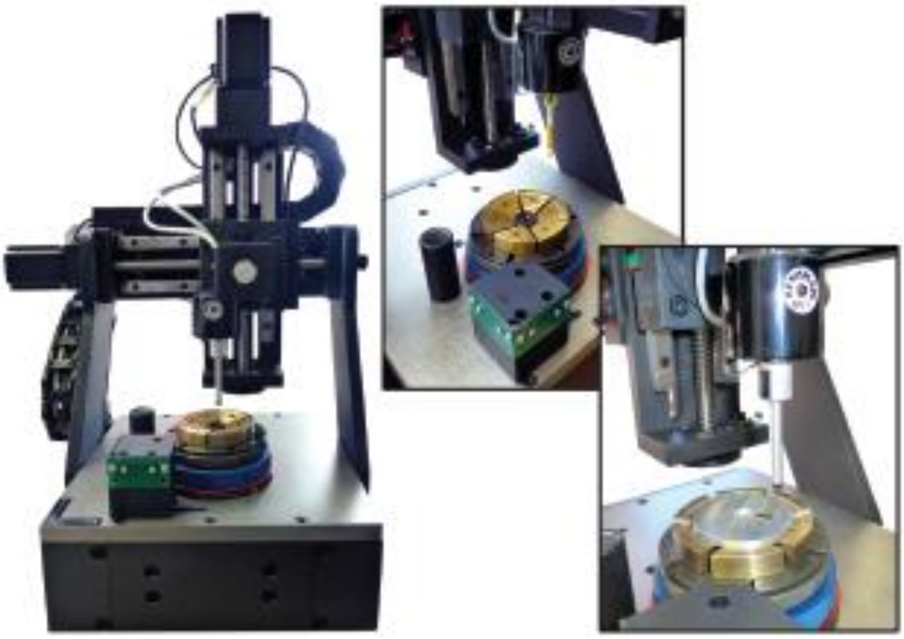
SENIS
magnetic & current measurement

# Magnetic Field Mapper
## MMS-1A-RS

Software Version: MMS-A_V2.1

# Operating Manual



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# SAFETY PRECAUTIONS:

- ! Do not connect the device to any power source other than the one specified in this document;
- ! If you discover any abnormalities while checking the device, before operation or during operation, stop using the device immediately;
- ! Do not disassemble or modify the device. Only manufacturer approved technicians are allowed to repair, disassembly and perform device modifications;
- ! Remove the power plug prior to carrying out device maintenance and/or device checks;
- ! Do not use any cables other than the ones specified in this document;
- ! Do not subject the device to impacts;
- ! Keep the top of the device and interior of the protective cabinet clear of all foreign objects; only magnets under the test are allowed inside of the cabinet;
- ! Use device in a place where it can be maintained in the horizontal position;
- ! When moving the device, first lift it and then carry it; do not move the device by pulling the cables;
- ! When removing the plug, hold and pull the plug itself; do not remove it by pulling the cable;
- ! Do not apply undue force to plugs, cables or the sensor;
- ! Do not unplug any cables while measurement is in progress; always stop the program prior to unplugging the cables;
- ! Do not touch the system or magnet under the test during the measurement;
- ! Do not use abrasive means for cleaning the scanning surface;
- ! The PC cards must not be removed or the hardware drivers uninstalled. Always consult manufacturer before attempting to install devices.

# 1. INTRODUCTION

Magnetic Field Mapper MMS-1A-RS is the high-end version of the SENIS Magnetic Field Mapping Systems. It allows users to perform a fast, high resolution mapping of magnetic flux density around an electromagnet or permanent magnet. The map of the magnetic field can be presented in the form of color coded 2D or 3D isometric visual display. Measured data are analyzed in real-time, which provides data analysis capabilities for an advanced inspection, characterization and quality control of permanent magnets.

Due to unique features of the applied fully integrated 3-axis Hall probe (single Si-chip), all three components of the magnetic field (Bx, By, Bz) are measured simultaneously at virtually same point. The magnetic field sensitive area of the applied Hall probes is within a 150µm x 150µm square, which allows measurements of the homogeneous and non-homogeneous magnetic fields. The mapping system is controlled by an extremely easy-to-use-software, built on MS Windows platform and LabVIEW. Magnet scanning profiles are fully customizable.

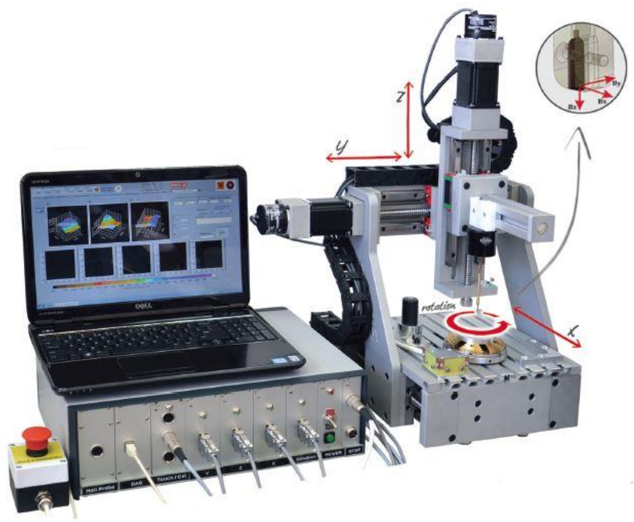


*Fig. 1 – Magnetic Field Mapping System*

# 2. GENERAL DESCRIPTION

## 2.1 OVERVIEW

MMS-1A-RS is fully computer controlled magnetic field scanner. It allows motion in all four axes simultaneously (X-, Y-, Z-direction and rotation). The three-axis Hall probe measures magnetic field flux around the magnet and provide the measured data for data visualization and analysis in the Mapper software or exports the measured data for further customers offline analysis.

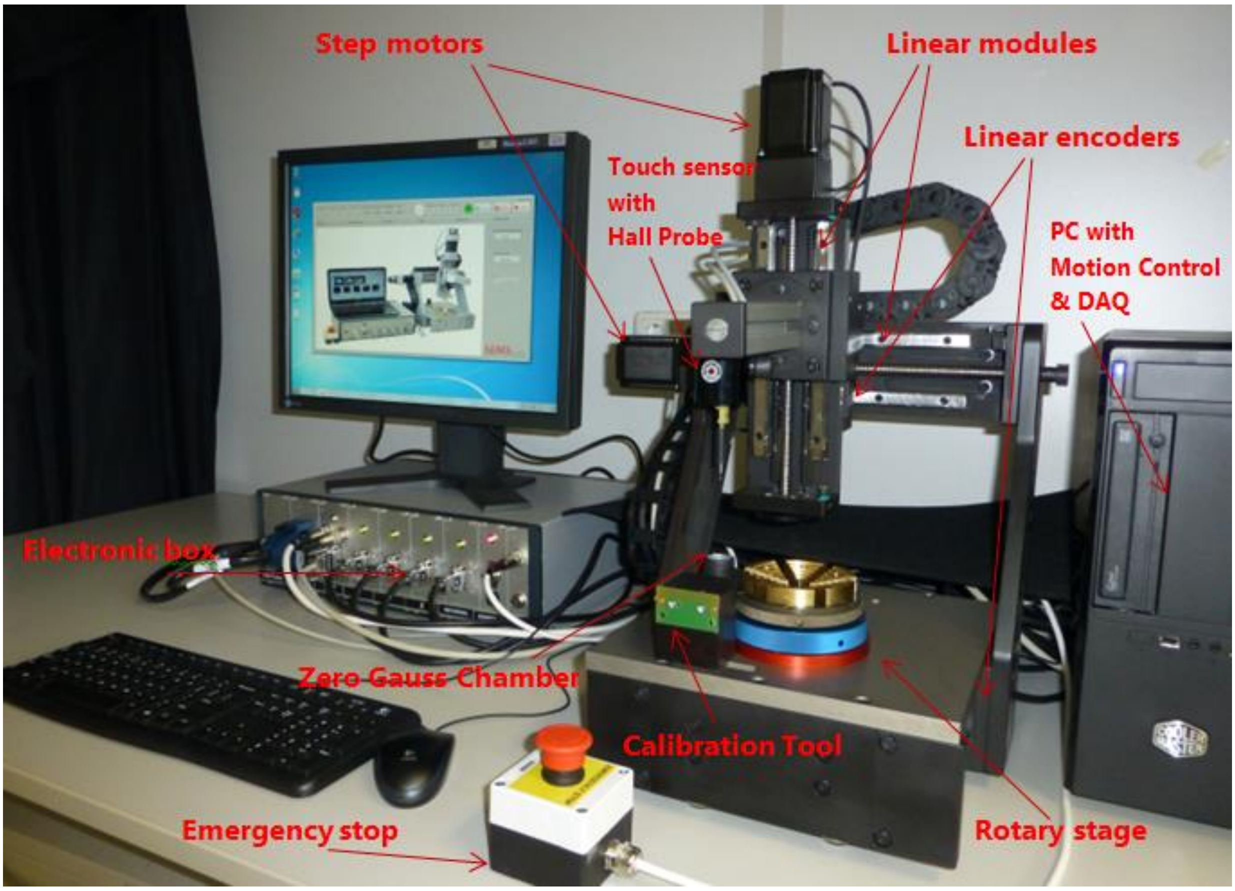



*Fig. 2. – MMS-1A-RS consisting parts*

The MMS-1A-RS Magnetic Field Mapper consists of the three main parts:

1. A SENIS **high-resolution magnetic-field-to-voltage transducer** (in short: magnetic transducer), which consists of one **tree-axis Hall probes and an electronic module** for analog signal processing that also provides the interface to the data acquisition and visualization system. The Hall probe and its corresponding electronic module build the magnetic field transducer unit.

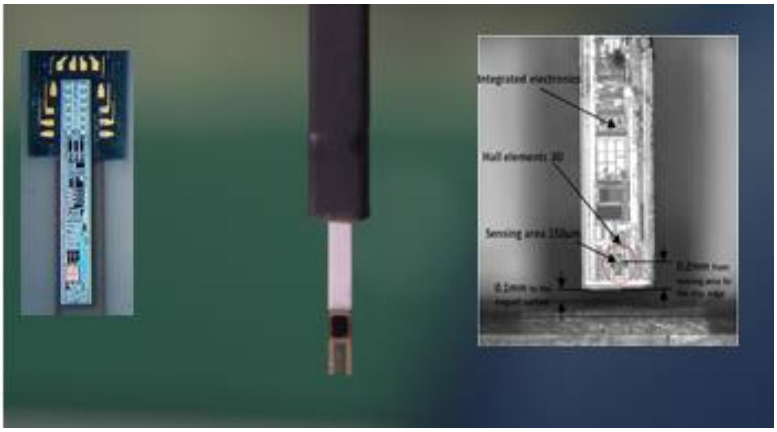


*Fig. 3 – SENIS' integrated Hall Probe; left and right- Photos of the Si-chip*

The magnetic transducer is enclosed into an electronic box that also houses the power supply, step motor drivers, encoder electronics, touch sensor control and current supply for calibration tools.


*Fig. 4 – Electronic Box*

The Hall probe is mounted on a touch sensor (tactile sensor), that reacts whenever the probe touches an object. This feature provides an effective protection from the probe mechanical damage (motion is stopped as soon as touch sensor reacts); it also allows an absolute magnet positioning; and touch sensor can be, in combination with an optional stylus, used for the dimensional measurement of objects under tests, transforming in that case the magnetic field mapper into easy-to-use coordinate measuring machine (CMM). The touch sensor has a robust design and an adjustable probe force (over-travel range is several mm) to help optimize its performance.


*Fig. 5 – Touch Sensor with Hall probe mounted on it*

The MMS-1A-RS is also equipped with an Emergency Stop taster (as safety equipment) that, when activated, breaks the power supply for the motor drivers.

*Fig. 6 – Emergency Stop taster*

2. **Mechanical Probe Positioning System or Cartesian Moving Platform** (CMP) for automatic positioning of the Hall probe at desired locations around the customer's magnet assembly that needs to be measured. The CMP consists of three linear modules driven by step motors and controlled through the high-resolution linear encoders.

*Fig. 7 – Mechanical Probe Positioning System or Cartesian Movin Platform*

Applied encoders help determine the exact position of the probe and help eliminate mechanical transfer elements, such as bearings.

*Fig. 8- Linear Encoders mounted on each linear module*

The rotary stage is positioned on the mapper base table. It is driven by a step motor and controlled through the incremental rotary encoder. A non-magnetic multi-jaw scroll chuck is mounted on the rotary stage as a very precise magnet holder.

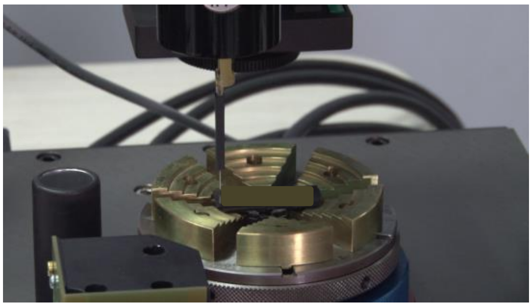


*Fig. 9 – Rotary stage with the multi-jaw scroll chuck*

A Tool for the in-filed calibration of the Hall probe's magnetic field sensitive area position is mounted on the mapper base table. This calibration tool consists of two mutually orthogonal PCBs with a current carrying conductor. The calibration is achieved by measuring the well-defined magnetic field above the current conductor. The two PCBs are fixed on a mechanically well-defined cube, providing for a precise holder for rectangular-form magnets.

A Zero Gauss Chamber (ZGC) for Hall probe offset canceling is mounted on the mapper table. It also serves as the Probe Home Position.

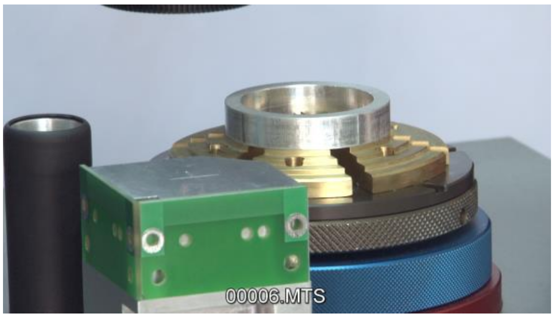



*Fig. 10 – Field Sensitive Volume Calibration tool and Zero Gauss Chamber*

The boundary mechanical switches protect the mechanical parts (linear module) from damage (motion on-off switches for over-travel prevention).

3. A customized **data acquisition and digital processing system** that triggers the magnetic field measurement at desired location, converts the analog signals of the Hall probe into digital numbers, combines these numbers with the appropriate position coordinates, and provides the consolidated function Magnetic Field Vector = function of the Probe coordinates for further visualization, analysis and reports. The mapping system is controlled by a Computer (PC) that includes the Motion Control (NI 73xx), which controls the motor drivers for all three mechanical axes and for the rotary stage; and DAQ (NI 62xx) that receives data from magnetic transducer.

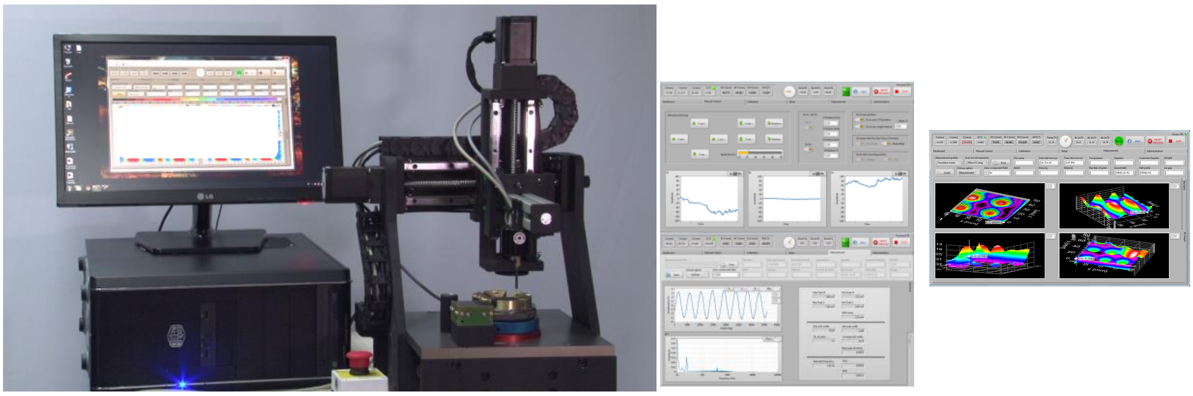


*Fig. 11 – Computer with the mapper software running on it*

Motion Control provides a simultaneous control of all four axes and allows the definition of complex scanning paths (circles, 3D contouring, etc.). A direct synchronization (position vs. measured magnetic field) between Motion Control and NI DAQ is provided through the on-board real-time system integration bus.

Several calibration algorithms are implemented in the mapper software (calibration of the field sensitive volume, of rotation axis, of homogeneity, etc.).

