 & RN181086.

2. Uncertainties of measurement are at a 95% confidence level.

3.

$$E_n = \frac{\text{LAB} - \text{REF}}{\sqrt{(U_{\text{LAB}}^2 + U_{\text{REF}}^2)}}$$

Values of $|E_n| \geq 1.0$ require investigation.

4. E_n ratios are based on laboratory's reported uncertainties and calibration data from NMI.

5. Confidentiality: Refer to the *Guide to Proficiency Testing, Australia (2019)*.

SUMMARY OF REPORTED RESULTS

DIGITAL MULTIMETER ROUND FIVE

| DC CURRENT | | | | | | | | | | | | | | | | | |
|-------------------|----------------|------------|------------------|---------|----------------|------------|------------------|---------|----------------|------------|------------------|---------|----------------|------------|------------------|---------|----------------|
| RANGE (A) | NOMINAL (A) | LAB 2 (µA) | | | | LAB 3 (µA) | | | | LAB 4 (µA) | | | | LAB 6 (µA) | | | |
| | | CORR. | U _{LAB} | LAB-REF | E _n | CORR. | U _{LAB} | LAB-REF | E _n | CORR. | U _{LAB} | LAB-REF | E _n | CORR. | U _{LAB} | LAB-REF | E _n |
| 0.01 | 0.01 | -0.61 | 7 | -0.04 | -0.01 | -0.02 | 6.83 | 0.55 | 0.08 | -0.25 | 0.97 | 0.32 | 0.31 | 3 | 6 | 3.57 | 0.59 |
| 0.1 | 0.1 | -8.3 | 70 | -3.30 | -0.05 | -5.1 | 14.7 | -0.10 | -0.01 | -3.21 | 9.7 | 1.79 | 0.18 | 7.2 | 57 | 12.20 | 0.21 |
| 3 | 1 | -452 | 700 | -162.00 | -0.23 | -308 | 1363 | -18.00 | -0.01 | -239.8 | 330 | 50.20 | 0.15 | 2 | 918 | 292.00 | 0.32 |

| AC CURRENT | | | | | | | | | | | | | | | | | |
|-------------------|----------------|------------|------------------|---------|----------------|------------|------------------|---------|----------------|------------|------------------|---------|----------------|------------|------------------|---------|----------------|
| RANGE (A) | NOMINAL (A) | LAB 2 (µA) | | | | LAB 3 (µA) | | | | LAB 4 (µA) | | | | LAB 6 (µA) | | | |
| | | CORR. | U _{LAB} | LAB-REF | E _n | CORR. | U _{LAB} | LAB-REF | E _n | CORR. | U _{LAB} | LAB-REF | E _n | CORR. | U _{LAB} | LAB-REF | E _n |
| 1 | 0.01@57Hz | 8.0 | 125 | 9.50 | 0.08 | 3 | 7 | 4.50 | 0.38 | -1.584 | 4.7 | -0.08 | -0.01 | -7 | 12 | -5.50 | -0.36 |
| 1 | 0.01@1kHz | 8.0 | 125 | 9.50 | 0.08 | 2 | 7 | 3.50 | 0.30 | -1.285 | 4.7 | 0.22 | 0.02 | -6.4 | 12 | -4.90 | -0.32 |
| 1 | 0.1@400Hz | -34 | 1250 | -4.50 | -0.004 | 42 | 70 | 71.50 | 0.90 | -11.02 | 47 | 18.48 | 0.31 | 36 | 26 | 65.50 | 1.45 |
| 1 | 0.1@1kHz | -29 | 1250 | -5.00 | -0.004 | 35 | 70 | 59.00 | 0.75 | -13.16 | 47 | 10.84 | 0.18 | 27 | 26 | 51.00 | 1.13 |
| 3 | 1@57Hz | -189 | 12500 | -204.50 | -0.02 | 120 | 705 | 104.50 | 0.15 | -90.6 | 470 | -106.10 | -0.22 | 0 | 1234 | -15.50 | -0.01 |
| 3 | 1@400Hz | -160 | 12500 | -153.50 | -0.01 | 192 | 705 | 198.50 | 0.28 | -63.5 | 470 | -57.00 | -0.12 | 0 | 1231 | 6.50 | 0.01 |
| 3 | 1@1kHz | n/a | n/a | n/a | n/a | 291 | 705 | 291.00 | 0.41 | -41.2 | 470 | -41.20 | -0.09 | -0.02 | 1231 | -0.02 | 0.00 |

