Ilmenauer MECHATRONIK

Operating manual

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Table of content

Versions

Date	Annotations
2019/04/16	Initial release.
2019/08/05	Editorial changes.
2020/04/15	Editorial changes.
2020/04/24	Editorial changes.
2020/06/15	Editorial changes.
2022/02/08	Editorial changes (AG).

1 Important notes

This document describes solely the use of the MagHyst® Upgrade Kit. Information and documentations to MagHyst modular® are not included. For those see the according documents.

1.1 Icons in this manual

Symbol	Annotation
⚠	Caution, special tips

1.2 Unpacking

Check that everything is complete. The following items are included in the delivery:

- USB stick with documentations and software
- USB dongle WIBU

2 Software installation

Besides the installation of the MagHyst® Software and their components (see according documentation) further components have to be installed on the PC.

2.1 CodeMeter

The evaluation software “Solenoid Evaluator” can be started using software CodeMeter in conjunction with the enclosed USB dongle. The software CodeMeter is supplied. The software even can be downloaded from www.codemeter.de

Follow the on-screen instructions for installation of CodeMeter. It is recommended to install the software for all users of the PC and without changes using the “Custom Setup”.

Afterwards the USB dongle must be connected with the PC. The dongle includes the licenses and authorizes for starting the software “Solenoid Evaluator”.

CodeMeter is installed as a background process. It is not necessary to start the software when starting the system.

⚠ The loss of the USB dongle occurs that the software „Solenoid Evaluator“ cannot be executed anymore. The dongle should be connected to a PC-internal USB slot to prevent abuse by third persons.

⚠ The simultaneous use of a debugger and by CodeMeter encrypted software occurs, that the license on the USB dongle will be deactivated to protect the software. If this occurs inadvertently please contact the Ilmenauer Mechatronik GmbH.

2.2 NI LabVIEW Runtime 2020 SP1 64 bit

Solenoid Evaluator is based on LabView Runtime Engine 2020 SP1 64bit. The installer is located on the provided USB stick or can be downloaded from *https://www.ni.com/de-de/support/downloads/software-products/download.labview.html#369642. For* the download it is necessary to create a free user account at National instruments. It is very important to install exactly the specified version because newer versions of LabView Runtime Engine are not compatible downwards!

Installation of LabView Runtime Engine can be started by setup.exe. Then follow the on-screen instructions. Don't make any special configurations.

2.3 ODBC for PostgreSQL (optional)

If you use MagHyst® automation the measured and test data is saved in PostgreSQL database. A library to talk to the PostgreSQL DBMS using ODBC have to be installed.

2.4 Solenoid Evaluator

Solenoid Evaluator is based on LabView Runtime Engine 2020 SP1 64bit and is encrypted with CodeMeter. That's why it is necessary all components are installed correctly.

Solenoid Evaluator should be saved as a local copy. Thereby it is necessary that the folder has no access restrictions (e.g c:/programme/…). Furthermore, it is recommended to create a desktop link.

First you have to configure the import folder. This has to be identically with the export folder of the MultiChannel software. It can be chosen via „File → Load from ASCII". Confirm with „SELECT".The standard folder is "C:\SolenoidEvaluator\measurements"

Next open "Options → Paths". Evaluations exported from Solenoid Evaluator will be saved in the selected folder.

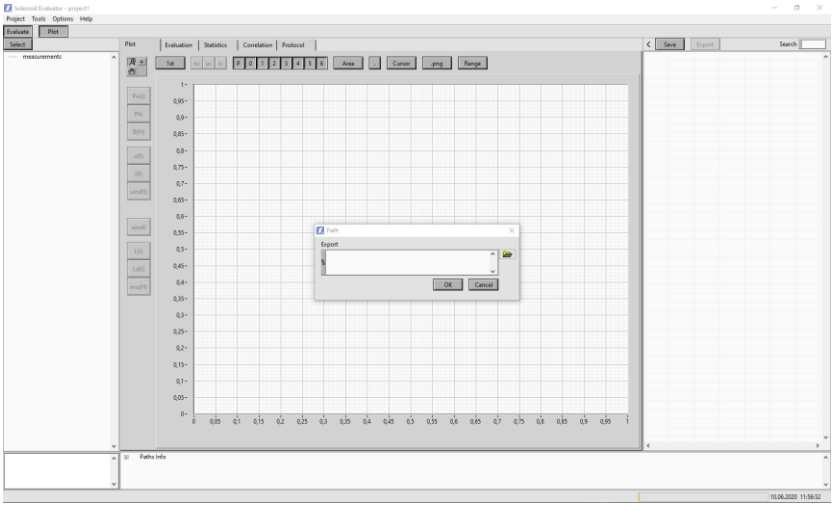

Figure 1: Setting up Solenoid Evaluator paths

Closing the software via „File → Exit" saves the selection. With the next software start the configuration will be loaded automatically.

3 Solenoid Evaluator

As Solenoid Evaluator contains numerous evaluation settings, it is very useful to be able to save and restore the condition of parameters and paths. Therefore, the project concept has been implemented into the software.