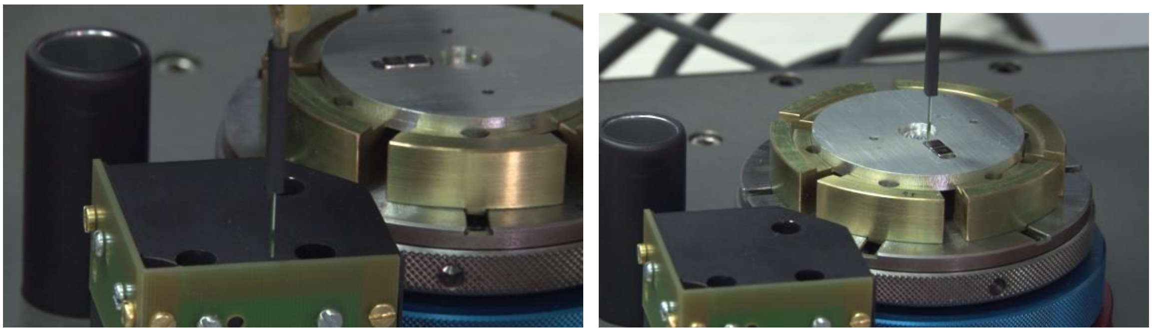


*Fig. 12 – Mapper Calibration Tools*

## 2.2 KEY FEATURES AND APPLICATIONS

The Magnetic Field Scanner MMS-1A-RS offers:

- Scanning volume (X x Y x Z):
  - standard: 135 x 135 x 135 $mm^3$
  - optional: up to 500 x 500 x 500 $mm^3$
- Scanning speed: adjustable, up to 100 mm/s
- Linear encoders with the zero point detection for X-, Y and Z-linear modules (2µm resolution)
- Scanning spatial resolution for linear modules: down to ±2µm
- Point-to-point and continuous (on-the-fly) magnetic field scanning
- Absolute magnet positioning utilizing Touch Sensor
- Rotary stage with the encoder (±0.022° resolution) and zero position detection
- Multi-jaw scroll chuck as a precise magnet holder
- 3-axis fully integrated CMOS Hall probe (Bx, By, Bz) with the spatial resolution (By: 0.02 x 0.005 x 0.02$mm^3$; Bx & Bz: 0.14 x 0.01 x 0.14 $mm^3$); high angular accuracy (0.1° calibrated). Hall probe has virtually no planar effect. An integrated temperature sensor is used for an effective temperature compensation of the probe.
- Up to 3 selectable magnetic field measurement ranges (100mT, 500mT, 2'000mT)
- Accuracy of magnetic field measurement: better than 0.1%
- Magnetic field measurement resolution: 50µm at 100mm/s, 5µm at 10mm/s, 1µm at 2mm/s
- Measurement sampling rate 30kSamples/s (3-axis Hall probe and temperature)
- Calibration of the probe's sensitive area
- DC and AC field measurements from DC to 2.5kHz (-3dB point); optional: up to 25kHz for 3-axis probe and 75 kHz for 1-axis probe

The user-friendly software, based on LabVIEW on MS Windows platform, offers the following features:

- Color coded 2D and 3D isometric representation of the magnetic field
- User defined scanning paths, scanning resolution and movement speed
- Command editor for scanning path definition
- Automatic color coding of magnetic field with appropriate legend
- Zoom and rotate of 2D and 3D images
- Magnetic field and magnetic angle measurement presentation
- Movable cursor displaying X and Y coordinate and magnetic flux density value
- Report generation (PDF and txt files)
- Measurement range selection
- Dimensional measurement
- Calibration mode
- Setup mode
- Probe positioning via mouse and via keyboard
- Operator and Administrator permissions
- Probe returns to the start measuring point after the full scan is performed

The magnetic Field Mapper MMS-1A-RS can be efficiently applied for:

- DC and AC magnetic field measurement of all three components (3-axis) of the magnetic field
- Quality assessment tool in production lines for permanent magnets used for sensors in automotive industry, consumer electronics industry, energy monitoring, etc. (pass/fail analysis with defined tolerances)
- Powerful testing tool for the development of magnet systems in research laboratories
- Magnetic field mapping around small simple magnets or multi-pole magnets
- Magnetic field peak and zero value detection of magnetic encoders or code-plates as well as magnetic poles counting
- Magnetic field homogeneity (magnetic angle) measurement
- Statistical analysis of measured data (import/export measured data, images and reports)
- OPTION: Dimensional measurement of objects under test (CMM)
- OPTION: Cracks and inhomogeneity detection in magnetic materials (also non-magnetized)
- Magnetic field mapping of electronic circuit PCB’s (such as smartphones, tablets, etc.)

## 2.3 MAPPER SOFTWARE DESIGN

The LabVIEW modular software of the MMS-1A-RS is implemented as a four-tier (layer) structure (hardware control layer, software logic layer, presentation layer – graphical user interface and utilities). The Motion Control software module is autonomous and fully separated from the magnetic field measurement algorithms.

The software is fully parameterized – all measurement algorithms and scanning paths are fully customizable. Novel calibration routines and measurement algorithms are implemented. Software and hardware diagnostics is implemented for testability and maintainability.

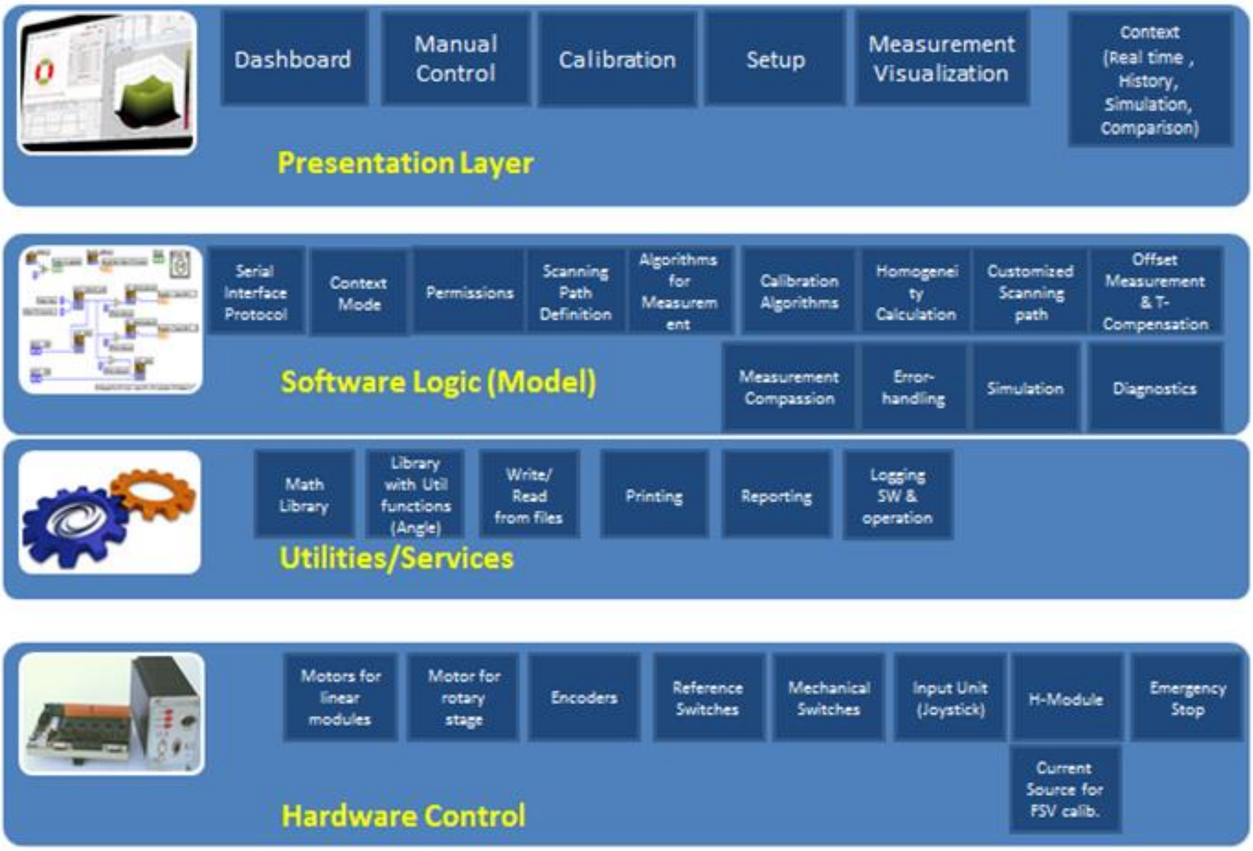



*Fig. 13 – Four-Layer Modular Software Design*

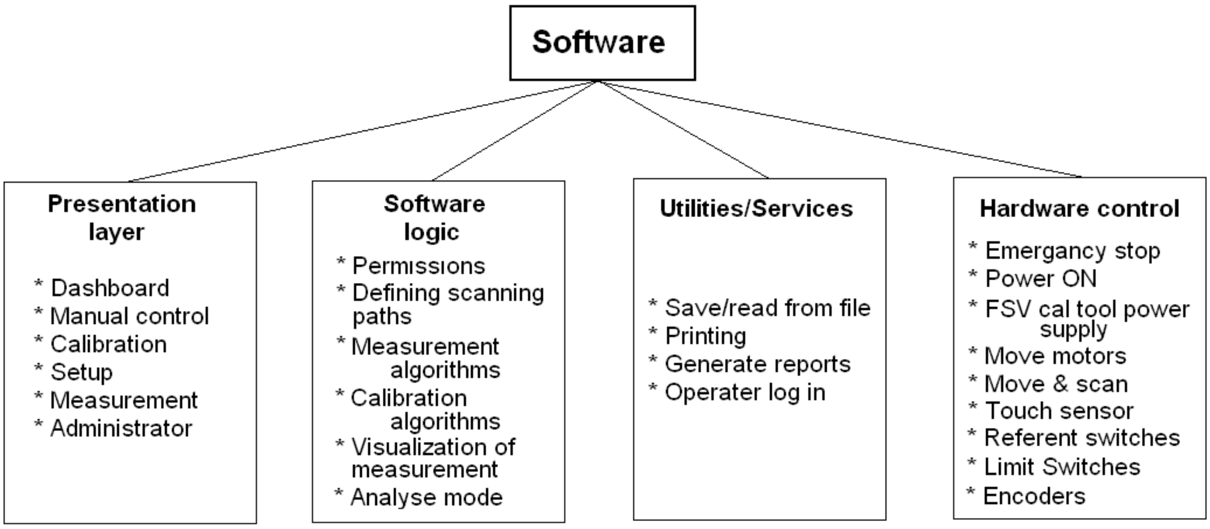



*Fig. 14 – Mapper Software Block Diagram*

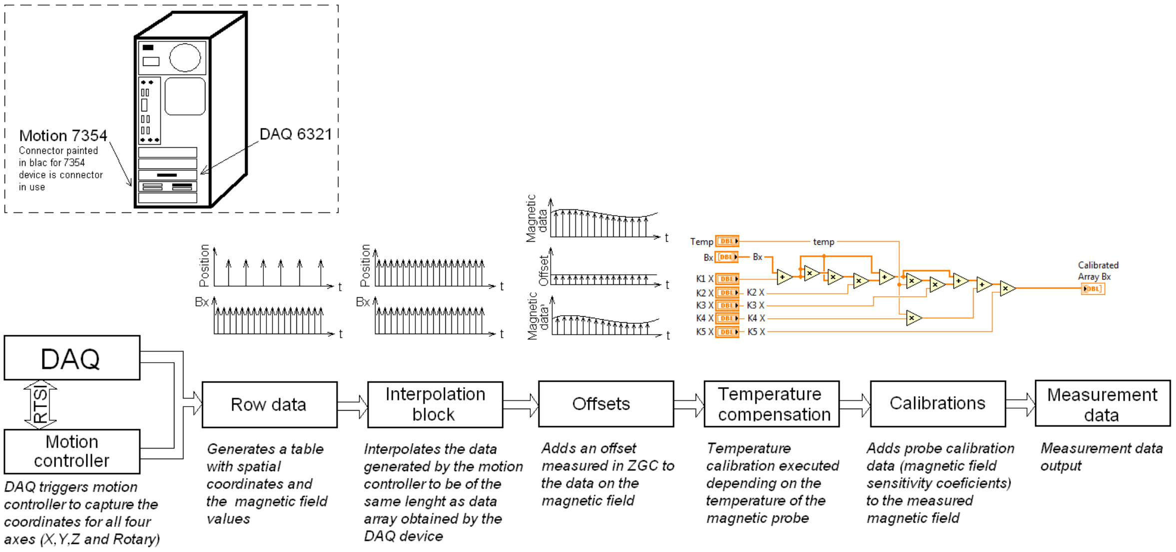



*Fig. 15 – Mapper Software Data Flow*

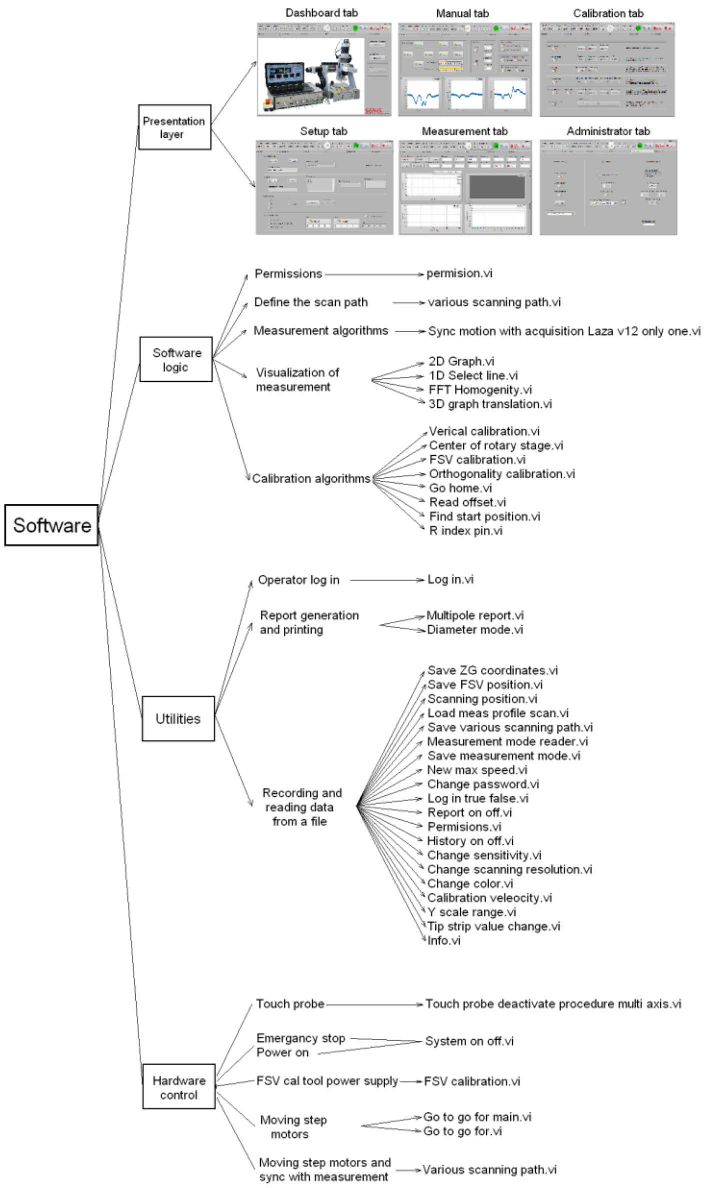



*Fig. 16 – Mapper Software Modules*

## 2.4 FOLDERS AND FILES

The Mapper program files, calibration and measurement data are organized in a directory structure, which helps an intuitive software usage. SENIS provides following folder structure on each delivered configuration.

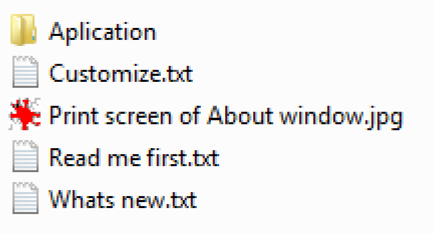



*Fig. 17 – Mapper Software Folder Structure – All executables are stored under Application folder, which can be stored enyrywhere in the customers directory structure*

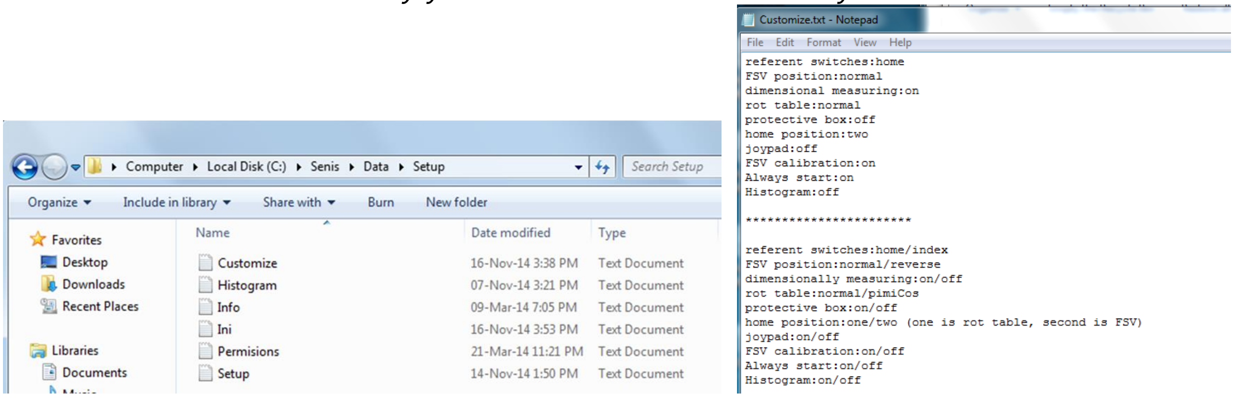



*Fig. 18 – Customize.txt file (located in the Setup folder) contains data that describe customers mapper configuration. The customizing includes the special rotary stages, protective box, special measurements, etc.*

