Study of Compton Scattering

Introduction

Compton scattering is an example of inelastic scattering of light by a charged particle, where the wavelength of the scattered light is different from that of the incident radiation. In 1920, Arthur Holly Compton observed scattering of x-rays from electrons in a carbon target. He found that the scattered x-rays have a longer wavelength than the incident x-rays. The shift of the wavelength increased with scattering angle according to the Compton formula:

$$\lambda_\theta - \lambda_0 = \Delta\lambda = \frac{h}{m_e c}(1 - cos\theta) \qquad (1)$$

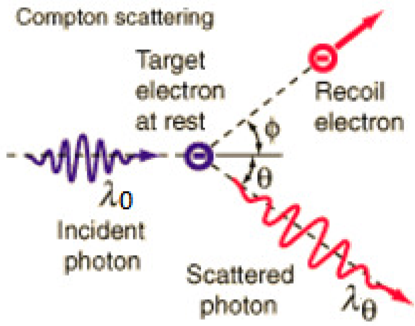

Fig.1: Compton scattering

where λ_θ and λ_0 are wavelengths of incident and scattered photon respectively, h is the planck's constant, m_e is the rest mass of electron, c is the velocity of light, θ and ϕ are angles of scattered photon and recoil electron respectively (Fig. 1). The value of ($h/m_ec = 0.02426\ A^0$) is called Compton wavelength of electron. In terms of energy Eq. 1 can be rewritten as

$$E_\theta = E_0 \frac{1}{1+(\gamma.(1-\cos\theta))} \qquad (2)$$

where E_θ and E_0 are energy of incident and scattered photon respectively and $\gamma = \frac{E_0}{m_e c^2}$. For high energy photons with ($\lambda \ll 0.02\ A°$ or $E \gg 511keV$), the wavelength of the scattered radiation is always of the order of the Compton wavelength whereas for low energy photons ($E \ll 511keV$), the Compton shift is very small. In other words, in non-relativistic energy regime, Compton scattering results approaches the results predicted by classical Thompson scattering.

Compton's experiment had a lot of significance that time since it gave a clear and independent evidence of particle-like behaviour of light. Compton was awarded the Nobel Prize in 1927 for the "discovery of the effect named after him".

The differential Compton scattering cross section was correctly formulated by Klein-Nishina in 1928 using quantum mechanical calculations. This formula is famously known as Klein-Nishina formula which is expressed as follows:

$$\frac{d\sigma}{d\Omega} = r_0^2\left(\frac{1+cos^2\theta}{2}\right)\left(\frac{1}{(1+\gamma(1-cos\theta)^2}\right)\left[\frac{\gamma^2(1-cos\theta)^2}{(1+cos^2\theta)(1+\gamma(1-cos\theta))} + 1\right] \qquad (3)$$

Here, $r_0 = (e_0/4\pi\varepsilon_0 mc^2)$ is the is the classical electron radius and has the value $r_0 = 2.818 \times 10^{-15}$ m. This result is for the cross section averaged over all incoming photon polarizations. By integrating Eq. (7) over all angles, the total cross section can be obtained.

In our experiment gamma rays from a Cesium-137 source are used as the source of photons that are scattered. Difference in the incident and scattered energy and wavelength of the photons is determined by a calibrated scintillation detector placed at different scattering angles. The relative intensities I_θ of the scatter radiation peaks can be compared with the predictions of the Klein-Nishina formula for the differential effective cross section ($\frac{d\sigma}{d\Omega}$) by calculating the calibration factor C using the formula below:

$$C = \frac{1}{n} . \sum_{\theta=0}^{n} \frac{I_\theta}{\left(\frac{d\sigma}{d\Omega}\right)} \quad (4)$$

Objective:

(I) **Energy calibration of scintillation detector**

(II) **Determination of change in wavelength of the scattered gamma radiation as a function of the scattering angle**

(III) **Determination of the differential cross-section using Klein-Nishina formula and calculation of calibration factor.**

Apparatus:

1. Cs-137 radioactive gamma source
2. Mixed preparation radioactive source for calibration (Am-241 and Cs-137)
3. Source holder in form of a lead block with a hole of 12 mm diameter at the centre to accommodate radioactive sources. Additional blind hole for inserting a steel pin as angular direction indicator
4. NaI scintillation detector and its holder with lead shielding for defined direction of incoming gamma radiation
5. High voltage power supply (1.5kV)
6. Cylindrical pure aluminium/copper rod as centre of scattering.
7. Additional lead shielding (movable) to reduce the intensity of unscattered gamma radiation, particularly for small scattering angles and short distances between source, scatterer and detector.
8. Multichannel analyzer (256 channels) and Related software in a desktop PC
9. Experimental panel with graduated angular scale

Experimental Setup:

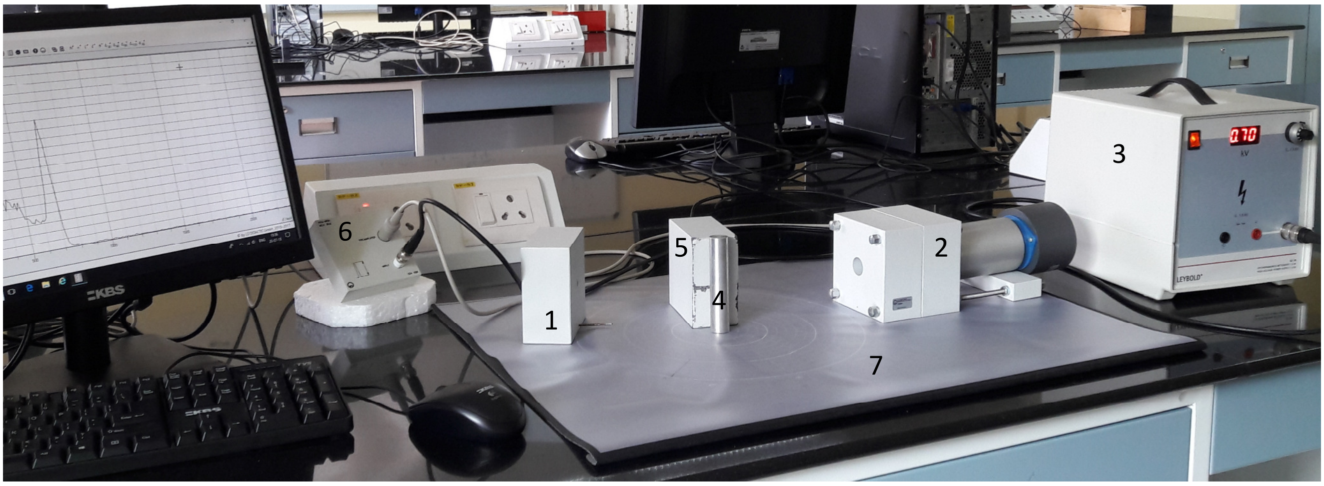

Fig 2. Experimental set up for Compton scattering experiment consisting of Source holder, Scintillator detector with lead shielding, High voltage supply, Scatterer, Additional movable shielding, MCA and a Experimental panel with angular scale (shown respectively as nos. 1-7)

The complete experimental set up is shown in Fig.2 and can be visualized in the following sequence. A radioactive Cs-137 source produces 662 KeV γ-rays which can escape the shielded cavity only through a small hole. The beam is collimated and reaches an aluminium rod (the target or scatterer). Some portion of the γ-rays are scattered by the electrons in the target which are detected and counted by the scintillator detector. The detected signal is further processed by an MCA and the complete spectrum is displayed on the computer. By placing the source at different angles on the experimental angular panel, the scattered radiations are collected to study the angular dependence of Compton scattering.

Procedure:

Spend some time to understand each part of the set up. Assemble all the accessories to set up the experiment as shown in Fig. 2. Familiarize yourself with the software required to acquire and analyze the spectra (refer to the software manual provided separately). **Set the operating voltage for the detector at an optimized value of ~ 0.7kV.**

(I) Calibration

Using the mixed source (refer Annexure I for details of the source), record the calibration spectra at $\theta = 0$ without the scatterer. Calibrate the channels of MCA with peak energy of the acquired spectrum and save it in the computer.

(II) Energy of scattered γ-rays as a function of θ

Using the Cs-137 source (refer Annexure II for details of the source), record a spectrum for every desired scattering angle θ. Use additional shielding as necessary. A typical spectrum after calibration is shown in Fig.3. For a reliable determination of the peak energy of the scattered radiation E_θ, a measurement with and without scatterer should be made for every θ. Evaluation of the difference of the two spectra is obtained using the software. Now analyze the spectra to determine the peak scattered energy and I_θ.

Notes:

1) The measuring time per scattering angle must be selected according to the desired accuracy and the distances between source, scatterer and detector.

2) Greater distances between source, scatterer and detector increase the angular resolution, but require longer measuring times due to the lower counting rates.

3) At small scattering angles, particularly for short distances, additional lead shielding is required to suppress the background caused by unscattered radiation.

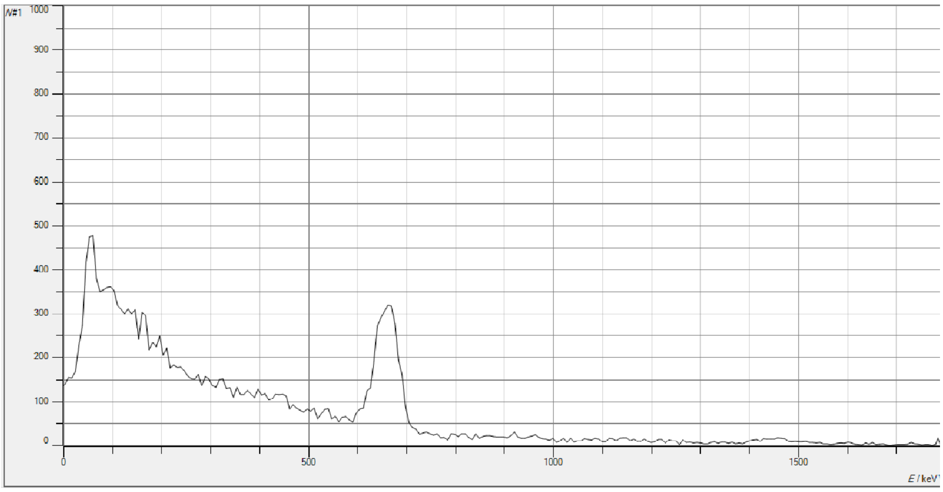

Fig. 3: A typical gamma ray spectrum obtained for Cs-137 after calibration

(III) Differential cross section and calibration factor:

Calculate the differential scattering cross-section using Eq. 3 and plot it as a function of θ. Determine the calibration factor C using Eq.4.

Graphs/Results/Discussion:

References:

1. Manual from supplier (LD-didactic)
2. https://www.physics.wisc.edu/undergrads/courses/spring2017/407/experiments/compton/compton.pdf
3. R.P. Singhal and A.J. Burns, American Journal of Physics **46**, 646 (1978)

PHYSICS CHEMISTRY BIOLOGY ENGINEERING

LD DIDACTIC

11/17-W03-Wz

Instruction sheet 559 835

Radioactive preparations, Set of 3 (559 835)

Regulations

When the „Radioactive preparations s, Set of 3“ is used, country specific regulations such as the Radiation Protection Regulation („Strahlungschutzverordnung“, StrlSchV) in Germany have to be observed.

The preparations have been submitted to a prototype test and are approved for teaching purposes at schools in Germany without special permit in accordance with StrlSchV from 26 July 2001.

The preparations are subject to the conditions quoted in the type approval, which is delivered together with the preparations. This approval has to be kept by the owner of the approved device.

Radioactive preparations have to be protected against loss and against access by unauthorized persons. This can be achieved by keeping the preparations s in a lockable cabinet used solely for this purpose.

Please observe maximum radiation regulations for storage of more than one preparation, especially in combination with other preparations.

The radioactive preparations have to be stored in the protective container used for delivery to make sure the emitted radiation stays below 1 microsievert per hour in 10 cm distance from the surface.

In Germany, no leakage test is necessary within the first ten years, then in 5 years intervall.

A visual inspection is required once a year, in case the preparations is damaged, a leak test is required.

The sources must not be disposed in normal waste.

Administrative requirements

The “Radioactive preparations, Set of 3” is a type certified device with the type reference BfS 01/10. The type approval was conferred in accordance with the StrlSchV from 26 July 2001.

- Keep the copies of the type approval and the quality certificate as documents.
- In other countries, observe applicable regulations.

Handling of the preparations requires at least supervision by someone with the necessary technical qualification.