Within the project file (.proj), data such as paths and states of control elements are saved. Loading and saving options can be found in the menu (Chapter 3.2.3). Loading restores all paths and settings that have been saved within the project. Exiting Solenoid Evaluator shows a dialog box with options to save or not to save and to cancel the closing oft he software.

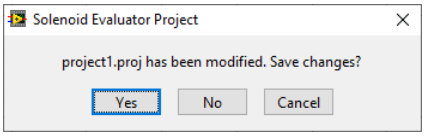

Figure 2: saving changes on exit

If no project file is existent, the software will setup all parameters and paths to a predefined state and create a project file named „project1.proj“ in the software folder.

3.1 Menu

3.1.1 File

The file menu has options to load, save and to upload files and settings.

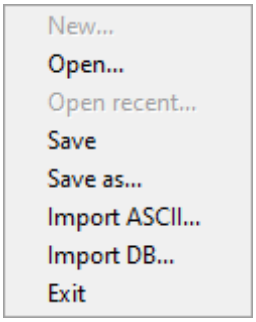

Figure 3: File menu

Currently inactive options within the file menu are shown greyed out.

Projects can be loaded via *File* → *Open...* Within the dialog box (Figure 4: Open project) a new name for the project has to be entered.

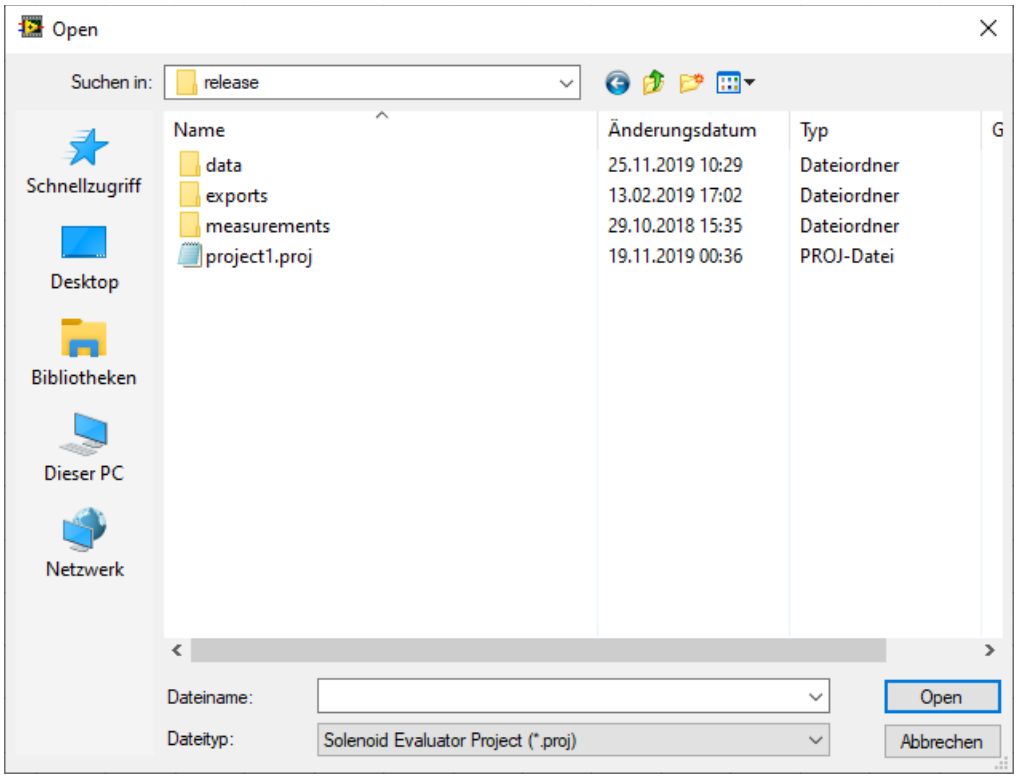

Figure 4: Open project

If there have been changes made to the actual project when opening another one, a new dialog box will open, to let you save your changes.

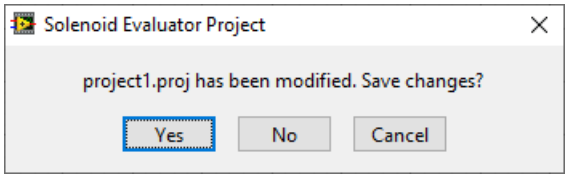

Figure 5: Saving changes

Save and *Save as...* will either save the current project status or save the project with a new name.

Import ASCII… opens a dialog box to select the import folder with saved ASCII-measurements.

