



METAS UncLib C# - User Reference V2.6.0

Michael Wollensack

July 2022

Contents

1	Introduction	2
2	Global uncertainty settings	2
2.1	Using Metas.UncLib	2
2.2	Additional global settings	2
3	Create an uncertainty object	3
4	Calculations with uncertainty objects	4
4.1	Math functions	4
4.2	Linear algebra	4
4.3	Numerical routines	5
5	Get properties of an uncertainty object	5
6	Storage functions	6
6.1	Store a computed uncertainty object	6
6.2	Reload a stored uncertainty object	6
A	Physical constants	7
A.1	CODATA 2014	7
A.2	CODATA 2014 for conventional electrical units 90	8
A.3	CODATA 2018	9



1 Introduction

This document is a quick reference sheet. For more details refer to the [METAS UncLib](#) help with the installation of the software.

The [METAS UncLib C#](#) library supports creation of uncertainty objects and subsequent calculation with them as well as storage of the results. It's able to handle complex-valued and multivariate quantities. It has been developed with Microsoft Visual Studio 2013 and it requires the .NET Frame-work V4.5. There are three namespaces for uncertainty propagation: [LinProp](#), [DistProp](#) and [MCProp](#).

LinProp supports linear uncertainty propagation $V_{out} = J V_{in} J'$.

DistProp supports higher order uncertainty propagation, i.e. higher order terms of the Taylor expansion of the measurement equation are taken into account.¹

MCProp supports Monte Carlo propagation.¹

2 Global uncertainty settings

2.1 Using Metas.UncLib

`using Metas.UncLib.Core;` Use the linear uncertainty propagation.
`using Metas.UncLib.LinProp;`

`using Metas.UncLib.Core;` Use the higher order uncertainty propagation.
`using Metas.UncLib.DistProp;`

`using Metas.UncLib.Core;` Use the Monte Carlo uncertainty propagation.
`using Metas.UncLib.MCProp;`

2.2 Additional global settings

`DistProp.Misc.Global.MaxLevel` Set the higher order uncertainty propagation maximum level. Default value: 1 (1 corresponds to [LinProp](#))

`MCProp.Misc.Global.n` Set the Monte Carlo uncertainty propagation sample size. Default value: 100000

¹preliminary implementation



3 Create an uncertainty object

Square brackets indicate vector or matrix.

`UncNumber x = new UncNumber(value);` Creates a new uncertain number without uncertainties.

`UncNumber x = new UncNumber(value, standard_unc, (idof));` Creates a new real uncertain number with value, standard uncertainty and inverse degrees of freedom (optional).

`UncNumber x = Unc.RealUncNumber(value, standard_unc, (idof));` Creates a new real uncertain number with value, standard uncertainty and inverse degrees of freedom (optional).

`Complex<UncNumber> x = Unc.ComplexUncNumber(value, [covariance], (idof));` Creates a new complex uncertain number. Covariance size: 2×2

`UncNumber[] x = Unc.RealUncArray([value], [covariance], (idof));` Creates a new real uncertain array. Covariance size: $N \times N$

`Complex<UncNumber>[] x = Unc.ComplexUncArray([value], [covariance], (idof));`
Creates a new complex uncertain array. Covariance size: $2N \times 2N$

`UncNumber x = Unc.RealUncNumberFromSamples([samples], (desc), (p));` Creates a new real uncertain number from samples with a description (optional) and a probability (optional).

`Complex<UncNumber> x = Unc.ComplexUncNumberFromSamples([samples], (desc), (p));`
Creates a new complex uncertain number from samples with a description (optional) and a probability (optional). The complex uncertain number contains the correlation between real and imaginary parts.

`UncNumber[] x = Unc.RealUncArrayFromSamples([samples], (desc), (p));` Creates a new real uncertain array from samples with a description (optional) and a probability (optional). The real uncertain array contains the correlation between the different entries.

`Complex<UncNumber>[] x = Unc.ComplexUncArrayFromSamples([samples], (desc), (p));`
Creates a new complex uncertain array from samples with a description (optional) and a probability (optional). The complex uncertain array contains the correlation between real and the imaginary parts and the different entries.

