Technical Protocol

Version 1.0 (28 April 2011)

SUPPLEMENTARY COMPARISON
ON
DIGITAL MULTIMETER
(P1-APMP.EM-S8)

Comparison Co-ordinated by:

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Contents

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SUPPLEMENTARY COMPARISON ON DIGITAL MULTIMETER (P1-APMP.EM-S8)

1. Introduction

At the 8th Meeting of APMP Developing Economies' Committee (DEC) on 12th April 2004 in Kuala Lumpur, Malaysia, it was decided to initiate an international comparison of digital multimeter calibration. The artifact i.e. digital multimeter will be supplied by the National Physical Laboratory, India (NPLI). This comparison was proposed to test the capabilities of the NMIs in measuring the following quantities:

DC voltage, DC current, DC resistance, AC voltage and AC current

The NPLI agreed to act as the pilot laboratory and coordinate this comparison and 16 laboratories agreed to participate.

This protocol was prepared in accordance with the "Guidelines for CIPM key comparisons" [1].

2. Travelling Standard

2.1 Description of the standard

The travelling standard is a 6½ digit multimeter (Fluke model 8846A). This instrument can measure DC voltage up to 1000 V, DC current up to 10 A, resistance up to 1 GΩ, AC voltage up to 1000 V, and AC current up to 10 A. The details of the digital multimeter are given in Table 1:

Table 1

General Information	
Power supply requirement	100 V / 120 V / 220 V / 240V ± 10 %
Power line frequency	50 Hz to 60 Hz
Power consumption	28 VA peak (12 W average)
Warm-up time	1 Hour
Operating temperature range	0 °C to 50 °C
Operating humidity range	0 % to 80 % relative humidity
Temperature coefficient (18 °C - 28 °C)	Not specified
Transport Information	
Storage temperature range	–40 °C to 70 °C
Dimension (H × W × D)	89 mm (H) × 217 mm (W) × 297 mm (D)
Shipping container (H × W × D)	167 mm (H) × 470 mm (W) × 360 mm (D)
Weight	3.6 kg
Shipping Weight	6.0 kg

2.2 Quantities to be measured

The quantities to be measured are DC voltage, DC current, DC resistance, AC voltage and AC current. The details of the measured parameters are given in Table 2.

Table 2

Parameter	Nominal value
DC Voltage	100 mV, 1 V, 10 V, –10 V, 100 V and 1000 V
DC Current	10 mA and 1 A
DC Resistance	100 Ω, 1 kΩ and 10 kΩ (using 4-wire)
AC Voltage	100 mV, 1 V, 10 V, 100 V and 700 V at 40 Hz and 1 kHz
AC Current	10 mA and 1 A at 40 Hz and 1 kHz

2.3 Method of computation of the Comparison Reference Value

The Comparison Reference Value (CRV) will be computed by weighted mean of the results from laboratories with independent realizations of relevant primary standards [2-4].

3. Organization of Comparison

3.1 Comparison communication

All communication must be directed to **apmp_dmm@nplindia.org**. In case of any problem, participants can contact A K Saxena and A K Govil (refer to paragraph 8).

3.2 Participants

The list of participating institutes with persons responsible for the comparison is given in Annexure-1.

3.3 Time schedule

The circulation of the travelling standard has been organized in loops of not more than four laboratories in order to allow close monitoring of the behavior of the standard. Each laboratory will have at least four weeks for measurement and transportation. The circulation time schedule is given in Annexure-2.

If unforeseen circumstances prevent a laboratory from carrying out its measurements within the time allotted, it should send the travelling standard without delay to the laboratory next in line with information to pilot lab. If time allows, the laboratory may be able to carry out measurements towards the end.

3.4 Transportation, unpacking, handling and packing

The artifact will be transported using an **ATA Carnet** for custom clearance where possible. A separate comparison loop will be organized for those participants that do not qualify for the **ATA Carnet** scheme.

