Progress Towards Producing DCCs with Standard Structured Measurand Information

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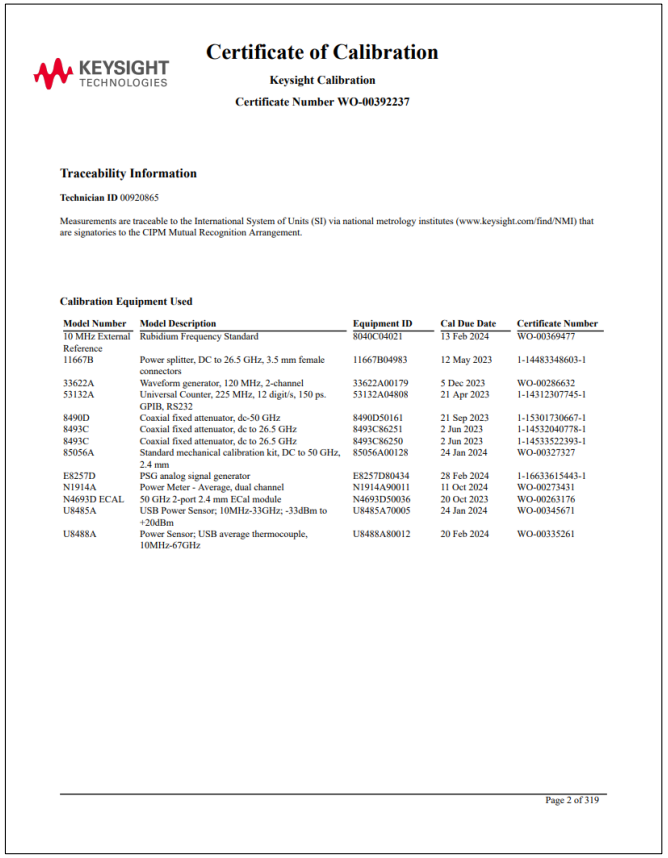
Introduction

Today's situation: non-machine-readable calibration certificates

- The quality monitoring processes are (especially from the customer's point of view) cumbersome.
- Manual use of the data is time-consuming and prone to errors.
- The data is not forgery-proof.

Certificate of Calibration



KEYSIGHT TECHNOLOGIES

Certificate of Calibration

Keysight Calibration

Certificate Number WO-00392237

Traceability Information

Technician ID 00920865

Measurements are traceable to the International System of Units (SI) via national metrology institutes (www.keysight.com/find/NMI) that are signatories to the CIPM Mutual Recognition Arrangement.

Calibration Equipment Used

Model Number	Model Description	Equipment ID	Cal Due Date	Certificate Number
10 MHz External Reference	Rubidium Frequency Standard	8040C04021	13 Feb 2024	WO-00369477
11667B	Power splitter, DC to 26.5 GHz, 3.5 mm female connectors	11667B04983	12 May 2023	1-14483348603-1
33622A	Waveform generator, 120 MHz, 2-channel	33622A00179	5 Dec 2023	WO-00286632
53132A	Universal Counter, 225 MHz, 12 digit/s, 150 ps. GPIB, RS232	53132A04808	21 Apr 2023	1-14312307745-1
8490D	Coaxial fixed attenuator, dc-50 GHz	8490D50161	21 Sep 2023	1-15301730667-1
8493C	Coaxial fixed attenuator, dc to 26.5 GHz	8493C86251	2 Jun 2023	1-14532040778-1
8493C	Coaxial fixed attenuator, dc to 26.5 GHz	8493C86250	2 Jun 2023	1-14533522393-1
85056A	Standard mechanical calibration kit, DC to 50 GHz, 2.4 mm	85056A00128	24 Jan 2024	WO-00327327
E8257D	PSG analog signal generator	E8257D80434	28 Feb 2024	1-16633615443-1
N1914A	Power Meter - Average, dual channel	N1914A90011	11 Oct 2024	WO-00273431
N4693D ECAL	50 GHz 2-port 2.4 mm ECal module	N4693D50036	20 Oct 2023	WO-00263176
U8485A	USB Power Sensor; 10MHz-33GHz; -33dBm to +20dBm	U8485A70005	24 Jan 2024	WO-00345671
U8488A	Power Sensor; USB average thermocouple, 10MHz-67GHz	U8488A80012	20 Feb 2024	WO-00335261