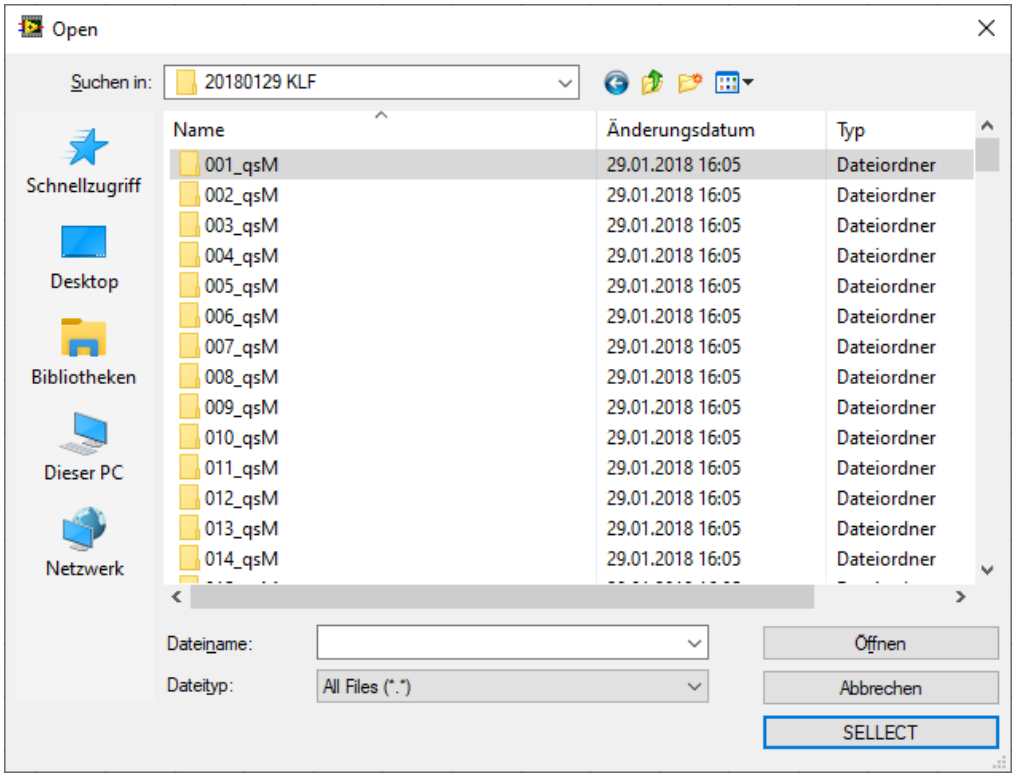

Figure 6: ASCII Import

The connection to a PostgreSQL database for MagHyst® automation can be configured with the menu entry *Import DB…* and the corresponding dialog box (Figure 7: Database import)

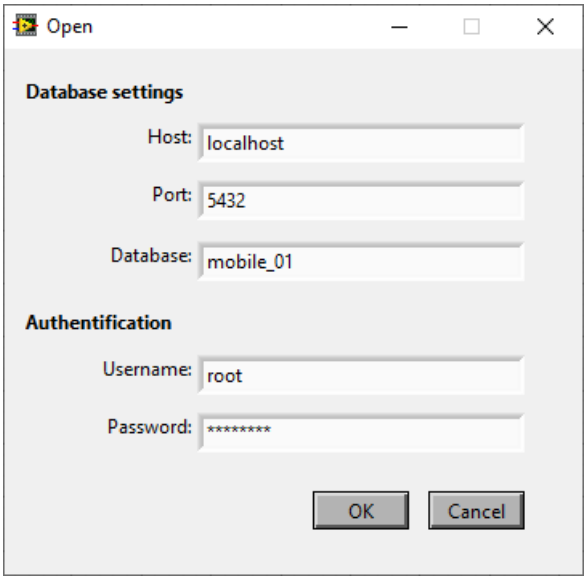

Figure 7: Database import

For a connection to the server, host-name and port number have to be typed to the corresponding fields. The database name has to be entered to the field *Database*. For *Username* and *Password*, the login data have to be entered.

3.1.2 Tools

This menu contains the two functions Freeze and Last Curve

Last Curve activates a function that automatically selects the latest ASCII measurement in the chosen folder. This measurement will be evaluated and displayed. If a new measurement is stored in the folder by another software, it will be evaluated automatically.

Freeze will lock all curves that are currently shown in the evaluation tab. When new curves are calculated, the frozen curves will also be displayed in gray. Frozen curves will stay in the plot until the checkbox next to Freeze is removed.

3.1.3 Options

Within the menu item *Paths* the folder to which PNG-images, ASCII-files and protocols with saved chart data will be exported can be specified.