| RESISTANCE | | | | | | | | | | | | | | | | | |
|-------------------|-----------|------------------|----------|----------------|-----------|------------------|----------|----------------|-----------|------------------|---------|----------------|-----------|------------------|---------|----------------|--|
| NOMINAL (Ω) | LAB 2 (Ω) | | | | LAB 3 (Ω) | | | | LAB 4 (Ω) | | | | LAB 6 (Ω) | | | | |
| | CORR. | U _{LAB} | LAB-REF | E _n | CORR. | U _{LAB} | LAB-REF | E _n | CORR. | U _{LAB} | LAB-REF | E _n | CORR. | U _{LAB} | LAB-REF | E _n | |
| 100 | 0.003 | 0.005 | 0.004 | 0.83 | -0.00047 | 0.0036 | 0.0009 | 0.23 | 0.00121 | 0.0081 | 0.003 | 0.32 | -0.00824 | 0.008 | -0.007 | -0.84 | |
| 100 000 | 0.9 | 20 | 1.10 | 0.05 | 3.1 | 3.63 | 3.30 | 0.85 | -0.31 | 8.7 | -0.11 | -0.01 | -2.7 | 4.6 | -2.50 | -0.52 | |
| 10 000 000 | 9960 | 10000 | 10015.00 | 1.00 | 21773 | 2853 | 21828.00 | 7.57 | -41 | 4700.0 | 14.00 | 0.003 | -650 | 2894 | -595.00 | -0.20 | |

Notes: 1. Reference Laboratory: National Measurement Institute (NMI), Australia. Ref No: RN200025 & RN181086.

2. Uncertainties of measurement are at a 95% confidence level.

3.
$$E_n = \frac{\text{LAB} - \text{REF}}{\sqrt{U_{\text{LAB}}^2 + U_{\text{REF}}^2}}$$

Values of $|E_n| \geq 1.0$ require investigation.

4. En ratios are based on laboratory's reported uncertainties and calibration data from NMI.

5. Confidentiality: Refer to the *Guide to Proficiency Testing, Australia (2019)*.

APPENDIX B

Reference Values

REFERENCE VALUES

Keysight 34465A

DC VOLTAGE

| RANGE (V) | NOMINAL (V) | REFERENCE (μ V) | |
|--------------|----------------|----------------------|------------------|
| | | CORR. | U _{REF} |
| 0.1 | 0 | 0.00 | 0.25 |
| 0.1 | 0.1 | 0.85 | 0.85 |
| 0.1 | -0.1 | 0.05 | 0.85 |
| 1 | 1 | 3.5 | 41 |
| 1 | -1 | 2.0 | 41 |
| 10 | 5 | 25 | 20 |
| 10 | 10 | 60 | 30 |
| 10 | -5 | -20 | 20 |
| 10 | -10 | -45 | 30 |
| 100 | 100 | -350 | 2800 |
| 100 | -100 | 550 | 2800 |
| 1000 | 100 | 0 | 3500 |
| 1000 | 1000 | 1500 | 25500 |
| 1000 | -1000 | 500 | 25500 |

