

User manual

RePCal

(Version 1.0)

Summary

RePCal is a COM object developed by the LNE providing a set of functions for calculation of quantities required for Reciprocity pressure Calibration of microphones in couplers. These includes the calculation of parameters of air and the acoustic transfer admittance of a plane wave coupler according to the standards IEC 61094-2:2009 [1], IEC 61094-2:2009/AMD1:2022 [2] and the formulations provided in the reference D. Rodrigues et al. Metrologia 2023 [3].

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(LNE)

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2 Introduction

RePCal is a COM object developed by the LNE providing a set of functions for calculation of quantities required for Reciprocity pressure Calibration of microphones in couplers. These includes the calculations of parameters of air and the acoustic transfer admittance of a plane wave coupler according to the standards IEC 61094-2:2009 [1], IEC 61094-2:2009/AMD1:2022 [2] and the formulations provided in the reference D. Rodrigues et al. Metrologia 2023 [3].

RePCal has been developed for Windows operating computers. It implements a Microsoft Component Object Model (COM) server by creating a Python interface, registered in the Windows Registry. When the COM object up and running, any automation-capable language, such as Python, Visual Basic, Delphi, or Perl, can use it. RePCal is a 64 bit application, it cannot be installed in a 32 bit operating system.

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3 Third party software component

Supplementary material of reference D. Rodrigues et al. Metrologia 2023 [3].

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4 Installation

RePCal has been developed for Windows 64 bit operating computers, it cannot be installed in a 32 bit operating system. It shall be registered in the Windows Registry from command line. The Windows user running this process should have permission to write in the Windows registry.

1. Save the RePCal.exe file in a folder of your choice
2. Run the windows command prompt as an administrator
3. Enter the following command and click Run to register the COM object in the Windows Registry,

```
Path\RePCal.exe --register
```

where "Path" specify the location of the exe file "RePCal.exe".

Once it is registered, any automation-capable language, such as Python, Visual Basic, Delphi, or Perl, can use it.

Example with VBA:

```
Dim rpc As Object  
Set rpc = VBA.CreateObject("RepCal")
```

The software can be unregistered from the Windows Registry with the command line :

```
Path\RePCal.exe --unregister
```

5 Public methods

5.1 about

Returns information's about RePCal.

Syntax:

expression.about()

expression: A variable that represents a RePCal object.

Return value:

Data type	Description
String	Information about Re(p)Cal including: <ul style="list-style-type: none">- Software name- Version- Release date- Copyright

Example with VBA:

```
Dim rpc As Object
Set rpc = VBA.CreateObject("RePCal")

Dim info as String
info = rpc.about()
```

5.2 show_console

Returns/sets a Boolean value that determines whether the console window is visible.

Syntax:

expression.show_console(*Arg1*)

expression: A variable that represents a RePCal object.

Parameters:

Name	Required/Optional	Data type	Description
<i>Arg1</i>	Required	Boolean	-

Return value:

Data type	Description
Boolean	Boolean value that determines whether the console window is visible.

Remarks

Default value is True.

Example with VBA:

```
Dim rpc As Object
Set rpc = VBA.CreateObject("RePCal")

Dim IsShow as Boolean
IsShow = rpc.show_console(True)
```

5.3 logging

Returns/sets a Boolean value that determines whether the log information printed in the console.

Syntax:

expression.logging(*Arg1*)

expression: A variable that represents a RePCal object.

Parameters:

Name	Required/Optional	Data type	Description
<i>Arg1</i>	Required	Boolean	-

Return value:

Data type	Description
Boolean	Boolean value that determines whether the log information printed in the console

Remarks

Default value is False.

Example with VBA:

```
Dim rpc As Object
Set rpc = VBA.CreateObject("RePCal")

Dim IsLog as Boolean
IsLog = rpc.logging(True)
```

5.4 density

Returns the density of air in kg m⁻³ according to IEC 61094-2:2009 Appendix F.

Syntax:

expression.density(*Arg1*, *Arg2*, *Arg3*)

expression: A variable that represents a RePCal object.