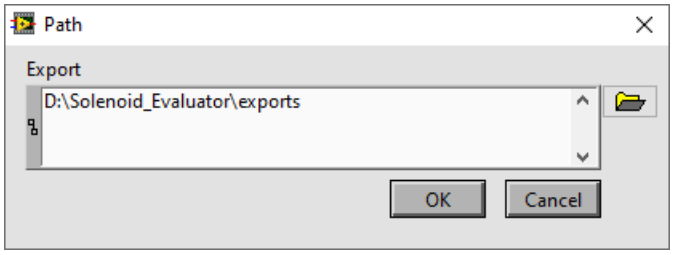

Figure 8: Export path

3.1.4 Help

Manual will show this document as PDF file. *About* will show the Splash-Screen with information about the Software version

The Interface of Solenoid Evaluator is divided into three main areas:

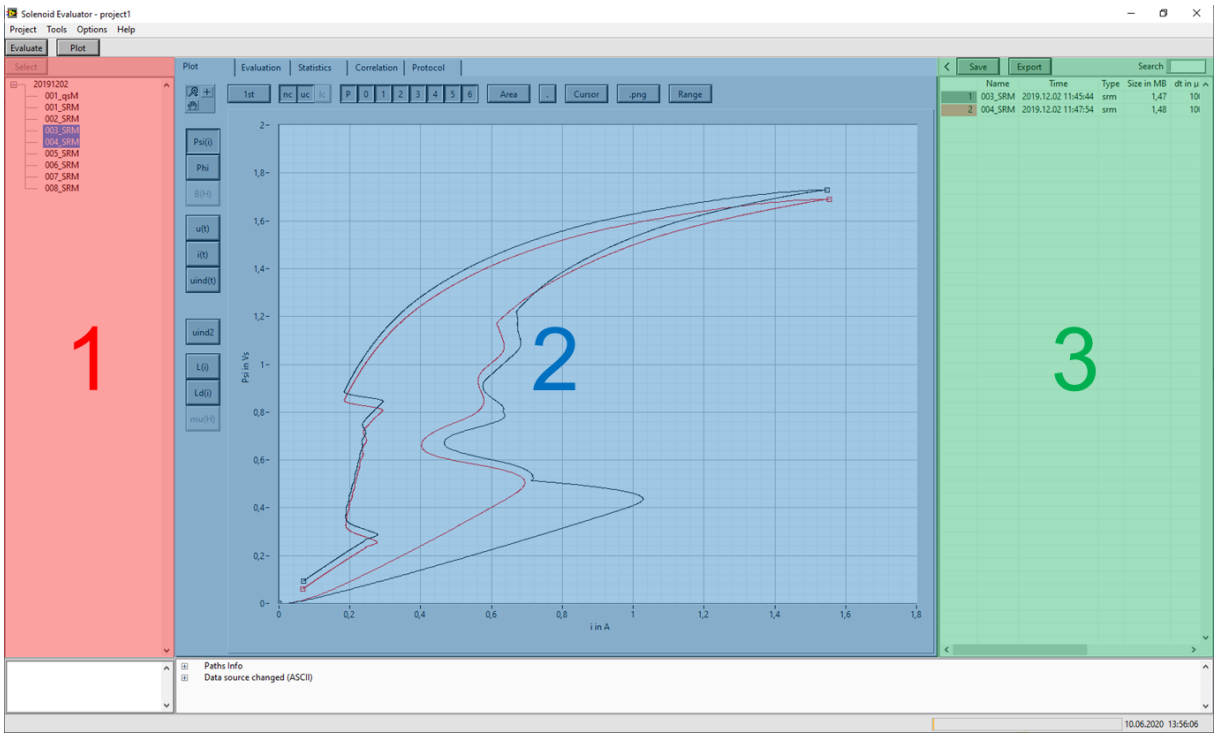

Figure 9: Working areas of the Solenoid Evaluator interface

In the selection area 1 the measurements available in the chosen folder are shown. Clicking a measurement chooses it for further evaluations. The evaluation area is used both for graphic presentation of the evaluated measurements and the evaluation settings (Tabs “Plot and Evaluation”). In the table area, the imported text files and evaluation results are shown tabular.

3.2 Selection

The Solenoid Evaluator workflow is divided into 3 phases: 1. Choose separate measurements from the tree 2. Evaluate the chosen measurements 3. Graphic display of the curves

The measurements are chosen by clicking on them in the tree. CTRL and SHIFT buttons can be used to select more than one measurement. Choosing measurements shows primary data about the measurement in the table, e.g. name of the measurement, time of the measurement, type, size on harddisk, dt (sampling time) and the measured resistance.

Figure 10: Evaluate and Plot buttons

The buttons *Evaluate* and *Plot* (Figure 10: Evaluate and Plot buttons) activate and control the options to complement the data within the evaluation table with determined data (*Evaluate* button) and the graphic presentation of the curves (*Plot* button). The evaluation data includes flux- and current values of the characteristic points P0 – P7 and friction (see chapter **Fehler! Verweisquelle konnte nicht gefunden werden.**), times of the characteristic points, test results and cutting values of the curves.

Both buttons have two modes: one-time activation of evaluation/plot of measurements and the continuous activation of one or both options.

The one-time activation of evaluation/plot offers more flexibility. After selection of elements in the tree, the measurements can be selected and filtered within the table, e.g. by text pattern. Afterwards, separate measurements and evaluation results can be added and/or curves can be plotted. Therefore, the specific measurements have to be selected and the corresponding button *Evaluate* or *Plot* has to be pressed.