`UncNumber x = new UncNumber(); x.Init(value, [sys_inputs], [sys_sensitivities]);`
Creates a new uncertain number by setting sensitivities with respect to uncertain inputs.²

²`LinProp` uncertainty objects only



4 Calculations with uncertainty objects

4.1 Math functions

- $x + y$
- $x - y$
- $\text{Math.Sqrt}(x)$
- $\text{Math.Exp}(x)$
- $\text{Math.Log}(x)$
- $\text{Math.Log10}(x)$
- $\text{Math.Log}(x, y)$
- $\text{Math.Pow}(x, y)$
- $\text{Math.Ellipk}(x)$
- $x * y$
- x / y
- $-\text{x}$
- $\text{Math.Sin}(x)$
- $\text{Math.Cos}(x)$
- $\text{Math.Tan}(x)$
- $\text{Math.Asin}(x)$
- $\text{Math.Acos}(x)$
- $\text{Math.Atan}(x)$
- $\text{Math.Ellipe}(x)$
- $\text{Math.Sinh}(x)$
- $\text{Math.Cosh}(x)$
- $\text{Math.Tanh}(x)$
- $\text{Math.Asinh}(x)$
- $\text{Math.Acosh}(x)$
- $\text{Math.Atanh}(x)$
- $\text{Math.Sign}(x)$
- $\text{Math.Real}(x)$
- $\text{Math.Imag}(x)$
- $\text{Math.Abs}(x)$
- $\text{Math.Angle}(x)$
- $\text{Math.Conj}(x)$
- $\text{Math.Atan2}(x, y)$

4.2 Linear algebra

`LinAlg.Dot(M1, M2)` Matrix multiplication of matrix M_1 and M_2

`LinAlg.Lu(M)` LU decomposition of matrix M

`LinAlg.Det(M)` Determinate of matrix M

`LinAlg.Inv(M)` Matrix inverse of M

`LinAlg.Solve(A, Y)` Solve linear equation system: $Ax = y$

`LinAlg.LstSqrSolve(A, Y)` Least square solve over determined equation system

`LinAlg.WeightedLstSqrSolve(A, Y, W)` Weighted least square solve over determined equation system

`UncLinAlg.NonLinearEig(A)` Non-linear eigenvalue problem²: $A_0V + A_1VD + A_2VD^2 + \dots + A_{(n-1)}VD^{(n-1)} = 0$

²`LinProp` uncertainty objects only



4.3 Numerical routines

`NumLib.PolyFit(x, y, n)` Fit polynom to data

`NumLib.PolyVal(p, x)` Evaluate polynom

`NumLib.Interpolation(x, y, n, xx)` Interpolation

`NumLib.Interpolation2(x, y, n, xx)` Interpolation with linear uncertainty propagation

`NumLib.SplineInterpolation(x, y, xx, boundaries)` Spline interpolation

`NumLib.SplineInterpolation2(x, y, xx, boundaries)` Spline interpolation with linear uncertainty propagation

`NumLib.Integrate(x, y, n)` Integrate

`NumLib.SplineIntegrate(x, y, n)` Spline integrate

`NumLib.Fft(v)` Fast Fourier transformation

`NumLib.Ifft(v)` Inverse Fast Fourier transformation

`UncNumLib.Dft(v)` Discrete Fourier transformation²

`UncNumLib.Idft(v)` Inverse discrete Fourier transformation²

5 Get properties of an uncertainty object

`Unc.GetValue(y)` Returns the expected value.

`Unc.GetFcnValue(y)` Returns the function value.

`Unc.GetStdUnc(y)` Computes the standard uncertainty.

`Unc.GetCoverageInterval(y, p)` Computes the coverage interval.

`Unc.GetMoment(y, n)` Computes the n-th central moment.

`Unc.GetCorrelation([y1 y2 ...])` Computes the correlation matrix.

`Unc.GetCovariance([y1 y2 ...])` Computes the covariance matrix.