Parameters:

Name	Required/Optional	Data type	Description
<i>Arg1</i>	Required	Real	Static pressure in hPa
<i>Arg2</i>	Required	Real	Temperature in °C
<i>Arg3</i>	Required	Real	Humidity rate in %

Return value:

Data type	Description
Real	Density of air in kg m ⁻³

Example with VBA:

```
Dim rpc As Object
Set rpc = VBA.CreateObject("RePCal")

Dim rho as Double
rho = rpc.density(1013.25, 23, 50)
```

5.5 celerity

Returns the zero-frequency speed of sound in m s^{-1} according to IEC 61094-2:2009 Appendix F.

Syntax:

expression.celerity(*Arg1*, *Arg2*, *Arg3*)

expression: A variable that represents a RePCal object.

Parameters:

Name	Required/Optional	Data type	Description
<i>Arg1</i>	Required	Real	Static pressure in hPa
<i>Arg2</i>	Required	Real	Temperature in °C
<i>Arg3</i>	Required	Real	Humidity rate in %

Return value:

Data type	Description
Real	Zero-frequency speed of sound in m s^{-1}

Example with VBA:

```
Dim rpc As Object
Set rpc = VBA.CreateObject("RePCal")

Dim c0 as Double
C0 = rpc.celerity(1013.25, 23, 50)
```

5.6 ratio_c

Returns the ratio of specific heats according to IEC 61094-2:2009 Appendix F.

Syntax:

expression.ratio_c(*Arg1*, *Arg2*, *Arg3*)

expression: A variable that represents a RePCal object.

Parameters:

Name	Required/Optional	Data type	Description
<i>Arg1</i>	Required	Real	Static pressure in hPa
<i>Arg2</i>	Required	Real	Temperature in °C
<i>Arg3</i>	Required	Real	Humidity rate in %

Return value:

Data type	Description
Real	Ratio of specific heats (unitless)

Example with VBA:

```
Dim rpc As Object
Set rpc = VBA.CreateObject("RePCal")

Dim kappa as Double
kappa = rpc.ratio_c(1013.25, 23, 50)
```

5.7 viscosity

Returns the viscosity of air in Pa s according to IEC 61094-2:2009 Appendix F.

Syntax:

expression.**viscosity**(Arg1, Arg2, Arg3)

expression: A variable that represents a RePCal object.

Parameters:

Name	Required/Optional	Data type	Description
Arg1	Required	Real	Static pressure in hPa
Arg2	Required	Real	Temperature in °C
Arg3	Required	Real	Humidity rate in %

Return value:

Data type	Description
Real	Viscosity of air in Pa s

Example with VBA:

```
Dim rpc As Object
Set rpc = VBA.CreateObject("RePCal")

Dim mu as Double
mu = rpc.viscosity(1013.25, 23, 50)
```

5.8 thermal_conductivity

Returns the thermal conductivity of air in J m⁻¹ s⁻¹ K⁻¹ according to IEC 61094-2:2009 Appendix F.

Syntax:

expression.**thermal_conductivity**(Arg1, Arg2, Arg3)

expression: A variable that represents a RePCal object.

Parameters:

Name	Required/Optional	Data type	Description
Arg1	Required	Real	Static pressure in hPa
Arg2	Required	Real	Temperature in °C
Arg3	Required	Real	Humidity rate in %

Return value:

Data type	Description
Real	Thermal conductivity of air in J m ⁻¹ s ⁻¹ K ⁻¹

Example with VBA:

```
Dim rpc As Object
Set rpc = VBA.CreateObject("RePCal")

Dim ka as Double
ka = rpc.thermal_conductivity(1013.25, 23, 50)
```

5.9 specific_heat_capacity_p

Returns the specific heat capacity at constant pressure in $\text{J kg}^{-1} \text{K}^{-1}$ according to IEC 61094-2:2009 Appendix F.

Syntax:

expression.specific_heat_capacity_p(*Arg1*, *Arg2*, *Arg3*)

expression: A variable that represents a RePCal object.

Parameters:

Name	Required/Optional	Data type	Description
<i>Arg1</i>	Required	Real	Static pressure in hPa
<i>Arg2</i>	Required	Real	Temperature in °C
<i>Arg3</i>	Required	Real	Humidity rate in %

Return value:

Data type	Description
Real	Specific heat capacity at constant pressure in $\text{J kg}^{-1} \text{K}^{-1}$

Example with VBA:

```
Dim rpc As Object
Set rpc = VBA.CreateObject("RePCal")

Dim cp as Double
cp = rpc.specific_heat_capacity_p(1013.25, 23, 50)
```

5.10 thermal_diffusivity

Returns the thermal diffusivity of air in $\text{m}^2 \text{s}^{-1}$ according to IEC 61094-2:2009 Appendix F.