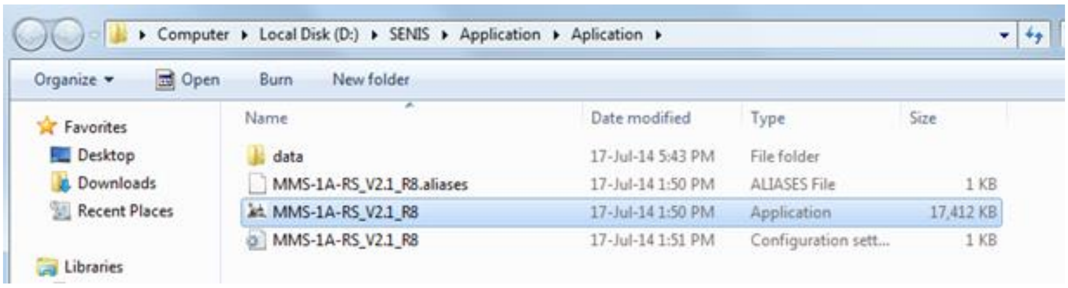



*Fig. 19 – Executable file (example only)*

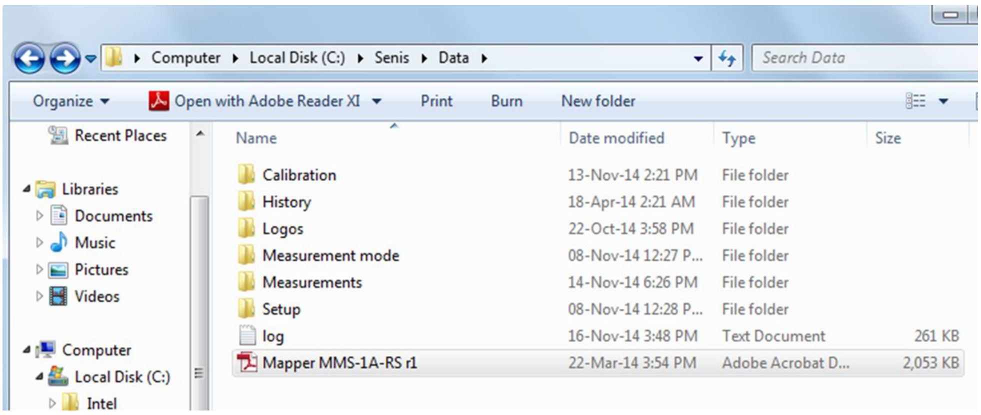



*Fig. 20 – Measurement and & Calibration data are stored under data folder*

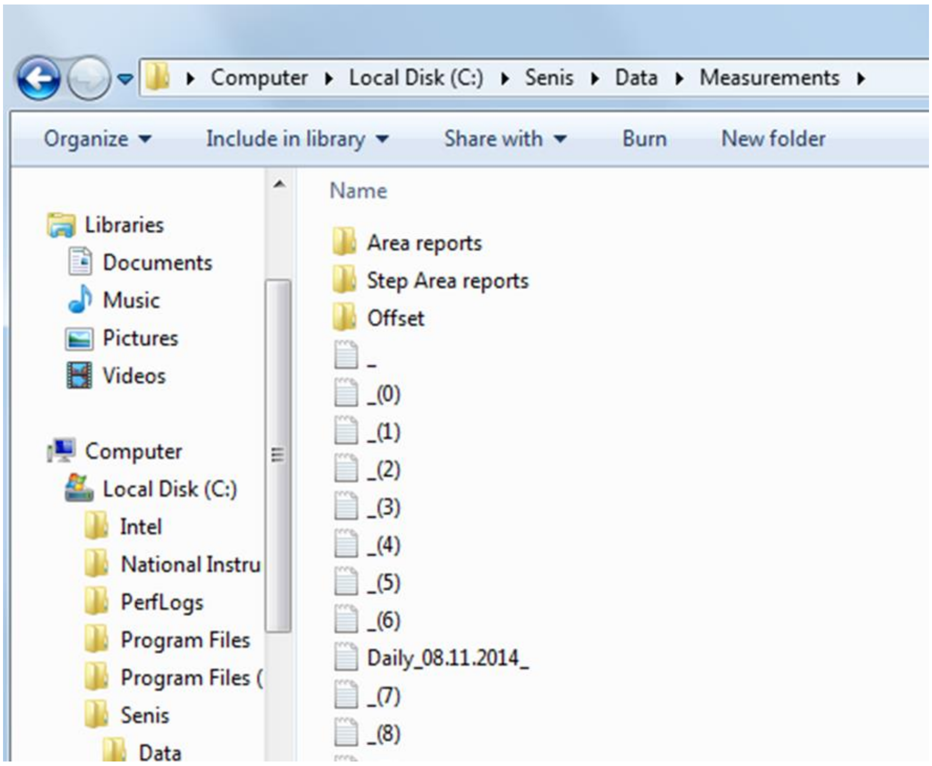
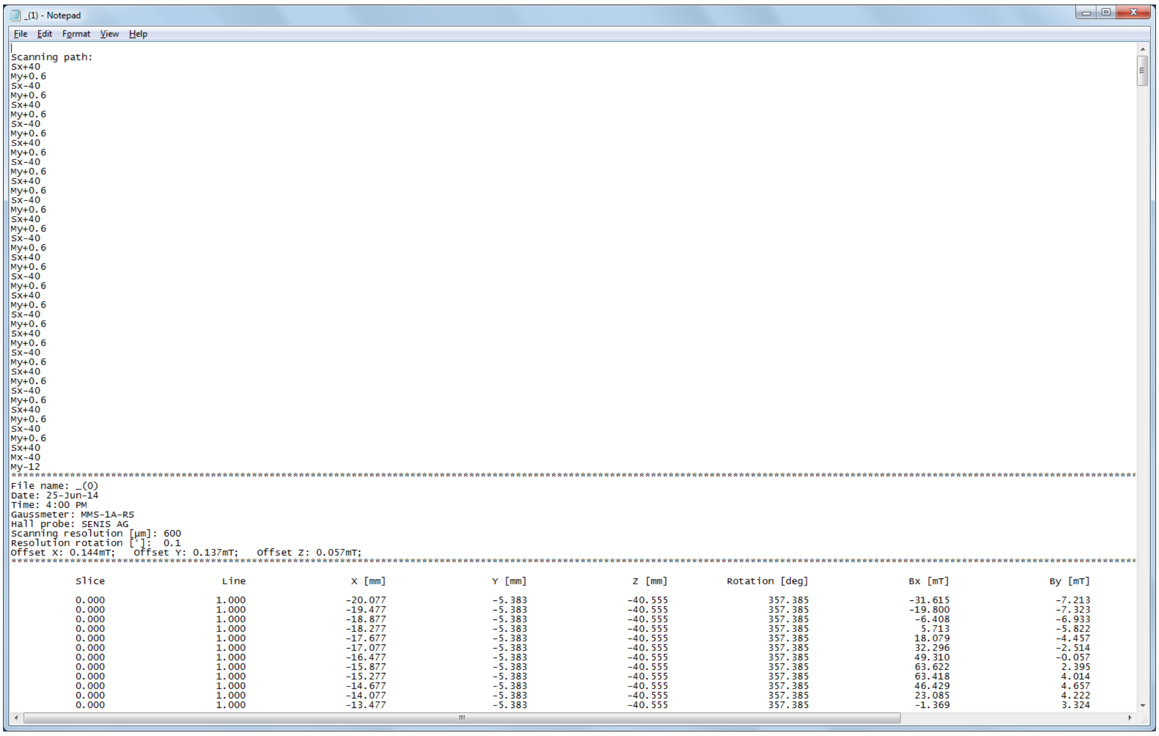



*Fig. 21 – Measurement data in the Measurements folder*



_(1) - Notepad

File Edit Format View Help

```
Scanning path:
Sx+40
My+0.6
Sx-40
My+0.6
Sx+40
My+0.6
Sx-40
My+0.6
Sx+40
My+0.6
Sx-40
My+0.6
Sx+40
My+0.6
Sx-40
My+0.6
Sx+40
My+0.6
Sx-40
My+0.6
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My+0.6
Sx-40
My+0.6
Sx+40
My+0.6
Sx-40
My+0.6
Sx+40
Mx-40
My-12
****************************************************************************************************
File name: _(0)
Date: 25-Jun-14
Time: 4:00 PM
Gaussmeter: MMS-1A-RS
Hall probe: SENIS AG
Scanning resolution [µm]: 600
Resolution rotation [°]:  0.1
Offset X: 0.144mT;   Offset Y: 0.137mT;   Offset Z: 0.057mT;
****************************************************************************************************
```

| Slice | Line | X [mm] | Y [mm] | Z [mm] | Rotation [deg] | Bx [mT] | By [mT] |
|---|---|---|---|---|---|---|---|
| 0.000 | 1.000 | -20.077 | -5.383 | -40.555 | 357.385 | -31.615 | -7.213 |
| 0.000 | 1.000 | -19.477 | -5.383 | -40.555 | 357.385 | -19.800 | -7.323 |
| 0.000 | 1.000 | -18.877 | -5.383 | -40.555 | 357.385 | -6.408 | -6.933 |
| 0.000 | 1.000 | -18.277 | -5.383 | -40.555 | 357.385 | 5.713 | -5.822 |
| 0.000 | 1.000 | -17.677 | -5.383 | -40.555 | 357.385 | 18.079 | -4.457 |
| 0.000 | 1.000 | -17.077 | -5.383 | -40.555 | 357.385 | 32.296 | -2.514 |
| 0.000 | 1.000 | -16.477 | -5.383 | -40.555 | 357.385 | 49.310 | -0.057 |
| 0.000 | 1.000 | -15.877 | -5.383 | -40.555 | 357.385 | 63.622 | 2.395 |
| 0.000 | 1.000 | -15.277 | -5.383 | -40.555 | 357.385 | 63.418 | 4.014 |
| 0.000 | 1.000 | -14.677 | -5.383 | -40.555 | 357.385 | 46.429 | 4.657 |
| 0.000 | 1.000 | -14.077 | -5.383 | -40.555 | 357.385 | 23.085 | 4.222 |
| 0.000 | 1.000 | -13.477 | -5.383 | -40.555 | 357.385 | -1.369 | 3.324 |

*Fig. 22 – Example of a measurement file (scanning path in the header and then Bx, By and Bz with the correponding spatial coordinates*

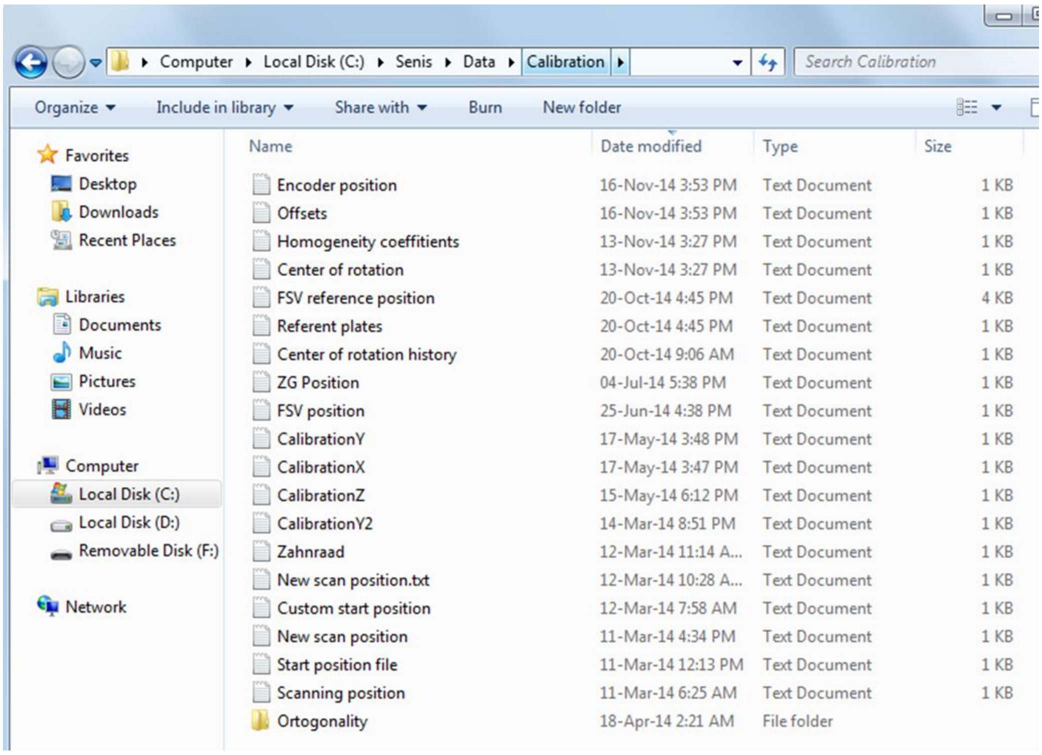



*Fig. 23 – Calibration data in Calibration folder*

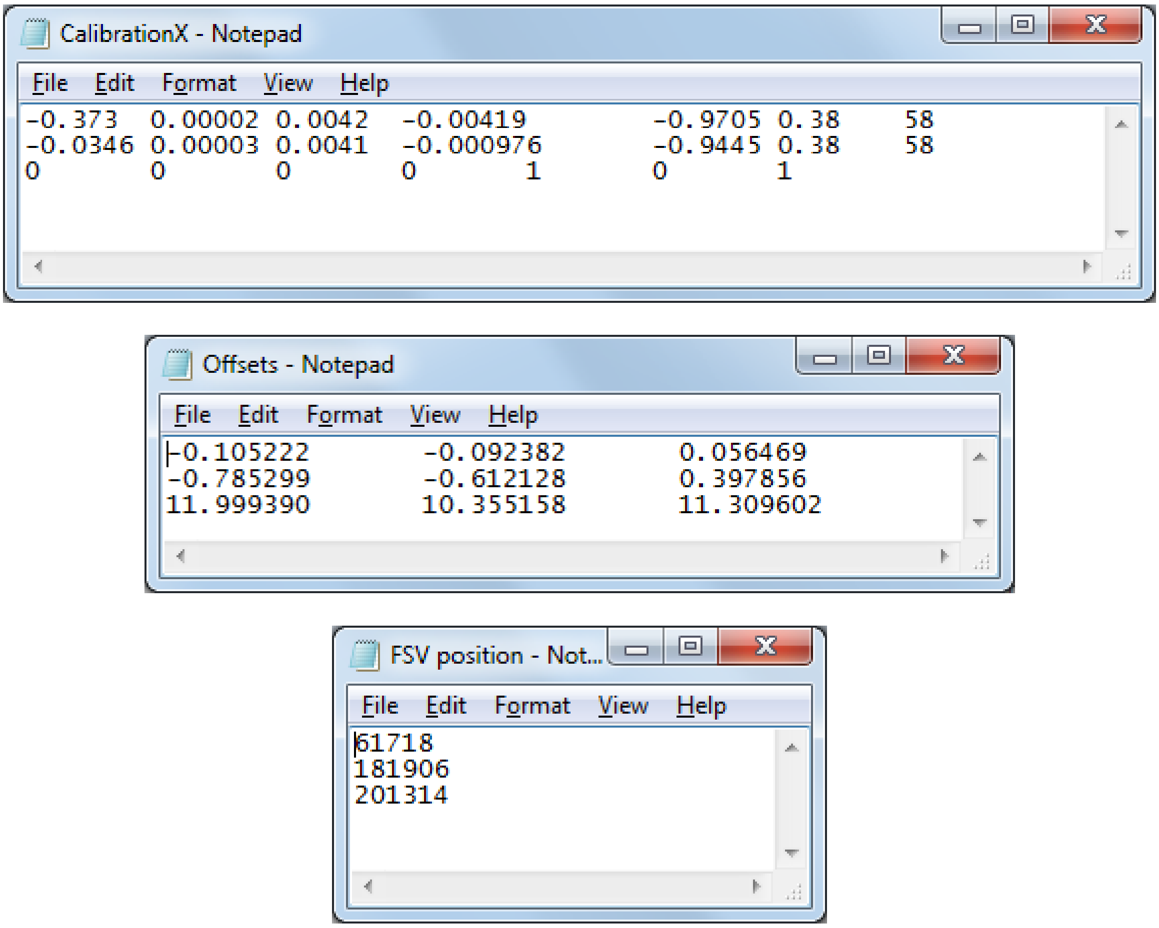



*Fig. 24 – Exapmples of calibration files*

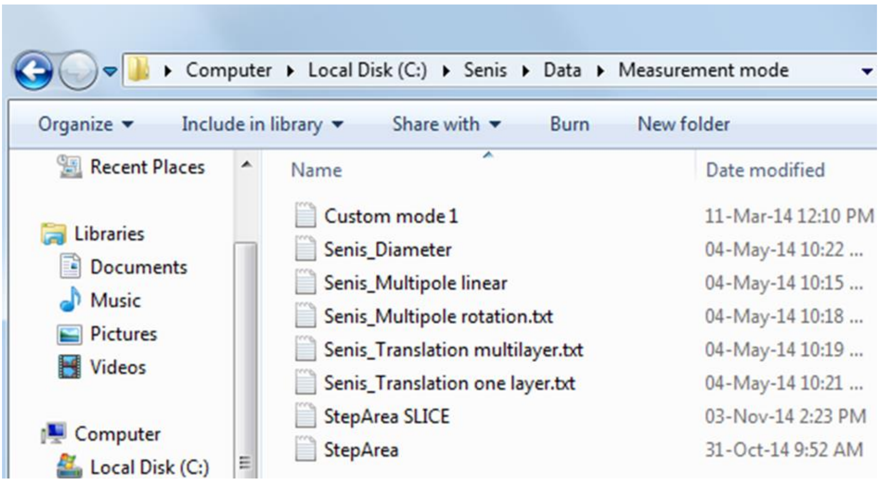



*Fig. 25 – Scaning paths and measurement profiles are stored under Measurement mode folder*