`Unc.GetIDof(y)` Computes the inverse degrees of freedom.²

`1.0 / Unc.GetIDof(y)` Computes the degrees of freedom.²

`Unc.GetJacobi(y)` Returns the sensitivities to the virtual base inputs (with value 0 and uncertainty 1).²

`Unc.GetJacobi2(y, x)` Computes the sensitivities of y to the intermediate results x.²

`Unc.GetUncComponent(y, x)` Computes the uncertainty components of y with respect to x.²

²`LinProp` uncertainty objects only



6 Storage functions

6.1 Store a computed uncertainty object

`y.BinarySerialize(filepath)` Binary serializes uncertainty object `y` to file.

`Misc.Storage.BinarySerialize(y, filepath)` Binary serializes uncertainty object `y` to file.

`y.BinarySerializeToByteArray()` Binary serializes uncertainty object `y` to byte array.

`Misc.Storage.BinarySerializeToByteArray(y)` Binary serializes uncertainty object `y` to byte array.

`y.XmlSerialize(filepath)` XML serializes uncertainty object `y` to file.

`Misc.Storage.XmlSerialize(y, filepath)` XML serializes uncertainty object `y` to file.

`y.XmlSerializeToString()` XML serializes uncertainty object `y` to string.

`Misc.Storage.XmlSerializeToString(y)` XML serializes uncertainty object `y` to string.

6.2 Reload a stored uncertainty object

`y.BinaryDeserialize(filepath)` Reloads uncertainty object from binary file.

`Misc.Storage.BinaryDeserialize<T>(filepath)` Reloads uncertainty object from binary file.

`y.BinaryDeserializeFromByteArray(d)` Reloads uncertainty object from byte array.

`Misc.Storage.BinaryDeserializeFromByteArray<T>(d)` Reloads uncertainty object from byte array.

`y.XmlDeserialize(filepath)` Reloads uncertainty object from XML file.

`Misc.Storage.XmlDeserialize<T>(filepath)` Reloads uncertainty object from XML file.

`y.XmlDeSerializeFromString(s)` Reloads uncertainty object from XML string.

`Misc.Storage.XmlDeSerializeFromString<T>(s)` Reloads uncertainty object from XML string.



A Physical constants

`Const<UncNumber>` is equal to the newest physical constants `Const2018<UncNumber>`, see subsection A.3.

A.1 CODATA 2014

The following list contains the exact physical constants:

`Const2014<UncNumber>.deltavCs` Hyperfine transition frequency of Cs-133 in Hz

`Const2014<UncNumber>.c0` Speed of light in vacuum in m/s

`Const2014<UncNumber>.mu0` Vacuum magnetic permeability in Vs/Am

`Const2014<UncNumber>.ep0` Vacuum electric permittivity in As/Vm

`Const2014<UncNumber>.Kcd` Luminous efficacy in lm/W

`Const2014<UncNumber>.Mu` Molar mass constant in kg/mol

The following list contains the physical constants with uncertainties:

`Const2014<UncNumber>.G` Newtonian constant of gravitation³ in m³/(kg*s²)

`Const2014<UncNumber>.alpha` Fine-structure constant³

`Const2014<UncNumber>.Ryd` Rydberg constant³ in 1/m

`Const2014<UncNumber>.mpsme` Proton-electron mass ratio³

`Const2014<UncNumber>.Na` Avogadro constant³ in 1/mol

`Const2014<UncNumber>.Kj` Josephson constant³ in Hz/V

`Const2014<UncNumber>.k` Boltzmann constant³ in J/K

`Const2014<UncNumber>.Rk` von Klitzing constant in Ohm

`Const2014<UncNumber>.e` Elementary charge in C

`Const2014<UncNumber>.h` Planck constant in Js

`Const2014<UncNumber>.me` Electron mass in kg

`Const2014<UncNumber>.mp` Proton mass in kg

`Const2014<UncNumber>.u` Atomic mass constant in kg

`Const2014<UncNumber>.F` Faraday constant in C/mol

`Const2014<UncNumber>.R` Molar gas constant in J/(mol*K)

`Const2014<UncNumber>.eV` Electron volt in J

³The correlation matrix of this physical constants is used in METAS UncLib to generate uncertainty objects which are correlated. The other physical constants are computed out of this set and the exact physical constants, e.g.: $Rk = \mu_0 * c_0 / (2 * \alpha)$ and $e = 2 / (Kj * Rk)$.