Syntax:

expression.thermal_diffusivity(*Arg1*, *Arg2*, *Arg3*)

expression: A variable that represents a RePCal object.

Parameters:

Name	Required/Optional	Data type	Description
<i>Arg1</i>	Required	Real	Static pressure in hPa
<i>Arg2</i>	Required	Real	Temperature in °C
<i>Arg3</i>	Required	Real	Humidity rate in %

Return value:

Data type	Description
Real	Thermal diffusivity of air in $\text{m}^2 \text{s}^{-1}$

Example with VBA:

```
Dim rpc As Object
Set rpc = VBA.CreateObject("RePCal")

Dim alphas as Double
alphas = rpc.thermal_diffusivity(1013.25, 23, 50)
```


5.11 y_mic

Returns the complex acoustic admittance of a microphone (in $\text{Pa}^{-1} \text{s}^{-1} \text{m}^3$) for a specific frequency from a lumped parameter representation as specified in IEC 61094-2:2009 Appendix E, involving the equivalent volume at low frequencies, the resonance frequency, and the loss factor of the diaphragm.

Syntax:

expression.y_mic(Arg1, Arg2, Arg3, Arg4, Arg5, Arg6, Arg7, Arg8, Arg9, Arg10)

expression: A variable that represents a RePCal object.

Parameters:

Name	Required/Optional	Data type	Description
Arg1	Required	Real	Frequency in Hz
Arg2	Required	Real	Microphone equivalent volume at low frequencies in m^3
Arg3	Required	Real	Microphone resonance frequency in Hz
Arg4	Required	Real	Loss factor of the diaphragm (unitless)

Return value:

Data type	Description
Array [Real, Real]	Complex acoustic admittance of a microphone $\text{Pa}^{-1} \text{s}^{-1} \text{m}^3$ in at frequency Arg1 in the format [Real part, Imaginary part]

Example with VBA:

```
Dim rpc As Object
Set rpc = VBA.CreateObject("RePCal")

Dim ym as Double
ym = rpc.y_mic(1000, 9.3e-10, 23000, 1.05)
```

5.12 yt_iec_lf

Returns the complex acoustic transfer admittance of a plane wave coupler (in $\text{Pa}^{-1}\cdot\text{s}^{-1}\cdot\text{m}^3$) for a specific frequency according to the low frequency model provided in IEC 61094-2:2009/AMD1:2022, § A.2 when the complex correction factor Δ_H is applied to the geometrical coupler volume in Equation (3).

Syntax:

expression.yt_iec_lf(Arg1, Arg2, Arg3, Arg4, Arg5, Arg6, Arg7, Arg8, Arg9, Arg10)

expression: A variable that represents a RePCal object.

Parameters:

Name	Required/Optional	Data type	Description
<i>Arg1</i>	Required	Real	Frequency in Hz
<i>Arg2</i>	Required	Real	Radius of the cylinder in m
<i>Arg3</i>	Required	Real	Length of the cylinder with frontal depth of microphones in m
<i>Arg4</i>	Required	Real	Enclosed air density in kg m^{-3}
<i>Arg5</i>	Required	Real	Specific heat ratio (unitless)
<i>Arg6</i>	Required	Real	Adiabatic speed of sound in m s^{-1}
<i>Arg7</i>	Required	Real	Thermal diffusivity in $\text{m}^2 \text{s}^{-1}$
<i>Arg8</i>	Required	Real	Equivalent volume of the transmitter microphone at frequency <i>Arg1</i> in m^3
<i>Arg9</i>	Required	Real	Equivalent volume of the receiver microphone at frequency <i>Arg1</i> in m^3
<i>Arg10</i>	Optional	Positive integer ≥ 1	Number of terms $N_m=N_n$ for calculation of E_p eq. A.2 in IEC 61094-2:2009/AMD1:2022 Default value: 512

Return value:

Data type	Description
Array [Real, Real]	Complex acoustic transfer admittance of the plane wave coupler in $\text{Pa}^{-1}\cdot\text{s}^{-1}\cdot\text{m}^3$ at frequency <i>Arg1</i> in the format [Real part, Imaginary part]

Remarks

The default value is used for *Arg10* when *Arg10* < 1.