Safety notes

The "Radioactive preparations, Set of 3 α, β, γ" is approved for teaching purposes at schools according to the StrlSchV. As the preparation emits ionizing radiation, radiation safety procedures have to be obeyed, especially the following safety rules:

- Prevent access to the preparation by unauthorized persons.
- Before using the preparation, make sure that it is intact.
- To ensure *minimum exposure time*, take the preparation out of the protective container only as long as is necessary for carrying out the experiment.
- To ensure *maximum distance*, hold the preparation only at the upper end of the aluminium rod.
- Never place any preparations active end within a few cm to the human body including the eye.
- With the object of *shielding*, keep the preparations in their protective container.
- To ensure *minimum activity*, lay only the preparation needed for the experiment on the table.
- Never let the preparations touch Acetone, strong acids or strong bases.
- Never heat or cool the preparations to a temperature outside room temperature conditions.

1 Description

The "Radioactive preparations, Set of 3" is used for an energy analysis with the semiconductor detector (α radiation) and the scintillation counter (γ and β radiation). It consists of three cylindrical aluminium rods with the radioactive substances Am-241, Sr-90 and Cs-137 being inserted each in one pocket hole at the front surface. At the back end of the aluminium rod, there is a name plate with the name of the nuclide.

The preparations are classified as preparations with type approval. In Germany, it is approved as equipment for teaching purposes with the type reference BfS 01/10.

2 Technical data

Weight:	3* 120 g
Dimensions:	each 100 mm × 31 mm dia.
Preparations :	each 85 mm × 12 mm dia.

Am-241:

Activity:	74 kBq

Sr-90:

Activity:	45 kBq

Cs-137:

Activity:	74 kBq

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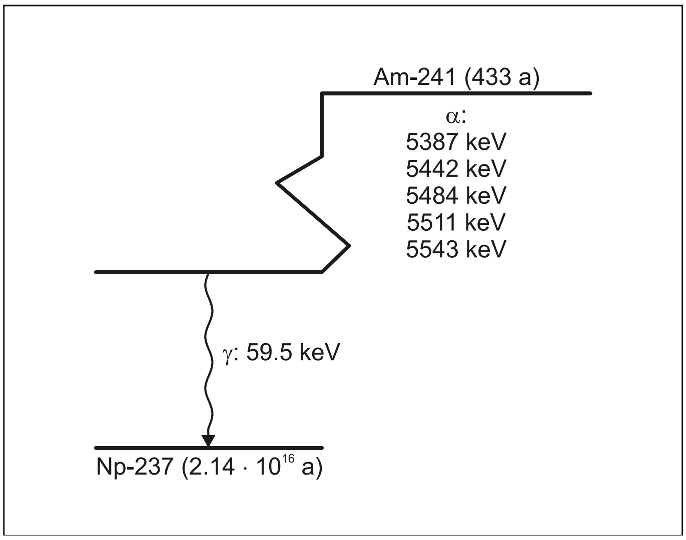
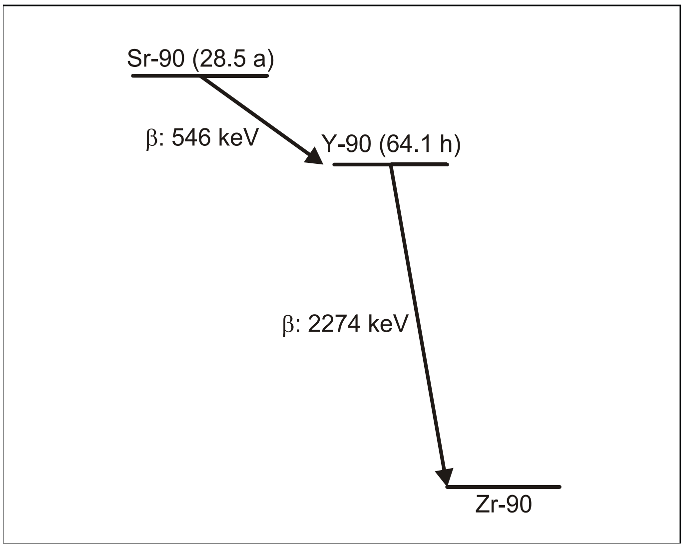
3 Simplified energy level diagrams

3.1 Am-241



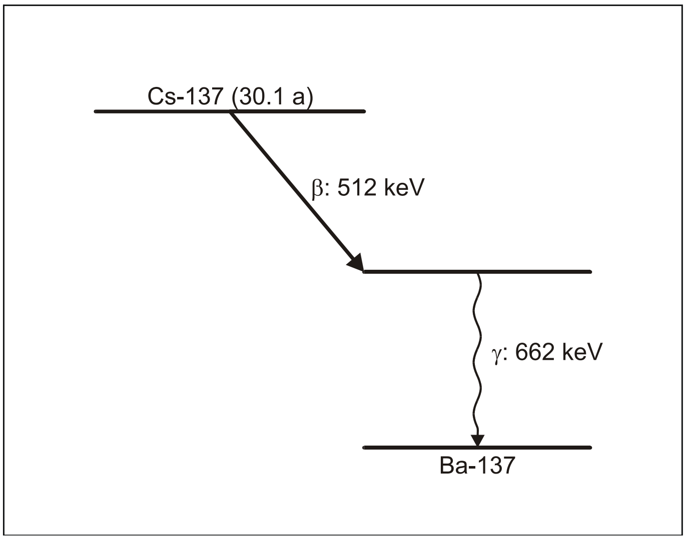
The cover reduces the energy of the emitted α radiation to 4.5 MeV.

3.2 Sr-90



The low-energy β particles emitted by Sr-90 are absorbed completely in the cover. Therefore only the high-energy β particles emitted by the daughter nuclide Y-90 escape from the preparations .

3.3 Cs-137



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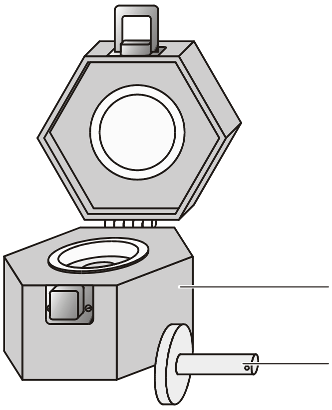


Instruction sheet 559 809

Cs-137 preparation, 3.7 MBq (559 809)

1 Safety container
2 Radioactive preparation

Regulations

When the Cs-137 preparation is handled, country specific regulations concerning protection from damage caused by ionizing radiation must be observed, for example, the Radiation Protection Regulation (Strahlenschutzverordnung or StrSchV from October 13, 1976) in Germany.

This preparation is type-approved and may be used without authorisation for teaching purposes at schools in accordance with the StrSchV. In general, however, use of the preparation has to be notified to the appropriate authority.

The preparation is subject to the rules quoted in the enclosed type approval. This approval has to be kept by the owner of the approved appliance.

Radioactive preparations have to be protected against being lost and against access by unauthorised persons. This can be achieved by storing the preparations in a lockable cabinet which is only used for this purpose.

In general, only teachers who are appointed radiation protection officers are authorised to handle radioactive preparations according to § 31 Abs. 4 StrlSchV. According to § 56 Abs. 3 StrlSchV, students are only allowed to take part in the experiments if a teacher who is appointed radiation protection officer is present and supervises them.

Administrative measures

The Cs-137 preparation 3.7 MBq is a type approved appliance with the type mark Nds. 151/96.

- Keep the copy of the type approval and the certificate of quality as they are important documents.
- In the Federal Republic of Germany, purchase of the preparations has to be notified to the appropriate authority and after a period of at most 10 years their tightness has to be checked by an expert body.
- In other countries, the corresponding regulations have to be observed.

Important: according to § 77 Abs. 2 StrlSchV, LEYBOLD DIDACTIC has notified delivery of purchased radioactive preparations to the authority appropriate for the purchaser. However, this does not release the purchaser from his duty of notifying the purchase.

Safety notes

The Cs-137 preparation 3.7 MBq is type approved for teaching purposes at school in accordance with StrlSchV. Since the preparation produces ionizing radiation, the following safety rules must nevertheless be kept to:

- Prevent access to the preparation by unauthorized persons.
- Before using the preparation make sure that it is intact.
- To ensure *minimum exposure time,* take the preparation out of the safety container only as long as is necessary for carrying out the experiment.
- To ensure *maximum distance,* hold the preparation only at the upper end of the metal holder and keep it away from your body as far as possible.
- For the purpose of *shielding*, keep the preparation in its safety container.
- To ensure *minimum activity*, only put that preparation on the experiment table that is needed for the current experiment.

1 Description

The Cs-137 preparation 3.7 MBq is a relatively strong radiator with a source that is almost pointlike. The diameter of the active ball is approx. 1 mm.

Because of the pointlike source, an energy of the order of magnitude of an electron's rest mass and a relatively high radiant flux, this preparation is particularly suited for experiments on Compton scattering, in particular, in conjunction with the apparatus set Compton (559 800).

The preparation is classified as a preparation with type approval. In the Federal Republic of Germany, it is approved as an appliance for teaching purposes with the type mark Nds. 151/96.

2 Scope of supply

1 preparation Cs-137 3.7 MBq

1 safety container

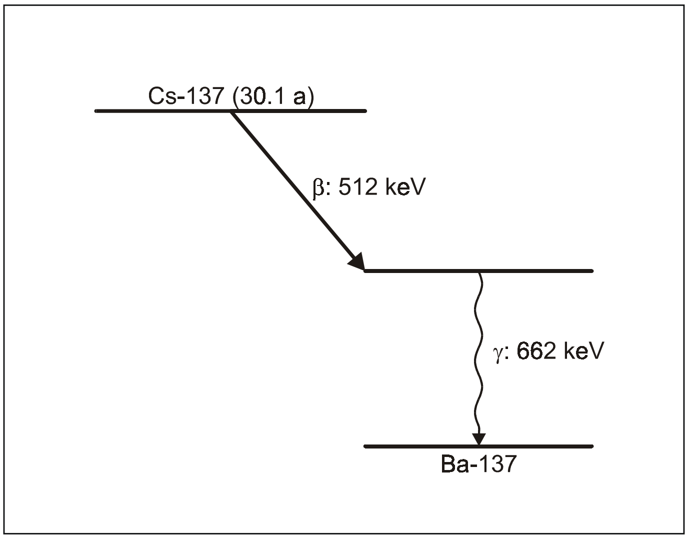
3 Technical data

Weight:	1000 g
Dimensions:	100 mm × 100 mm × 80 mm (safety container included)
Activity:	3.7 MBq

4 Remark

Due to the high radiant flux, the maximum counting rate that is meaningful for the detector is prone to be exceeded.

5 Energy-level diagram



Simplified energy-level diagram of Cs-137

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Introduction

This manual is intended to provide an overview of the many exciting possibilities of the CASSY Lab software. The text is identical to the help texts that can be accessed using the mouse for all program functions.

The help texts in the program provide the following additional support:

- You can jump directly to cross-referenced information using the mouse.
- You can load experiment examples and settings by clicking on them.
- The help system permits both indexed and full-text search modes.

Installation

CASSY Lab 2 can be installed either

- automatically after inserting the CD-ROM or
- manually by executing the file **setup.exe**

and following the instructions that appear on the screen.

Important information after installing CASSY Lab 2

Using the software with CASSY-S (Sensor-CASSY, Sensor-CASSY 2, Power-CASSY, Profi-CASSY, CASSY-Display, Pocket-CASSY, Pocket-CASSY 2 Bluetooth, Battery for Pocket-CASSY 2 Bluetooth, Mobile-CASSY and Micro-CASSY)

The first time you start CASSY Lab, you should enter your activation code, which you can find in your bill of delivery and your invoice under the number 524 220. The software then supports CASSY without restrictions (CASSY support without the activation code is limited to 16 sessions).

Using the software with other measuring instruments

CASSY Lab supports other measuring instruments, the Joule and wattmeter and the Universal measuring instrument physics/chemistry/biology without requiring an activation code.

Manual

CASSY Lab is supplied with a comprehensive manual. In order to exploit the full potential of CASSY Lab 2, you need to read and understand this manual completely. You can do this in several ways:

- Open the manual from CD-ROM
- Order the printed manual (524 221en).
- Download the manual from the Internet (in Adobe PDF format).
- Use the software help function (text identical to the printed manual, context-sensitive and with numerous jump links and enhanced search capabilities).

Getting started

- Displays the introduction
- Displays experiment examples

You can also read the supplied experiment examples and use these for further evaluations without CASSY. You can use the program settings from the examples to run new measurements, and match these to your experiment conditions.

Support

If there should be any questions left despite the comprehensive help with its numerous experiment examples, please mail to cassy@ld-didactic.de.

Updates

We have an ongoing commitment to expanding and enhancing CASSY Lab 2 – particularly in response to the comments and experiences of our users.