AC VOLTAGE

| NOMINAL (V) | FREQ (kHz) | REFERENCE (mV) | |
|----------------|---------------|----------------|------------------|
| | | CORR. | U _{REF} |
| 0.01 | 1 | 0.0012 | 0.0039 |
| 0.1 | 1 | 0.0110 | 0.0115 |
| 1 | 0.057 | 0.030 | 0.075 |
| 1 | 1 | 0.015 | 0.070 |
| 1 | 50 | -0.520 | 0.175 |
| 10 | 0.057 | 0.00 | 0.75 |
| 10 | 1 | -0.20 | 0.75 |
| 10 | 50 | -5.45 | 1.75 |
| 100 | 0.057 | 4.0 | 8.0 |
| 100 | 1 | 3.0 | 8.0 |
| 100 | 50 | -57.0 | 17.5 |
| 750 | 0.057 | -102 | 57 |
| 750 | 1 | -125 | 57 |
| 750 | 50 | -825 | 135 |

REFERENCE VALUES

Keysight 34465A

DC CURRENT

| RANGE (A) | NOMINAL (A) | REFERENCE (μ A) | |
|--------------|----------------|----------------------|-----------|
| | | CORR. | U_{REF} |
| 0.01 | 0.01 | -0.57 | 0.26 |
| 0.1 | 0.1 | -5.0 | 2.9 |
| 3 | 1 | -290 | 45 |

AC CURRENT

| RANGE (A) | NOMINAL (A) | REFERENCE (μ A) | |
|--------------|----------------|----------------------|-----------|
| | | CORR. | U_{REF} |
| 1 | 0.01 @ 57Hz | -1.5 | 10 |
| 1 | 0.01 @ 1kHz | -1.5 | 10 |
| 1 | 0.1 @ 400Hz | -30 | 37 |
| 1 | 0.1 @ 1kHz | -24 | 37 |
| 3 | 1 @ 57Hz | 16 | 115 |
| 3 | 1 @ 400Hz | -7 | 115 |
| 3 | 1 @ 1kHz | 0 | 115 |

RESISTANCE

| NOMINAL (Ω) | REFERENCE (Ω) | |
|-------------------------|------------------------|-----------|
| | CORR. | U_{REF} |
| 100 | -0.0014 | 0.0017 |
| 100 000 | -0.2 | 1.4 |
| 10 000 000 | -55 | 420 |

Ref No: RN200025 & RN181086.

REFERENCE VALUES

Keysight 34465A

DC VOLTAGE

| RANGE (V) | NOMINAL (V) | REFERENCE (μ V) | |
|--------------|----------------|----------------------|-----------|
| | | CORR. | U_{REF} |
| 0.1 | 0 | 0.00 | 1.05 |
| 0.1 | 0.1 | 0.85 | 1.45 |
| 0.1 | -0.1 | 0.05 | 1.45 |
| 1 | 1 | 7.5 | 11 |
| 1 | -1 | -1.5 | 11 |
| 10 | 5 | 25 | 50 |
| 10 | 10 | 55 | 100 |
| 10 | -5 | 20 | 50 |
| 10 | -10 | 40 | 100 |
| 100 | 100 | 150 | 365 |
| 100 | -100 | 200 | 365 |
| 1000 | 100 | 0 | 3500 |
| 1000 | 1000 | 2000 | 14500 |
| 1000 | -1000 | -500 | 14500 |

AC VOLTAGE

| NOMINAL (V) | FREQ (kHz) | REFERENCE (mV) | |
|----------------|---------------|----------------|-----------|
| | | CORR. | U_{REF} |
| 0.01 | 1 | 0.0031 | 0.0080 |
| 0.1 | 1 | 0.0400 | 0.0145 |
| 1 | 0.057 | 0.035 | 0.110 |
| 1 | 1 | 0.025 | 0.110 |
| 1 | 50 | -0.290 | 0.205 |
| 10 | 0.057 | 0.35 | 1.15 |
| 10 | 1 | 0.10 | 1.15 |
| 10 | 50 | -2.85 | 2.05 |
| 100 | 0.057 | 4.0 | 12.0 |
| 100 | 1 | 3.5 | 12.0 |
| 100 | 50 | -35.5 | 21.0 |
| 750 | 0.057 | 110 | 150 |
| 750 | 1 | 115 | 150 |
| 750 | 50 | -530 | 155 |