Example with VBA:

```
Dim rpc As Object
Set rpc = VBA.CreateObject("RePCal")

Dim Yt() as Variant
Yt = rpc.yt_iec_lf(10, 4.65e-3, 10.4e-3, 1.19, 1.40, 345.87, 2.12e-5, 9.3e-10, 9.4e-10)
```

5.13 yt_iec_lfe

Returns the acoustic transfer admittance of a plane wave coupler (in $\text{Pa}^{-1} \cdot \text{s}^{-1} \cdot \text{m}^3$) for a specific frequency according to the extended low frequency model provided in IEC 61094-2:2009/AMD1:2022, § A.2 when the complex correction factor Δ_H is applied to the cross-sectional area in Equation (4).

Syntax:

expression.yt_iec_lfe(Arg1, Arg2, Arg3, Arg4, Arg5, Arg6, Arg7, Arg8, Arg9, Arg10)

expression: A variable that represents a RePCal object.

Parameters:

Name	Required/Optional	Data type	Description
Arg1	Required	Real	Frequency in Hz
Arg2	Required	Real	Radius of the cylinder in m
Arg3	Required	Real	Length of the cylinder with frontal depth of microphones in m
Arg4	Required	Real	Enclosed air density kg m^{-3}
Arg5	Required	Real	Specific heat ratio (unitless)
Arg6	Required	Real	Adiabatic speed of sound in m s^{-1}
Arg7	Required	Real	Thermal diffusivity in $\text{m}^2 \text{s}^{-1}$
Arg8	Required	Array [Real, Real]	Complex acoustic admittance of the transmitter microphone in $\text{Pa}^{-1} \cdot \text{s}^{-1} \cdot \text{m}^3$ at frequency Arg1 in the format [Real part, Imaginary part]
Arg9	Required	Array [Real, Real]	Complex acoustic admittance of the receiver microphone in $\text{Pa}^{-1} \cdot \text{s}^{-1} \cdot \text{m}^3$ at frequency Arg1 in the format [Real part, Imaginary part]
Arg10	Optional	Positive integer ≥ 1	Number of terms $N_m=N_n$ for calculation of E_p eq. A.2 in IEC 61094-2:2009/AMD1:2022 Default value: 512

Return value:

Data type	Description
Array [Real, Real]	Complex acoustic transfer admittance of the plane wave coupler in $\text{Pa}^{-1} \cdot \text{s}^{-1} \cdot \text{m}^3$ at frequency Arg1 in the format [Real part, Imaginary part]

Remarks

The default value is used for Arg10 when Arg10 < 1.

Example with VBA:

```
Dim rpc As Object
Set rpc = VBA.CreateObject("RePCal")

Dim Ymt(), Ymr(), Yt() as Variant
Ymt = rpc.y_mic(10, 9.4e-10, 22000, 1.04)
Ymr = rpc.y_mic(10, 9.3e-10, 23000, 1.05)
Yt = rpc.yt_iec_lf(10, 4.65e-3, 10.4e-3, 1.19, 1.40, 345.87, 2.12e-5, Ymt, Ymr)
```

5.14 yt_iec_bb

Returns the acoustic transfer admittance of a plane wave coupler (in $\text{Pa}^{-1} \cdot \text{s}^{-1} \cdot \text{m}^3$) for a specific frequency according to the broadband model provided in IEC 61094-2:2009, Equations (4), (A.3), (A.4) and (A.5).

Syntax:

expression.yt_iec_bb(Arg1, Arg2, Arg3, Arg4, Arg5, Arg6, Arg7, Arg8, Arg9, Arg10)

expression: A variable that represents a RePCal object.