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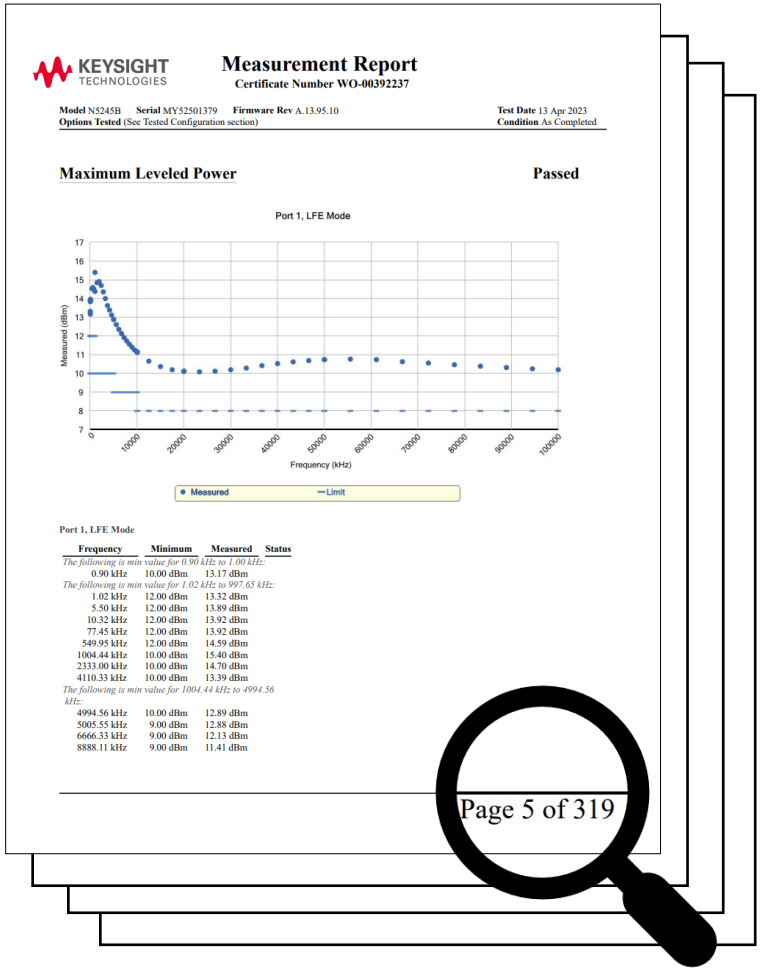
Measurement Report



KEYSIGHT TECHNOLOGIES

Measurement Report

Certificate Number WO-00392237

Model N5245B **Serial** MY52501379 **Firmware Rev** A.13.95.10 **Test Date** 13 Apr 2023
Options Tested (See Tested Configuration section) **Condition** As Completed

Maximum Leveled Power **Passed**

Port 1, LFE Mode

Port 1, LFE Mode

Frequency	Minimum	Measured	Status
The following is min value for 0.90 kHz to 1.00 kHz:			
0.90 kHz	10.00 dBm	13.17 dBm	
The following is min value for 1.02 kHz to 997.65 kHz:			
1.02 kHz	12.00 dBm	13.32 dBm	
5.50 kHz	12.00 dBm	13.89 dBm	
10.32 kHz	12.00 dBm	13.92 dBm	
77.45 kHz	12.00 dBm	13.92 dBm	
549.95 kHz	12.00 dBm	14.59 dBm	
1004.44 kHz	10.00 dBm	15.40 dBm	
2333.00 kHz	10.00 dBm	14.70 dBm	
4110.33 kHz	10.00 dBm	13.39 dBm	
The following is min value for 1004.44 kHz to 4994.56 kHz:			
4994.56 kHz	10.00 dBm	12.89 dBm	
5005.55 kHz	9.00 dBm	12.88 dBm	
6666.33 kHz	9.00 dBm	12.13 dBm	
8888.11 kHz	9.00 dBm	11.41 dBm	