An enclosure is provided for the digital multimeter so that it can be shipped as freight. This enclosure has dimensions and weight as shown in table 1. Extreme temperatures or pressure changes as well as violent impacts should be avoided. With the travelling standard, one receipt form (Annexure-5), dispatch form (Annexure-6) and one checklist will be sent for each participant in the current loop. The pilot laboratory must be informed of receipt of the artifact and its dispatch to the next laboratory using the forms provided.

When shipping the standard, the shipping checklist form should be carefully followed in order to include all the material for the next laboratory.

3.5 Failure of travelling standard

In case of damage or malfunction of the travelling standard, this must be immediately reported to the pilot laboratory.

3.6 Financial aspects

Each participant laboratory is responsible for its own costs for the measurements, transportation to the next participant, insurance of the shipment to the next participant and any customs charges as well as any damage that may occur within its country.

4. Measurement Instructions

4.1 Tests before measurements

After arrival of the travelling standard, it should be checked for any physical damage. Ensure that the mains voltage setting is applicable to the local supply, and check that the instrument is functioning correctly. It should be allowed to stabilize in a temperature and possibly, humidity controlled environment for at least 24 hours before commencing measurements.

4.2 Measurement conditions

1. The digital multimeter should be used in the configurations given in Annexure 3.
2. The instrument will be supplied without input leads. The input voltage, current and resistance are defined at the input terminals of the instrument.
3. A single earth connection must be used in the measurement setup to avoid ground loops.
4. The minimum settling time given in the table should be used after first application of the test signal.
5. The standard ambient conditions for measurement are

   Temperature: (23 ± 1) °C
   Relative humidity: 50% ± 10%

6. Before making DC measurements, for each point, a zero value should be applied and Auto Zero (check function) should be executed.
7. The measurement result is the correction for the Digital Multimeter calculated as: DMM correction = True (Applied) value – DMM reading.

Any standard method may be used for calibrating the digital multimeter. For example, the participant laboratories may use the following techniques:

- Direct comparison with a multifunction calibrator;
- Direct comparison with DC reference voltage standard and standard resistors; and
- Indirect comparison using voltage drop method for currents.

The calibration method must be presented in detail in the comparison report.

5. Uncertainty of Measurement

5.1 Uncertainty components

All contributions to the measurement uncertainty should be listed in the report submitted by each participant.

Even though some contributions to the uncertainty are specific to each method of measurement, it may be useful to consider the following list to try to assure more comparable uncertainty evaluations (the list may be considered as the guidelines).

1. Reference voltage standard (for dc voltage parameter);
2. Standard resistor (for resistance parameter);
3. Reference divider (for high voltage);
4. Multifunction calibrator (for all or some of the parameters);
5. Thermal electromotive force (emf) (for low dc voltage);
6. Drift of the calibrator / reference standard since last calibration;
7. Effect of offset, non-linearity and differences in the gain of calibrator (when using a calibrator as the reference);
8. Repeatability; and
9. Finite resolution of the DMM to be calibrated.

5. 2 Uncertainty budget

The uncertainty must be calculated according to the "Guide to the Expression of Uncertainty in Measurement" [5] for a 95% confidence level. In uncertainty evaluations, all uncertainty components taken into account should be included. The coverage factor and the effective degrees of freedom should be reported.

6. Measurement results of the laboratories

Results should be communicated to the pilot laboratory within 30 days of completing the measurements. An early report helps in evaluating the behavior of the travelling standard. A format-of-results form (Annexure-4) is given in order to help summarize the essential information. The report should contain (for each measurement):

- A detailed description of the method used;
- The conditions of the measurement: values of temperature, humidity, with their limits of variation;
- Results of measurement;
- Standard uncertainties for each contributor;
- Combined standard uncertainty;
- Coverage factor;
- Effective degrees of freedom;
- Expanded uncertainty; and
- A detailed uncertainty budget.

7. Final report of the comparison

The process that will lead to the preparation of the final report of the comparison is explained in the "Guidelines for CIPM key comparisons" [1]. In short it is reported here.