Parameters:

Name	Required/Optional	Data type	Description
Arg1	Required	Real	Frequency in Hz
Arg2	Required	Real	Radius of the cylinder in m
Arg3	Required	Real	Length of the cylinder with frontal depth of microphones in m
Arg4	Required	Real	Enclosed air density kg m^{-3}
Arg5	Required	Real	Specific heat ratio (unitless)
Arg6	Required	Real	Adiabatic speed of sound in m s^{-1}
Arg7	Required	Real	Viscosity of air in Pa s
Arg8	Required	Real	Thermal diffusivity in $\text{m}^2 \text{s}^{-1}$
Arg9	Required	Array [Real, Real]	Complex acoustic admittance of the transmitter microphone in $\text{Pa}^{-1} \cdot \text{s}^{-1} \cdot \text{m}^3$ at frequency Arg1 in the format [Real part, Imaginary part]
Arg10	Required	Array [Real, Real]	Complex acoustic admittance of the receiver microphone in $\text{Pa}^{-1} \cdot \text{s}^{-1} \cdot \text{m}^3$ at frequency Arg1 in the format [Real part, Imaginary part]

Return value:

Data type	Description
Array [Real, Real]	Complex acoustic transfer admittance of the plane wave coupler in $\text{Pa}^{-1} \cdot \text{s}^{-1} \cdot \text{m}^3$ at frequency Arg1 in the format [Real part, Imaginary part]

Example with VBA:

```
Dim rpc As Object
Set rpc = VBA.CreateObject("RePCal")

Dim Ymt(), Ymr(), Yt() as Variant
Ymt = rpc.y_mic(1000, 9.4e-10, 22000, 1.04)
Ymr = rpc.y_mic(1000, 9.3e-10, 23000, 1.05)
Yt = rpc.yt_iec_bb(1000, 4.65e-3, 10.4e-3, 1.19, 1.40, 345.87, 1.83e-5, 2.12e-5, Ymt, Ymr)
```

5.15 yt_rod_unified

Returns the acoustic transfer admittance of a plane wave coupler (in $\text{Pa}^{-1}\cdot\text{s}^{-1}\cdot\text{m}^3$) for a specific frequency according to the general analytical solution provided in [3] § 3.1.

Syntax:

expression.yt_rod_unified(*Arg1*, *Arg2*, *Arg3*, *Arg4*, *Arg5*, *Arg6*, *Arg7*, *Arg8*, *Arg9*, *Arg10*, *Arg11*, *Arg12*, *Arg13*)

expression: A variable that represents a RePCal object.

Parameters:

Name	Required/Optional	Data type	Description
<i>Arg1</i>	Required	Real	Frequency in Hz
<i>Arg2</i>	Required	Real	Radius of the cylinder in m
<i>Arg3</i>	Required	Real	Length of the cylinder with frontal depth of microphones in m
<i>Arg4</i>	Required	Real	Enclosed air density kg m^{-3}
<i>Arg5</i>	Required	Real	Specific heat ratio (unitless)
<i>Arg6</i>	Required	Real	Adiabatic speed of sound in m s^{-1}
<i>Arg7</i>	Required	Real	Viscosity of air in Pa s
<i>Arg8</i>	Required	Real	Thermal diffusivity in $\text{m}^2 \text{s}^{-1}$
<i>Arg9</i>	Required	Array [Real, Real]	Complex acoustic admittance of the transmitter microphone in $\text{Pa}^{-1}\cdot\text{s}^{-1}\cdot\text{m}^3$ at frequency <i>Arg1</i> in the format [Real part, Imaginary part]
<i>Arg10</i>	Required	Array [Real, Real]	Complex acoustic admittance of the receiver microphone in $\text{Pa}^{-1}\cdot\text{s}^{-1}\cdot\text{m}^3$ at frequency <i>Arg1</i> in the format [Real part, Imaginary part]
<i>Arg11</i>	Optional	Positive integer ≥ 1	Number of terms N_k in [3] § 3.1 Default value: $[0.2 f^{0.42}]$
<i>Arg12</i>	Optional	Positive integer ≥ 1	Number of terms $N_{m,v}$ in [3] § 3.1 Default value: $\text{Max}([30 f^{0.42}], 100)$
<i>Arg13</i>	Optional	Positive integer ≥ 1	Number of terms $N_{n,\mu}$ in [3] § 3.1 Default value: $\text{Max}([15 f^{0.42}], 100)$

Return value:

Data type	Description
Array [Real, Real]	Complex acoustic transfer admittance of the plane wave coupler in $\text{Pa}^{-1}\cdot\text{s}^{-1}\cdot\text{m}^3$ at frequency <i>Arg1</i> in the format [Real part, Imaginary part]

Remarks

The default values are used for *Arg11*, *Arg12* and *Arg13* if the arguments are < 1 .