- Download update from the Internet

New features in CASSY Lab 2

This section is intended for users who are familiar with CASSY Lab 1 and want to know quickly what has been changed with CASSY Lab 2:

- There is a central settings window where a quick overview of all of the settings can be found. In the case of major problems (e.g. wrong CASSY, wrong sensor box, syntax fault in a formula), a yellow (!) indicates what to do.
- Several tables and diagrams can be displayed on the screen at the same time. To do this, one of the tabs is simply dragged with the mouse and the display is dropped as desired. With a floating window, double-clicking the window title line sorts it back in.
- New features of Sensor-CASSY 2 are supported (4 channel measuring, 1 MHz sampling rate, pre-triggering, measuring of mains voltage. By means of the pre-triggering of Sensor-CASSY 2 and Pocket-CASSY, recording of measured values is possible in the time before the triggering event.
- Drag & Drop is realized consistently within and between the setting window, the upper button bar, the display instruments, the tables and the diagrams. This allows, for example, numeric values to be copied, evaluation texts to be shifted, sequences to be changed, and curves to be moved from one diagram to another.
- Evaluations are alive. The evaluation is already displayed while the evaluation range is being marked. The evaluation range can subsequently be modified by double-clicking the evaluation. By re-starting a (repeating) measurement, the old evaluations are not deleted but the new measurement is newly calculated and displayed.
- Additional evaluations (e.g. tangent, triangular interpolation, CAN/LIN decoder) add to the available options. Gaussian fits are now found under fits, the x-ray energies under markers and the peak center below the mean value.
- Freely selectable curve colors as well as transparent areas (e.g. for integrals and histograms) increase clarity.
- Symbols for measured and evaluated quantities are shown in display instruments, tables and diagrams, and evaluated results are displayed using italic fonts.
- Slower measurements can at the same time make use of different CASSY modules (e.g. Sensor-CASSY and Pocket-CASSY). Faster measurements continue to require a single CASSY or a cascade of CASSY modules (e.g. two Sensor-CASSYs plugged together) in order to ensure that the measurements are taken simultaneously.
- Inputs and outputs can, in most cases, be activated individually. E.g. the voltage source S can be activated without the relay R, or the obscuration time t_E can be activated without the obscuration time t_F.
- An automatic measuring range selection (Autorange) can be selected.
- It can be triggered onto the path s (±1 mm) of the Motion transducer box or that of the Timer S. This is helpful for measurements without a holding magnet.
- A stop condition is available which can automatically end measurements.
- Every text field in which a formula can be entered has its own help menu with information on allowed variables, functions and operators.
- The differential equations of model values can now be dependent on formulas which in turn depend on the model values. This allows a clearer notation of the differential equations.
- When a symbol is renamed, all dependent formulas are correspondingly changed automatically.
- The dependency of "old" in formulas is no longer necessary. Instead, the own symbol representing the formula can be used. If the "last old" was used in a convoluted way to access a specific element in a table (e.g. starting value U_0 = (n = 1) * UA1 + (n > 1) * last old), this is now possible in a much more elegant way by stating an index (e.g. starting value U_0 = UA1[1]).
- "last" and "next" is no longer required in formulas either. The same function offers universal access via an index (e.g. UA1[n-1] and UA1[n+1]).
- Multiple series of measurements are no longer separated from each other by means of an empty line in the same columns but side by side in new columns in the table. This simplifies the access or deleting of specific series of measurements in a diagram and the access of formulas to special series of measurements, e.g. UA1#1 accesses the voltage in the first series of measurements.
- Values of outputs, such as the voltage source S, are only calculated when they are output and are then saved in the table. If later on the formula for the output is changed, the same no longer applies retrospectively but only for later outputs. This logic has been changed in order to keep the measuring data record comprising input values and output values consistent.
- Several rapid and triggered digital measurements are possible by means of the Timer box or the Timer S and analogue inputs, e.g. the obscuration times at a light barrier and a force sensor.
- The recording of MCA spectra was made similar to other operations. The settings are entered in the central settings window (including the energy calibration). After the energy calibration, the energy can be dragged to the diagram in order to change the axes. Simultaneous measurements can be made via further CASSY inputs. The single channel operating mode of the MCA box is no longer available.

CASSY Lab 2 can load CASSY Lab 1 files. In most cases the old measurement can be either immediately repeated or evaluated.

There are only a few idiosyncrasies to be observed:

- The measured values for the obscuration times t_E and t_F at the Timer box are now evaluated in the formulas in the units in which they were measured, in milliseconds rather than seconds. The factor 1/1000 may have to be manually entered in the derived formulas. In this way these two measured values now behave like all the other measured values, with the exception of the measuring time t, which is evaluated in seconds as before wherever it occurs in formulas.
- Temporal derivations are now always calculated as time-weighted symmetrical derivations. This means that the derivations of measured values not recorded at equidistant times now fit with the measured value. Auxiliary formulas which were necessary for CASSY Lab 1 for compensating for this fault now become counter-productive.
- Most measured values can be recorded both for small and for larger measuring intervals. However, there are measured values which result in sensible values only for small time intervals (obscuration time t_E, obscuration n_E of the Timer box or of Timer S and path s of the Ultrasonic motion sensor S) or only for larger time intervals (e.g. events N_E, frequency f_E, temperature, CO_2 concentration, rel. air humidity). Measured values in those two categories now no longer can be measured together. Instead of the rapid obscuration counter n_E, the slower event counter N can be used and vice versa.
- The overview diagram of the MCA spectra and the option for adding and subtracting spectra are no longer available. Instead, the new options for the simultaneous display of several diagrams and formulas are available, which can access any series of measurements (e.g. NA#1-NA#2).
- There are very old serial measuring devices which are no longer supported by CASSY Lab 2.

On account of the numerous new features of CASSY Lab 2, export into the old CASSY Lab 1 data format is no longer possible.

User programs for CASSY

You can also program CASSY-S yourself. To assist you in this, we have placed the .NET assembly LD.Api.dll as well as a description of the protocol of the interface on the Web for free downloading.

Download SDK from the Internet

LabVIEW

Our LabVIEW driver for CASSY is also free available on the Internet. In addition to the VIs (Virtual Instruments) for driving CASSY, the driver also contains application examples.

Download LabVIEW driver from the Internet

LabVIEW is a registered trademark of National Instruments.

MATLAB

Our MATLAB driver for CASSY is also free available on the Internet. The driver also contains numerous application examples.

Download MATLAB driver from the Internet

MATLAB is a registered trademark of MathWorks.

CASSY Lab 2

Introduction

- Measurement
- Evaluation
- Experiment examples
- New features in CASSY Lab 2
- User programs for CASSY

CASSY Lab 2 supports one or more CASSY-S modules (Sensor-CASSY, Sensor-CASSY 2, Power-CASSY, Profi-CASSY, CASSY-Display, Pocket-CASSY, Pocket-CASSY 2 Bluetooth, Battery for Pocket-CASSY 2 Bluetooth, Mobile-CASSY and Micro-CASSY) at the USB port or at the serial interface of the computer. The software also supports a variety of other serial measuring instruments, the Joule and wattmeter and the Universal measuring instrument physics/chemistry/biology.

For CASSYs with a serial interface, the serial interface is selected in the Settings CASSYs.

Activation code

When using CASSY Lab 2 together with CASSY, you need to enter a 24-digit activation code. You can find this activation code in your bill of delivery and your invoice under the number 524 220; you must enter this number once, together with the name that appears on the invoice. This activates the software for CASSY. Please observe our copyright.

If you only intend to use CASSY Lab 2 with other devices, with the Joule and wattmeter or with the Universal measuring instrument physics/chemistry/biology, **no** activation code is necessary.

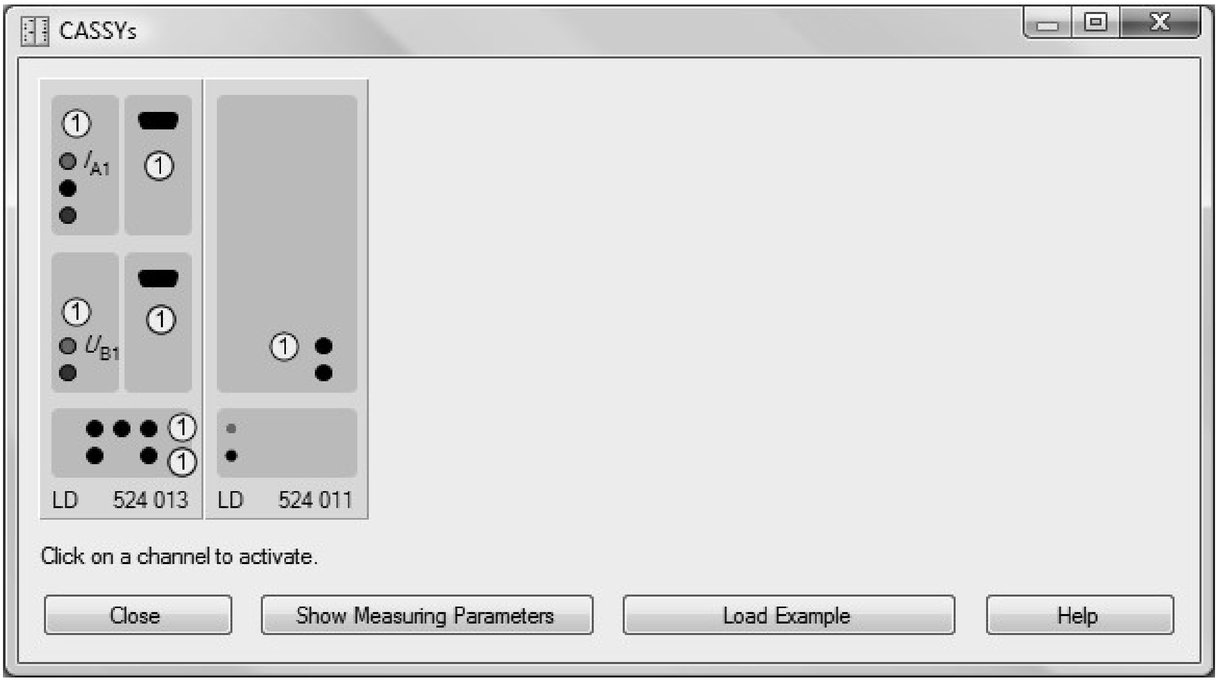
If you did not receive an activation code, please fax your invoice for CASSY Lab 2 (524 220) to +49-2233-604607. We will fax you the activation code as soon as possible. CASSY Lab can also be used with CASSY without the activation code for a limited time (up to 16 sessions).

Future versions, such as updates available for downloading on the Internet, will also use this activation code. This means that there are no restrictions on the use of updates.

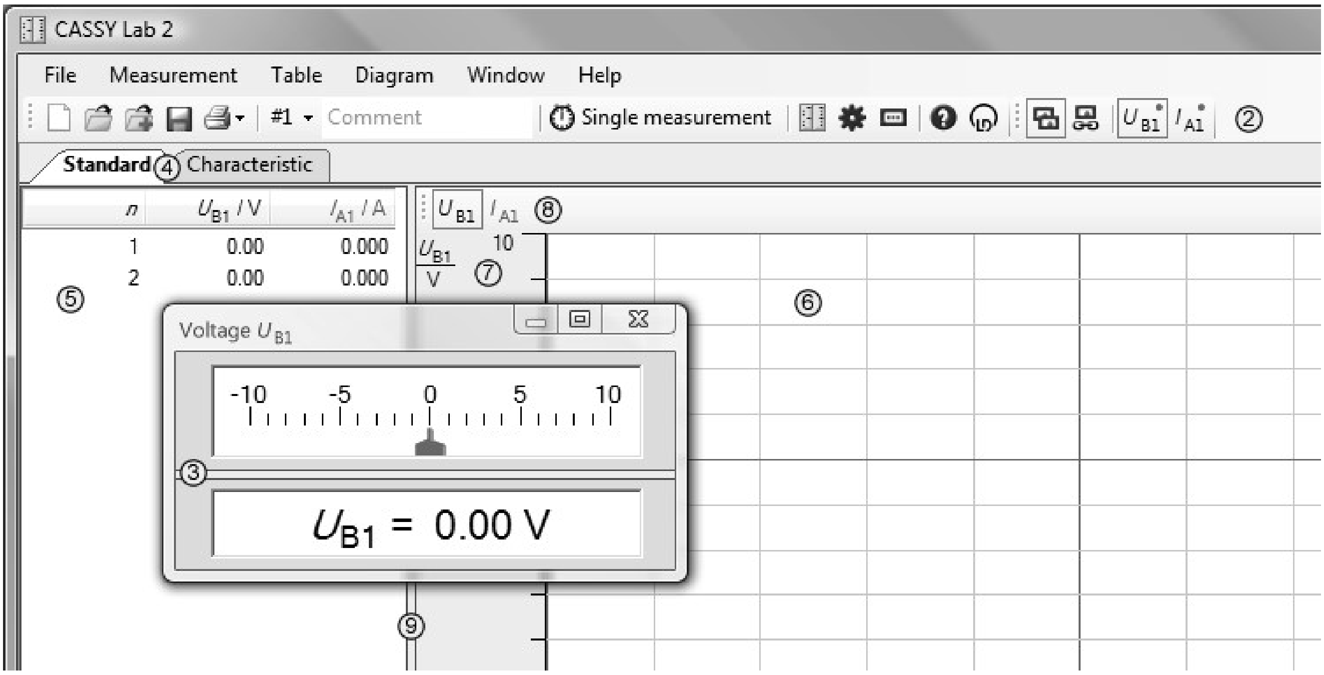
- Download update from the Internet

First measurements

If one or more CASSYs have been recognized, all CASSY modules are displayed with their current configuration (if applicable with the plugged in sensor boxes). To conduct a measurement, just click on the corresponding input or output ①.