REFERENCE VALUES

Keysight 34465A

DC CURRENT

| RANGE (A) | NOMINAL (A) | REFERENCE (μ A) | |
|--------------|----------------|----------------------|-----------|
| | | CORR. | U_{REF} |
| 0.01 | 0.01 | -0.28 | 1.24 |
| 0.1 | 0.1 | -3.1 | 9.4 |
| 3 | 1 | -310 | 580 |

AC CURRENT

| RANGE (A) | NOMINAL (A) | REFERENCE (μ A) | |
|--------------|----------------|----------------------|-----------|
| | | CORR. | U_{REF} |
| 1 | 0.01 @ 57Hz | -3 | 13 |
| 1 | 0.01 @ 1kHz | -2 | 13 |
| 1 | 0.1 @ 400Hz | 4 | 43 |
| 1 | 0.1 @ 1kHz | 7 | 43 |
| 3 | 1 @ 57Hz | 83 | 86 |
| 3 | 1 @ 400Hz | 50 | 86 |
| 3 | 1 @ 1kHz | 47 | 86 |

RESISTANCE

| NOMINAL (Ω) | REFERENCE (Ω) | |
|-------------------------|------------------------|-----------|
| | CORR. | U_{REF} |
| 100 | -0.0008 | 0.0033 |
| 100 000 | -0.9 | 1.9 |
| 10 000 000 | 210 | 810 |

RN182242 & RN200026.

APPENDIX C

Instructions to Participants

and

Results Sheets



DIGITAL MULTIMETER (ROUND 5) PROFICIENCY TESTING PROGRAM

INSTRUCTIONS TO LABORATORIES

EQUIPMENT

A Keysight Model 34465A Digital Multimeter with Serial Number: MY54502348 and a Keysight 34465A Digital Multimeter with Serial Number: MY57509255. The proficiency test item should be treated as a routine test item.

SETTING PROCEDURE

DC Voltage

DCV (Enter)

Config - INTEGRATION - NPLC (Enter) 100 (Enter) RANGE MANUAL (Enter) {Select 100 mV, 1 V, 10 V, 100 V or 1000 V} (Enter) - INPUT Z HI-Z (Enter) - AUTO ZERO ON - (Enter) NULL OFF (Enter)

UUT range programming command(s):

Range Command

0.1000V CONF:VOLT:DC 100E-3;;SENS:VOLT:DC:NPLC 100;;SENS:VOLT:DC:IMP:AUTO ON
1.0000V CONF:VOLT:DC 1;;SENS:VOLT:DC:NPLC 100;;SENS:VOLT:DC:IMP:AUTO ON
10.000V CONF:VOLT:DC 10;;SENS:VOLT:DC:NPLC 100;;SENS:VOLT:DC:IMP:AUTO ON 100.00V
CONF:VOLT:DC 100;;SENS:VOLT:DC:NPLC 100
1000.0V CONF:VOLT:DC 1000;;SENS:VOLT:DC:NPLC 100

DC Current

Shift DCV (DCI) (Enter)

Config - INTEGRATION - NPLC (Enter) 100 (Enter) RANGE MANUAL (Enter) {Select 10 mA, 100 mA or 3 A} (Enter) - AUTO ZERO ON - (Enter) NULL OFF (Enter)

UUT range programming command(s) :

Range Command

0.0100A CONF:CURR:DC 10E-3;;SENS:CURR:DC:NPLC 100
0.1000A CONF:CURR:DC 100E-3;;SENS:CURR:DC:NPLC 100
3.0000A CONF:CURR:DC 3;;SENS:CURR:DC:NPLC 100

AC Voltage

ACV (Enter)

Config - AC FILTER 3 HZ : SLOW (Enter) RANGE MANUAL (Enter) {Select 100 mV, 1 V, 10 V, 100 V or 750 V} (Enter) - NULL OFF (Enter)