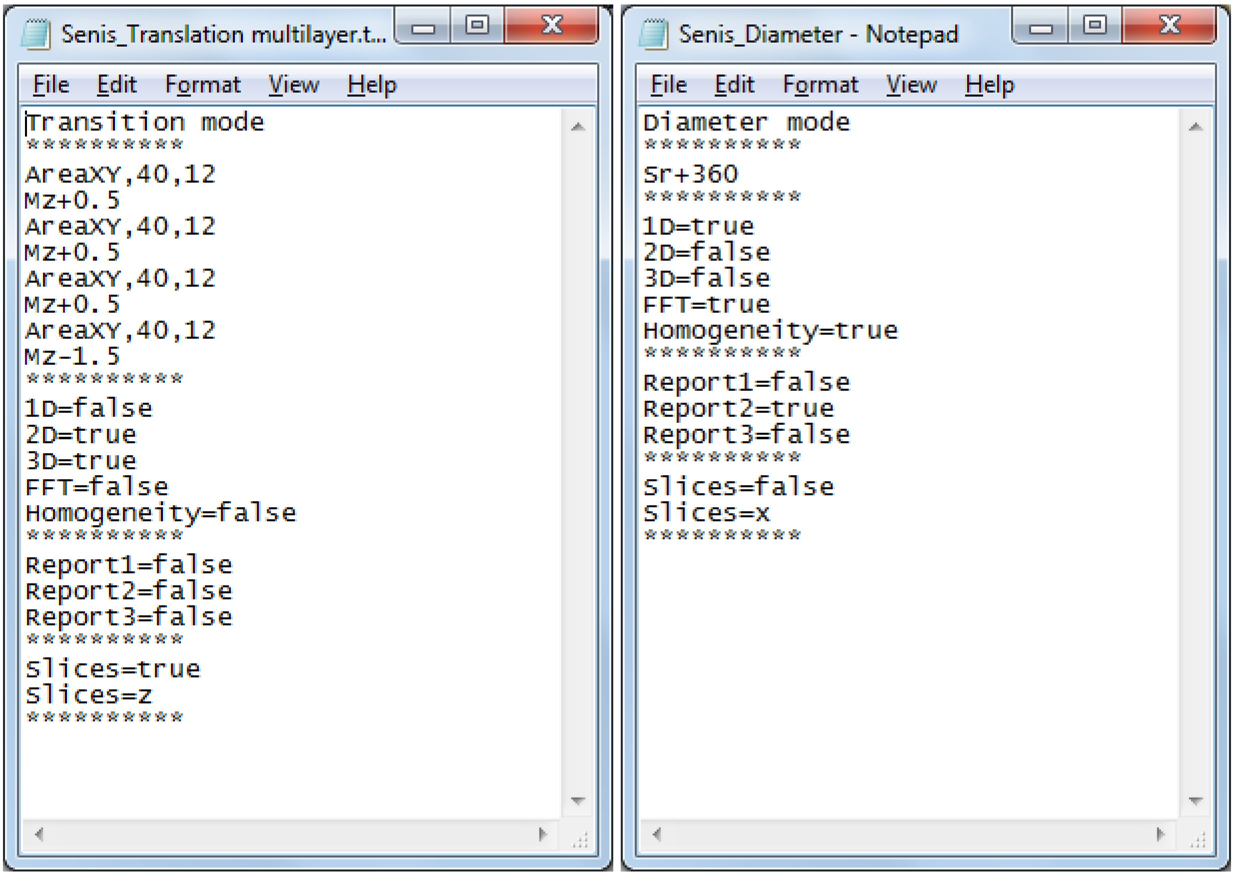



*Fig. 26 – Examples of measurement profile files*

## 2.5 CONNECTION DIAGRAMS

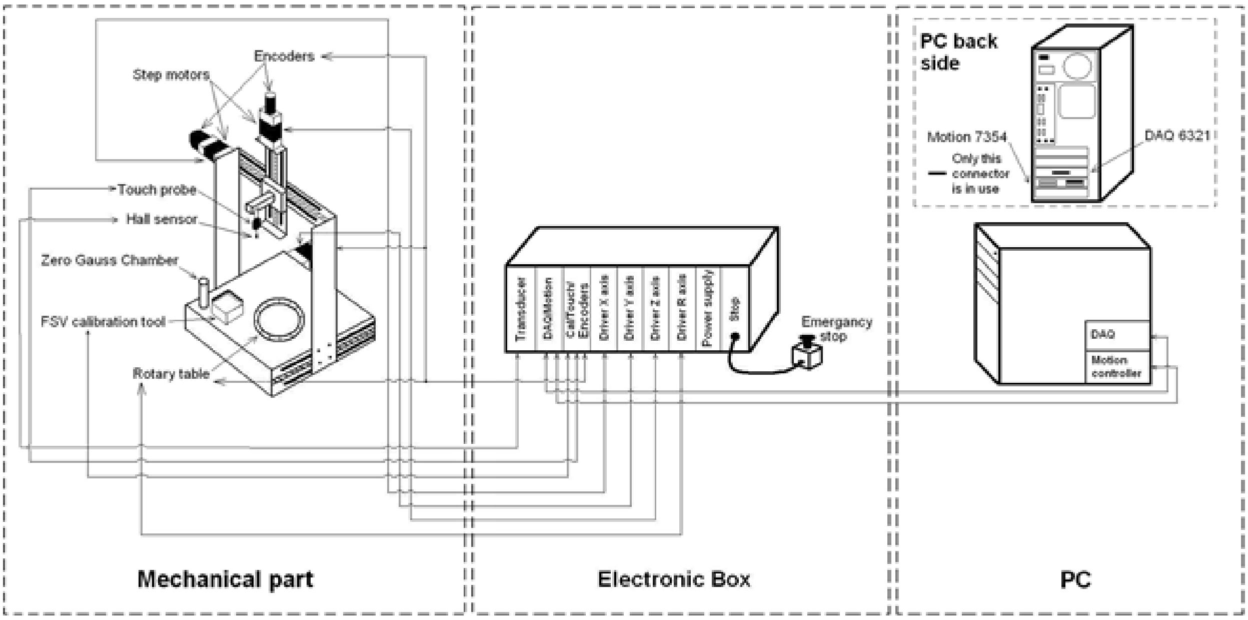



*Fig. 27 – Connection Diagram – Overview*

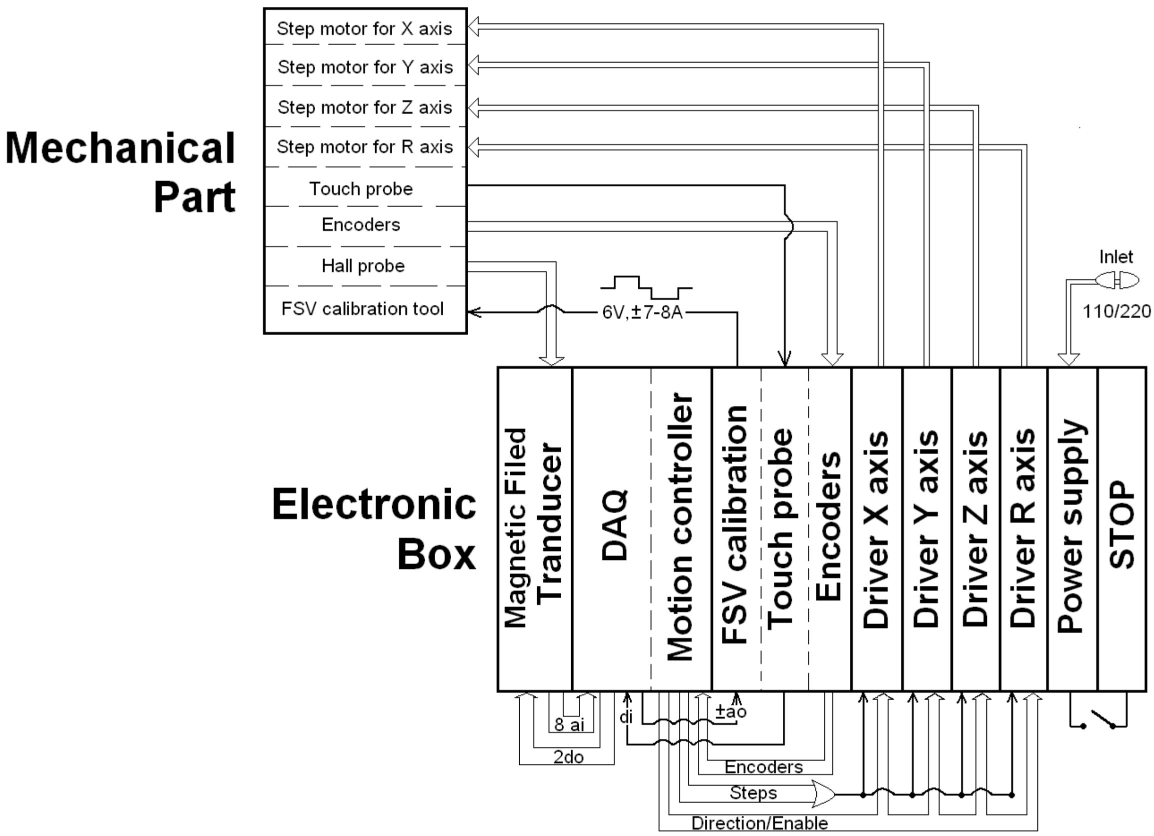



*Fig. 28 – Connection Diagram – Electronic Box*

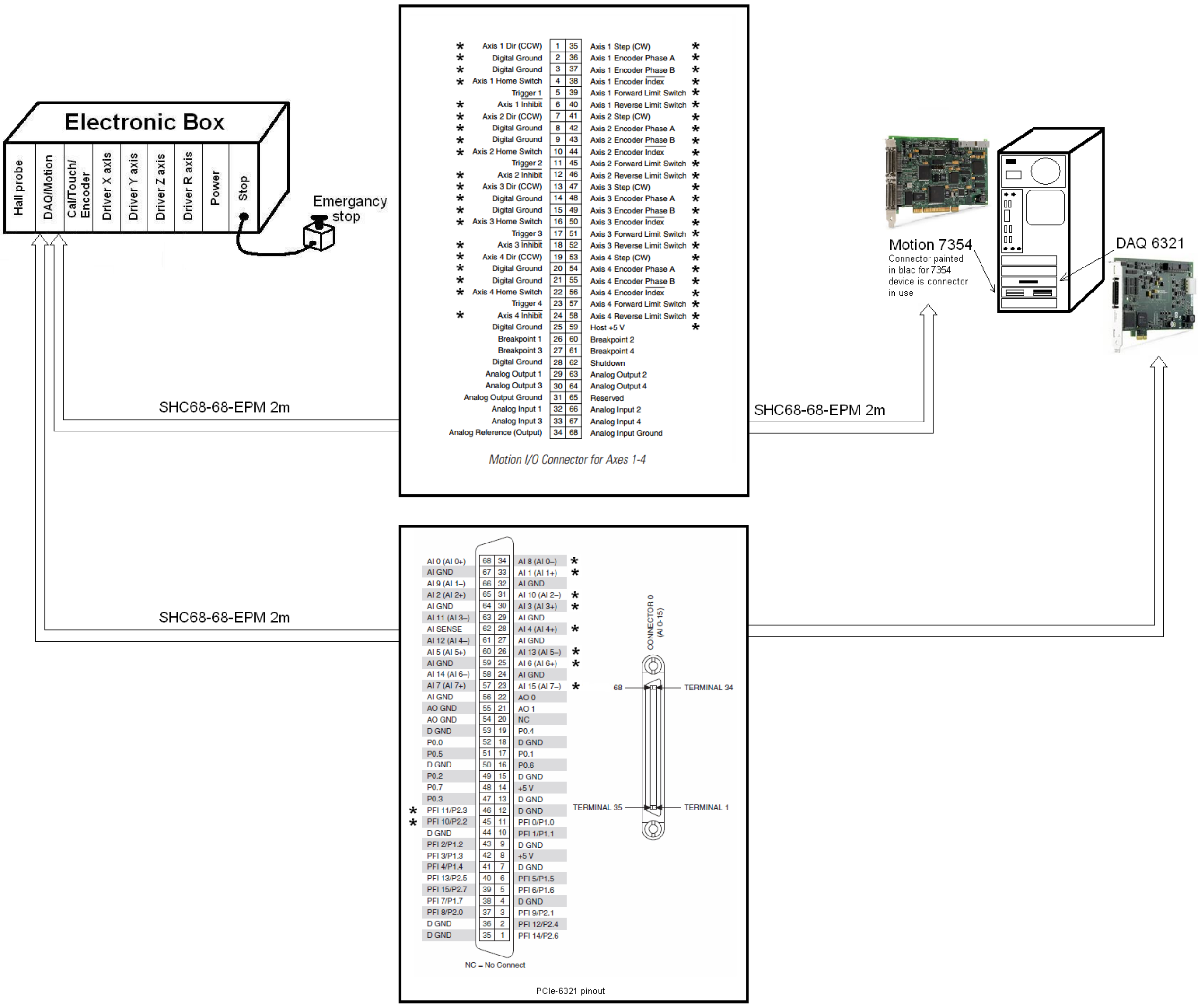



*Fig. 29 – Connection Diagram – Motion Control and DAQ*

# 3. PREPARATION FOR USE

## 3.1 UNPACKING GUIDE / DEVICE UNBLOCKING

### 3.1.1. Unpacking Procedure

It is highly recommended that the system unpacking and setup is performed by a certified SENIS AG engineer. If this is not the case, SENIS AG cannot be held responsible for any system malfunction or damage.

The process of unpacking the Mapper is described on the following figures.
Please take care when turning the machine in order not to damage the cables, switches or other Mapper parts. Since the Hall Probe is fragile, special care must be taken for any handling closed to the measuring probe and its holder.


*Fig. 30 – The mapper is delivered in a sutable wooden box*

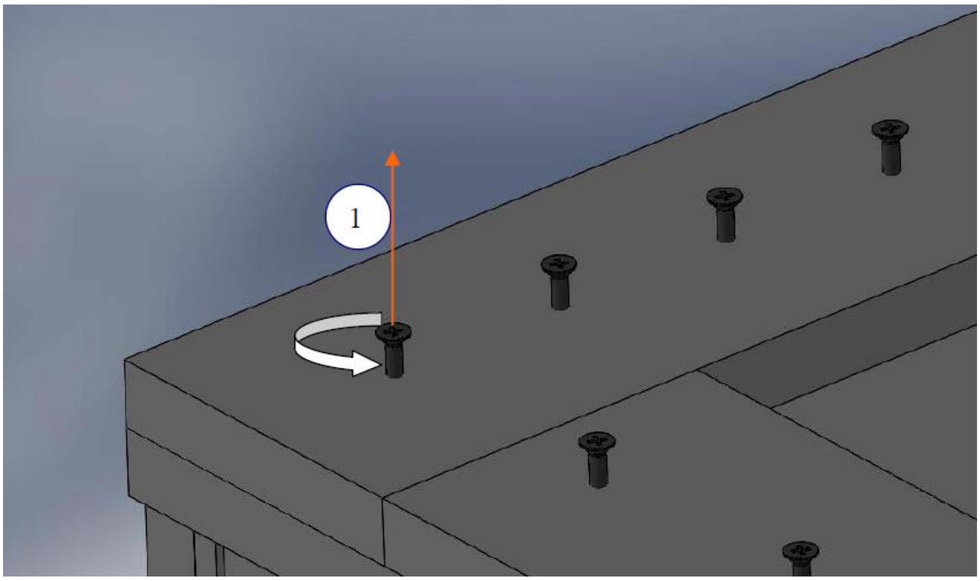



*Fig. 31 - Unscrew the top cover of the box*

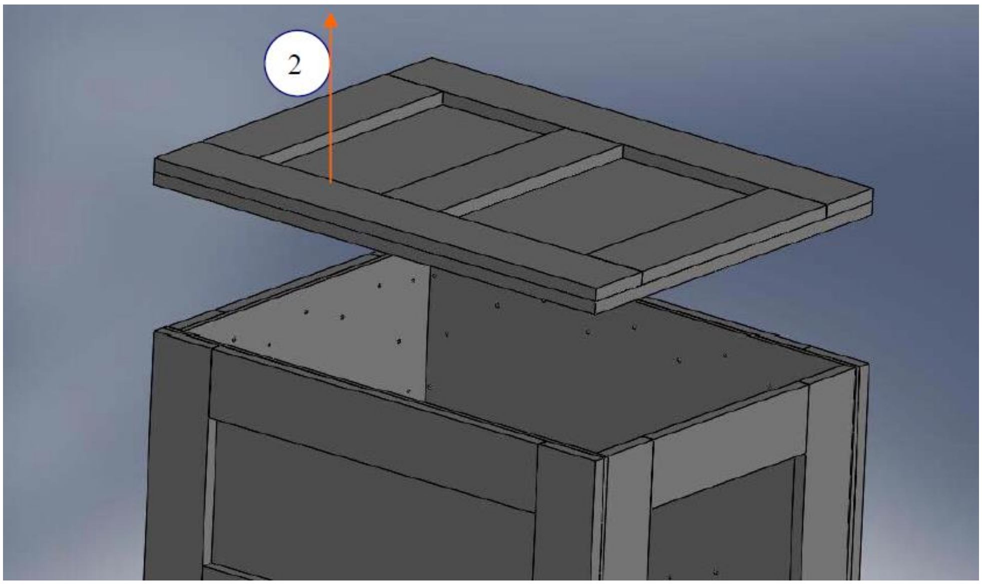



*Fig. 32 – Remove the cover*

*Fig. 33 – Mapper System packed in the wooden box (the photo is only an example)*

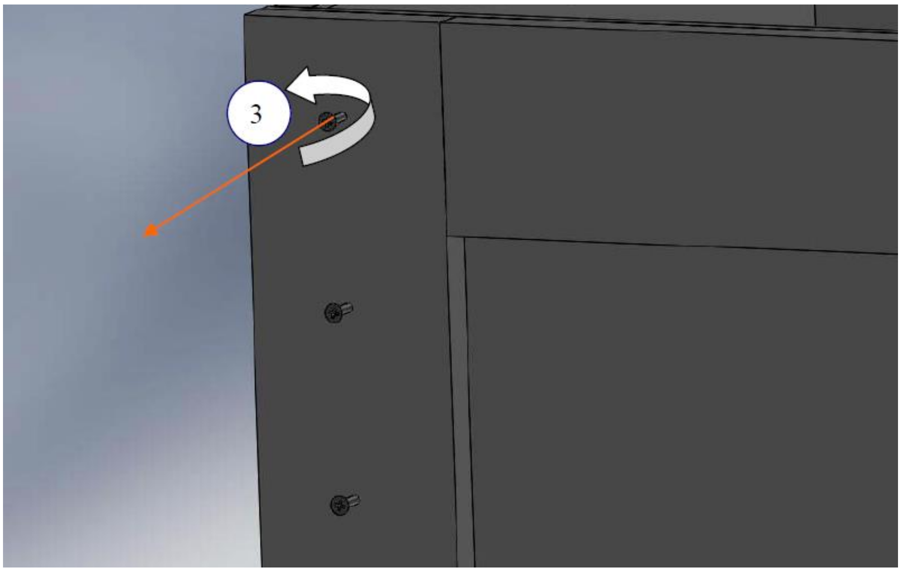



*Fig. 34 – Unscrew the frot side of the box*

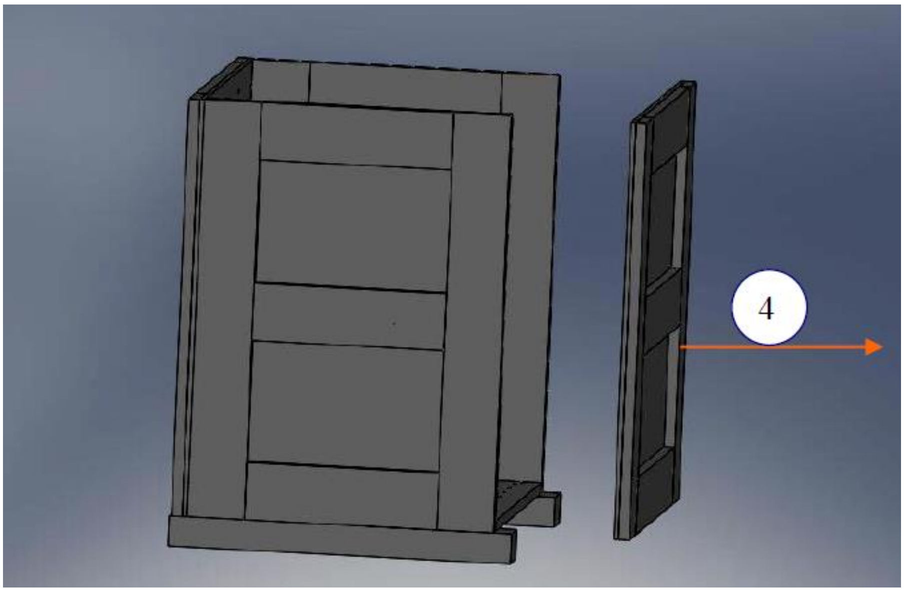



*Fig. 35 – Remove the front side of the box*

*Fig. 36 – Mapper is fixed on the mapper holder board*

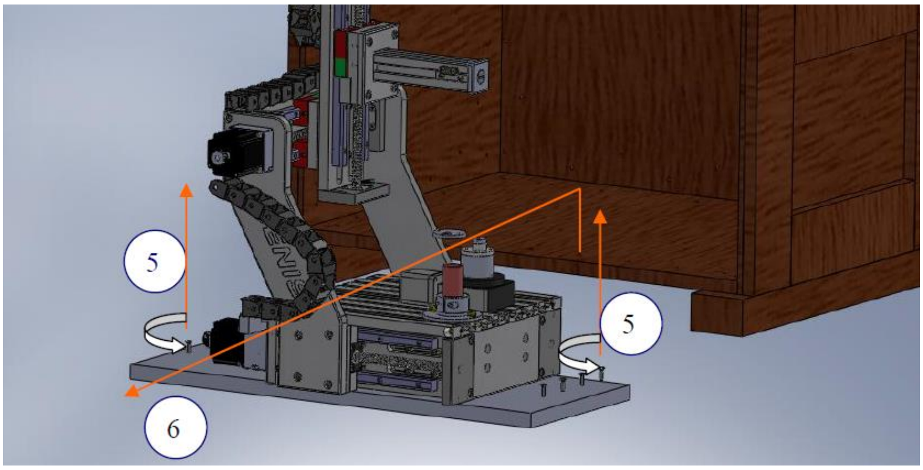



*Fig. 37 – 5) Unscrew the Mapper holder board from the top; 6) Pull-out the bord with the Mapper*