An active input or output (channel) is then marked in color and placed among the channel buttons ② at the top right of the main window (here I_{A1} and U_{B1}). These buttons are the fastest way to display or close a display instrument ③ for that channel (left mouse button) or to change a setting (right mouse button). In addition, the channel initially appears automatically in the table ⑤ and in the diagram ⑥.



You can access the basic functions quickly using the menu or the buttons ② in the top bar:

File Measurement Table Diagram Window Help

In the button line a brief **comment** on the measuring series can also be entered.

Below this bar, you can toggle between the displays of the table ④ and the diagram ⑤ by clicking on one of the display tabs ⑥ when different Displays have been defined (here **Standard** and **Characteristic**). The table and diagram can be enlarged or reduced with respect to each other by moving the boundary ⑨ with the mouse.

Displays can be sorted differently or displayed differently by dragging their tabs ④ (e.g. several diagrams simultaneously), and they can be turned into floating windows. With a floating window, double-clicking the window title line sorts it back in.

At many points, **both** mouse buttons (left and right) can be used to execute different functions:

Control element	Left mouse button	Right mouse button
① CASSY setup	Activate and modify a channel	Activate and modify a channel
② Channel button	Open and close a display instrument, drag and drop in ② and ⑤ through ⑧	Set up a channel
③ Display instrument	Move boundary between analog and digital display, drag and drop values in ⑤	Set up a channel
④ Name of display	Toggle to another defined display, change the layout	
⑤ Table	Edit measured values, drag and drop values within the table or the channels to ②	Set display attributes of table, e.g. font size, delete table rows
⑥ Diagram	Mark evaluation ranges	Settings and evaluations in diagram
⑦ Scale	Move scale	Set minimum, maximum and conversion of scale
⑧ Axis symbols	Toggle y-scale, drag and drop into ②	Set up a curve
⑨ Boundary	Move boundary between channel and diagram	

File menu

File → New (F4)

Deletes either the current measurement series maintaining the settings or, if the current measurement series is empty, all measured values, or, if no measured values are available, the current settings.

Applying this twice or three times completely deletes a measurement with its settings.

File → Open (F3)

Opens a measurement series with its settings and its evaluations.

The software is also equipped with a text import filter (file type ***.txt**).

File → Append

Appends a measurement series to an existing series (without loading its settings and evaluations as well). This is possible when the same measurement quantities are used for both series. Alternatively, a further measurement series can be measured and appended subsequently.

File → Save (F2)

Saves the current measurement series with its settings and its evaluations.

You can also save just the settings (without measurement data) to make it easier to repeat an experiment at a later date.

The software is additionally equipped with a text export filter (file type ***.txt**).

File → Page Setup

Establishes the paper format and margins for a printout.

File → Print Preview

Shows a preview of the printout of the current table or current diagram.

File → Print

Prints out the currently active table or diagram.

Text export and import

You can import and export text files quickly and easily by selecting the file type ***.txt** in the file selection dialog.

The data format begins with a header, in which all lines begin with a keyword. This specifies the measuring ranges, (MIN, MAX), the SCALE, the number of decimal places (DEC) and the actual definition of the measurement quantities (DEF). All lines except DEF are optional. The table of measured values follows the header.

You can view the exact syntax e.g. in the file that is created using the data export function.

Measurement menu

A measurement is configured by means of the measuring parameters and thereafter started and stopped by means of this menu.

Measurement → Start/Stop Measurement (F9)

Starts and stops a new measurement.

Alternatively, you can stop measurements by setting a measuring time.

You can use the right mouse button to open the table display menu in the table and the evaluation menu in the diagram.

Measurement → Continue Measurement

Continues a measurement. A measurement can be continued if the selected time interval is 100 ms or greater and there is measuring time remaining.

Measurement → Append new Measurement Series

The Append function enables sequential recording of multiple measurement series. In the case of the automatic recording of measured values, this switch has to be set only once in order to append all subsequent measurements. In the case of the manual recording of the measured values, the switch has to be reset every time that a new measurement series is started.

If more than one measurement series is being recorded, the serial index for the series is appended to the symbols in order to distinguish them by series, e.g. U_{A1}#1 and U_{A1}#2. This allows the measurement series to be distinguished from one another for the assignment of column headings in tables and the axis assignment of a diagram.

Alternatively, the individual measurement series can first be recorded one after another and saved individually. When loading multiple comparable measurement series (with identical quantities), measured series can also be appended "retroactively".

This selection is identical to Measuring Parameters → Append new measurement series.

Measurement → Select Measurement Series

Selects the current measurement series. The current measurement series is

- the measurement series into which values are entered if no new measurement series is appended
- the measurement series which is deleted when the current measurement series is deleted
- the measurement series whose values are dragged by Drag & Drop from the channel buttons into the table and the diagram.

Measurement → Delete Current Measurement Series

Deletes the currently selected measurement series. Here all the values are deleted which were recorded during this measurement series even if they are not currently being displayed.

Table menu

You can change the table display also by clicking on the right mouse button when the pointer is over the table.

Editing measured values

Individual measured values can be edited after being clicked on using the left mouse button or they can be dragged to different measured value cells (Drag & Drop).

Selecting rows

When the Shift key or the Alt key are pressed at the same time, one or more rows of the table can be selected. Once rows have been selected, the selection is taken into account for Table → Copy Table, and with File → Print → Print Table the selected rows can be used as the print area.

The selected rows can be deselected by double-clicking on a table cell.

Status line

A single selected table row is displayed in the status line at the bottom of the screen. You can toggle display of this information in a larger window on and off by pressing or **F6**.

Table → Change Column Header

Activates the Settings Display. Here the table column headers can be edited.

Alternatively, you can move columns back and forth between channel buttons and the table using drag and drop.

Table → Select Font Size

The table's font size is selectable. Small, medium and large fonts can be selected.

Table → Delete last Row in Table (Alt+L)

Deletes the last row in the current measuring series in the table.

Table → Copy Table

Copies the table in text format into the Windows clipboard. Once there, it are available for further processing in other Windows programs.

Table → Copy Window

Copies the main window as a bitmap into the Windows clipboard. Once there, it is available for further processing in other Windows programs.

Diagram menu

You can access a wide variety of powerful graphical evaluation functions in the diagram also by clicking the right mouse button.

- Change Axis Assignment
- Display Coordinates
- Select Line Width
- Select Value Display
- Select Rulers
- Show Grid
- Zoom
- Zoom Off
- Set Marker
- Text
- Vertical Line
- Horizontal Line
- Measure Difference
- X-Ray Energies
- Draw Mean
- Calculate Peak Center
- Fit Function
- Calculate Integral
- Calculate Poisson Distribution
- Calculate Gaussian Distribution
- Calculate Minimum and Maximum
- Calculate Form Factor
- Calculate Ripple
- Find Equivalence Point
- Carry out Triangular Interpolation
- Find Systole and Diastole
- Decode CAN/LIN Message
- Delete Last Evaluation
- Delete All Evaluations
- Delete Range (only Measured Values)
- Copy Diagram
- Copy Table

Selecting a measured value

By clicking on a measured value, it becomes selected in the diagram and at the same time its y-value is selected in the table. This selection can by changed by selecting a different y-value in the table or deleted by selecting an x-value in the table.

Marking a curve section

In some cases, you may wish to mark a particular curve section for which the evaluation function is to perform a calculation.

To mark a curve section, hold down the left mouse button and drag the pointer to the end of the curve section. Alternatively, you can also click on the starting and end points.

When a part of a curve is selected, the selected range is displayed in cyan and the evaluation is calculated.

Editing an evaluation

An evaluation can be edited by double-clicking the evaluation. When the range is edited, the evaluation is re-calculated.

If the range is shifted out of the diagram, the evaluation is deleted.

The evaluations are automatically re-calculated whenever the measurement is re-started without first selecting Append new Measurement Series or whenever the measured values are changed (e.g. when recording a spectrum).

Status line

Evaluation results always appear in the status line at the bottom of the window. You can toggle display of this information in a larger window on and off by pressing or **F6**.

Drag & drop functionality

Using the mouse, you can drag the evaluation results from the status line and drop them in the table or the diagram. In this way diagrams can be created which depend on the results of the evaluation or you can rapidly enter the evaluation results in a diagram.

If several evaluation results are displayed in the status line, the status line is copied from the evaluation result on which the mouse was positioned when it was dragged.

Diagram → Change Axis Assignment

Activates the Settings Display. This lets you change the assignment of the diagram. Mathematical conversion of axes is also possible.

Alternatively, you can move the axis assignments back and forth between the channel buttons and the diagram using drag and drop.

Diagramm → Display Coordinates (Alt+C)

When you activate this function, the status line shows the current coordinates of the mouse pointer, as long as it is over a diagram. The coordinate display remains active until you deactivate this menu point by selecting it again, or an evaluation shows a result in the status line.

You can also insert the current coordinates in the diagram. However, make sure that you access the evaluation function Text via the keyboard with Alt+T without changing the coordinates of the mouse pointer, as otherwise the wrong coordinates would be adopted.

Diagram → Select Line Width

You can modify the line width for display of the diagrams and the evaluations which you carry out in them. You can choose between thin, medium and thick lines.

Diagram → Select Value Display

CASSY Lab provides six functions for customizing the display of measured values.

Show Values	Display as squares, triangles, circles, pound characters, …
Show Connecting Lines	Connecting lines between measurement points
Akima Interpolation	Values between the measuring points interpolated according to Akima's method
sinc Interpolation	Values between the measuring points interpolated with sinc(x)=sin(πx)/πx
Show Bars	Values shown by bars
Show Axes	Zero lines of x and y axis

The Akima and sinc interpolations are neither calculated over gaps in the domain of definition nor during a measurement. During the measurement, the points are only connected by straight lines. Only after the measurement does the interpolation calculate the curve sections between the measuring points. The sinc interpolation is ideal for signals that do not contain any frequency components higher than half the sampling frequency. In this case it leads to 10-fold oversampling.

Diagram → Select Rulers

In the diagram the x-ruler and y-ruler can be displayed or hidden.

Diagram → Show Grid

Allows you to toggle a grid on and off in the diagram.

Diagram → Zoom (Alt+Z)

After activating this menu point, define the range which you wish to magnify. Use the left mouse button to do this.

A previously zoomed display can be zoomed further. To reset a zoom, select Zoom Off.

Diagram → Zoom Off (Alt+O)

Restores the currently selected section of the diagram to its original size.

Diagram → Set Marker

This software provides five different mark-up functions.

Diagram → Set Marker → Text (Alt+T)

This text function lets you label all parts of the diagram using any text you wish to enter. Once you have entered your text, just move it to the desired position and anchor it with the left mouse button.

After all evaluations which return a numerical value in the status line, these numerical values are suggested as a text insertion which you can accept, edit or reject.

Diagram → Set Marker → Vertical Line (Alt+V)

This function lets you draw vertical lines in any positions in the diagram. The respective position is given in the status line.

Diagram → Set Marker → Horizontal Line (Alt+H)

This function lets you draw horizontal lines in any positions in the diagram. The respective position is given in the status line.

Diagram → Set Marker → Measure Difference (Alt+D)

After clicking on a reference point, you can draw a line to any point in the diagram. The coordinate difference between the starting and end points of that line are given in the status line.

keV Diagram → Set Marker → X-Ray Energies

Displays a periodic table and inserts the relevant X-ray energies of the selected element as marks in the diagram provided the x-axis of the diagram has the unit keV.

Diagram → Draw Mean

After choosing mean value calculation, just select the curve section for which you wish to find the mean value with the left mouse button. The mean value appears in the status line along with its statistical error.

Diagramm → Calculate Peak Center

This function calculates the center of the marked peak and inserts this in the status line.

Diagramm → Fit Function

The software offers various best-fit operations:

Best-fit straight line	y=Ax+B
Line through origin	y=Ax
Tangent	y=Ax+B
Normal parabola	$y=Ax^2$
Parabola	$y=Ax^2+Bx+C$
Hyperbola 1/x	y=A/x+B
Hyperbola $1/x^2$	$y=A/x^2+B$
Exponential function	y=A*exp(-x/B)
Envelope of an oscillation	y=±A*exp(-x/B)+C (attenuation through air friction)
Gaussians of equal Width	y=Σ Gaussian curves with equal σ
Gaussians of specified Energy	y=Σ Gaussian curves with fixed μ and equal σ
f(x) **Free Fit**	y=f(x,A,B,C,D)

After choosing the corresponding operation, select the curve section you wish to apply it to using the left mouse button.