After the conclusion of the circulation of the travelling standard the pilot laboratory will prepare a first draft (draft A) of the final report and will send it to the participants. This draft

will be confidential. The draft will be prepared within 4 months from the end of the measurements.

The participants will have two months to send their comments on draft A. If a laboratory's result is anomalous, it can decide, at this stage, to withdraw its result or, if an explanation is found, can correct it. A laboratory may eventually request to make a second measurement of the travelling standard, but this will not hold up the final report.

On the basis of the comments received, the pilot laboratory prepares the second draft (draft B), where the withdrawn results will not appear or, in case of correction, the original and the corrected results, with the given explanation, are reported. Draft B will be submitted to the TCEM-APMP and, after approval, will become the Final Report. The Final Report will form the basis for the publication of results, if any.

8. Comparison coordinator

The Coordinator and Deputy Coordinator for this comparison at pilot laboratory are A K Saxena and A K Govil respectively and their addresses are:

A K Saxena
Head, LF & HF Impedance and DC Standards
Electrical Metrology
Room No. 9
National Physical Laboratory
Dr. K.S. Krishnan Road
New Delhi – 110012 INDIA

Tel.: +91-11-45609314
Fax: +91-11-45609310
E-mail: aksaxena@nplindia.org

A K Govil
Head, LF & HF Voltage, Current & Microwave Standards
Electrical Metrology
Room No. 11
National Physical Laboratory
Dr. K.S. Krishnan Road
New Delhi – 110012 INDIA

Tel.: +91-11-45609344
Fax: +91-11-45609310
E-mail: akgovil@nplindia.org

References

1. Guidelines for CIPM key comparisons (available on the BIPM website: http://www.bipm.org/pdf/guidelines.pdf).
2. J. Randa, “Proposal for KCRV & Degree of Equivalence for GTRF Key Comparisons”, Document of Working Group on radio frequency quantities of the CCEM, GT-RF/2000-12, September 2000 and references therein.
3. Cox M. G., The evaluation of key comparison data: An introduction, *Metrologia*, 2002, 39, 587-589 and references therein.
4. Cox M. G., The evaluation of key comparison data, *Metrologia*, 2002, 39, 589-595 and references therein.
5. Guide to the Expression of Uncertainty in Measurement, JCGM 100:2008, First edition September 2008 (available on the BIPM website: http://www.bipm.org/utils/common/documents/jcgm/JCGM_100_2008_E.pdf)