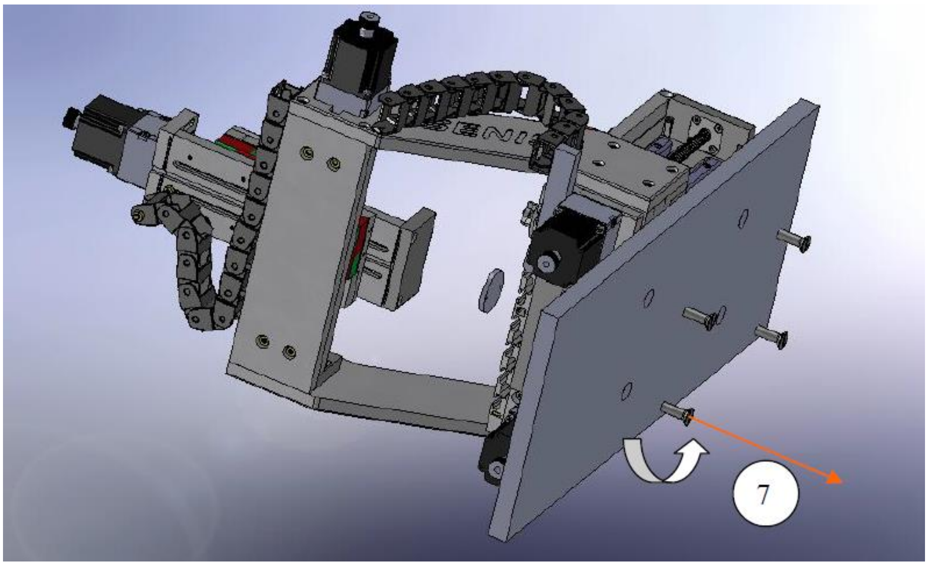



*Fig. 38 – Turn the machine and lay it on the side. Unscrew the M10 screws*

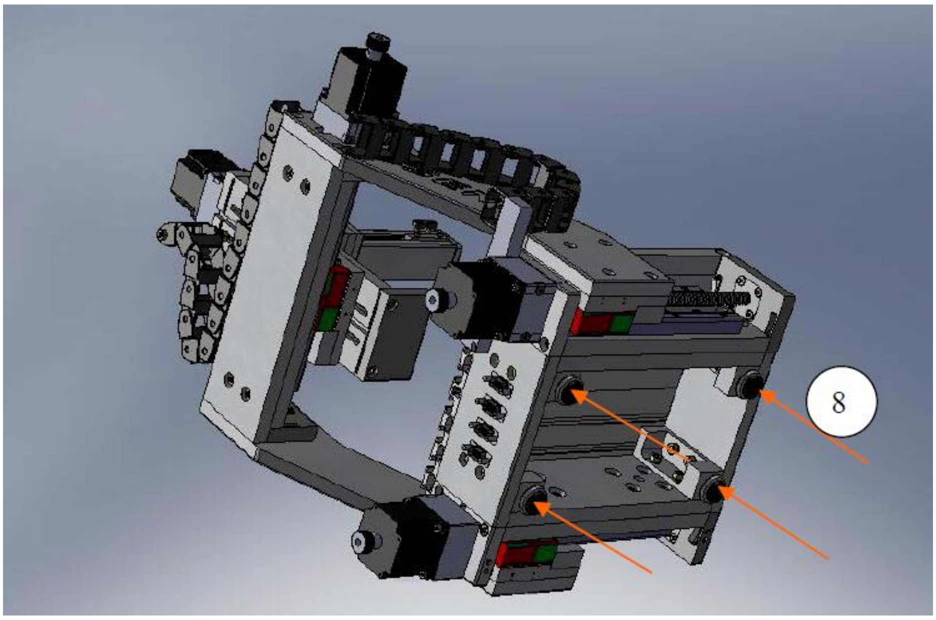



*Fig. 39 – Screw-in the adjustable feets, which are delivered with the machine*

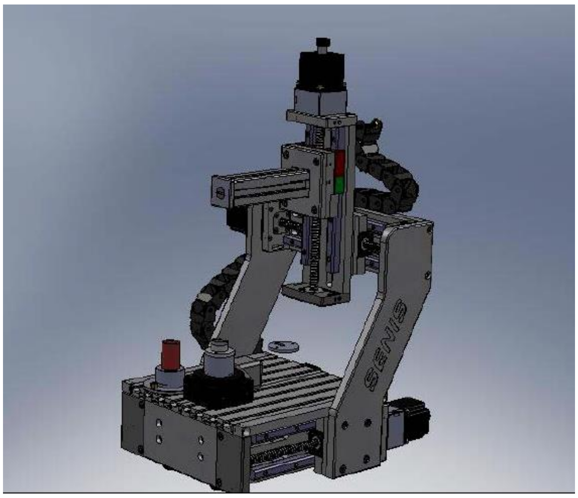


*Fig. 40 – Place the Mapper on the firm and stable table*

### 3.1.2 Unblocking Procedure

The unblocking procedure is described on the following figures. Blockers have to be carefully removed from all three linear modules (X, Y and Z axes). Please pay attention during the unblocking in order not to damage the border switches.

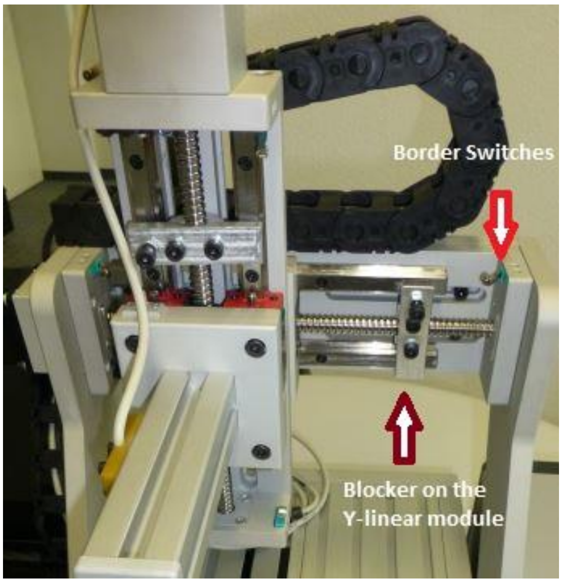



*Fig. 41 – Blocker and Border Switch on the Y-axis*

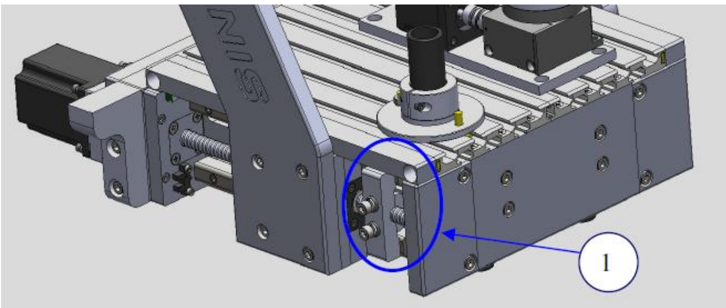



*Fig. 42 – Linear module in unblocked state*

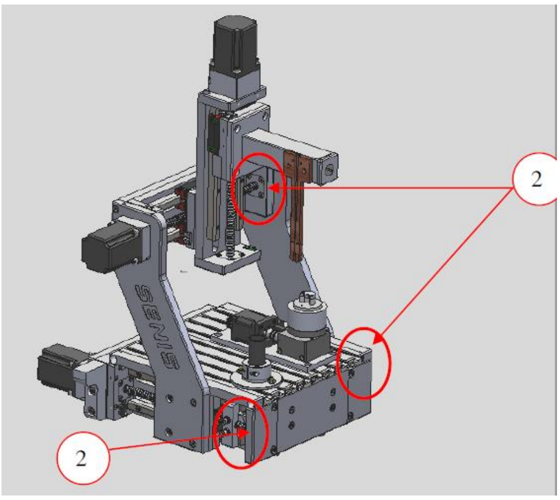



*Fig. 43 – Position of blockers*

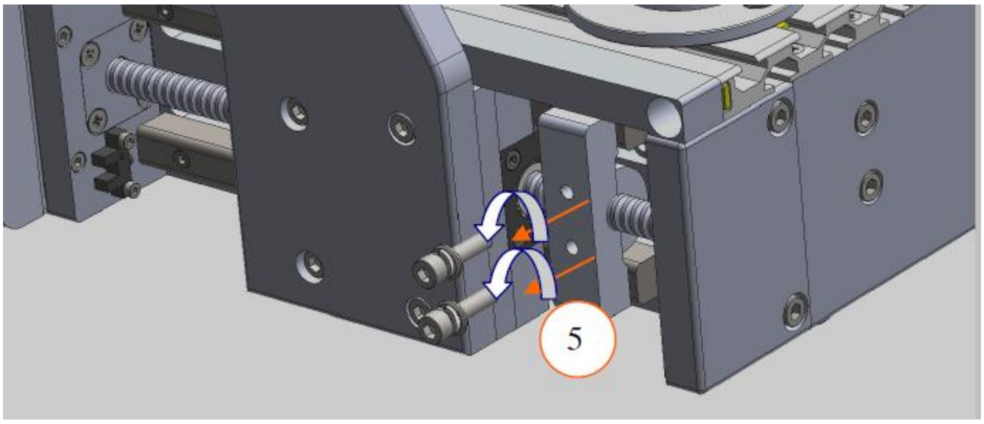



*Fig. 44 – Unscrew the hexagonal screws*

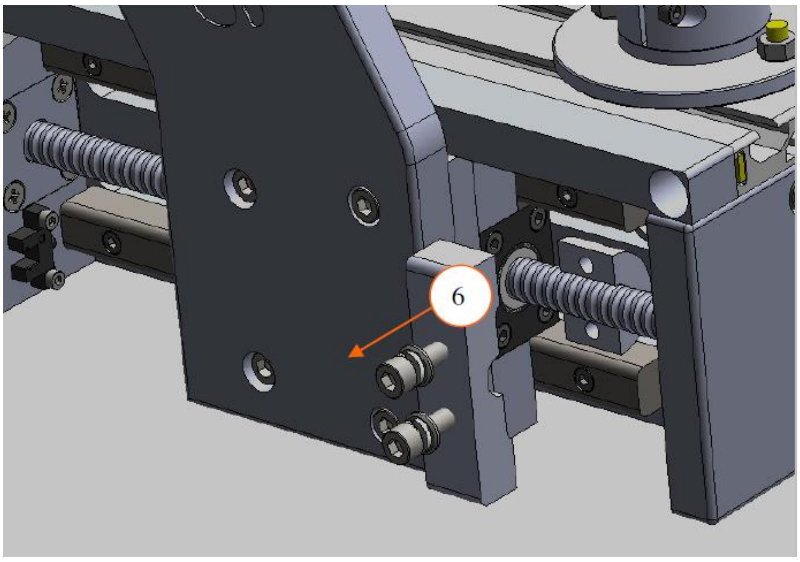



*Fig. 45 – Pull out the blocker*

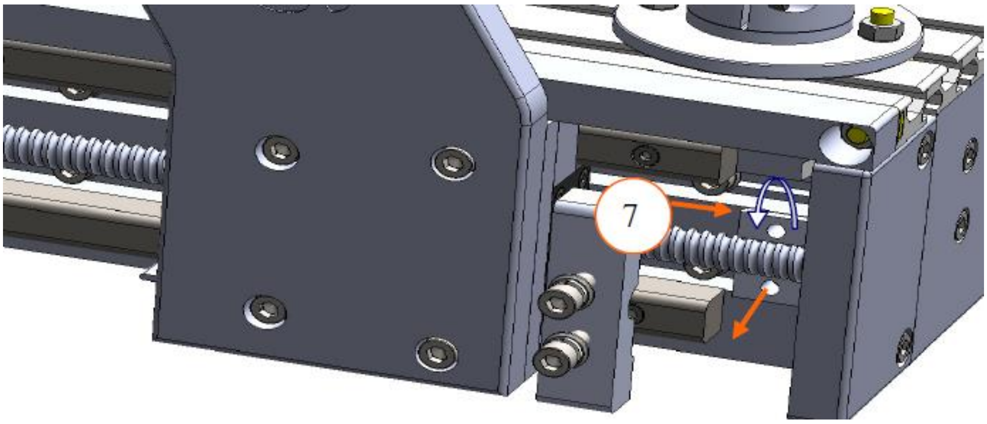



*Fig. 46 – Rotate and remove the screwing part*

## 3.2 INSTALLATION & SETUP

### 3.2.1 Package Content

1) Mechanical Probe Positioning System includes: Cartesian Moving Platform, Touch Sensor with Probe Holder and Hall Probe, Rotation Stage, Zero Gauss Chamber, Magnet Holder and FSV Calibration Tool.

*Fig. 47 – Mechanical Probe Positioning System*

2) Electronic Box (WxDxH: 32x45x14cm / 5kg), including the power cord

*Fig. 48 – Electronic Box (please note the configuration of the electronic box may differ, depending on the ordered configuration)*

3) Desktop Computer (WxDxH: 15x47x37cm / 5kg) with a Windows 7 operating system and a MMS-1A-RS software installation on it (CD is also included), USB A/B cable, keyboard and mouse.

   NOTE: The monitor is not delivered – Customer is responsible for providing the monitor for its configuration. SENIS recommends a 22" monitor (at least) with a resolution of 1920x1080 (or full HD).

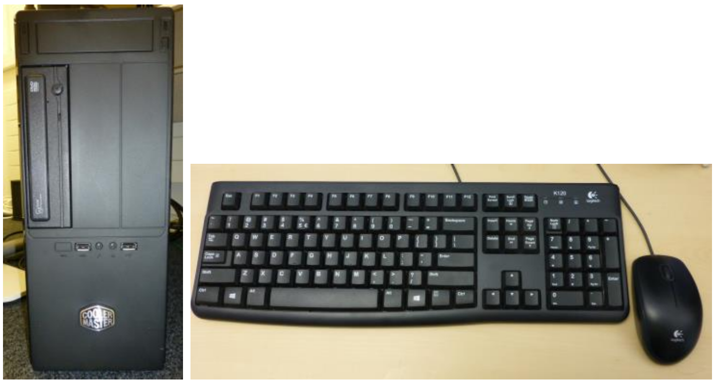


*Fig. 49 – Desktop Computer and keyboard, mouse*

4) *Cables for connecting the Cartesian Moving Plaform, Electronic Box and Computer*

*Fig. 50 – Connecting Cables*

5) Emergency Stop Taster


*Fig. 51 – Emergency Stop Switch*

6) Documentation

### 3.2.2. Connecting the System

Since most of the items are already connected inside the Electronic Box, only a few connections are needed to make the system fully operational. A proper way to connect the Electronic Box to the Cartesian Moving System and to the PC is shown in the Figure below (connector positions on the Electronic Box may differ depending on the system configuration).


*Fig. 52 – Electronic Box Connectors*


*Fig. 53 – Mechanical Probe Positioning System Connectors*

*Fig. 54 – Computer Connectors*

### 3.2.3 Connecting Instruction

- Connect the probe, the touch sensor, the step motors, the encoders and the rotating stage from the Cartesian Moving Platform to the electronic box.
- Connect the NI Motion Control and the NI DAQ (Data Acquisition Card) from Electronic Box to the PC.
- Connect the keyboard, the mouse and the monitor (NOTE: Monitor is not delivered) to the PC
- Connect the Emergency Stop Switch to the Electronic Box.
- On the rear side of the Electronic Box there is the IEC connector along with the electronic fuse (250 V(a.c.) / 110 V (a.c.), 20x5mm). Plug-in the power cord into the IEC socket on the back panel of the Electronic Box and then into the wall socket.
- The PC and the monitor have its own power supply.

  NOTE 1: All inputs/outputs are labeled (label plates) on the Electronic Box, on the PC and on the back panel of the Mapper.

  NOTE 2: In case a Magnetic Field Mapper is labeled by a CE mark, it has its validity only if the Protective Cabinet is mounted.

### 3.2.4 System SETUP

It is highly recommended that the system setup is performed by a certified SENIS AG engineer. If this is not the case, SENIS AG will not be held responsible for any system malfunction or damage. The set files on the installation disk will not match your system if the system was disassembled before shipping. Each time any system component is physically moved, the set files must be changed!

After the system is unpacked and fixed on the stable table, all system components should be visually inspected. A special attention has to be paid to the boundary switches located on both sides of each linear module of the mechanical probe positioning system.