Example with VBA:

```
Dim rpc As Object
Set rpc = VBA.CreateObject("RePCal")

Dim Ymt(), Ymr(), Yt() as Variant
Ymt = rpc.y_mic(1000, 9.4e-10, 22000, 1.04)
Ymr = rpc.y_mic(1000, 9.3e-10, 23000, 1.05)
Yt = rpc.yt_rod_unified(1000, 4.65e-3, 10.4e-3, 1.19, 1.40, 345.87, 1.83e-5, 2.12e-5, Ymt, Ymr)
```

5.16 yt_rod_lf

Returns the acoustic transfer admittance of a plane wave coupler (in $\text{Pa}^{-1}\cdot\text{s}^{-1}\cdot\text{m}^3$) for a specific frequency according to the low frequency solution provided in [3] § 3.3.

Syntax:

expression.yt_rod_lf(*Arg1*, *Arg2*, *Arg3*, *Arg4*, *Arg5*, *Arg6*, *Arg7*, *Arg8*, *Arg9*, *Arg10*, *Arg11*)

expression: A variable that represents a RePCal object.

Parameters:

Name	Required/Optional	Data type	Description
<i>Arg1</i>	Required	Real	Frequency in Hz
<i>Arg2</i>	Required	Real	Radius of the cylinder in m
<i>Arg3</i>	Required	Real	Length of the cylinder with frontal depth of microphones in m
<i>Arg4</i>	Required	Real	Enclosed air density kg m^{-3}
<i>Arg5</i>	Required	Real	Specific heat ratio (unitless)
<i>Arg6</i>	Required	Real	Adiabatic speed of sound in m s^{-1}
<i>Arg7</i>	Required	Real	Viscosity of air in Pa s
<i>Arg8</i>	Required	Real	Thermal diffusivity in $\text{m}^2 \text{s}^{-1}$
<i>Arg9</i>	Required	Array [Real, Real]	Complex acoustic admittance of the transmitter microphone in $\text{Pa}^{-1}\cdot\text{s}^{-1}\cdot\text{m}^3$ at frequency <i>Arg1</i> in the format [Real part, Imaginary part]
<i>Arg10</i>	Required	Array [Real, Real]	Complex acoustic admittance of the receiver microphone in $\text{Pa}^{-1}\cdot\text{s}^{-1}\cdot\text{m}^3$ at frequency <i>Arg1</i> in the format [Real part, Imaginary part]
<i>Arg11</i>	Optional	Positive integer ≥ 1	Number of terms $N_m=N_n$ for calculation of E_p eq. A.2 in IEC 61094-2:2009/AMD1:2022 Default value: 1024

Return value:

Data type	Description
Array [Real, Real]	Complex acoustic transfer admittance of the plane wave coupler in $\text{Pa}^{-1}\cdot\text{s}^{-1}\cdot\text{m}^3$ at frequency <i>Arg1</i> in the format [Real part, Imaginary part]

Remarks

The default value is used for *Arg11* if the arguments are < 1 .

Example with VBA:

```
Dim rpc As Object
Set rpc = VBA.CreateObject("RePCal")

Dim Ymt(), Ymr(), Yt() as Variant
Ymt = rpc.y_mic(1000, 9.4e-10, 22000, 1.04)
Ymr = rpc.y_mic(1000, 9.3e-10, 23000, 1.05)
Yt = rpc.yt_rod_lf(1000, 4.65e-3, 10.4e-3, 1.19, 1.40, 345.87, 1.83e-5, 2.12e-5, Ymt, Ymr)
```

6 References

- [1] IEC 61094-2:2009. Measurement microphones-Part2: Primary method for the pressure calibration of laboratory standard microphones by the reciprocity method. IEC standard, 2009.
- [2] IEC 61094-2:2009/AMD1:2022. Amendment 1 — Measurement microphones-part 2: Primary method for pressure calibration of laboratory standard microphones by the reciprocity technique. IEC standard, 2022.
- [3] D. Rodrigues, P. Vincent. Toward a unified formulation of the acoustic transfer admittance of cylindrical cavities for reciprocity calibration of microphones. *Metrologia*, 2023. DOI 10.1088/1681-7575/ace3c4.