Annexure-1: Participant details

No.	Name and address of laboratory	Contact person	Shipping address	ATA CARNET
1.	SCL (Standard and Calibration Laboratory) 36/F., Immigration Tower, 7 Gloucester Road, Wanchai, Hong Kong	Mr. Johnny C.Y. PoonE mail: cypoon@itc.gov.hk	36/F, Immigration Tower, Gloucester Road, Wanchai, Hong Kong	Yes
2.	Measurement Units, Standard and Services Department No 101, Park Road, Colombo 05, Sri Lanka	Mr. R.D.M. Alanka E mail: metrolg@sltnet.lk	Measurement Units, Standard and Services Department No. 101, Park Road, Colombo 05, Sri Lanka	Yes
3.	Kazakhstan Institute of Metrology 11, Orynbor str ., Astana, 010000 Republic of Kazakhstan	Mr. Marat Konkanov E mail: marconzenti@bk.ru	11, Orynbor str., Astana, 010000, Republic of Kazakhstan	No
4.	National Measurement Institute, Australia PO Box 264, Lindfield, NSW 2070, Australia	Mr. Louis Marais E mail: louis.marais@measurement.gov.au	NMI Receiving store, Bradfield Road, West Lindfield, NSW 2070, Australia	Yes
5.	Electrical Quantities Metrology Laboratory, National Institute for Standards (NIS) Tersa St. EL Haram Giza. Egypt. P.O. Box 136, Giza. Code 12211	Prof. Dr. Nadia Nassif Tadros E mail: nntadros@yahoo.com, halaabdelmegeed@yahoo.com	Head of Electrical Quantities Metrology Laboratory, National Institute for Standards (NIS), Tersa St. EL Haram, Giza, Egypt. P.O. Box 136 Giza. Code 12211	No
6.	National Metrology Institute South Africa CSIR Campus, Bld 5 Meiring Naude Road, Brummeria, PRETORIA 0001	Mr. P. J. Prinsloo E mail : fprinsloo@nmisa.org	CSIR Campus, Bld 5, Meiring Naude Road Brummeria PRETORIA 001 South Africa	Yes
7.	Electrical Measuring Instrument Laboratory, Electrical Metrology Department National Institute of Metrology (Thailand) 3/4-5 Moo 3, Klong 5, Klong Luang, Pathumthani 12120 Thailand	Ms. Jutarat Tanarom or Mr. Narat Rujirat E mail: jutarat@nimt.or.th narat@nimt.or.th	National Institute of Metrology (Thailand), 3/4 -5 Moo 3, Klong 5, Klong Luang, Pathumthani 12120 Thailand	Yes
8.	Measurement Standards Laboratory, National Institute of Standards & Industrial Technology P O Box 3042 Boroko, National Capital District, Papua New Guinea	Joe Panga/Victor Gabi E mail: Joe.Panga@nisit.gov.pg Victor.Gabi@nisit.gov.pg	Measurement Standards Laboratory, National Institute of Standards & Industrial Technology, P O Box 3042 Boroko, National Capital District, Papua New Guinea	No
9.	Vietnam Metrology Institute No. 8 – Hoang Quoc Viet Str. – Cau Giay Dist – Hanoi City – Vietnam	Mr. Phung Thi Kieu Linh E mail: linhptk@vmi.gov.vn	Vietnam Metrology Institute No. 8 – Hoang Quoc Viet Str. – Cau Giay Dist – Hanoi City – Vietnam	No

No.	Name and address of laboratory	Contact person	Shipping address	ATA CARNET
10.	Jordan National Metrology Institute Royal Scientific Society, Jordan National Metrology Institute P.O. Box: 1438, Str. Ahmad Al-Tarawneh, Al-Jubeiha (11941), Amman, Jordan	Eng, Ibrahim Sehweil E mail: jnmi-emd@rss.jo	P.O. Box: 1438, Str. Ahmad Al-Tarawneh Al-Jubeiha (11941), Amman, Jordan	No
11.	Electrical Standard Laboratory of Mongolian Agency for Standardization and Metrology Mongolia, Ulaanbaatar 210351, Peace street -46A, P.O. Box 48	Ariuntungalag Jargal E mail: r_aagii@yahoo.com masm@mongol.net	Mongolia, Ulaanbaatar 210351, Peace street - 46A, P.O. Box 48	Yes
12.	National Metrology Laboratory Industrial Technology Development Institute (NML-ITDI) Metrology Building –ITDI, DOST Compound. Gen Santos Avenue Biscutan, Taguig City, Metro Manila, Philippines 1631	Sabino Paulo B. Leones, Jr E mail: paulo_leones@yahoo.com	Metrology Building –ITDI, DOST Compound. Gen Santos Avenue Biscutan, Taguig City, Metro Manila, Philippines 1631	No (Remarks)
13.	National Metrology Laboratory, SIRIM Berhad Lot PT 4803, Bandar Baru Salak Tinggi 43900 Sepang, Selangor, Malaysia	Dr. Mohd Nasir Zainal Abidin E mail: mohd.nasir_z.abidin@sirim.my	National Metrology Laboratory, SIRIM Berhad, Lot PT 4803, Bandar Baru Salak Tinggi, 43900 Sepang, Selangor, Malaysia	Yes (Remarks)
14.	Electrical Metrology Sub. Division – Metrology Division – Puslit KIM – LIPI Komplek PUSPIPTEK, Serpong (15314) Tangerang, Banten – INDONESIA	Ahnan Ma'ruf E mail: ahnan@kim.lipi.go.id	Puslit. KIM – LIPI, Gd. 420, Komplek PUSPIPTEK, Serpong (15314) Tangerang, Banten – INDONESIA	No
15.	National Standards and Calibration Laboratory (NSCL), Barzeh, Pre-fabricated Houses Area, P.O. Box: 30116, Damascus – Syria	Dr. Samir Al Zaher E mail: nscl@nscl.sy	National Standards and Calibration Laboratory (NSCL), Barzeh, Pre-fabricated Houses Area, P.O. Box: 30116, Damascus - Syria	No
16.	National Physical Laboratory (Council of Scientific and Industrial Research) Dr K S Krishnan Marg New Delhi 110012 India	A K Saxena/ A K Govil apmp_dmm@nplindia.org alternate: aksaxena@nplindia.org akgovil@nplindia.org	National Physical Laboratory (Council of Scientific and Industrial Research) Dr K S Krishnan Marg New Delhi 110012 India	Yes