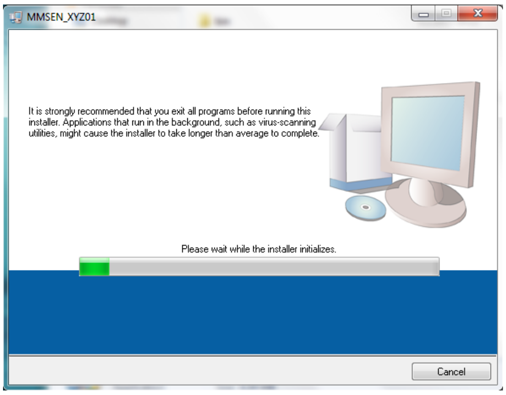
After the system is successfully inspected, it is ready for startup:

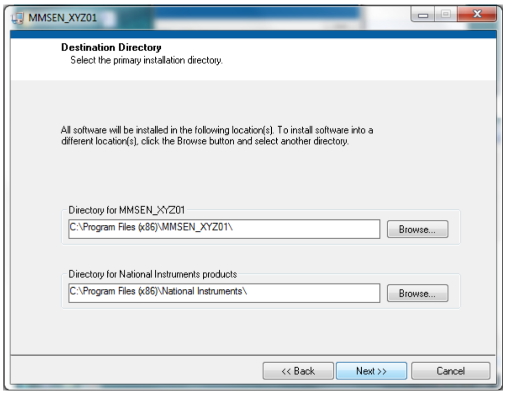
1. Turn the computer on.
2. Do not start the Mapper software program before turning on the Electronic Box. Prior to turning on the Electronic Box, make sure the Emergency Stop Switch is not closed (otherwise the Electronic Box cannot be turned on).
3. Make sure the Emergency Stop Switch is released.
4. Turn on the Electronic Box by setting the on/off switch on the front panel of the Electronic Box to “on”. Note, this doesn’t turn on the Electronic Box yet and no LED indicators will be turn on. After the switch is on “on” position, press the green button to turn the system on. This procedure is required in order to protect the system from an unattended startup (e.g. after a power blackout). Once the system is on, one red LED and five green LEDs on the front panel of the electronic box will be on.
5. ONLY FOR CE VERSION OF THE MAPPER: The Protective Cabinet door has a magnetic switch, which ensures that the door is closed while the system is moving. When the system is turned on, a green switch light is on. When the door is closed, a yellow light starts flashing. If the door is open, the yellow light is off. While the system is in operation (probe is moving), the door is locked and can’t be opened. In this situation, the yellow light is fully on. All software buttons which move the linear modules are disabled as long as the protective cabinet door is open. To enable these controls close the door on the cabinet.
6. After turning on the system, the Mapper software on the PC can be started. Note that each time the program starts, it will check if any of the boundary switches are closed and will open them if needed. In this way the system is protected from any damage.
7. Verify the functionality (chapter 3.4 of this Document)
8. The MMS-1A-RS Mapping System is delivered in the calibrated state. The system software has few built-in functions for the self-calibration (such as offset canceling and position calibration).
   NOTE: Recalibrate the system (Vertical Calibration, Start Position etc. according to the 3.5 and 4.2 chapter of this document) only if required, after a mechanical displacement.

### 3.2.5 Mapper Software Installation

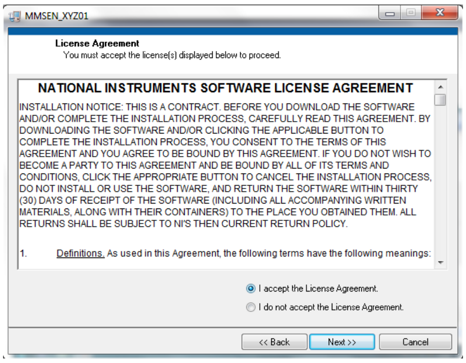
The System has been delivered with the pre-installed Mapper software. Use the following procedure **ONLY** for setting-up a new system (PC).

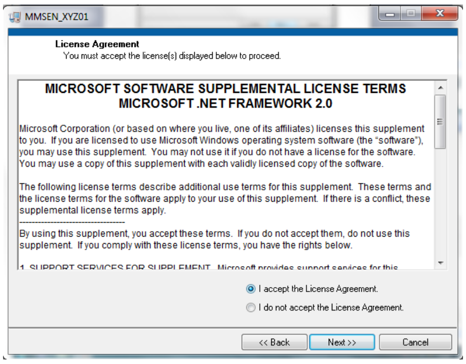
1. Insert the installation CD into the CD-ROM drive;
2. Go to Install -> MMSEN_XYZ01 Installer -> Volume;
3. Double click on the setup icon;
4. Select the destination directory; use the default settings (recommended); click the "Next" button;



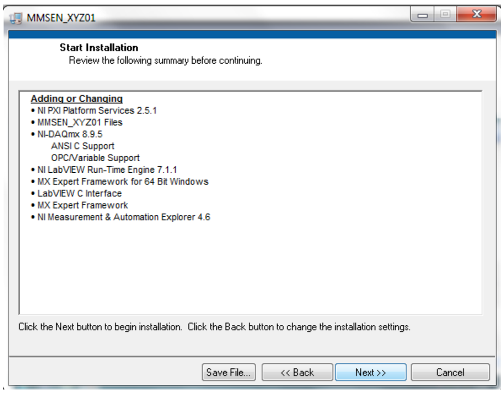




5. Please accept both License Agreements; click the "Next" button;

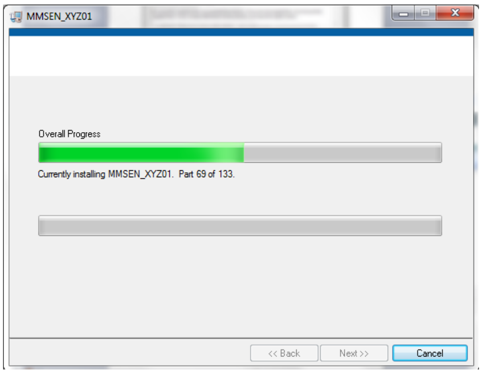


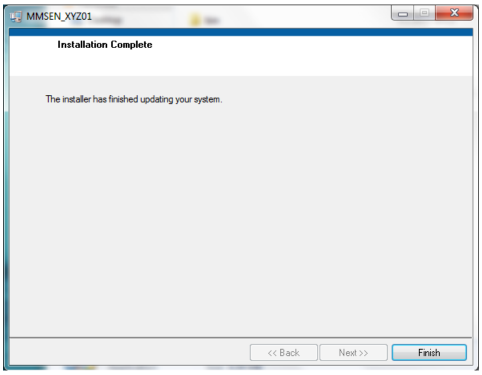




6. Start the Installation; click the "Next" button. The list of installable products may differ depending on the PC configuration;

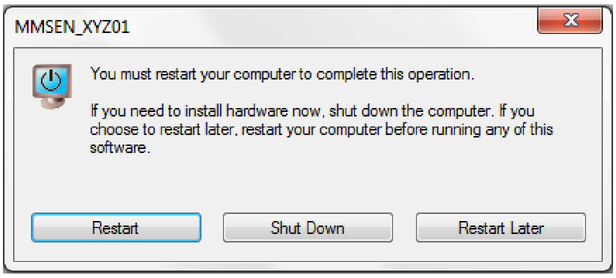



7. Wait until the installation completes; click the "Next" button ; the number of installed products may differ depending on the PC configuration;




8. After the installation, restart the computer;



## 3.3 OPERATIONAL CONDITIONS

- The room temperature is kept stable;

- The system is not exposed to an external magnetic or electric field;

- There are no ferromagnetic objects close to the system;

- The mapping system must be fixed on a stable table, no mechanical vibrations are allowed;

- Do not touch the system while in operation;

- Do not pull any cables while in operation;

- Do not unplug any cables while in operation;

- The scanning surface is clean, no objects or dust are allowed for operation;

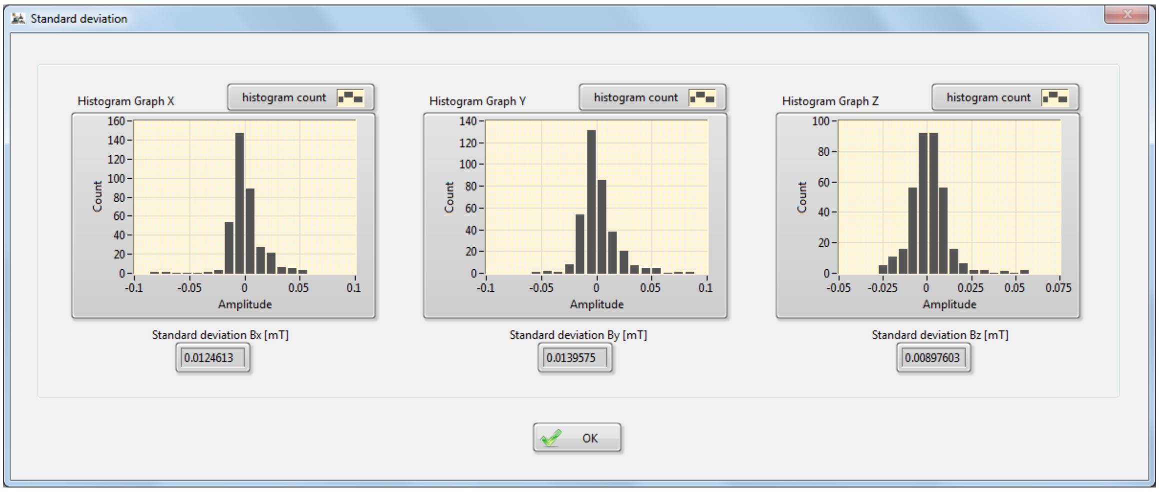
- The Electronic Box is turned on at least 3 minutes before starting the measurement.

## 3.4 FUNCTIONAL VERIFICATION

After the Mapper software is started, the "Initialization…" message will appear on the Dashboard screen. During the Initialization, the Motion Control and the DAQ will be initialized and made ready for operation.


*Fig. 55 – Mapper Software Start screen – Dashboard Tab during the Initialization Phase*

Prior to starting the program, a Histogram will show the probe noise and provide the first information of the probe health and the environmental conditions (magnetic and electromagnetic disturbances). This option can be switched on/of in the Customize.txt file.




After Initialization process, the Power ON/OFF indicator will turn from red to green. To continue with functional verification of the system, go to "Manual Control" screen by selecting the appropriate tab. The screen shows eight buttons for triggering the probe movement in various directions, as showed in Figure below:


*Fig. 56 – Manual Control Tab. This screen is used for manual control of the Mapper.*

Please verify the correct movement by selecting the “Linear Speed” slider at approx. 5mm/s position (slow). Then click and hold the “Z axis +” button until the probe comes out from the Zero Gauss Chamber (previously check that the protection around the probe was removed). Click and hold for few seconds each of the mentioned arrows and make sure that the system is moving in the appropriate direction. Also, note that each linear module is equipped with the linear encoder and two boundary switches. The encoder markers and switches are used as positioning reference and as mechanical system protection. To make sure that the switches are working properly click and hold each arrow (except for rotation, since the rotation table has no boundary switches). Hold each arrow until the module moves to the boundary switch. Upon hitting the switch the module will automatically stop, the power supply will be disconnected; and any further movement of the system in the previous direction will be disabled. The system has to be moved in opposite direction automatically or, after the software is shut-down, manually.

Repeat the same procedure for all remaining arrows. Be very careful not to hit or damage the probe (especially when using “Go TO” and “Go FOR” commands). Emergency Stop is very important safety equipment; therefore its functionality has also to be checked. The role of the emergency stop switch is to immediately stop any system movement. Also, this switch terminates the power supply of the system and indicates to the software that unexpected circumstances have been occurred. The system will not function unless the Emergency stop switch is properly connected to the Electronic Box.
To check if the Emergency Stop is working properly, activate this switch while the system and the software are on. The system will stop moving immediately, and all LEDs will turn off, indicating that the system has no power supply.

To put the system back in operation, release the emergency switch and turn on the system by pushing the green button again (note that the on/off switch is in the “on” position and there is no need to toggle it). After the power is restored, the software will wait for ten seconds at most, before confirming the normal operating conditions.

To turn off the system, the user should first exit the program and then turn off the whole device. The only appropriate way to exit the program is by using the "QUIT" button in the top right corner of the screen. This icon is disabled while any measuring task is in progress. A task in progress can be aborted by clicking the "ABORT PROCESS" button.

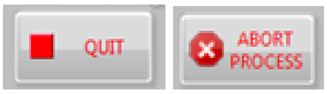



*Fig. 57 – QUIT and ABORT PROCESS Buttons*

After exiting the Mapper software program, turn off the hardware simply by moving the on/off switch to "off" position.

The next check is to navigate the Probe to Mapper's Zero coordinate. Please click "Go to zero XYZ position" button:


*Fig. 58 – Position the probe in the machine zero position*

The probe will be positioned in the zero coordinates (with the appropriate tolerance) of the Mapper. Also the rotary stage will be positioned in its 0° position.


*Fig. 59 – Machine Coordinates Display Fields*

The last check is to position the Hall probe in the Zero Gauss Chamber.


*Fig. 60 – "Go Home" button positions the probe in the Zero Gauss Chamber*

After clicking the "Go Home" button, the probe will move to each of the three references (XYZ) and then will navigate in to the Zero Gauss Chamber in the position calibrated in-factory. This position is stored in the calibration file *ZG Position.txt* in the Calibration folder.

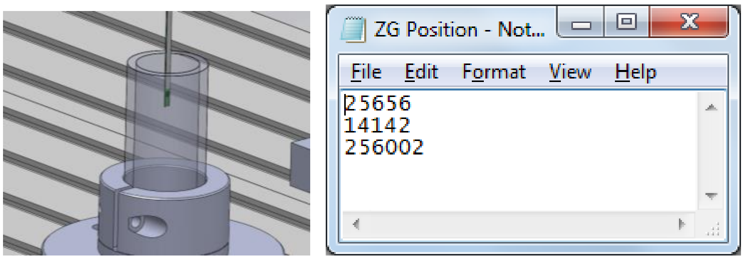



*Fig. 61 –Probe positioned in the Zero Gauss Chamber in the position stored in the calibration file*

⚠ After clicking on the "GO HOME" button, closely monitor the probe movement. If the calibration files are false, there is the possibility that the probe could collide with an object. Prevent this happening by terminating the program using the "Emergency Stop" switch.

After the probe is positioned in the Zero Gauss Chamber, the Hall Probe Offset will be read and the readings in the fields "Offset Bx", "Offset By" and "Offset Bz" will update.

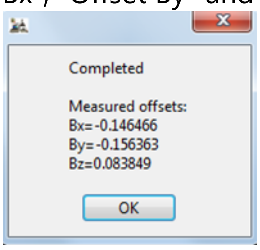



*Fig. 62 – Message on the screen after the "Go Home" is activated and the probe is positioned in the Zero Gauss Chamber*

## 3.5 MAPPER CALIBRATION

### 3.5.1 Overview

The MMS-1A-RS will be in-factory calibrated and delivered. The following calibration algorithms are implemented in the Magnetic Field Mapper System MMS-1A-RS and can be used at customers for re-calibration:

1. **Absolute Magnet Positioning & MFSV Calibration** (Alignment) – Determination of the position of the magnetic field sensitive volume (MFSV), relative to the coordinate system of the FSV Calibration tool; and its relation to the coordinate system of the rotary stage (center of rotation)

2. **Axis of Rotation Calibration (Center of Homogeneity of Ring Magnets)** – Determination of the center of rotation (rotary stage), i.e. the calibration of the most homogeneous point of ring magnets

3. **Hall Probe Orthogonality Calibration (Optional)** – Determination of the tilt, roll and pitch angles of the Hall Probe mounted on a touch sensor or on a probe holder (determination of the Hall probe sensitivity vectors mismatch)

All calibration procedures will be started from the *Calibration Tab* in the Mapper software:

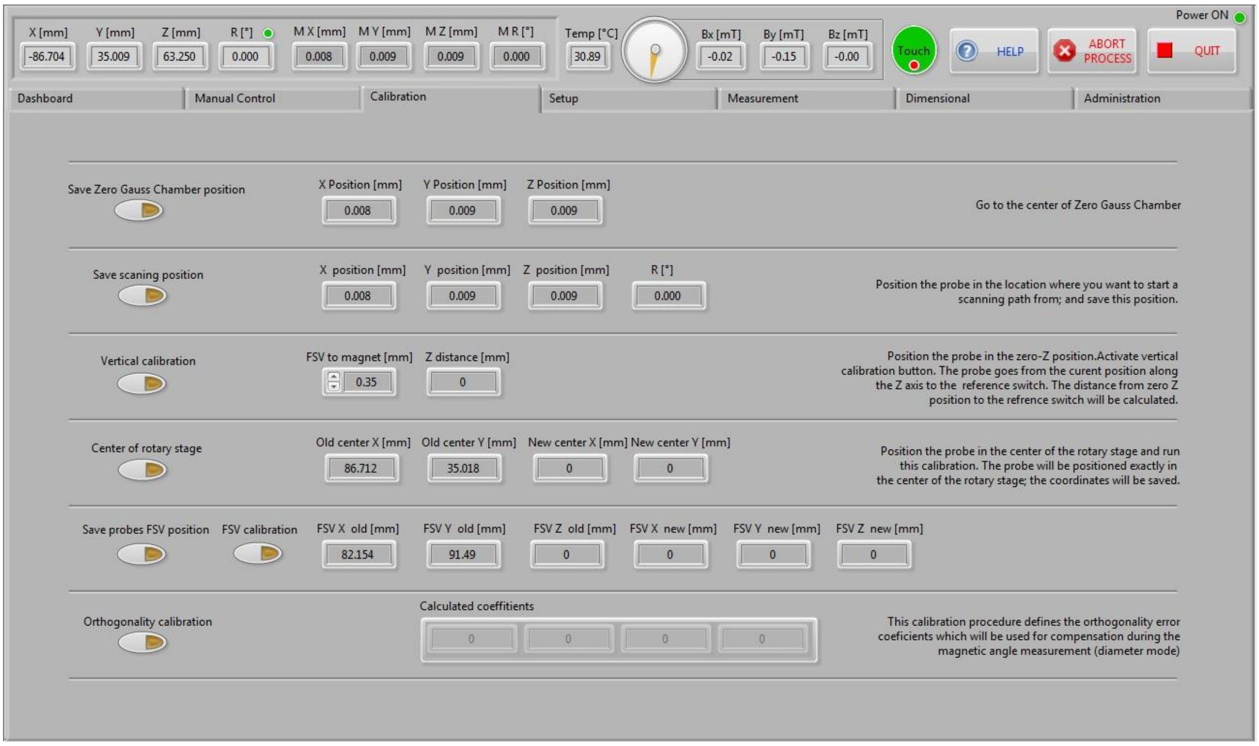



*Fig. 63 – Calibration Tab in the Mapper software. This Tab is used as a dashboard for launching calibration procedures please see the chapter 4.2 of this document)*

### 3.5.2 Absolute Magnet Positioning & MFSV Calibration

In order to accurately map the magnetic field on the defined distance from a permanent magnet, it is important to locate the position of the magnetic field sensitive volume relative to the coordinate system of the magnetic field mapper.