UUT range programming command(s):

| <i>Range</i> | <i>Command</i> |
|--------------|--|
| 0.1000 V | CONF:VOLT:AC 0.1;:SENS: VOLT:AC:BAND 3 |
| 1.0000 V | CONF:VOLT:AC 1;:SENS: VOLT:AC:BAND 3 |
| 10.000 V | CONF:VOLT:AC 10;:SENS: VOLT:AC:BAND 3 |
| 100.00 V | CONF:VOLT:AC 100;:SENS: VOLT:AC:BAND 3 |
| 750.00 V | CONF:VOLT:AC 750;:SENS: VOLT:AC:BAND 3 |

AC Current

Shift ACV (ACI) (Enter)

Config - AC FILTER 3 HZ : SLOW (Enter) RANGE MANUAL (Enter) {Select 1 A or 3 A} (Enter) - NULL OFF (Enter)

UUT range programming command(s) :

| <i>Range</i> | <i>Command</i> |
|--------------|-------------------------------------|
| 1.0000 A | CONF:CURR:AC 1;:SENS:CURR:AC:BAND 3 |
| 3.0000 A | CONF:CURR:AC 3;:SENS:CURR:AC:BAND 3 |

Resistance

4 Wire Ohms

Shift Ω 2W (Ω 4W) (Enter)

Config - INTEGRATION - NPLC (Enter) 100 (Enter) RANGE MANUAL (Enter){Select 100 OHM} (Enter) - OFFSET COMP ON (Enter) - NULL OFF (Enter)

2 Wire Ohms

(Ω 2W) (Enter)

Config - INTEGRATION - NPLC (Enter) 100 (Enter) RANGE MANUAL (Enter) {Select 100 KOHM or 10 MOHM} (Enter) - OFFSET COMP ON (Enter) - AUTO ZERO ON (Enter) - NULL OFF (Enter)

MEASUREMENTS TO BE CARRIED OUT

Consider this as a job for a normal customer. Use techniques and equipment that will allow you to report your measurements and uncertainties to your Calibration and Measurement Capability (CMC).

Please do NOT adjust any settings, dismantle or attempt any maintenance or rectification.

The test item should have a minimum warm-up time of two hours.

IMPORTANT: Special care is required at 1000 V. The range should be selected Manually as the autorange does not react quickly enough when on long time interval.

DC Voltage

| <i>Range</i> | | <i>Calibration Points</i> |
|--------------|---|---------------------------|
| 0.1 | V | (0 V, 0.1 V, -0.1 V) |
| 1 | V | (1 V, -1 V) |
| 10 | V | (5 V, 10 V, -5 V, -10 V) |
| 100 | V | (100 V, -100 V) |
| 1000 | V | (100 V, 1000 V, -1000 V) |

Note: Zero offset should be measured, and then be removed when calculating and reporting the corrections on the nominal measurement points on ranges of 1 V to 1000 V above.

AC Voltage

| <i>Range</i> | | <i>Calibration Points</i> |
|--------------|---|---------------------------------|
| 0.1 | V | (10 mV and 100 mV @ 1 kHz) |
| 1 | V | (1 V@57 Hz, 1 kHz and 50 kHz) |
| 10 | V | (10 V@57 Hz, 1 kHz and 50 kHz) |
| 100 | V | (100 V@57 Hz, 1 kHz and 50 kHz) |
| 750 | V | (750 V@57 Hz, 1 kHz and 50 kHz) |

DC Current

| <i>Range</i> | | <i>Calibration Points</i> |
|--------------|----|---------------------------|
| 10 | mA | (10 mA) |
| 100 | mA | (100 mA) |
| 3 | A | (1 A) |

Note: Zero offset should be measured, and then be removed when calculating and reporting the corrections on the nominal measurement points on all the ranges above.

AC Current

| <i>Range</i> | | <i>Calibration Points</i> |
|--------------|---|----------------------------|
| 1 | A | (10 mA@57 Hz, 1 kHz) |
| 1 | A | (100 mA@400 Hz, 1 kHz) |
| 3 | A | (1 A@57 Hz, 400 Hz, 1 kHz) |

Resistance

| <i>Range</i> | | <i>Calibration Points</i> | <i>Measurement Functions</i> |
|--------------|------------|---------------------------|------------------------------|
| 100 | Ω | (100 Ω) | 4 wire Ohms function |
| 100 | k Ω | (100 k Ω) | 2 wire Ohms function |
| 10 | M Ω | (10 M Ω) | 2 wire Ohms function |

NOTE: The correction is the value that needs to be added to the meter indication to make it indicate the true value or correction = true value - indicated value.