Annexure-2: Circulation Scheme

Circulation Scheme for Participants covered under ATA Carnet
Travelling standard: Fluke model 8846A S/N 9481013

Laboratory	Receipt of Travelling Standard (DD/MM/YY)	Departure of Travelling standard (DD/MM/YY)	Report Dispatch (DD/MM/YY)
Loop 1			
NPL, India	---	16-05-11	---
NMI, Australia	27-05-11	27-06-11	27-07-11
NMI, South Africa	11-07-11	12-08-11	12-09-11
ESLMASM, Mongolia	22-08-11	09-09-11	09-10-11
MUSSD, Sri Lanka	26-09-11	28-10-11	28-11-11
NPL, India	28-11-11	---	---
Loop 2			
NPL, India	---	28-12-11	---
NIM, Thailand	13-01-12	10-02-12	10-03-12
SCL, Hong Kong	27-02-12	30-03-12	30-04-12
NML, Malaysia	16-04--12	18-05-12	18-06-12
NMI, Australia	28-05-12	29-06-12	29-07-12
NPL, India	30-07-12	---	---

Circulation Scheme for Participants not covered under ATA Carnet
Travelling standard: Fluke model 8846A S/N 9273015

Laboratory	Receipt of Travelling Standard (DD/MM/YY)	Departure of Travelling standard (DD/MM/YY)	Report Dispatch (DD/MM/YY)
Loop 1			
NMI, Australia	11-04-11	29-04-11	29-05-11
NPL, India	30-05-11	29-07-11	---
VMI, Vietnam	29-08-11	29-09-11	29-10-11
NML, Philippines	10-10-11	11-11-11	11-12-11
NISIT, Papua New Guinea	21-11-11	02-12-11	02-01-12
KIM-LIPI, Indonesia	19-12-11	09-01-12	09-02-12
NPL, India	09-02-12	---	---
Loop 2			
NPL, India	---	09-03-12	---
KIM, Kazakhstan	09-04-12	04-05-12	04-06-12
NIS, Egypt	21-05-12	22-06-12	22-07-12
NSCL, Syria	02-07-12	03-08-12	03-09-12
JNMI, Jordan	27-08-12	07-09-12	07-10-12
NPL, India	08-10-12	09-11-12	---
NMI, Australia	19-11-12	---	19-12-12

Annexure-3: Operational Settings

Digital Multimeter Fluke 8846A for P1-APMP.EM-S8 Comparison

1. Manual range selection must be made for all measurements. Select the range before applying the test signal to the multimeter.
2. The front input terminals must be used for all measurements.
3. Reset the instrument to default settings before starting measurements (see page 3-26 of the Users Manual [1]).
4. Refer to table 3 for additional measurement setup requirements.