METAS UncLib C# - User Reference V2.6.0

A.2 CODATA 2014 for conventional electrical units 90

The following list contains the exact physical constants:

`Const2014_90<UncNumber>.deltavCs` Hyperfine transition frequency of Cs-133 in Hz

`Const2014_90<UncNumber>.c0` Speed of light in vacuum in m/s

`Const2014_90<UncNumber>.mu0` Vacuum magnetic permeability in Vs/Am

`Const2014_90<UncNumber>.ep0` Vacuum electric permittivity in As/Vm

`Const2014_90<UncNumber>.Kcd` Luminous efficacy in lm/W

`Const2014_90<UncNumber>.Mu` Molar mass constant in kg/mol

`Const2014_90<UncNumber>.Kj` Conventional value of Josephson constant in Hz/V

`Const2014_90<UncNumber>.Rk` Conventional value of von Klitzing constant in Ohm

`Const2014_90<UncNumber>.e` Elementary charge in C

`Const2014_90<UncNumber>.h` Planck constant in Js

The following list contains the physical constants with uncertainties:

`Const2014_90<UncNumber>.Na` Avogadro constant in 1/mol

`Const2014_90<UncNumber>.F` Faraday constant in C/mol

`Const2014_90<UncNumber>.k` Boltzmann constant in J/K



METAS UncLib C# - User Reference V2.6.0

A.3 CODATA 2018

The following list contains the exact physical constants:

`Const2018<UncNumber>.deltavCs` Hyperfine transition frequency of Cs-133 in Hz

`Const2018<UncNumber>.c0` Speed of light in vacuum in m/s

`Const2018<UncNumber>.h` Planck constant in Js

`Const2018<UncNumber>.e` Elementary charge in C

`Const2018<UncNumber>.k` Boltzmann constant in J/K

`Const2018<UncNumber>.Na` Avogadro constant in 1/mol

`Const2018<UncNumber>.Kcd` Luminous efficacy in lm/W

`Const2018<UncNumber>.Kj` Josephson constant in Hz/V

`Const2018<UncNumber>.Rk` von Klitzing constant in Ohm

`Const2018<UncNumber>.F` Faraday constant in C/mol

`Const2018<UncNumber>.R` Molar gas constant in J/(mol*K)

`Const2018<UncNumber>.eV` Electron volt in J

The following list contains the physical constants with uncertainties:

`Const2018<UncNumber>.G` Newtonian constant of gravitation⁴ in m³/(kg*s²)

`Const2018<UncNumber>.alpha` Fine-structure constant⁴

`Const2018<UncNumber>.mu0` Vacuum magnetic permeability in Vs/Am

`Const2018<UncNumber>.ep0` Vacuum electric permittivity in As/Vm

`Const2018<UncNumber>.Ryd` Rydberg constant⁴ in 1/m

`Const2018<UncNumber>.me` Electron mass in kg

`Const2018<UncNumber>.are` Electron relative atomic mass⁴

`Const2018<UncNumber>.arp` Proton relative atomic mass⁴

`Const2018<UncNumber>.mpsme` Proton-electron mass ratio

`Const2018<UncNumber>.mp` Proton mass in kg

`Const2018<UncNumber>.u` Atomic mass constant in kg

`Const2018<UncNumber>.Mu` Molar mass constant in kg/mol

⁴The correlation matrix of this physical constants is used in METAS UncLib to generate uncertainty objects which are correlated. The other physical constants are computed out of this set and the exact physical constants, e.g.: $\mu_0 = 2 * h / (e * e * c_0) * \alpha$ and $\epsilon_{p0} = 1.0 / (c_0 * c_0 * \mu_0)$.