DOCUMENTS TO BE SUBMITTED

Within **two weeks** of receipt of the artefact, the participant is requested to return the artefact and results sheet to:

Dr Michael Li
Proficiency Testing Australia
7 Leeds St, Rhodes NSW 2138

FINAL REPORT

A final report will be issued at the end of the program with each laboratory only identified by a **confidential code number**.

GENERAL INFORMATION

For general information, please contact Dr Michael Li, PTA,

Tel: +61 2 9736 8397 Fax: +61 2 9743 6664 Email: michael.li@pta.asn.au

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Lab Code

**DIGITAL MULTIMETER (ROUND 5)
PROFICIENCY TESTING PROGRAM
RESULTS SHEET**

DC VOLTAGES

| RANGE (V) | NOMINAL VALUE (V) | LAB CORRECTION (μ V) | LAB UNCERTAINTY(μ V) |
|-----------|-------------------|---------------------------|---------------------------|
| 0.1 | 0 | | |
| 0.1 | 0.1 | | |
| 0.1 | -0.1 | | |
| 1 | 1 | | |
| 1 | -1 | | |
| 10 | 5 | | |
| 10 | 10 | | |
| 10 | -5 | | |
| 10 | -10 | | |
| 100 | 100 | | |
| 100 | -100 | | |
| 1000 | 100 | | |
| 1000 | 1000 | | |
| 1000 | -1000 | | |

DC CURRENT

| RANGE (A) | NOMINAL VALUE (A) | LAB CORRECTION (μ A) | LAB UNCERTAINTY(μ A) |
|-----------|-------------------|---------------------------|---------------------------|
| 0.01 | 0.01 | | |
| 0.1 | 0.1 | | |
| 3 | 1 | | |

RESISTANCE

| NOMINAL VALUE (Ω) | LAB CORRECTION (Ω) | LAB UNCERTAINTY (Ω) |
|----------------------------|-----------------------------|------------------------------|
| 100 | | |
| 100000 | | |
| 10000000 | | |



Lab Code

**DIGITAL MULTIMETER (ROUND 5)
PROFICIENCY TESTING PROGRAM
RESULTS SHEET**

AC VOLTAGES

| RANGE (V) | FREQUENCY (kHz) | NOMINAL VALUE (V) | LAB CORRECTION (mV) | LAB UNCERTAINTY(mV) |
|-----------|-----------------|-------------------|---------------------|---------------------|
| 0.1 | 1 | 0.01 | | |
| 0.1 | 1 | 0.1 | | |
| 1 | 0.057 | 1 | | |
| 1 | 1 | 1 | | |
| 1 | 50 | 1 | | |
| 10 | 0.057 | 10 | | |
| 10 | 1 | 10 | | |
| 10 | 50 | 10 | | |
| 100 | 0.057 | 100 | | |
| 100 | 1 | 100 | | |
| 100 | 50 | 100 | | |
| 750 | 0.057 | 750 | | |
| 750 | 1 | 750 | | |
| 750 | 50 | 750 | | |

AC CURRENT

| RANGE (A) | FREQUENCY (kHz) | NOMINAL VALUE (A) | LAB CORRECTION (μA) | LAB UNCERTAINTY(μA) |
|-----------|-----------------|-------------------|---------------------|---------------------|
| 1 | 0.057 | 0.01 | | |
| 1 | 1 | 0.01 | | |
| 1 | 0.4 | 0.1 | | |
| 1 | 1 | 0.1 | | |
| 3 | 0.057 | 1 | | |
| 3 | 0.4 | 1 | | |
| 3 | 1 | 1 | | |

Laboratory Name:

Temperature (°C):

Testing Officer:

Report Date:

End of Report
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