The evaluation without graphical presentation has benefits, if only the tabular results are important. This mode is used for big amount of data (e.g. for creation of arrays of curves or scatter plots), as otherwise every step will be slowed down due to calculation time.

Pressing and holding one of the buttons for more than a second switches this function to the continuous mode. Evaluation/Plot of the measurement selected within the tree will be executed directly.

Working in continuous mode is useful, if small numbers of measurements shall be analyzed quickly. The selected element within the tree will automatically be evaluated and shown in the plot, depending on whether one or both buttons are active

The selection area has a tree structure and supports the standard functions of selection of tree elements with CTRL- and SHIFT key. The database structure is shown chronologically in the tree. Clicking the elements year, month, day etc. selects all chonologically subordinate measurements. Next to the day, the belonging number of saved measurements is shown in brackets. (Figure 10)

The ASCII view shows the measurements in chosen folder as a tree (Figure 10 right)

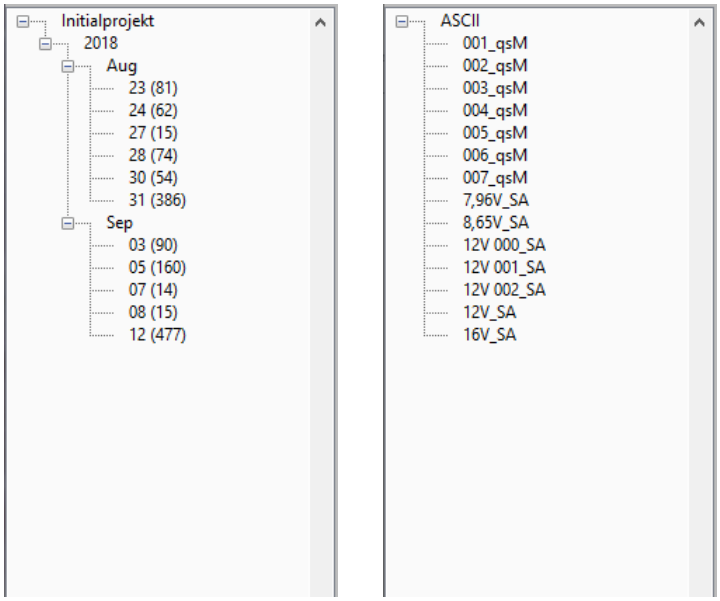

Figure 11: Database structure (left) and ASCII folder (right)

The software has additional options for measurements stored within databases. The button “select” (Figure 12) opens an input window (Figure 13), where measurements can be selected by name or time range.

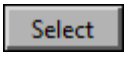

Figure 12: Select button

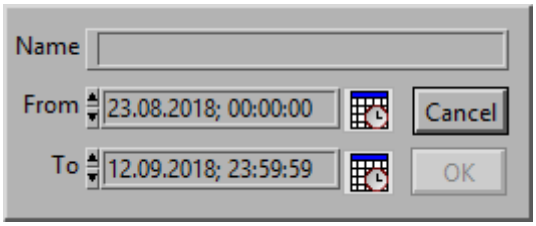

Figure 13: Select window

The select button is only active for databases.

3.3 Plot

The Plot/Evaluation area (figure 9) has a tab structure with the tabs Plot, Evaluation and Statistics.

The tab Plot consists of the plot area and the control buttons. Depending on their number, shown curves are colorized. For less than 10, each curve has its unique color. Arrays of more than 10 curves are all shown in black.

Using the buttons on the left, the shown curve of the measurement can be switched. The following curves are available:

- Psi(i) for linked magnetic flux Ψ(i)
- B(H) for flux density B(H)
- u(t) for measured voltage u(t)
- i(t) for measured current i(t)
- uind(t) for measured induced voltage $u_{ind}(t)$
- uind2 for measured induced voltage $u_{ind2}(t)$
- L(i) for inductance L(i)
- dL(i) for differential inductance dL(i)
- mu(H) for relative permeability μ(H)

At the top of the evaluation area different buttons to adjust the display are available. Therewith the visualization can be customized.

Figure 14: Plot options

From left to right the buttons have the following functions:

- Quadrant display: 1th / 2th / 3th / 4th / 1&4 / all
- Choice of curve segment: S1 / S2 / S3 / all
- Plot of evaluated points
    - Clicking P selects all points from P0 to P6
    - Buttons 0 – 6 select the the respective points
- Area enables the area between P1 to P2 on the lower curve and P4 to P5 on the upper curve. This area correlates with mechanical losses or friction during armature movement.
- "-" or "." Measured curve as a continuous line or measures points are shown
- "Cursor" activates a crossbar that can be positioned via click on the curve. Number of the measurement and coordinates of the selected point are shown in status bar of the window. If automatic point estimation (P1, P2, P4, P5) works not perfectly, the manual estimation of the point position is possible. Setting the point happens, when one of the buttons 1, 2, 4, 5 is pressed, while the cursor is activated, and the focus is on the graph. A text field with the name of the point shows left of the status bar. Evaluation and actualization of both graph and table are started.