SENIS Magnetic Field Mapper MMS-1A-RS is equipped with a tool that allows a very precise positioning of the permanent magnet as well as the accurate positioning of the magnetic field sensitive volume (MFSV) of the Hall probe on the desired distance from the magnet surface.

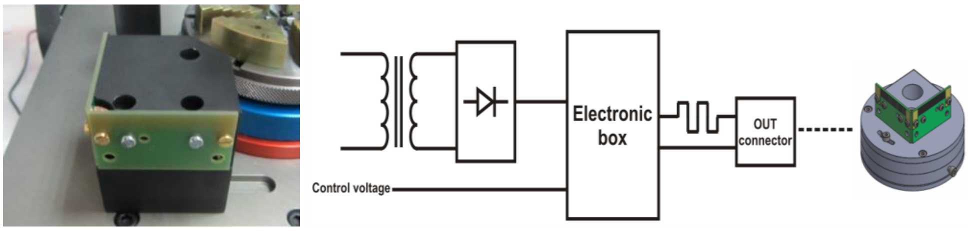



*Fig. 64 - MFSV Tool a) Photo; b) Block Diagram*

The MFSV Tool consists of a prismatic platform made of Aluminum and two PCBs fixed on the platform under an angle of 90°. The magnet will be positioned on the platform by means of two reference walls.

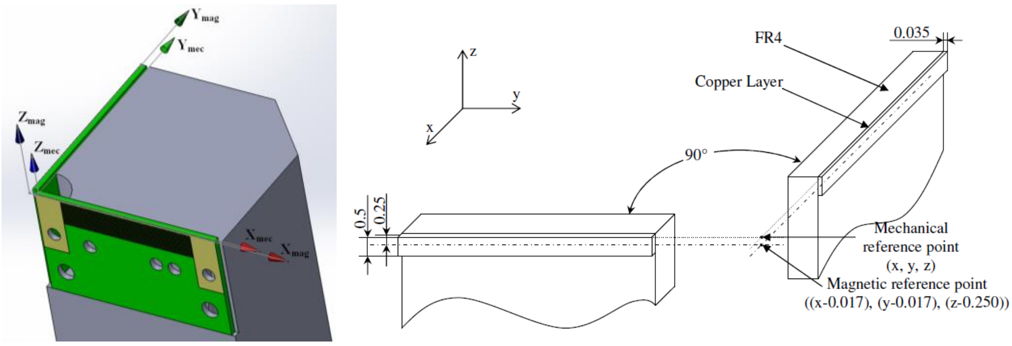



*Fig. 65 - The reference walls orientation on the MFSV Tool. XYZmec is the coordinate system of the MFSV Tool and the XYZmag is the coordinate system of the magnet.*

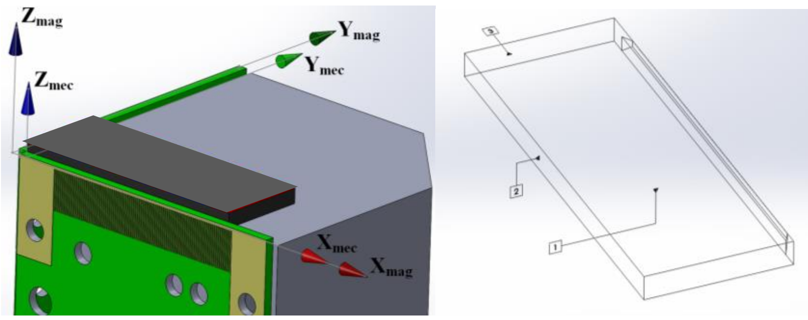



*Fig. 66 - a) Magnet positioning in the MFSV Tool; b) Definition of the referent surfaces on the magnet. The bottom surface 1 is a main surface for the magnet positioning, the side surface 2 is referencing surface and the side surface 3 is the boundary surface.*

The relation between the XYZmag and XYZmec coordinate systems is determined by standard distance measurement methods as shown in the Figure 6.

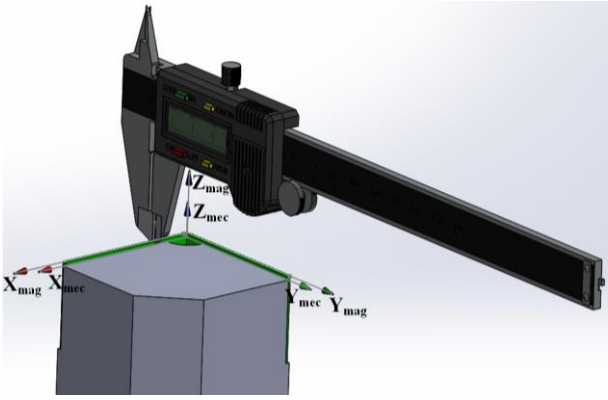



*Fig. 67 - Measurement of the distance between the two reference walls on the MFSV Tool*

The position of the MFSV of the Hall Probe relative to the coordinate system XYZmag is determined through the contact-less magnetic field measurement. For this purpose, the magnetic field, generated by the current carrying conductor will be measured by the 3D Hall probe. The Hall probe is navigated over the PCBs in the x, y and z directions to determine the XYZmag coordinates.

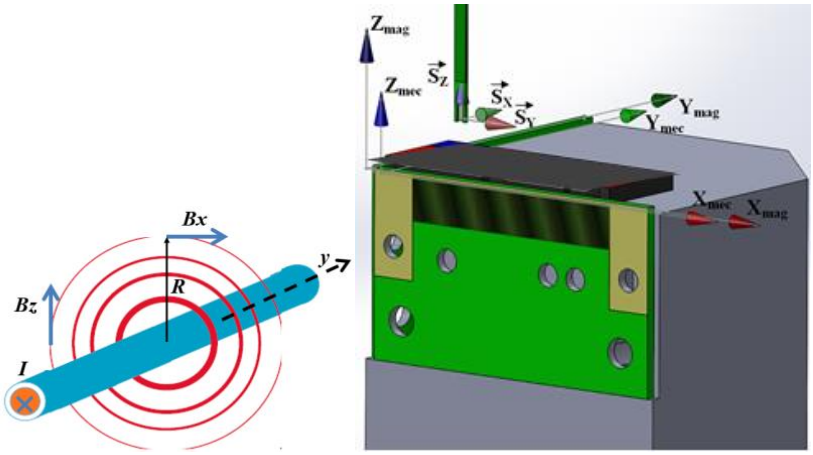



*Fig. 68 - Measurement of the magnetic field over the current carrying conductor*

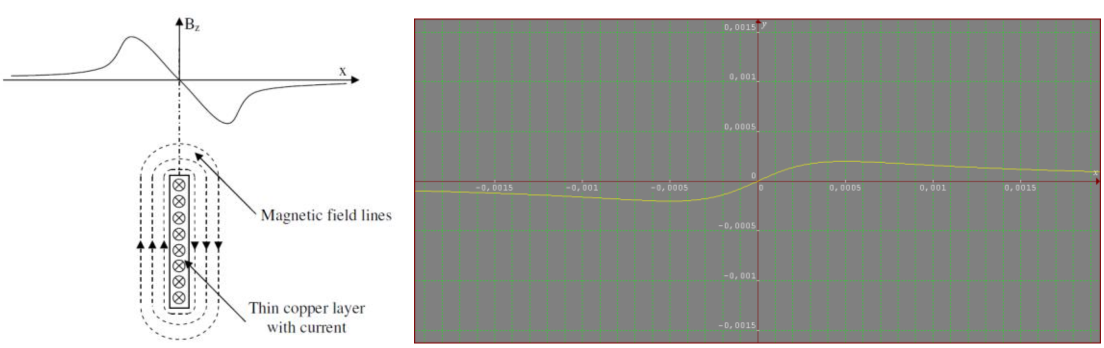



*Fig. 69 - Dependence of the Bz magnetic field component on the distance (measured over PCB)*

The relation between the XYZmag and the coordinate system of the rotation table (axes of rotation and vertical distance) can be determined using the obtained axis of rotation and the vertical distance, measured by the touch sensor and the Hall probe (to touch the reference points of the MFSV Tool and of the rotary table, as shown on the Figure below).

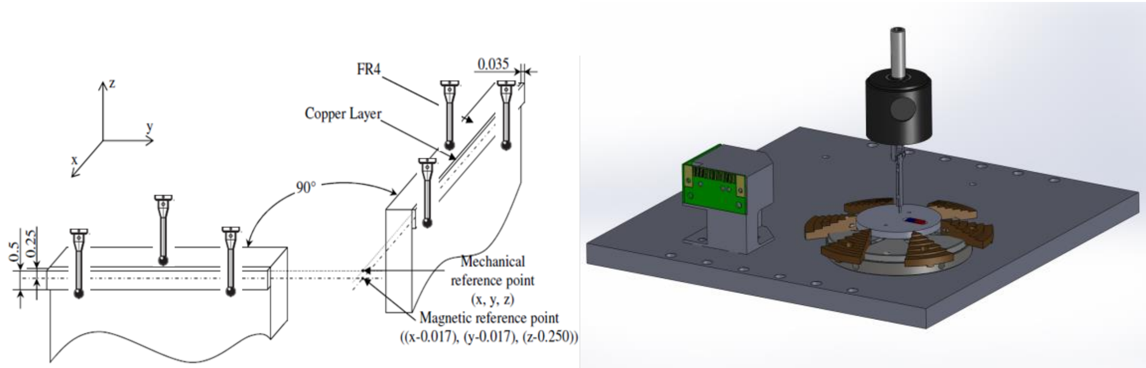



*Fig. 70 - Determination of the relation between the coordinate systems of the MFSV Tool and the rotary stage using a stylus mounted on the touch sensor a) or touch sensor and the Hall probe b)*

Please note that changing the Hall probe or touch sensor, requires the adjusting of the start position for FSV calibration. Please contact SENIS tech support for further instructions when replacing the probe (spare probe) or touch sensor.

Please note that the calibration of vertical distance (Z-axis) in the older versions of Magnetic Field Mapper software was differently executed (touching the surface and providing the distance between the FSV and probe-tip). This procedure required the information of the FSV position in the Hall probe.

### 3.5.3 Axis of Rotation Calibration (Center of Homogeneity of Ring Magnets)

The axis of rotation can be determined by using an appropriate tool that is fixed on the rotary stage.

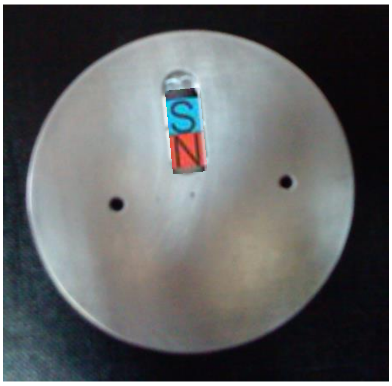


*Fig. 71 - Tool for the axis of rotation determination*

The rotation table rotates in the way that the referent magnet (tool) in the appropriate position shown in the Figure below.

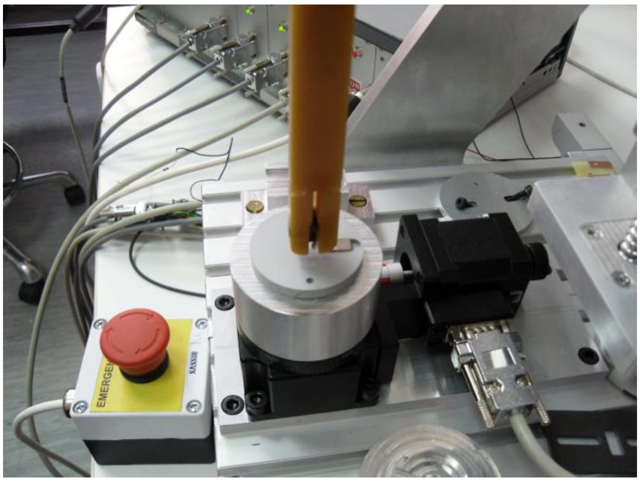


*Fig. 72 – Probe positioned for the calibration procedure*

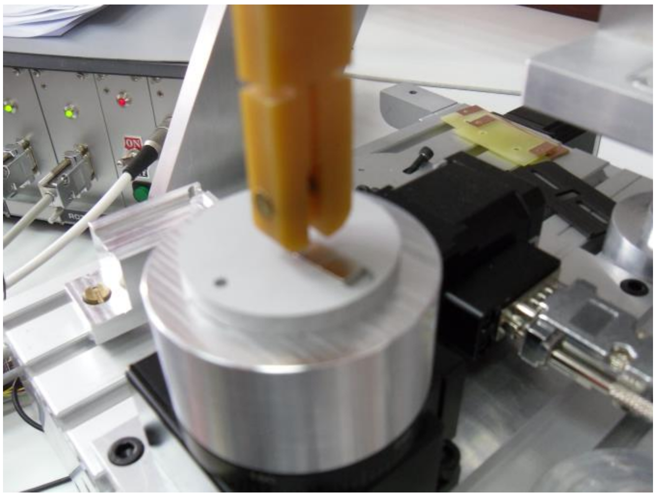


*Fig. 73 - Calibration procedure for center of rotation determination*

The probe is then navigated towards the magnet (in Y direction) until the measured component of the magnetic field Bz reaches the zero value. Then the rotation table rotates 180° and the probe moves again towards the magnet until By reaches zero. Then the probe moves for the half of distance between the two zero-crossings and positions in the center of the Y-direction. The second cycle of positioning in the center of rotation is similar to the first one, with the difference that probes now moves in the X direction, instead of Y. The above described algorithm is good enough for simple measurements, but for the accurate magnetic field mapping it is not accurate enough (tool tilting not considered, zero-crossing not sharp, unknown reference magnet inhomogeneity).

For a very accurate magnetic field mapping, the above procedure can be used only to approximately position the probe in the axis of rotation. The following calibration is then used for an accurate definition of the center of rotation.

If the Hall probe is in the axis of rotation it always “sees” the same magnetic field vector which rotates together with the magnet. In that case the measured components of the field Bx and By will have only the main harmonic. But if the Hall probe is positioned off-axis, then the inhomogeneity of the field will result in the generation of the high order harmonics. This fact is used to find the exact position of the rotation axis.

The aligning procedure for concurrence of the axis of rotation with the sensitive volume of the sensor does not require any special tools; it uses the magnet under test for this purpose (or the same calibration tool shown in the Figure 71). The sensor should be positioned approximately in the axis of rotation. The magnet under test is then rotating, and the output voltages of the channels X and Y of the Hall probe are measured.

If the sensor is not in the axis of rotation of the magnet, the higher harmonics will be present in the Fourier order. The ratio of the sum of the amplitudes of the second and the first harmonics can be used as the measure for the error of overlapping of the probe position and the rotation axis of the magnet.

This theoretical insight is exploited to align the sensitive volume of the Hall probe and the rotation axis of the magnet. The best alignment will result in the minimum of the error function.

The advantage of this method is that it does not rely on the accuracy of the used Hall probe: the two measurement channels of the Hall probe do not need to have equal sensitivities. Also, sensitivity vectors of measurement channels may not be strictly perpendicular. And the offsets and the influence of local DC external magnetic fields are also cancelled.

The coefficients that are obtained through above algorithm are then used in the Mapper software during the magnetic field mapping.

# 4. OPERATING INSTRUCTIONS

## 4.1 OVERVIEW

The Operator Interface of the MMS-1A-RS Mapper Software is organized in 6 tabs/screens, each of them covering functional unit:

1. *Dashboard Tab* – Start screen for overview of the mapper software functionality
2. *Manual Control Tab* – for manually navigating the probe
3. *Calibration Tab* - for launching of calibration procedures
4. *Setup Tab* – for setting-up of measurement profiles
5. *Measurement Tab* – for starting measurements and visualizing measurement results
6. *Administration Tab* – for system set-up and administration

## 4.2 OPERATION INSTRUCTION

### 4.2.1 Dashboard Tab


*Fig. 74 – Dashboard Screen appears on the software start*

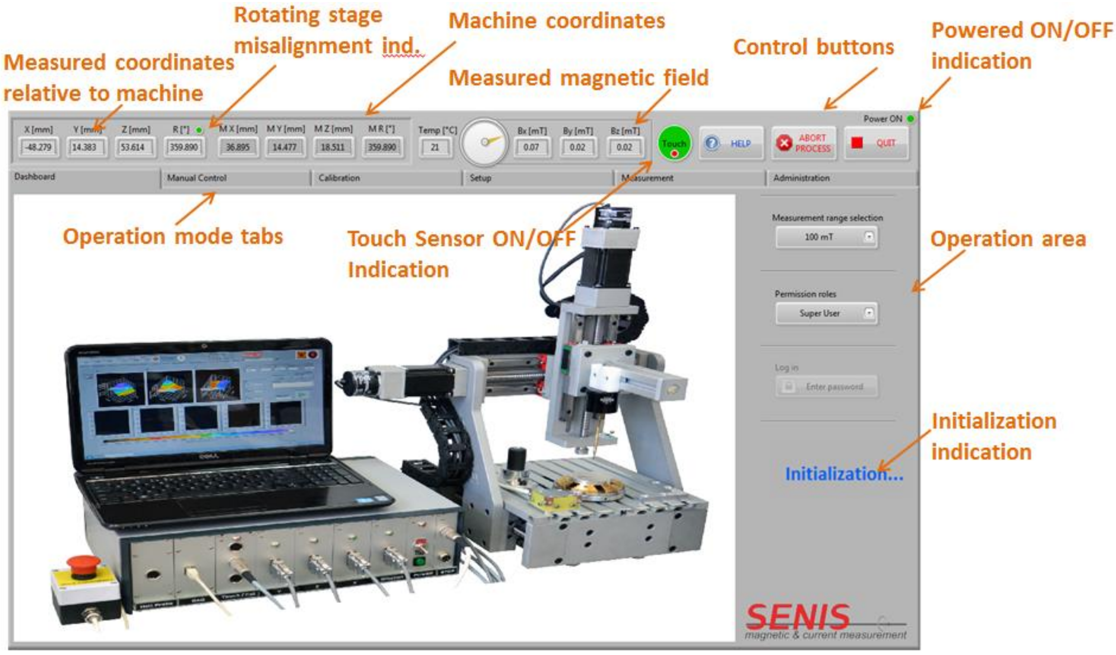



*Fig. 75 – Basic screen elements*

NOTE: Themeasurement selection range is available only if the system was delivered with this option.