In the simplest case the Gaussian fits match precisely a Gaussian curve in the selected range. If a sum of several Gaussian curves is to be fitted the number and approximate position of the individual maxima (peaks) must be specified. This is done by means of markers set in advance (peak centers, vertical lines or selected x-ray energies).

Gaussians of equal width matches the amplitudes A_i and positions μ_i of all Gaussian curves and for this always uses the same width σ:

$$\sum_i A_i \cdot e^{-\frac{(x-\mu_i)^2}{2\sigma^2}}$$

Gaussian curves of a specified energy only fits the amplitudes A_i and the width σ. This is particularly suitable for marked x-ray energies.

To define a **free fit**, you need to specify the function f(x,A,B,C,D) and meaningful starting values before marking the range. The standard rules apply for entering the function. Choose starting values that are as realistic as possible to increase the chances of obtaining a successful fit. If it is not possible to fit the function, try repeating this process with different starting values. In addition, individual parameters A, B, C or D can be maintained constant during the fit.

During the fit, the current parameters of the operation (A, B, C and D) appear in the status line.

∫dx Diagram → Calculate Integral

The value of the integral corresponds to the area which is enclosed by the curve section selected by means of the left-hand mouse button and the x-axis, by the peak area, or by the area which is enclosed by the selected curve section from the origin. The value of the integral appears in the status line.

The result of a MCA measurement, however, is not a real integral over the x-axis (energy or channels), but simply the sum over the channels the unit being "events".

Diagram → Other Evaluations → Calculate Poisson Distribution

(only suitable for frequency distributions)

The total number n of events, the mean value μ and the standard deviation σ are calculated in the marked range of the histogram and displayed in the status line and the Poisson distribution calculated on the basis of these appears in the diagram:

$$y = n\frac{\mu^x}{x!}e^{-\mu}$$

Diagram → Other Evaluations → Calculate Gaussian Distribution
(only suitable for frequency distributions)

The total number n of events, the mean value μ and the standard deviation σ are calculated in the marked range of the histogram and displayed in the status line and the Gaussian distribution calculated on the basis of these appears in the diagram:

$$y = \frac{n}{\sigma\sqrt{2\pi}} \cdot e^{-\frac{(x-\mu)^2}{2\sigma^2}}$$

Diagram → Other Evaluations → Calculate Minimum and Maximum

The minimum and the maximum of the selected range are calculated and are displayed in the status line.

Diagram → Other Evaluations → Calculate Form Factor
(only suitable for periodic curves)

For the marked range $[t_1,t_2]$ of a periodic signal (e.g. U(t)) the following values are calculated and displayed in the status line:

Rectified mean value (mean of the absolute value)
$$U_{\text{ABS MEAN}} = \frac{1}{t_2 - t_1} \cdot \int_{t_1}^{t_2} |U(t)| \cdot \mathrm{d}t$$

Root-mean-square value
$$U_{\text{RMS}} = \sqrt{\frac{1}{t_2 - t_1} \cdot \int_{t_1}^{t_2} U^2(t) \cdot \mathrm{d}t}$$

Form factor
$$f = \frac{U_{\text{RMS}}}{U_{\text{ABS MEAN}}}$$

For these calculations, always an integer number of periods should be marked.

Diagram → Other Evaluations → Calculate Ripple
(only suitable for periodic curves)

For the marked range $[t_1,t_2]$ of a periodic signal (e.g. U(t)) the following values are calculated and displayed in the status line:

Mean value
$$U_{\text{MEAN}} = \frac{1}{t_2 - t_1} \cdot \int_{t_1}^{t_2} U(t) \cdot \mathrm{d}t$$

Root-mean-square value
$$U_{\text{RMS}} = \sqrt{\frac{1}{t_2 - t_1} \cdot \int_{t_1}^{t_2} U^2(t) \cdot \mathrm{d}t}$$

Ripple
$$r = \frac{\sqrt{U^2{}_{\text{RMS}} - U^2{}_{\text{MEAN}}}}{U_{\text{MEAN}}}$$

For these calculations, always an integer number of periods should be marked.

Diagram → Other Evaluations → Find Equivalence Point
(only useful for titration curves of pH over volume)

The equivalence point and the pK value are determined for the marked range of the titration curve and displayed in the status line. In the case of strong acids or bases (with pK < 1), it is recommendable to mark only the area immediately before and after the equivalence point in order to avoid the output of an incorrect pK value.

Diagram → Other Evaluations → Carry out Triangular Interpolation

For the triangular interpolation two ranges are selected in which initially a straight line is fitted.

Between the two straight lines a vertical line is fitted in such a way that the two triangles between the vertical line, the two straight lines and the measured curve, end up having the same area.

The position of the vertical line is displayed in the status line.

Diagram → Other Evaluations → Find Systole and Diastole

(only suitable for blood-pressure curves)

The systole and diastole are determined for the marked range of the blood pressure curve and displayed in the status line

Diagram → Other Evaluations → Decode CAN/LIN Message

By clicking on a CAN message or LIN message this is decoded and the result is displayed in the status line.

Diagram → Delete Last Evaluation

Undoes the most recent evaluation operation.

Diagram → Delete All Evaluations

Undoes all evaluation operations of this display.

Diagram → Delete Range (only Measured Values)

The measured values of the marked curve section are deleted. This only applies to measured values that are displayed on the y-axis. Values that are calculated (e.g. by means of a formula) or values on the x-axis cannot be deleted.

Diagram → Copy Diagram

Copies the diagram as a bitmap or metafile into the Windows clipboard. Once there, it are available for further processing in other Windows programs.

Diagram → Copy Window

Copies the main window as a bitmap into the Windows clipboard. Once there, it is available for further processing in other Windows programs.

Window menu

Window → Show Bluetooth CASSYs

Displays the CASSYs that can be connected by Bluetooth.

Window → Show CASSY Modules (F5)

Displays the current arrangement of CASSY modules and sensor boxes.

Window → Show Settings

Displays the current settings (e.g. CASSYs, computer, displays).

Window → Show Measuring Parameters

Displays the current measuring parameters.

Window → Toggle Large Display of Status Line On/Off (F6)

Toggles large display of the status-line information on and off.

Window → Toggle Display Instruments Off/On (F7)

Closes all open display instruments or reopens them.

Window → Group Display Instruments (F8)

Groups all of the open display instruments so that they can be shifted, scaled-down or scaled-up together.

Window → Align Display Instruments

Arranges all of the open display instruments in order next to one other or on top of one other.

Help menu

Help → Help (F1)

Opens this help file.

Help → New in CASSY Lab 2

Displays the most important changes in comparison to CASSY Lab 1.

Help → Experiment Examples

Displays an overview of all of the experiment examples included with CASSY.

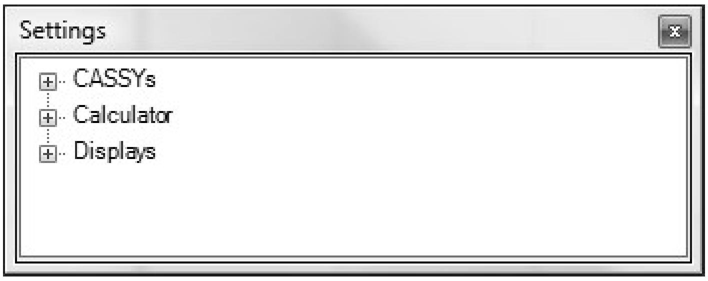
Help → About ...

Displays the current version number of the software and enables entry of the activation code.

Settings and Measuring Parameters

Window → Show Settings

All settings can be made in this central dialog window. The tree diagram provides three root nodes for this:

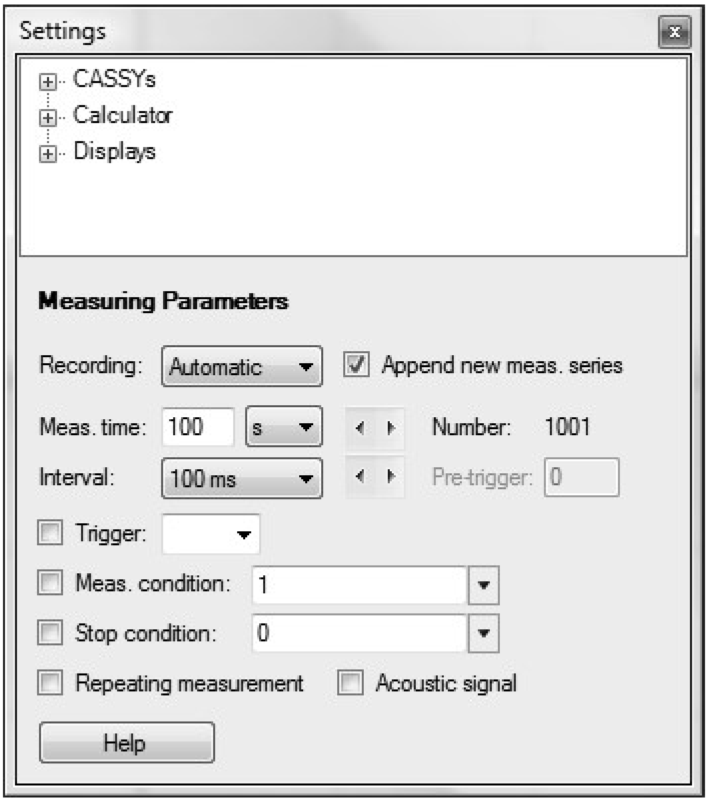


- CASSYs (definition of the inputs and outputs of the connected CASSYs)
- Calculator (definition of additional values)
- Displays (changes the column assignments of the tables and axis assignments in the diagrams)

If in the tree structure in one of the sub-nodes a problem is identified (e.g. wrong CASSY, wrong sensor box, syntax fault in one of the formulas), the first visible (higher-level) node shows a yellow , which alerts the user to the problem.

Window → Show Measuring Parameters

The measuring parameters are also displayed during every setting of an input or output and whenever no node is selected in the tree diagram.



The defaults that appear in this dialog depend on the currently connected sensor boxes. This simplifies matching to a particular measuring task, as the typical sensor box configuration is already finished.

Automatic recording

The software determines the exact time for the recording of a measured value. After a measurement is started with or **F9**, the software first waits for any **trigger** that may have been set, and then records one measured-value row each time the predefined time interval elapses. The **interval**, the **number** of measuring points per measurement as well as the total **measuring time** can be matched to the individual requirements before starting the experiment. You can select continuous display by setting a **repeating measurement**.

For intervals below 100 ms, Sensor-CASSY 2 and Pocket-CASSY support a pre-trigger which indicates how many measured values are to be recorded before the actual trigger time t = 0. For time intervals above 100 ms the pre-trigger is always available.

At time intervals above 10 ms, the software evaluates the **measuring condition** and the **stop condition** in addition to the trigger, and can also emit an **acoustic signal** when a measured value is recorded. The measuring condition and the stop condition are formulas.

A measuring condition not equal to 0 means ON="Measured-value recording possible", while a measuring condition equal to 0 means OFF="Measured-value recording inhibited". The measuring procedure is active once the measurement has been started **and** the result of the formula is ON. For example, if you want to run a measurement on 21 April 1999 between 1:00 p.m. and 2:00 p.m. (13:00 and 14:00 hours), you can use the formula: date = 21.4.1999 and time >= 13:00 and time <= 14:00.

A stop condition not equal to 0 means ON="Measurement stopped", while a stop condition equal to 0 means OFF="Measurement not stopped".

For some measurement quantities (e.g. rate, frequency, transit time, obscuration time, path when using the GM box or the timer box), the software does not evaluate the specified time interval. In this case the measurement is controlled by the gate time or the measurement pulses themselves.

Manual recording

The user determines the exact time for the recording of a measured value. At each start with ⏱ or **F9** the software records precisely **one** measured-value row, i.e. the current display values of the instruments are entered in the table and the diagram. Thus, manual recording must be executed repeatedly in order to capture a complete measurement series.

Append new measurement series

The Append function enables sequential recording of multiple measurement series. In the case of the automatic recording of the measured values, this switch has to be set only once in order to append all subsequent measurements. In the case of the manual recording of the measured values, the switch has to be reset every time that a new measurement series is started.

If more than one measurement series is being recorded, the serial index for the series is appended to the symbols in order to distinguish them by series, e.g. U_{A1}#1 and U_{A1}#2. This allows the measurement series to be distinguished from one another for the assignment of column headings in tables and the axis assignment of a diagram.

Alternatively, the individual measurement series can first be recorded one after another and saved individually. When loading multiple comparable measurement series (with identical quantities), measured series can also be appended "retroactively".