Figure 15: Designation of the point at manual point input

For a manual input, the point determination during evaluation has to be disabled (see 3.4 Evaluation), otherwise the point coordinates manually set up are overwritten by the calculated ones during actualization.

- Graphical export of displayed curves as .png
- The button “Range” activates the test area for the Psi(i) graph

To operate the graphs, the graph-palette (Figure 16) is used

Figure 16: Graph palette

The graph palette has the following options: zooming, cursor, panning-tool

For zooming different tools are available. They can be chosen after click on the magnifier icon:

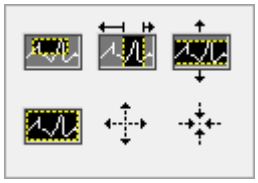

Figure 17: Zoom options

The functions allow:

-  Zoom in on a freely selectable rectangle
-  Zoom in on the completely height and a free selectable part of the x-axis
-  Zoom in on the completely width and a free selectable part of the y-axis
-  Show the complete curve
-  Zoom in – as long as „click“
-  Zoom out – as long as „click“

For a fast reset of the zoom settings click once more on the button of the respective curve (for example Psi(i) → recommended)

3.4 Evaluation

The tab has subordinated tabs:

- Pre-Processing
- Resistance
- Curves
- Points
- Additional points
- Polynomial
- Tolerances

3.4.1 Pre-Processing

The tab Pre-Processing includes three functions to preprocess saved *u(t)*, *i(t)*, *uind1(t)*, *uind2(t)*, *psi(i)* and *B(H)* curves: *Low pass* filter, multiplication with a constant *Factor* and addition off an offset.

The control elements are arranged in columns. With the checkboxes, the filters can be activated for the individual curves. The filter has two types of FIR (finite impulse response): sinc- or rectangular. The rectangular filter corresponds the averaging of $N = f_c/f_s$ points, where f_c and f_s are the cutoff frequency and the sampling frequency. The frequencies are specified in Hz. *Factor* and *Offset* are preset to 1 and 0. Currently, *Factor* is only available for the *uind2(t)* and *psi(i)* curves and *Offset* is only available for *u(t)*, *i(t)*, *uind1(t)* and *uind2(t)*.

3.4.2 Resistance

From the dropdown list in the *Resistance* tab, sources and procedures for the determination of the resistance for the measurement types (SRM and QSM) can be selected: “defined” sets the resistance to the value in the “Defined Resistance” input field, “table” uses the uploaded resistance values from the chart and “curve U/I” calculates the resistance from the given SRM curve.

3.4.3 Curves

There are different ways to calculate the Psi(i)-curve. The control elements to choose the procedure to determine $\Psi(i)$ can be found in the tab *Psi(i)*. Measurements that are saved as ASCII file normaly already contain a $\Psi(i)$-curve. That is the standard option to display the $\Psi(i)$ in the graph. If $\Psi(i)$ is not available, as usual for measurements from databases, $\Psi(t)$ is calculated by integration of the given uind(t) as $\Psi(t) = \int u_{ind}(t)dt$. If the induced voltage $u_{ind}(t)$ is not available, dhe flux $\Psi(t)$ is calculated as $\Psi(t) = \int u(t) - R \cdot i(t)dt$. Switching between these two options happens automatically. If “ignore Psi(i)” is activated, the software always calculates $\Psi(i)$ from $u_{ind}(t)$, even if the $\Psi(i)$-curve is available. To calculate the $\Psi(i)$-curve directly from $u(t)$, $i(t)$ and R, “ignore Uind(t)” should also be activated. As the $\Psi(i)$-curves are always calculated by integration, an integration error can’t be ruled out. The QSM-$\Psi(i)$-curve gets a small misalignment. By activation of the option “centering curve”, the the $\Psi(i)$-curve will be positioned symmetrically to the origin of ordinates.

3.4.4 Points

The basic version of Solenoid Evaluator has the function to determine characteristic points. The present process delivers 7 characteristic points for each measurement:

- P0, coercive point
- P1, begin of the armature movement (engaging)
- P2, end of the armature movement (engaging)
- P3, maximum current and flux
- P4, begin of the return movement (disengaging)
- P5, end of the return movement (disengaging)
- P6, remanence point

The tab *Points* implement two methods and control elements for the procedures of point determination. Control element *[P0,P3,P6]* enables or disables the determination of characteristic points P0, P3 and P6. No parametrization of the method is needed.