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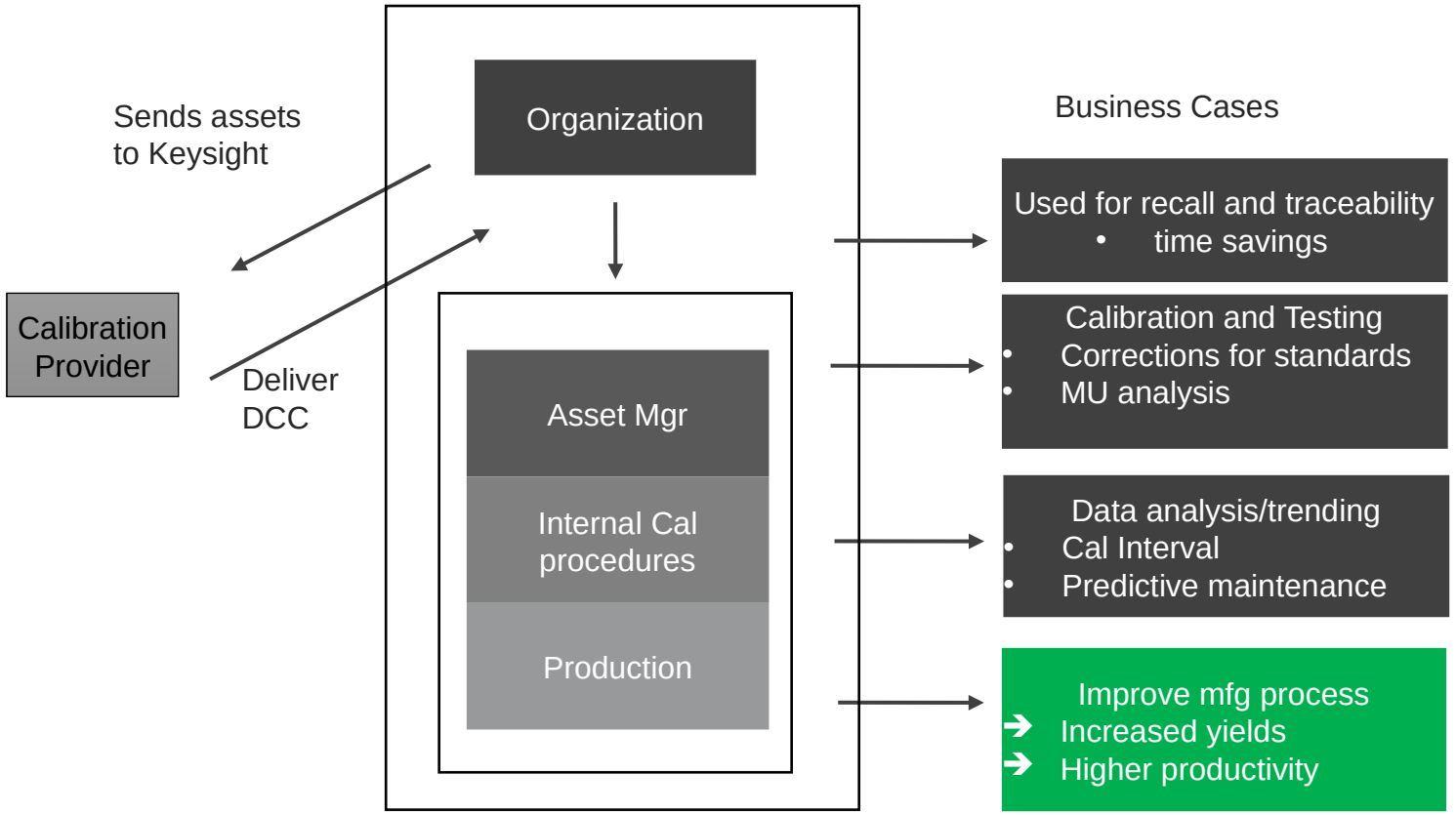
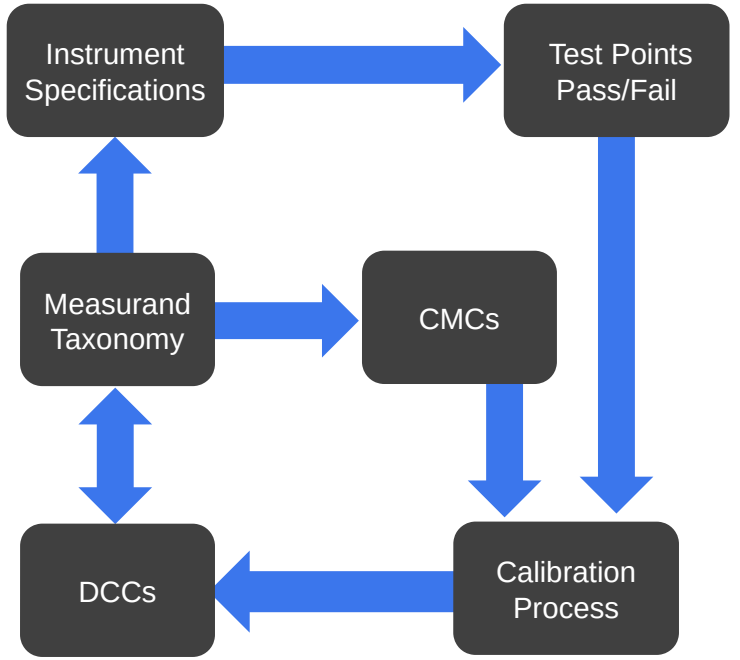
DCC Key Benefits for Manufacturing Organizations