This selection is identical to Measurement → Append new Measurement Series

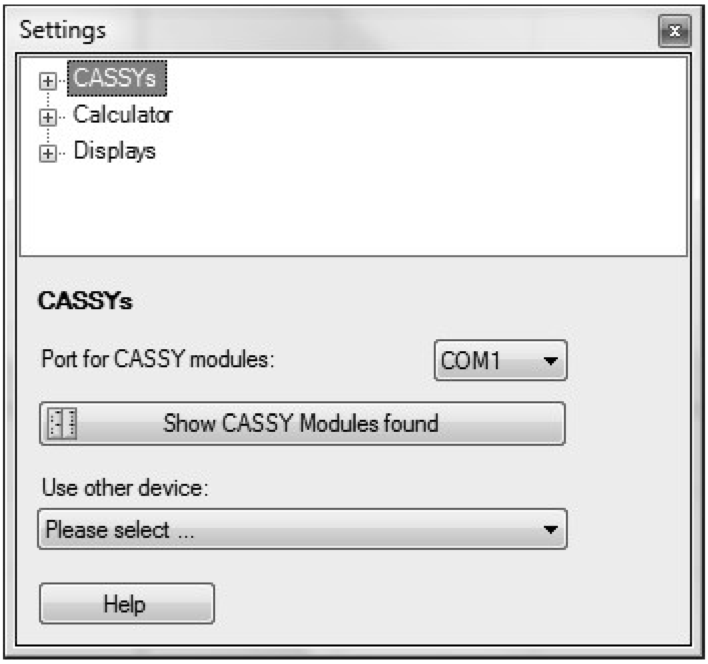
Changing and deleting measured values / entering parameters

You can edit all measured values (except time and formulas) in the table. To do this, click on the corresponding table row and edit the numerical value using the keyboard.

You can delete measured values in several ways:

- Measurement → Delete Current Measurement Series
- Table → Delete last Row in Table
- Diagram → Delete Range

Settings CASSYs

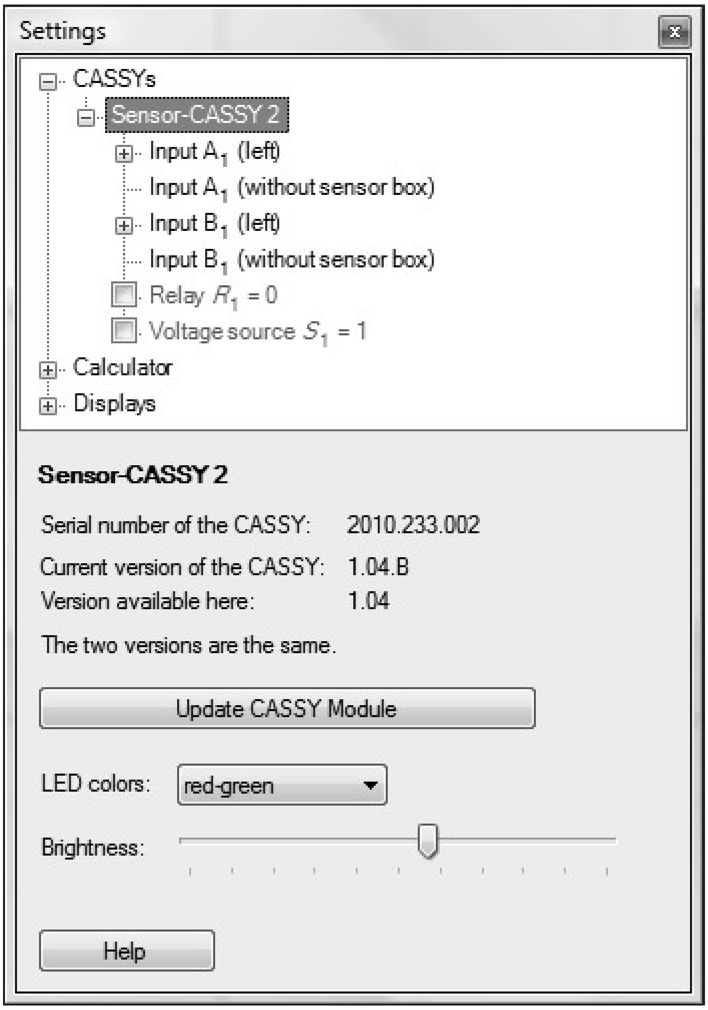


Here the interface can be specified where serial CASSY modules are to be searched for. CASSYs with USB interfaces are found automatically.

Even when a CASSY module is to be connected to a USB port on the computer via a USB serial adapter, it remains a serial CASSY module. Here the serial interface on the USB serial adapter has to be specified, which e.g. can be identified in the Windows device manager.

Show CASSY Modules found opens a window where all identified CASSYs are displayed.

If other devices are used for the measurement, they can be selected here.



The CASSY module described here identifies the detected device and the version information of the CASSY module. If the version of the software implemented in the CASSY module is newer or older than this software, a message is generated. Selecting **Update CASSY Module** causes this software version to overwrite the software implemented in the CASSY module (regardless of whether it is newer or older).

For CASSY-Display and for Mobile-CASSY, the data logger can also be read here, and the real-time clock in CASSY can be set to the computer system time.

For Sensor-CASSY 2, the colors and the brightness of the LEDs on the sides can be set here.

Hint

If this software is older than the CASSY module or you wish to update your software, you can download the latest version from our website: http://www.ld-didactic.com.

- Download update from the Internet

Analog input settings / Timer input settings

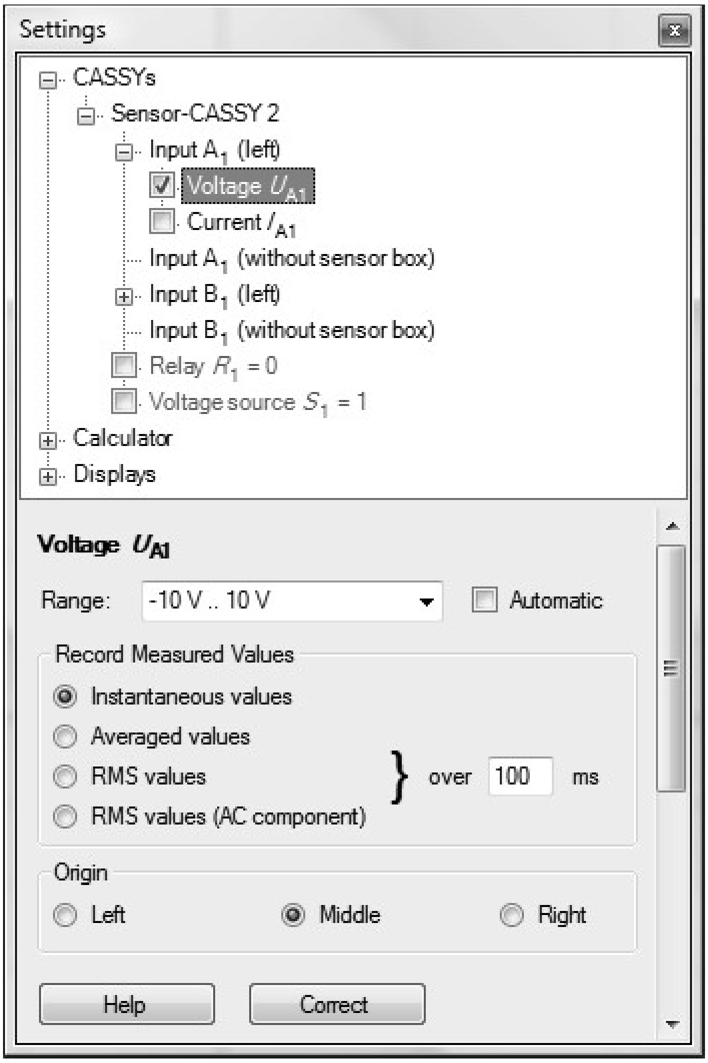
Sensor-CASSY is equipped with two electrically isolated sensor inputs A and B, which can be used to capture voltage values (resp. current as well at input A) as well as other measurement quantities – as determined by the attached sensor box. CASSY Lab detects the sensor box and thus the measuring options **automatically**, i.e. the visual image of the CASSY arrangement shows the inputs with any sensor boxes that are connected. In this display they can also be configured for measuring by clicking on them.

The available measurement quantities and the measuring ranges thus depend on whether a sensor box is connected, and which one. You will need different sensor boxes for different measuring requirements (see also our product catalogue).

Sensor-CASSY 2 even provides four inputs A and B, of which the left-hand inputs A and B are electrically isolated and can be used at the same time as the right-hand sensor inputs A and B.

In addition to the function generator output for voltage or current, Power-CASSY also provides an analog input which is used to measure the other corresponding quantity.

Profi-CASSY is equipped with two analog inputs A and B with the fixed measuring range ±10 V.



The selected quantity can be measured as an instantaneous value, averaged over several values or output as the corresponding RMS value. Normally, measurement of **instantaneous values** without averaging will be sufficient. However, if the input signal shows noise or hum, you need to measure **averaged values**. AC voltages are usually measured as **RMS values**. If the time interval is less than 10 ms, the measured values recorded in the table and the diagram will deviate from those shown in the display instruments in the latter two cases. This means that it is possible to display the curve form and the RMS values simultaneously.

As a standard the averaged values and RMS values are calculated during a time interval of 100 ms. This time interval can be changed globally for all channels. If Power-CASSY or Profi-CASSY is used, this time interval is changed on every change in frequency of the output signal so that always an integer number of periods is evaluated.

If the accuracy of the measured values is not sufficient, you an increase this by executing a correction. This can be necessary e.g. when matching a special pH electrode to the software.

Special buttons (often hidden)

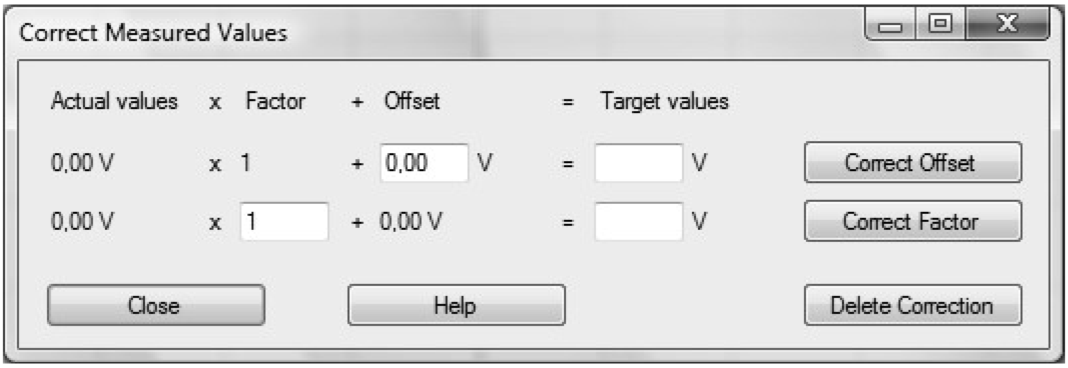
Box-LED	LED on the sensor box on/off, e.g. SMOOTH (bridge box) or COMPENSATION (prerequisite for tare compensation of B box)
→ 0 ←	Zero-point adjustment (takes current value as zero point), e.g. for path, force, pressure, events, collision
s ↔ –s	Sign inversion for path (motion sensing element with the BMW box)

There are also special input fields which make it much easier to use the BMW box, GM box and timer box (e.g. gate time, width of interrupter flag) and which are only visible when the corresponding box is attached.

When using the reaction test box, the reaction signal must first be requested by pressing a switch (hand or foot switch). The reaction itself must then occur after the pointer appears on the display instrument in accordance with the color of the pointer (red, green or yellow).

When using the climate box, you need to calibrate the humidity sensor (529 057) before the first measurement. The four values C1 to C4 printed on the sensor are provided for this purpose. You only need to enter these values once; they are then stored and retained in CASSY. These values do not need to be entered again, as they remain available for subsequent measurements with CASSY-Display.

Correct measured values



You can correct measured values in a variety of ways, all of them easily accessible via Windows dialogs.

You can enter an offset value and/or a factor to the left of the equal sign; the software then uses these values to calculate the displayed values to the right of the equals sign (target values) from the measured values displayed on the left of the equal sign (actual values). To calculate the correction, click on the appropriate button, **Correct Offset** or **Correct Factor.**

Alternatively, you can also define both target values, or one target value and one calculation value. **Delete Correction** cancels the correction.

Saving

A correction is saved with the other program settings. To ensure that the correction corresponds to the real situation when the program is loaded subsequently, be sure to use the same electrodes and sensor boxes on the same Sensor-CASSY (you may want to mark the electrodes, sensor boxes and CASSY devices).

Examples

Two buffer solutions with pH 3 and pH 9 are to be used for correction. The two target values are then 3 and 9 (enter these on the right side). When the pH electrode is immersed in the pH 3 solution, activate the button next to the target value (e.g. **Correct Offset**), and activate the other button (e.g. **Correct Factor**) for the pH 9 solution.