Control element *[P1,P2,P4,P5]* enables or disables the determination of characteristic points P1, P2, P4 and P5. Method of a “moving pipe” is used to detect the characteristic points on the Ld(i) curve. Note: Ld(i) calculation must be checked on in the tab *Curves*. The size of four separated pipes must be estimated experimentally to get the best results in point detection for a specified solenoid type. Three parameters in % describe the size of each of four pipes:

Begin, %	Start position of the pipe. Search of P1 and P5 start from minimal current values and search of P2 and P4 begins from maximal current values. Is needed to cut off the spikes on the Ld(i)
Length, %	Length of the pipe as a percentage of the maximal current
Diameter, %	Diameter of the pipe as a percentage of Ld value at the start position
Step size, %	Step size or resolution of the pipe movement as a percentage of the maximal current

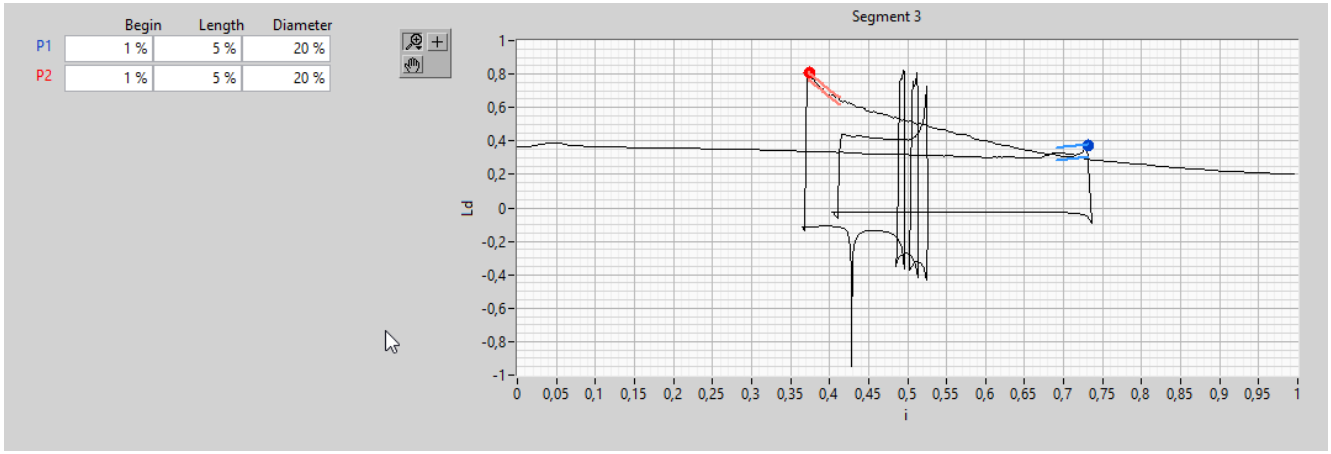

Figure 18: example of point P1, P2 detection

Some adjustment and iterations are always needed to get the best search results.

3.5 Additional points

Y-values at defined X-values can be detected for different curves. They will be shown on the plot and in the table.

Slope if the Psi(i) or Phi(Theta) curves can be calculated between two defined curves.

If the *Neutralization Current* option is active, the value of the neutralization current for polarized actuators is output in the *Neutr. Curr.* column.

3.6 Polynomial

The tab *Polynomial* offers the option to calculate the polynom. Is used for example for stroke calculation from the psi(i) curve. This option is activated with the checkbox “Calculate value”. In the dropdown menu “Argument x”, the argument has to be chosen from the given columns of the table. For determination of the value, a 4^{th}-order polynomial is used. The polynomial coefficients can be input separately to the input fields in front of the identifier of the order x^0 to x^4. Otherwise, with the button “Insert” the coefficients are assigned from the “Correlation” area.

3.7 Tolerances

Control elements in the tab *Tolerances* allow setting up on i- and two Ψ-areas for IO/NIO-tests for the appropriate points (P0, P3 and P6) in the Psi(i)-characteristics. Each area is defined by the middle value Mean and the relative width Tolerance, +%. An additional parameter for point P3 defines the position (current), where the P3-area is displayed.

Equal control elements are used for B(H) curves for automated IO/NIO of soft magnetic materials.

3.8 Statistics

The statistical evaluation starts with choosing of the needed values from the dropdown-list “Parameter”. In this list, the names of the currently displayed columns of the evaluation chart (see chapter 3.11) are available. If no measurements are chosen in the evaluation chart, all values from the selected column will be used for the statistical evaluation. If various measurements are selected, only these measurements will be used for the analysis.

The Plot (Figure 19) shows the values. The dropdown list “diagram” allows to choose between different display styles:

- Samples – for display of the values and their numbers
- Histogram – for display of a histogram
- Samples/Histogram – shows both values and histogram in one plot
- Time – shows the values depending of the time of the measurements time.

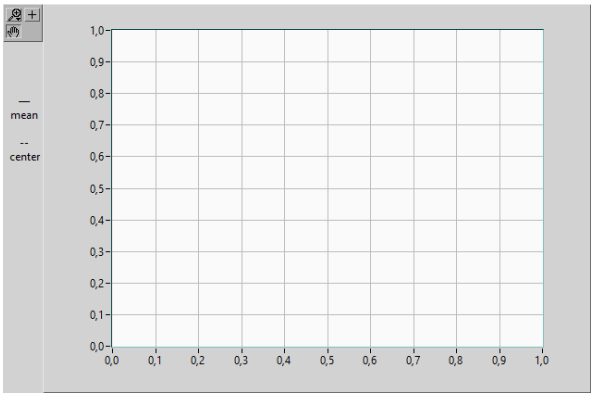

Figure 19: statistics plot

In the table () the results of the statistic evaluation are shown.