Look into the future



IndySoft & METROLOGY.NET



Measurand Taxonomy allows the META Data connection from the Instrument Specification, Test Points, CMC Uncertainties, Calibration Process/Procedure to collect the data for to the DCC

Digitalizing Measurands, Quantities, and Units

Sources for the description

Requirements

- Designed for machine use, **interoperable** and reusable
- Comprehensive—any unit system, any measurement scale, full measurand qualification

DCC integration of Standard Structured Measurand Information comes from three primary sources

- ISO/IEC 80000 quantities and units refactored for machine use as the NCSLI M-layer
- DCC Reference Types
- NCSLI Measurand Taxonomy

BIPM's SI Reference Point does provide a digital groundwork on which to build.

ISO/IEC 80000 Summary

Basic information

ISO-IEC 80000 provides a rich resource for quantity nomenclature; precise, concise, unambiguous definitions; symbols, units, explanations, etc.

ISO-IEC 80000 does not in itself provide FAIR digital functionality

- Not currently machine-readable, Multiple terms for the same quantity, Changing terms, No measurand detail

Examples:

Nice structure and data: name, symbol, concise definition, explanations, SI & non-SI units

changing terminology over time (without unique identifiers)

6-36 (5-6.3)	source voltage, source tension *fr* *tension (f) de source*	U_s	voltage (item 6-11.3) between the two terminals of a voltage source when there is no electric current (item 6-1) through the source	The name "electromotive force" with the abbreviation EMF and the symbol E is deprecated. See IEC 60050-131, item 131-12-22.

DCC Reference Types for Describing Quantities

Basic information

- Currently, the quantity is described mainly on a SI basis (e.g., <si:unitXMLList>).

Further descriptions are possible via refTypes:

- RefTypes in a DCC are unique identifiers for nodes, helping machines distinguish between similar nodes at the same level. Cascading of refTypes is possible.
- RefTypes enable efficient data retrieval and accurate content interpretation.
- A refType consists of two parts: a namespace (e.g., "basic") and a name (e.g., "temperature"), which help organize and identify the function of the refType.
- Different namespaces, such as the general "basic" or specialized ones like "mass," cater to specific needs, allowing for precise identification and interpretation across various fields and applications.
- PTB maintains refTypes in a publicly accessible database (https://digilab.ptb.de/dkd/refType/vocab/).