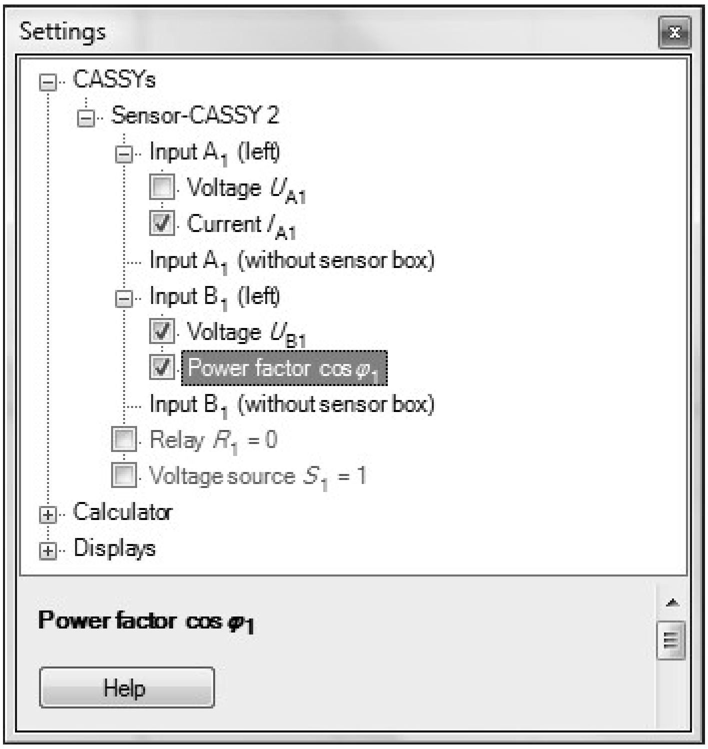
A conductivity electrode with the K-factor 1.07 must be matched to the software. To do this, simply enter the factor 1.07 in the second line as a factor and select **Correct Factor.**

Power factor cos φ / phase shift φ settings

Sensor-CASSY, Sensor-CASSY 2 and Profi-CASSY support the measurement of the power factor cos φ when effective values are measured at both voltage/current inputs. The power factor can be activated in the settings U_B when both inputs are activated.

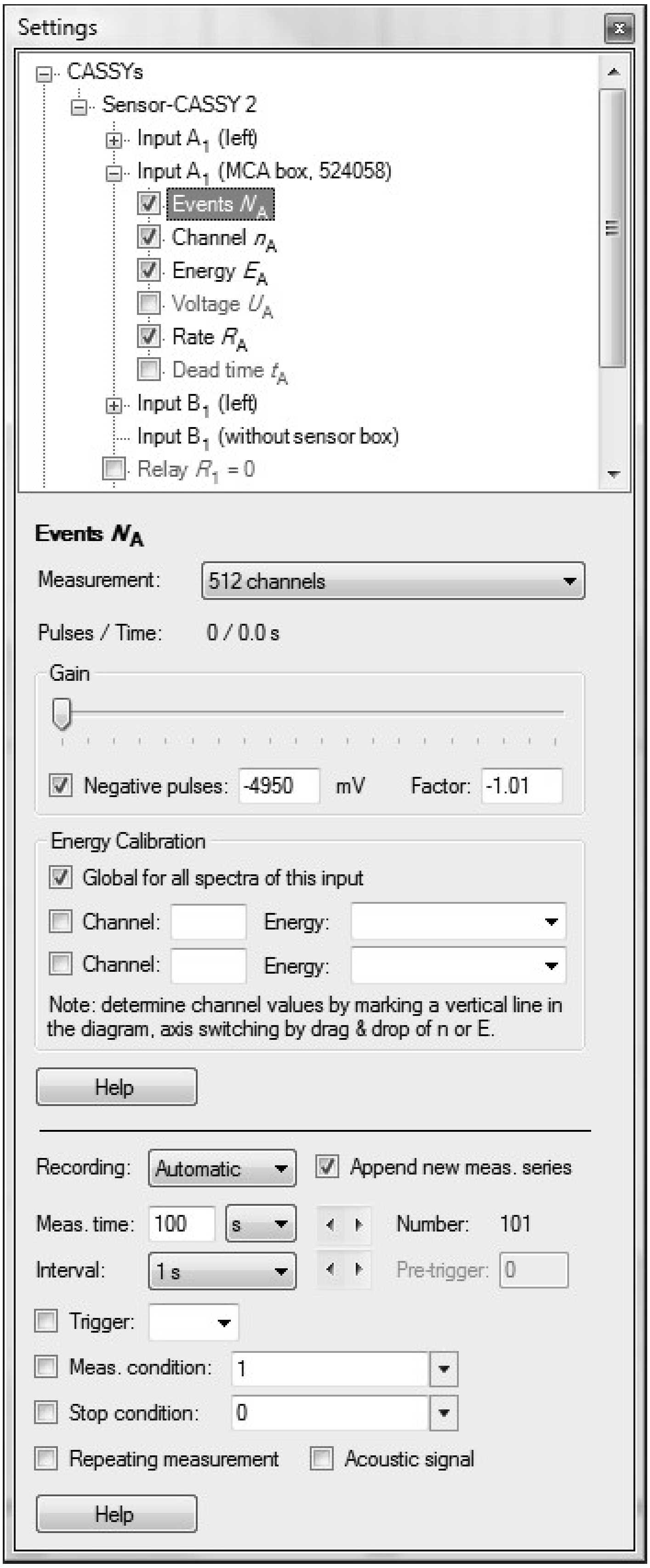
Power-CASSY supports the measurement of the phase angle φ between the current and the voltage which can be activated as required.

Profi-CASSY supports the measurement of the phase angle φ between output U_X and input U_A which can be activated as required.



The power factor and the phase shift can only be activated and de-activated. Other settings are not possible.

MCA box settings



Here the settings for the MCA box are made. In principle there are two operating modes:

Multichannel measurement

Under **Measurement** the number of desired channels is selected. The amplification is located below. The best result is achieved if the amplification is set to 1, 2, 5 or 10, or somewhat more.

The measuring time is as usual provided in the measuring parameters attached below.

Coincidence measurement

A coincidence measurement is only sensible if two MCA boxes are used, the first of which measures as normal and the second of which provides the coincidence trigger for the first box.

To do this the second MCA box requires a coincidence window which decides whether an event is to trigger the other box or not. This coincidence window can be set if, under measurement, **Coincidence trigger for other box** or **Anti-coincidence trigger for other box** is selected. In the first case, the other MCA box only makes a measurement when an event has been registered in this window. In the second case, the other MCA box only makes a measurement when an event outside of this window has been registered.

The time window for coincidences has a fixed default value of 4 µs.

Energy calibration

Recorded spectra are first divided into channels. If one or two channels are assigned to a known energy, a spectrum can be displayed in terms of energy.

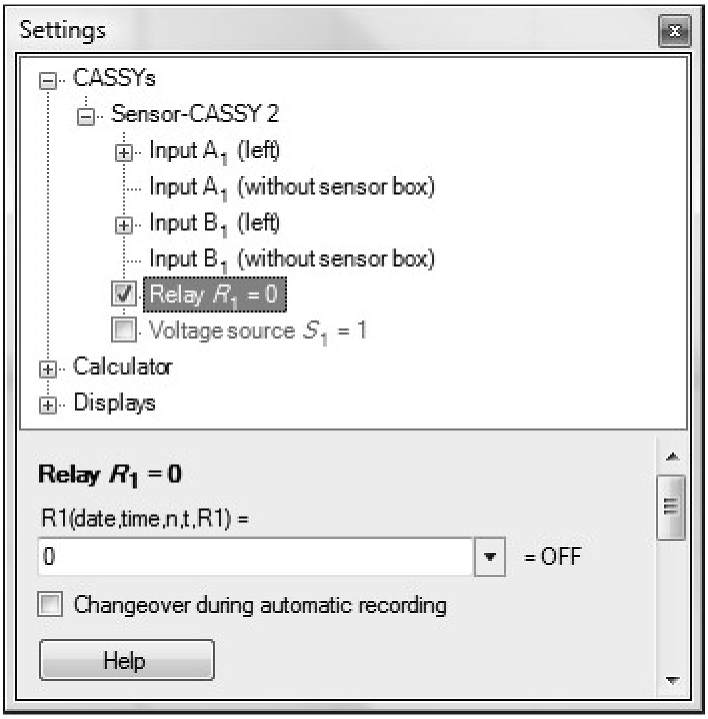
To do this, a vertical line simply has to be entered in the spectrum or a Peak center calculated. If no energy calibration has been carried out, the channel values of the vertical line or of the peak center are automatically entered in the corresponding input field. Alternatively, the values can be entered manually. As a third possibility, a Gaussian curve can be fitted. The result is then dragged from the status line into a **Channel** edit field using drag and drop. The two boxes for choosing the energies already contain default values for the customary radioactive preparations.

After one or two channels have been allocated to their energies, the channel E is allocated to the calibrated x-axis. The current channel x-axis can most simply be switched to the calibrated energy x-axis by drag & drop. To do this, the mouse is used to e.g. drag the channel button E into the diagram.

If the option **Global for all spectra of this input** has been chosen, the entered values are valid for all spectra recorded so far and also for all following spectra of this input. If this option has not been chosen, the calibration is valid for the current spectrum and all following spectra of this input.

Relay/voltage source settings

Sensor-CASSY and Sensor-CASSY 2 are equipped with a relay R and a voltage source S which can be adjusted using the knob. Both can be switched by the software. They must first be activated by clicking on them in the CASSY arrangement.



The easiest way to do this is to synchronize the relay with the start of a measurement (e.g. for a holding magnet at voltage source S). Simply activate **Changeover During Automatic Recording**.

However, you can also define the switching state using a formula. A formula can depend on any and all quantities that appear in the displayed list, and must be entered using the correct formula notation (see also the examples). A formula result not equal to 0 means ON="switched on", while a result equal to 0 means OFF="switched off". This formula is not evaluated during the measurement when **Changeover During Automatic Recording** is switched on.

As these formulas are calculated by the PC and their results are transmitted to the CASSY, in the best case changes at the relay and the voltage source are only possible every 10 ms.

PWM analog output

The voltage source S of Sensor-CASSY is actually a pulse width-modulated analog output. You can set the maximum voltage using the knob. The formula then controls not only OFF (=0) or ON (=1), but also allows intermediate values (e.g. 0.41 = alternately ON 41 % of the time and OFF 59 % of the time over a period of 10 ms). The function **Changeover During Automatic Recording** has no effect for these intermediate values.

Thus, this analog output lets you control modules for which only the average or the RMS value of the output voltage is relevant (e.g. the formula **saw(time/10)** would cause a small light bulb to become brighter for 5 s and then darker for 5 s).

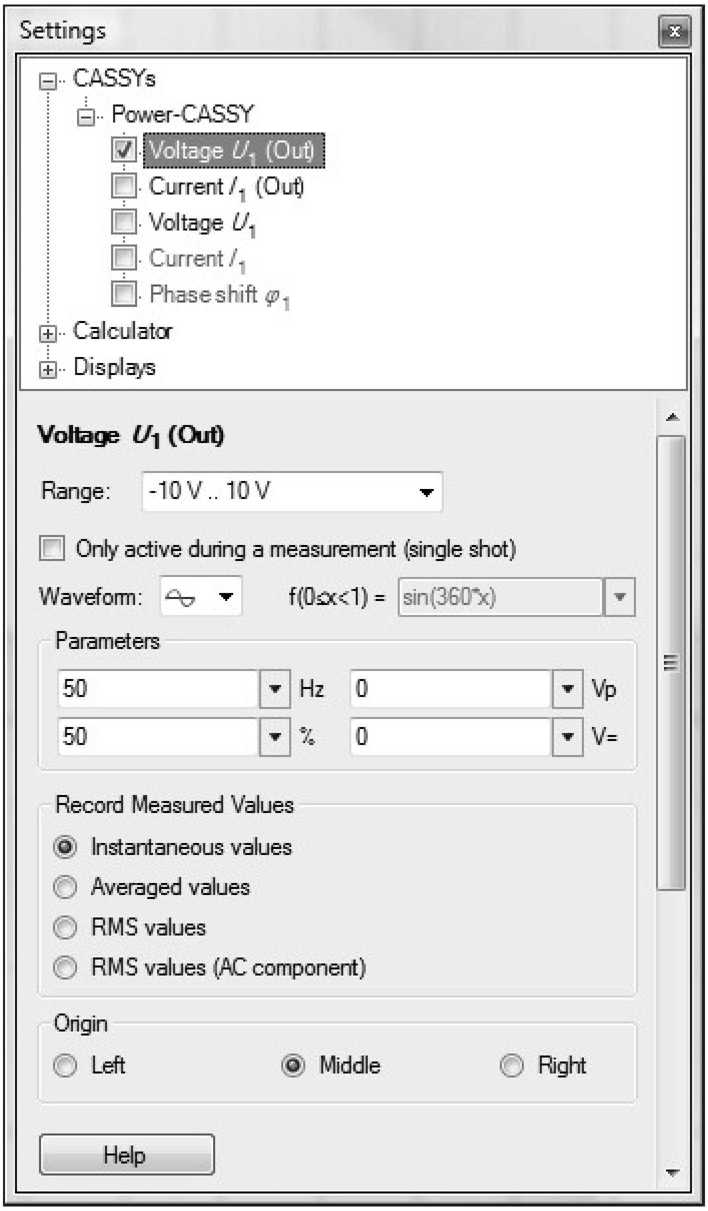
Sensor-CASSY 2 offers a real analog output which outputs fractions of the set maximum voltage as a constant voltage (without PWM).