Table 3

Parameter	DC Voltage	DC Current	Resistance	AC Voltage	AC Current
Connection	As per figure 4.1 page 4-4 of the Users Manual [1]	As per figure 4.4 (10 mA) and 4.5 (1 A) on page 4-11 of the Users Manual [1]	As per figure 4.2 page 4-9 of the Users Manual [1]	As per figure 4.1 page 4-4 of the Users Manual [1]	As per figure 4.4 (10 mA) and 4.5 (1 A) on page 4-11 of the Users Manual [1]
Input impedance	High Input Z (See page 3-10 of the Users Manual [1])	Not applicable [2]	Not applicable [2]	Not applicable [2]	Not applicable [2]
Filter selection	D FLTR off A FLTR off [4]	D FLTR off A FLTR off [4]	D FLTR off A FLTR off [4]	Select 3 HZ SLOW [4]	Select 3 HZ SLOW [4]
Display resolution	6 Digit, 100 PLC [3]	6 Digit, 100 PLC [3]	6 Digit, 100 PLC [3]	HIGH [3]	HIGH [3]
Zeroing	Required [5]	Required [5]	Required [5]	Not applicable	Not applicable
Settling time	5 minutes (min)	5 min for 10 mA, 30 min for 1 A	5 min	5 min	5 min for 10 mA, 30 min for 1 A

[1] Fluke 8845A/8846A Digital Multimeter Users Manual, July 2006, Rev. 2, 6/08
[2] Although it is possible to turn on the “HIGH INPUT Z” function on the front panel for these parameters, doing so does not change the input impedance of the Digital Multimeter
[3] Page 3-9 of the Users Manual [1]
[4] Page 4-4 to 4-6 of the Users Manual [1]
[5] Page 3-4 and 3-5 of the Users Manual [1]

Annexure-4: **Format of Measurement Results**

1. Participating Laboratory:

    a. Name of Laboratory: _____
    b. Address: _____
    c. Name of Contact Person: _____
    d. Tel No.: _____
    e. Fax No.: _____
    f. E-mail: _____

2. Standards and Instruments Used:

    a. Standard Used (Type or Model):

    b. Measuring Instruments (Model):

3. Measurement Method:

4. Measured Data:

    a. Environmental Conditions during measurements:

	Minimum	Average	Maximum
Temperature:	°C	°C	°C
Relative Humidity:	%	%	%

    b. Measurement Results:

Nominal Value	Mean Applied Value	Mean DMM reading	Mean DMM Correction	Uncertainty (95% C.L.)

Please Attach detailed Uncertainty Budgets as per “GUM” document:

Date _____

Signature _____

Annexure-5: RECEIPT FORM

SUPPLEMENTARY COMPARISON ON DIGITAL MULTIMETER (P1-APMP.EM-S8)

RECEIPT FORM

To:	_____	**From:**	_____
Attn:	_____	**Fax No.:**	_____
Fax No.:	_____	**Tel No.:**	_____
Date:	_____	**Pages:**	_____

The P1-APMP.EM-S8 comparison pack was received on ____ / ____ / _____ *(date)*

The contents of the transport case, checked against the Packing List, were:

☐ Complete (INCLUDING CARNET)

☐ Incomplete (*please list missing items*)

_____

After inspection, the 'travelling standard' (digital multimeter) is in working condition? _____ (Yes / No)

If no, is the damage serious? _____ (Yes / No)

Remarks, if any:

_____

_____

_____

Signature

Annexure-6: DISPATCH FORM

SUPPLEMENTARY COMPARISON ON DIGITAL MULTIMETER (P1-APMP.EM-S8)

DISPATCH FORM

Participating laboratory _____

Contact person _____

Phone _____ Fax _____ E-mail _____

The audit pack was dispatched on ____ / ____ / _____ *(date)*

Courier (if applicable) _____ Tracking no _____

Airline _____ Flight no _____ Dated _____

The contents of the pack have been inspected after measurement in our laboratory and were found to be in good condition. _____ (Yes / No)

Please give details of any problems

_____

_____

_____

_____

_____

Kindly send a copy to next Participant and the Pilot Laboratory.