NCSLI Measurand Taxonomy

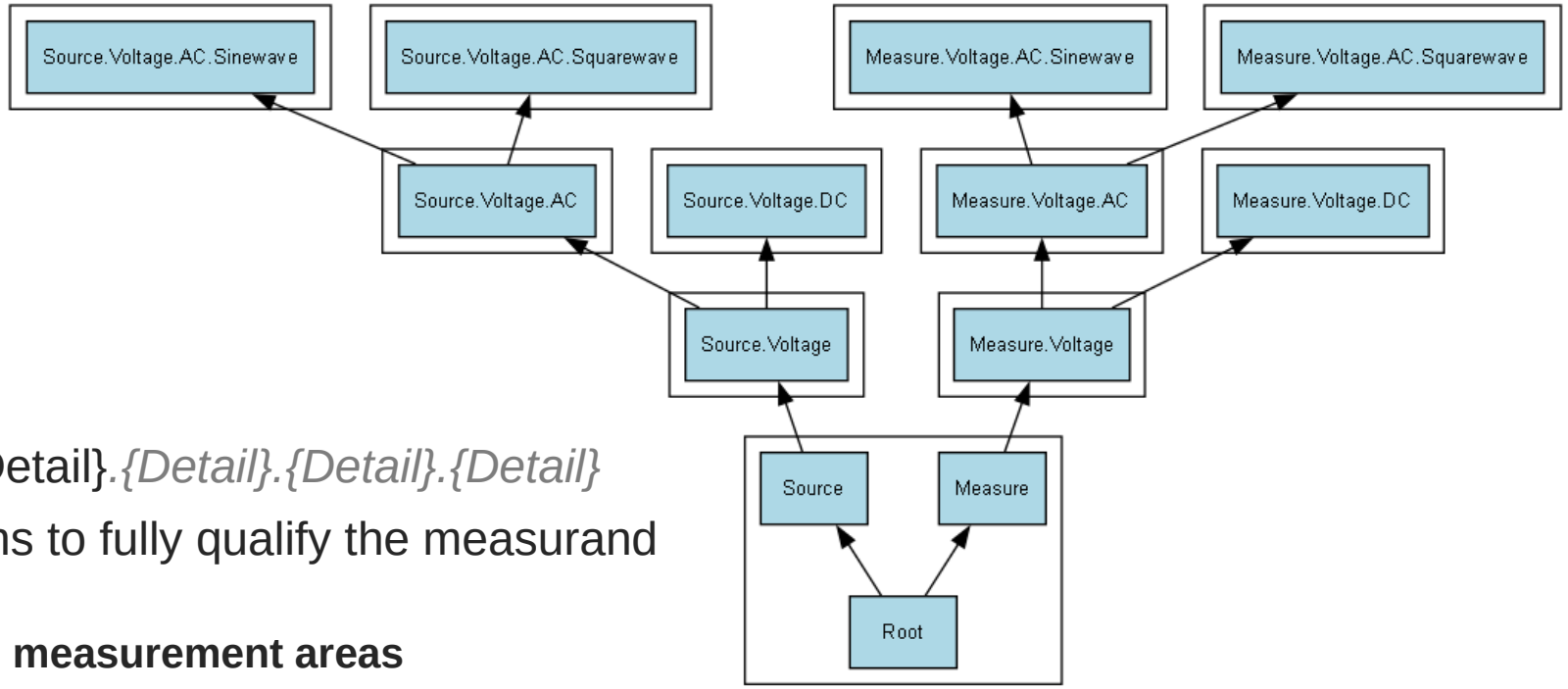
Information at a glance

Full support for influence quantities, quantity values, definitions, measurement ranges--everything required to fully qualify a measurand. XML, Machine readable

Examples

- Measure.Voltage.DC
- Source.Voltage.DC
- Source.Voltage.AC.Sinewave
- Measure.Power.AC.Sinewave

Sample AC voltage



Structured Format

- {Source or Measure}.{Quantity}.{Detail}*.{Detail}.{Detail}.{Detail}*
- Includes parameters and definitions to fully qualify the measurand

Developed ~200 initial taxa for common measurement areas

Github-based governance, taxon-submission and approval process model set up and running for new taxa

DCC Reference Types to Describe Quantities

Current and Future Solutions

Solution	Description	Advantage	Disadvantage
v1	PTB maintained refTypes	The DB can link to other taxonomies via ExactMatch or CloseMatch.	All necessary refTypes are not yet available.
v2	refTypes can be defined in a namespace on your own responsibility.	Flexibility, expandability and customization	Lack of standardization
Future	The envisioned </dcc:measurand> element can link all information.	All-encompassing solution	The element is not yet available in the current DCC schema 3.3.0.

PTB refTypes in the DCC

A real-world example of a 34405A digital multimeter

These refTypes are not yet part of the current TemaTres database.

```
<dcc:result>
        <dcc:name>
                <dcc:content lang="en">ZERO OFFSET – FRONT TERMINALS</c
        </dcc:name>
<dcc:data>
<dcc:list refType="basic_2IndexTable">
        <dcc:quantity refType="basic_tableIndex0">
                <dcc:name>
                        <dcc:content lang="en">2-Wire Ohms Zero Offset -
Range</dcc:content>
                </dcc:name>
            ...
        </dcc:quantity>
        <dcc:quantity refType="basic_tableIndex1">
                <dcc:name>
                        <dcc:content lang="en">2-Wire Ohms Zero Offset -
Input</dcc:content>
                </dcc:name>
             ...
        </dcc:quantity>
        <dcc:quantity refType="basic_measuredValue">
                <dcc:name>
                        <dcc:content lang="en">Measured Resistance</dcc:content>
                </dcc:name>
            ...
        </dcc:quantity>
</dcc:list>
```

ZERO OFFSET - FRONT TERMINALS **Passed**

Zero Offset Adjustments DONE

Post-Repair/Adjustment Data:

TEST CONDITIONS		MINIMUM	MEASURED	MAXIMUM	UNCERT.	Status
Range	*Input*					
2-Wire Ohms Zero Offset						
100 Ω	0 Ω	−208 mΩ	0 mΩ	208 mΩ	4.3 mΩ	
1 kΩ	0 Ω	−0.25 Ω	−0.01 Ω	0.25 Ω	0.018 Ω	
10 kΩ	0 Ω	−0.8 Ω	0.0 Ω	0.8 Ω	0.17 Ω	
100 kΩ	0 Ω	−7 Ω	0 Ω	7 Ω	1.7 Ω	
1 MΩ	0 Ω	−0.07 kΩ	0.00 kΩ	0.07 kΩ	0.015 kΩ	
10 MΩ	0 Ω	−0.5 kΩ	0.0 kΩ	0.5 kΩ	0.094 kΩ	
100 MΩ	0 Ω	−5 kΩ	0 kΩ	5 kΩ	0.58 kΩ	

Excerpt from the measurement report certificate number WO-0066

Crucial question: How can the measured value be described in a machine-readable and interpretable way beyond the physical quantity?

NCSLI-MII Taxonomy in the DCC

A Concrete Example

Measurand Taxon	Measurand-Parameter	Min. Range	Max. Range	Range UOM	Spec. Type	% Reading	% Span
Measure.Current.DC		-10	10	mA	Accuracy	0.05	0.015
Measure.Current.DC		-100	100	mA	Accuracy	0.05	0.005
Measure.Current.DC		-1	1	A	Accuracy	0.2	0.007
Measure.Current.DC		-10	10	A	Accuracy	0.25	0.007
Measure.Capacitance	.2Wire	0	1	nF	Accuracy	2	0.8
Measure.Capacitance	.2Wire	0	10	nF	Accuracy	1	0.5
Measure.Capacitance	.2Wire	0	100	nF	Accuracy	1	0.5
Measure.Capacitance	.2Wire	0	1	µF	Accuracy	1	0.5
Measure.Capacitance	.2Wire	0	10	µF	Accuracy	1	0.5
Measure.Capacitance	.2Wire	0	100	µF	Accuracy	1	0.5
Measure.Capacitance	.2Wire	0	1000	µF	Accuracy	1	0.5
Measure.Capacitance	.2Wire	0	10000	µF	Accuracy	2	0.5
Measure.Voltage.DC		-100	100	mV	Accuracy	0.025	0.008
Measure.Voltage.DC		-1	1	V	Accuracy	0.025	0.006
Measure.Voltage.DC		-10	10	V	Accuracy	0.025	0.005
Measure.Voltage.DC		-100	100	V	Accuracy	0.025	0.005
Measure.Voltage.DC		-1000	1000	V	Accuracy	0.025	0.005
Measure.Resistance	.2Wire	0	100	Ω	Accuracy	0.05	0.008
Measure.Resistance	.2Wire	0	1	kΩ	Accuracy	0.05	0.005
Measure.Resistance	.2Wire	0	10	kΩ	Accuracy	0.05	0.006
Measure.Resistance	.2Wire	0	100	kΩ	Accuracy	0.05	0.007
Measure.Resistance	.2Wire	0	1	MΩ	Accuracy	0.06	0.007
Measure.Resistance	.2Wire	0	10	MΩ	Accuracy	0.25	0.005
Measure.Resistance	.2Wire	0	100	MΩ	Accuracy	2	0.005

```
...
<dcc:refTypeDefinition>
      <dcc:name>
            <dcc:content>NCSLI Measurement Information Infrastructure (MII)</dcc:content>
      </dcc:name>
      <dcc:namespace>NCSLI</dcc:namespace>
      <dcc:link>raw.githubusercontent.com/NCSLI-MII/measurand-taxonomy/main/MeasurandTaxonomyCatalog.xml</dcc:link>
</dcc:refTypeDefinition>
...
...
<dcc:list refType="basic_2IndexTable NCSLI_Measure.Resistance">
...
            <dcc:quantity refType="basic_measuredValue">
                  <dcc:name>
                        <dcc:content lang="en">Measured Resistance</dcc:content>
                  </dcc:name>
          ...
            </dcc:quantity>
</dcc:list>
...
```

Conclusions

Key Findings & Takeaways

- The NCSLI-MII Taxonomy is a standardized framework for categorizing measurements, instrument functions, measurement capabilities, and their integration, and it can be made machine-readable through structured data formats like XML or JSON.
- This work demonstrates that the NCSLI-MII taxonomy can be linked to the DCC using refTypes. This capability accelerates DCC development and significantly expands the user base.
- For the unambiguous description of the measurand, a new element in the DCC schema is required, which would allow further information about the measurand like the version of the taxon.
- We are open to collaborating with additional partners to expand our pilot project.

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