An analog function generator output is provided by the Power-CASSY and the Profi-CASSY.

Function generator settings

Power-CASSY is a computer-controlled power function generator. The manipulated variable of the function generator is either the voltage U (voltage source) or the current I (current source). The device simultaneously measures the current I when used as a voltage source and the applied voltage U when used as a current source. The control and measuring ranges are user-definable.

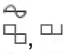
The Profi-CASSY also is a computer-controlled function generator at output X.



The output of the function generator can be actively limited to the actual measuring time **while a measurement is active (single shot)**. The function generator is then inactive between two measurements, so that no determination of mean or RMS values is possible then either.

The output curve form, frequency f (in Hz or kHz), amplitude A (in Vp or Ap), DC voltage offset O (in V= or A=) and duty factor (in %) can be set in specific ranges:

Power-CASSY

Curve form	Frequency f	Amplitude A	Offset O	Duty factor r
DC	-	-	-10 V..10 V / -1 A..1 A	-
	0.01 Hz - 10 kHz	-10 V..10 V / -1 A..1 A	-10 V..10 V / -1 A..1 A	0 % ..100 %
	0.01 Hz - 10 kHz	-10 V..10 V / -1 A..1 A	-10 V..10 V / -1 A..1 A	0 % ..100 %
	0.01 Hz - 10 kHz	-10 V..10 V / -1 A..1 A	-10 V..10 V / -1 A..1 A	0 % ..100 %
f(x)	0.01 Hz - 10 kHz	-10 V. 10 V / -1 A..1 A	-10 V..10 V / -1 A..1 A	-

Profi-CASSY

Curve form	Frequency f	Amplitude A	Offset O	Duty factor r
DC	-	-	-10 V .. 10 V	-
	0.01 Hz - 1000 Hz	-10 V .. 10 V	-10 V .. 10 V	0 % .. 100 %
,	0.01 Hz - 1000 Hz	-10 V .. 10 V	-10 V .. 10 V	0 % .. 100 %
,	0.01 Hz - 1000 Hz	-10 V .. 10 V	-10 V .. 10 V	0 % .. 100 %
f(x)	0.01 Hz - 1000 Hz	-10 V .. 10 V	-10 V .. 10 V	-

Square and triangular waves can be generated in two variations. The symmetrical curve form is between –A and +A. The asymmetrical curve from is between 0 and +A.

Negative amplitudes of A are allowed and mirror the signal through 0. The duty factor determines the ratio between the rising and falling curve sections. Thus, e.g. it is easy to convert a triangular signal (50 %) into a sawtooth signal (100 %).

In addition to the usual curve forms, the CASSY also offers a user-programmable curve form. To generate this, you need to enter a formula f(x) that describes that curve form. To determine the curve form, this function is evaluated in the variable x in the interval [0,1] and output with the specified frequency f, amplitude A and offset O. Formula entry is governed by the standard rules. In addition, the function **synth(a:b:c:...)** permits definition of a harmonic synthesis according to **a*sin(360*x) + b*sin(2*360*x) + c*sin(3*360*x) + ...** The signal is also output with the specified frequency f, amplitude A and offset O (see also the example sonic synthesis).

The formula input box is relatively small. You can use any standard text editor to generate longer formulas and then cut and paste these into the input box (right mouse button).

The values can be displayed as instantaneous values, averaged over multiple measured values or calculated as the RMS value. Normally, display of **instantaneous values** without averaging will be sufficient. When CASSY is active continuously (and not just during a measurement), it is also possible to display **averaged values** or **RMS values**. If the time interval is less than 10 ms, the measured values recorded in the table and the diagram will deviate from those shown in the display instruments in the latter two cases. This means that it is possible to display the curve form and the RMS values simultaneously.

Hint

Instead of fixed numerical values, you can specify formulas for frequency, amplitude, offset and duty factor. Thus, for example, the frequency of a sinusoidal oscillation or the output voltage can be controlled flexibly (e.g. for recording resonance curves or operating control systems). However, the initialization of the output of a new frequency (or amplitude, offset or duty factor) in CASSY may take a few 100 ms. The parameters can thus only be increased in steps, and not continuously.

Analog output Y settings

Apart from the analog output X, which can be used as a function generator, the Profi-CASSY provides another analog output Y, whose output level can be controlled via a program if a formula is assigned to it.

As this formula is calculated by the PC and its result is transmitted to the CASSY, in the best case changes at the analog output are only possible every 10 ms.

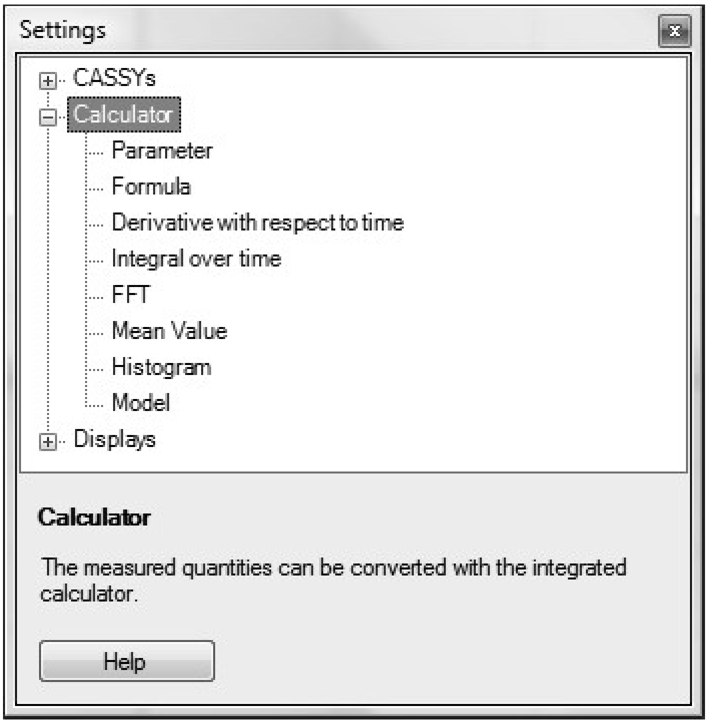
Digital input/output settings

The Profi-CASSY has 16 digital input and 16 digital outputs, which can be activated in groups of 8 inputs or outputs.

The inputs I_0 to I_{15} render the current input levels. To the outputs Q_0 to Q_{15} formulas can be assigned, whereby the output levels are controlled via a program.

As these formulas are calculated by the PC and their results are transmitted to the CASSY, in the best case changes at the digital output are only possible every 10 ms.

Settings Calculator



Some quantities cannot be measured directly using CASSY, and are thus not available as a CASSY channel. If you need to include these quantities in a table or diagram, you must define these quantities here.

New generates a new (data) record which begins with the name of the quantity. The new quantity must contain a symbol with which it can be addressed. This symbol should consist of as few (meaningful) letters as possible and may also consist of the & character followed by a letter. In this case, the corresponding Greek letter will be displayed (otherwise the Latin letter will be displayed). Apart from that, the values proposed for the measuring range and the scaling of the axes (important for analogue and graphical representations) and the number of significant decimal positions (important for digital and tabulated representations) have to be adapted to individual requirements.

Greek symbols

&a	&b	&c	&d	&e	&f	&g	&h	&i	&j	&k	&l	&m	&n	&o	&p	&q	&r	&s	&t	&u	&v	&w	&x	&y	&z
α	β	χ	δ	ε	ϕ	γ	η	ι	φ	κ	λ	μ	ν	ο	π	θ	ρ	σ	τ	υ	ϖ	ω	ξ	ψ	ζ
&A	&B	&C	&D	&E	&F	&G	&H	&I	&J	&K	&L	&M	&N	&O	&P	&Q	&R	&S	&T	&U	&V	&W	&X	&Y	&Z
Α	Β	χ	Δ	Ε	Φ	Γ	Η	Ι	ϑ	Κ	Λ	Μ	Ν	Ο	Π	Θ	Ρ	Σ	Τ	Υ	ς	Ω	Ξ	Ψ	Ζ

Parameter

The current value of a parameter is either entered in the settings window or by dragging the pointer of a display instrument. By setting the range to 0-1 and the number of decimal positions to 0, binary constants (switches) can be defined as well, which can be changed over by clicking on the display instrument. In order that parameters and constants can be easily distinguished from other channels, their pointers are magenta.

There are three different types of parameters:

- Constant (without table column)
- Manually into table
- Automatically into table

A constant is a quantity whose value can be accessed in formulas and models via the dedicated symbol of this constant. This provides an easy possibility of varying formulas or models, for example so that the result of the calculation agrees as accurately as possible with the measurement. If the value of a constant is modified this will apply to all measurement series - even retrospectively.

Manual parameters can only be entered in the table by hand via the keyboard or by drag & drop, and they are necessary whenever one wants to fill one's own table only with the evaluation results of other measurements.

Automatic parameters are automatically entered in their table column during a measurement; they can also be entered manually via the keyboard or by drag & drop. It is a good idea to enter the parameter **before** measuring, so that the right measurement points appear in the diagram immediately in manual mode and the old parameter value does not have to be used again.

Automatic and manual parameters can therefore have a different value in each table row and are usually not constant. For this reason the model cannot make use of them.

Formula

It is possible to define a new measurement quantity using a mathematical formula, regardless of known quantities. The known quantities are addressed via their symbols, which appear in the list the program displays. When entering the formula itself, be sure to observe the correct formula notation (see also the examples). In order that converted quantities can be easily distinguished from other channels, their pointers are violet.

Derivation, Integral, FFT (Fourier transform), Mean Value, Histogram

For time derivation, integral of time and FFT (Fourier transform), simply select the channel you wish to transform. To calculate the mean value, you additionally need to specify the time interval over which values are to be averaged. Meaningful mean values can only be generated when the interval over which the mean is taken is greater than the measuring interval. For the histogram, the channel width has to be specified in addition. For FFT, the software automatically generates the **frequency spectrum**, and for the histogram the software automatically generates the **frequency distribution** as a further display mode; this can be activated using the display tabs. In order that converted quantities can be easily distinguished from other channels, their pointers are violet.

Notes

A derivation impairs the resolution for shorter time intervals Δt. For example, if the resolution of a path measurement is Δs = 1 mm and the measurement uses a time interval of Δt = 100 ms, the first derivation $v(i) = (s(i+1)-s(i-1))/2\Delta t$ has a resolution of Δv = 0.005 m/s and the second a resolution of Δa = 0.025 m/s^2. At a time interval of Δt = 50 ms these errors increase to Δv = 0.01 m/s and Δa = 0.1 m/s^2. Thus, Δt should be set as high as possible (e.g. 200 ms for motions on a track or 50 ms for oscillating springs).

The maximum frequency of an FFT is half the scanning rate. Thus, if a time interval Δt = 10 µs (f = 100 kHz) is used for measuring, the frequency range of FFT extends to 50 kHz. The resolution in this frequency range, on the other hand, depends on the number of measured values. The more original measurement points are recorded, the better is the frequency resolution in the frequency spectrum.

Modeling

The modeling tool enables values measured on real objects to be compared with a mathematical model. In particular, suitable constants can be chosen and varied such that the model agrees with reality as accurately as possible. In contrast to a fit (e.g. free fit), where the equation that defines the function has to be known from the beginning, modeling just requires first order differential equations as an input.

For the mathematical definition of the model, the initial values at the time t_0 and the differential equations are specified. These numerical values or formulas have to be entered, whereby the correct formula notation has to be observed. Each formulas may depend on constants, whose values can be varied afterwards by dragging the pointer of the display instrument. In addition, the differential equations may depend on the measuring time t, on the defined model quantities and on formulas, which, in turn, may only depend on constants or on the measuring time t. All allowed dependencies of the differential equations are listed in front of their entry field. In order that model quantities can be easily distinguished from other channels, their pointers are blue.

The model can only calculate first order differential equations. If a higher order differential equation is to be calculated, the differential equation must be split up into several first order differential equations (see example).

The **start time** t_0, the **accuracy** and the **computing time** are properties for all of the modeling quantities and are for this reason directly set at the modeling node of the tree diagram.

The selectable **Accuracy** gives the truncation criterion, which determines when the numerical integration of the differential equations is terminated. A lower accuracy leads to a shorter computation time, but also to a greater error of the result.

The selectable **Computation Time** determines the maximum time available for the numerical integration of the differential equation. If the computation time selected is too short with regard to the specified accuracy, the calculated values start at the selected starting time, but stop too early.

Examples

The best-known example of a second order differential equation is certainly Newton's equation of motion F=m·a or s''=F(s,v,t)/m. In this case, the two model quantities are the path s and the velocity v, and the first differential equation