Parameter	Units	Number	Mean	Center	Min	Max	Delta	Delta %	Sigma	Sigma %	3 Sigma %

Figure 20: statistics table

The table shows the following statistics parameters:

- Parameter for the values name
- Units for the values unit
- Number for the number n of the specific value
- Mean for expected value μ
- Center für median x_c between maximum and minimum
- Min for minimum value x_{min} of the amount of values
- Max for maximum value x_{max} of the amount of values
- Delta for difference $x_{max} - x_{min}$ between minimum and maximum value
- Delta % for relative difference as $\frac{x_{max}-x_{min}}{x_c} 100\%$
- Sigma for standard deviation σ
- Sigma % for relative standard deviation as $\frac{\sigma}{x_c} 100\%$
- 3 Sigma % triple standard deviation as $3\frac{\sigma}{x_c} 100\%$
- Tolerance for tolerance range
- Tolerance % für relative tolerance range
- Cg and Cgk for capability indexes.

For determination of the capability indexes, three additional parameters are necessary:

RV (reference value), USL (upper specification limit) and LSL (lower specification limit). These parameters are defined with the specific input fields

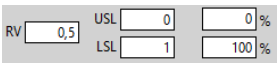

Figure 21: deviation

Instead of absolute values, the ULS- and LSL parameters can also be specified as a percentage relative to RV. This can be done with the input fields marked with the “%” symbol.

The Save button saves the data. The current plot is stored in PNG-format and the table will be saved as ASCII-file in the export folder.

Figure 22: saving statistic evaluation

3.9 Correlation

To determine elusive parameters of solenoids such as stroke and anchor position, the indirect determination with help of a measurable parameter can be used. An indirect evaluation obviously needs a learning phase, where this options are made for. The correlation verifies graphically, whether and how two values are dependent on each other. For a perfect proportional relation between two values their points on the graph are along an oblique line. Two dropdown menus “Parameter x” and “Parameter y”, that contain the current columns of the evaluation table, allow to select the needed parameters. Therefore, “Parameter x” is used as an independend argument for the indirect determination. “Parameter y” is the parameter to be determined. When valid parameters are chosen, the scatter diagram is shown in black and the corresponding polynomial 4^{th} order regression is shown in blue. The field Expression shows the polynomial.

3.10 Protocol

This option allows to create a protocol of the evaluation as a .doc file, that is saved in the export folder. The protocol consists of 8 elements. These elements are: Logo, Title, Text reference, Parameters, Results, Graph, Statistics and Correlation.

The logo is activated, if a valid path to a .png-file named “logo.png” is entered. Using the small right button with the folder-pictogramm, the path can be specified.

The title has the content: „MagHyst® measurement protocol“.

If the input field “Text reference” has content, this will be shown as reference text within the protocol.

The checkbox “Parameters” shows a table with measurement parameters:

Type	=	type of measurement
dt	=	sampling time

Voltage	=	applied voltage for SRM measurement
Ind. Voltage	=	induced voltage for QSM measurement
Max. Current	=	maximum current
Min. Current	=	minimum current for QSM measurement
Shunt Resistance	=	Shunt resistance
Bridge Eql. Volt.	=	voltage for bridge balancing
Bridge Eql. Time	=	delay for bridge balancing

Parameter	Value
Type	srm
dt in µs	100
Voltage in V	24
Max. Current in A	2

Figure 23: measurement parameter table

A parameter is only shown as a row within the parameter table if it is equal for all measurements. If for instance all measurements are SRM, a row Type: srm will be shown in the parameter table. The appropriate column “Type” will therefore be deleted from the measurement result table.

The checkbox “Results” activates the table with measurement and evaluation results. If checkbox “all” is activated, all columns of the table are displayed. Using the dropdown menu “columns”, the desired data can be selected. The “+” button ads another column to the dropdown menu. When the dropdown menu “columns” is used, the checkbox “all” will be disabled.

Checkbox “graph” activates the option to save the current plots within the protocol.

Checkbox “Correlation” allows to display the correlation results as coefficients in tabular style, the polynomial and the correlation graph.

If data for some parts of the protocol is not available, the appropriate control elements are disabled and greyed out.

3.11 Table

The table area allows to choose, sort and save the tabular items. Each row within the table is a measurement. Additional features for the color definition of the displayed curves are available.

Clicking < or > maximized or scales the table.

Highlighting measurements can be done by clicking on it in the table or by the text pattern given in the search field. Each change within the search field updates the highlighted measurements.

DEL-button deletes the highlighted measurements, SHIFT+DEL deletes all NOT selected measurements.

Clicking the header of a column sorts the data ascending by their content.

The save button (figure 23) saves the table data as ascii file. The individual values are separated by “TAB”, so that it is easy to import the data to Excel, Matlab etc.

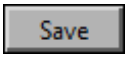

Figure 24: Save button