In *Dashboard Tab*, operator can select the measurement range and the User/Super User role.

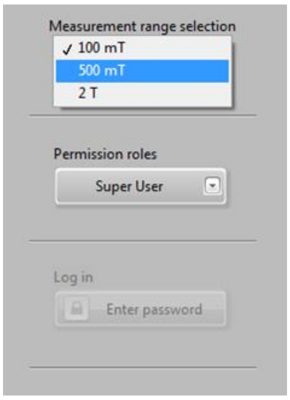



*Fig. 76 - Pull-down for measurement range selection. The calibrating coefficients for selected range will be loaded into the software automatically.*

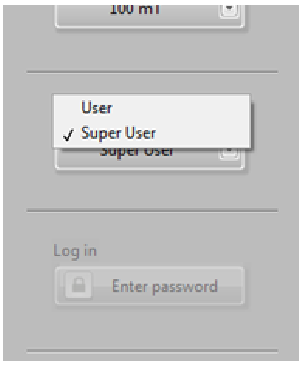



*Fig. 77 - Pull-down for User selection*

### 4.2.2 Manual Control Tab

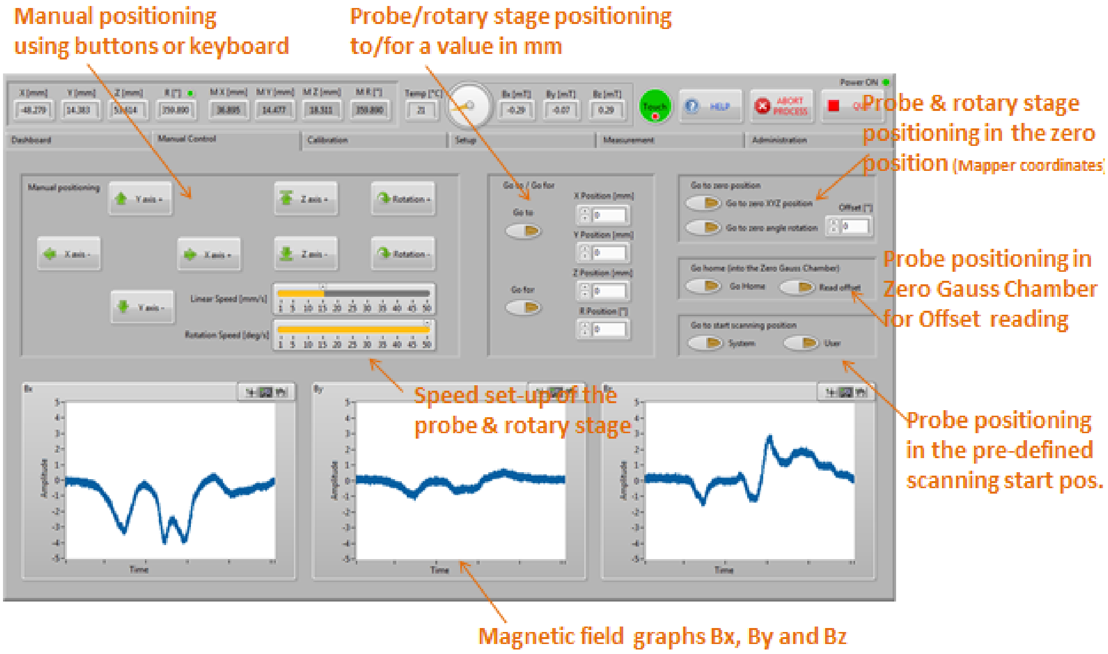
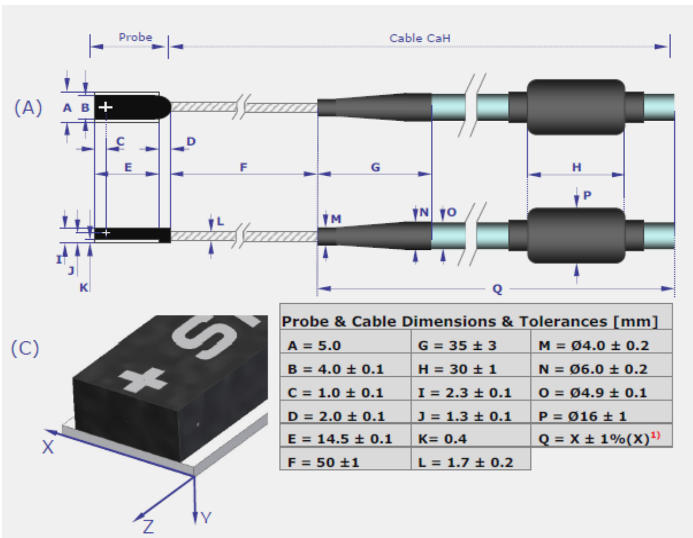



*Fig. 78 – Manual Tab for manual control of the probe movement*

In the *Manual Tab*, operator can navigate the probe in X-, Y- and Z-direction (+ = move up/down, right/left, forward/backword). Also the rotating stage can be controlled (+ = turn clockwise). The sliders for linear modules and for rotating stage set the desired spped.

At the top left corner of the screen there are the coordinate indicators X(mm), Y(mm), Z(mm) and R (°), which show the current position of the Hall probe and rotary stage. The Z indicator is showing the distance between the probe's FSV (Field Sensitive Volume) and the reference surface (e.g., the FSV is approx. 1mm away from the tip of the probe of type A, i.e. white cross sign in the Figure below). All values are in millimeters. For other probe types this distance can be different than 1mm, consult datasheet for details.




| Probe & Cable Dimensions & Tolerances [mm] | | |
|---|---|---|
| A = 5.0 | G = 35 ± 3 | M = Ø4.0 ± 0.2 |
| B = 4.0 ± 0.1 | H = 30 ± 1 | N = Ø6.0 ± 0.2 |
| C = 1.0 ± 0.1 | I = 2.3 ± 0.1 | O = Ø4.9 ± 0.1 |
| D = 2.0 ± 0.1 | J = 1.3 ± 0.1 | P = Ø16 ± 1 |
| E = 14.5 ± 0.1 | K= 0.4 | Q = X ± 1%(X)[1)] |
| F = 50 ±1 | L = 1.7 ± 0.2 | |

*Fig. 79 – Dimensions of the Hall Probe A and the positon of the FSV relative to the probe outer edges*

While the coordinate indicators X(mm), Y(mm), Z(mm) and R (°) show the current position of the Hall probe and rotary stage relative to the user's defined coordinate system (FSV Tool or center of the rotary stage), the MX(mm), MY(mm), MZ(mm) and MR (°) cordinate indicators show the probe position relative to the Mapper zero coordinates (defined by linear encoders.

The green indicator next to the R(°) field indicates that the start point of the rotation of the rotary stage is alligned with the index of the rotary encoder (=0°).


*Fig. 80 – Hall Probe coordinate indicators(M = coordinate system alligned to the Mapper)*

The middle-screen indicators display shows

- The probe temperature (temperature sensor integrated in the Hall probe is used for the temperature compensation of the magnetic field measurement).
- The total magnetic field orientation in the XY plane (magnetic field vector).
- Real-time values (current values) of all three components of the magnetic field in mT (Bx, By, Bz).

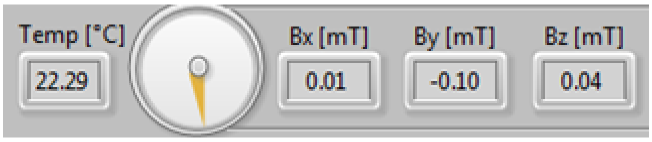



*Fig. 81 – Temperature and Magnetic Field value fields*

The plot of current values of all three components of the magnetic field is shown in the graphs in the botom part of the screen. These graphs can be zommed and panned.

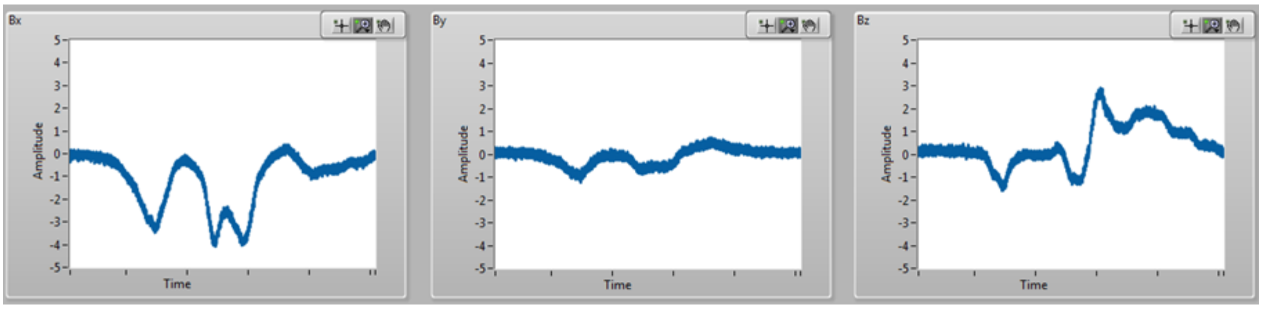



*Fig. 82 – Magnetic Field value plots (Amplitude vs Time)*

In the same tab, the probe can be navigated directly to the desired coordinates ("Go TO" buttons). It can be also navigated for a defined distance ("Go FOR" buttons). Please use this commands carfully, since the values given in the data fields next to the buttons are used for both commands.

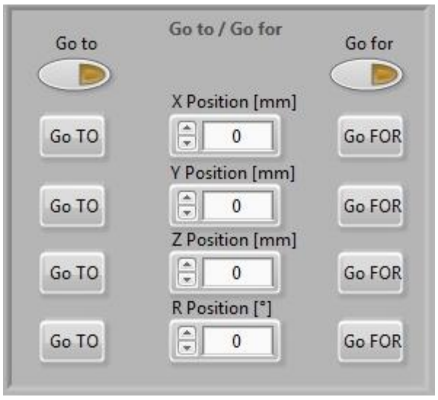



*Fig. 83 – "Go to" and "Go for" commands*

The right reference coordinate system (X=0, Y=0) is placed either in the center of rotation stage or at the lower left corner of the FSV tool (PCBs mounted on the metal cube). The Z coordinate shows the distance between the probe FSV and the reference surface.

The "Go to" button moves the probe to the desired position (coordinates) in the coordinate system (either all at once, or per-axis only). User should enter the desired point's coordinates and click this button. The probe will be moved simultaneously tin all directions (XYZ) to reach this point.

The "Go for" button moves the probe in each direction for the value given in the corresponding control fields (either all at once, or per-axis only). If the probe should be moved in all tree directions, it will be done simultaneously. If zero-value is entered in some of fields, the probe will not move in that direction. This button can be very useful for precise movement of the probe, especially when moving the probe near to an object.

At the top right corner of each tab there are three buttons and two indicators. The "Touch" indicator (green, red or orange) indicates the status of the touch sensor (red = touch sensor was triggered after touching an object; orange = dimensional, i.e. CMM mode; green = normal operation).

The small lamp within the touch sensor indicator, provides a reminder message (red = the touch sensor was triggered, there might be a FSV calibration required). This indicator is cleared (set to green) after each calibration process.

The activation of the "HELP" button opens the Operator Manual.

The "ABORT PROCESS" command terminates all system tasks and immediately stops the system. The "QUIT" button is used for closing the program. Note that the exit button is inactive during the mapping procedure. If you need to stop the process use "ABORT PROCESS"; if you need to terminate the program immediately, use the "Emergency Stop" button.

The "Emergency Stop" button is used to prevent system damage. For example, if the probe is approaching an object and there is a possibility of collision, press the "Emergency Stop" button, and the program will terminate immediately.

The Power ON/OFF lamp, indicates the ON/OFF status of the system.


*Fig. 84 – Controls and Indicators at the top right screen area*

The motion commands can be also provided by the keyboard.

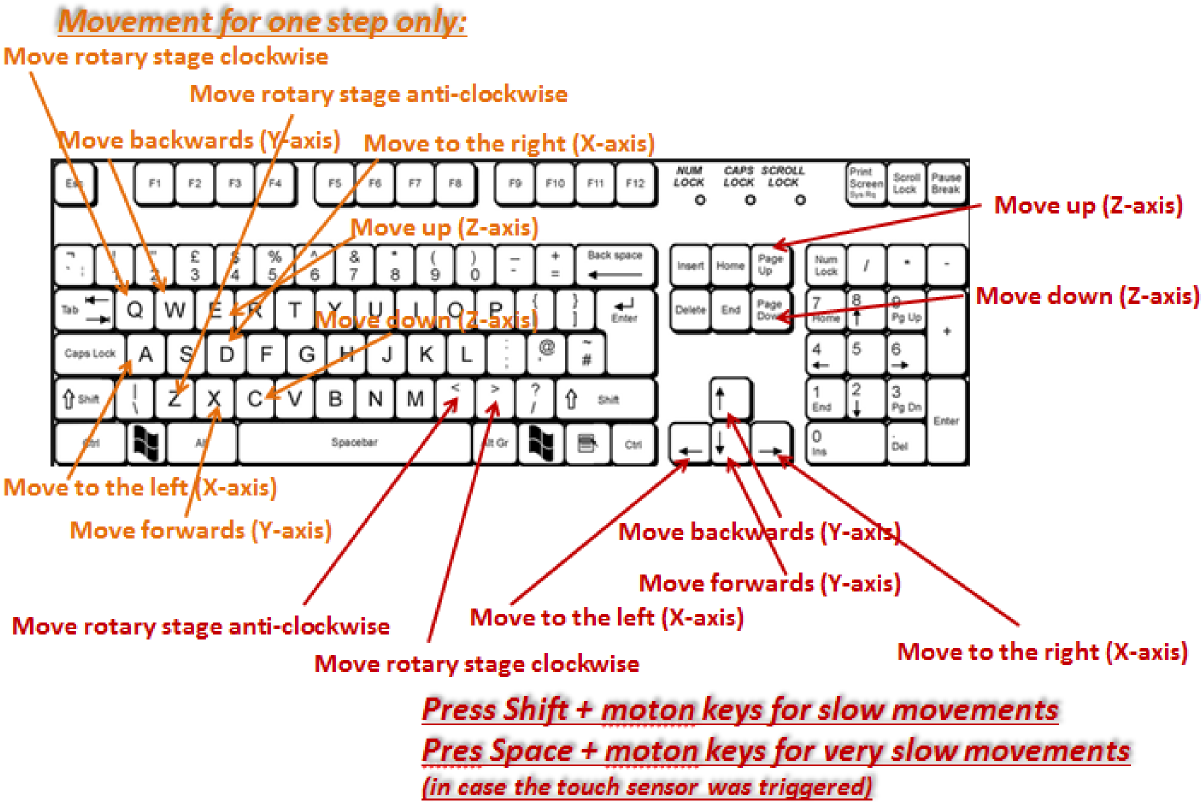



*Fig. 85 – Keys layout for Motion command by a Keyboard*

Further shortcuts are also implemented ("micro steps" – Space-button moves the probe for one step only):

- Space + W = Y+
- Space + X = Y-
- Space + A = X-
- Space + D = X+
- Space + E = Z+ **Usefull after probe touches the magnet and the probe does not move-up automatically** ⚠
- Space + C = Z –
- Space + Q = R+
- Space + Y = R-

The short-cut for "Go Home" (into Zero Gauss Chamber): Ctrl + * (in NumLock)

In addition to above functions, the *Manual Control Tab* includes the following command for an automatic positioning of the Hall probe:

- **Go to zero position** – this command positions the Hall probe into the Mapper zero coordinates (defined by encoder index); and also positions the rotary stage into the 0° position. Positioning of the rotary stage into zero-angle position can be executed separatelly. An offset (°) can be set to always position the rotary stage into 0° + offset value
- **Go Home** – positions the Hall probe into the Zero Gaus Chamber (or whatever "Zero Gauss Chamber" position set in the *Calibration Tab*) and automatically reads the Hall probe offsets, that are considered during the magnetic field measurement. There is also the "Read offset" command available for reading and compansanting offset on any desired position in the space.
- **Go to start scanning position** – positions the probe in a set starting coordinates for a scanning (Measurement start position). If activating the "System" button, the probe will be positioned in the system-set position (usually X=10, Y=10, Z=10). On "User" button activation, the probe will be position in the user defined scanning position. This position can be set in the *Calibration Tab* and stored in an user named file under C:\\Senis\Start position.

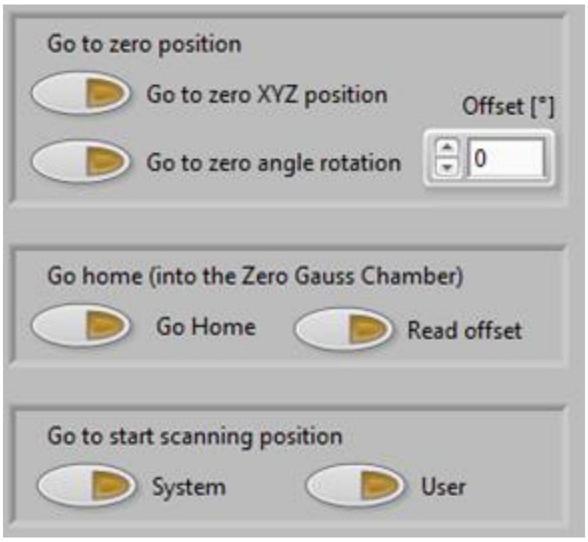



*Fig. 86 – Probe automatic positioning*

### 4.2.3 Calibration Tab

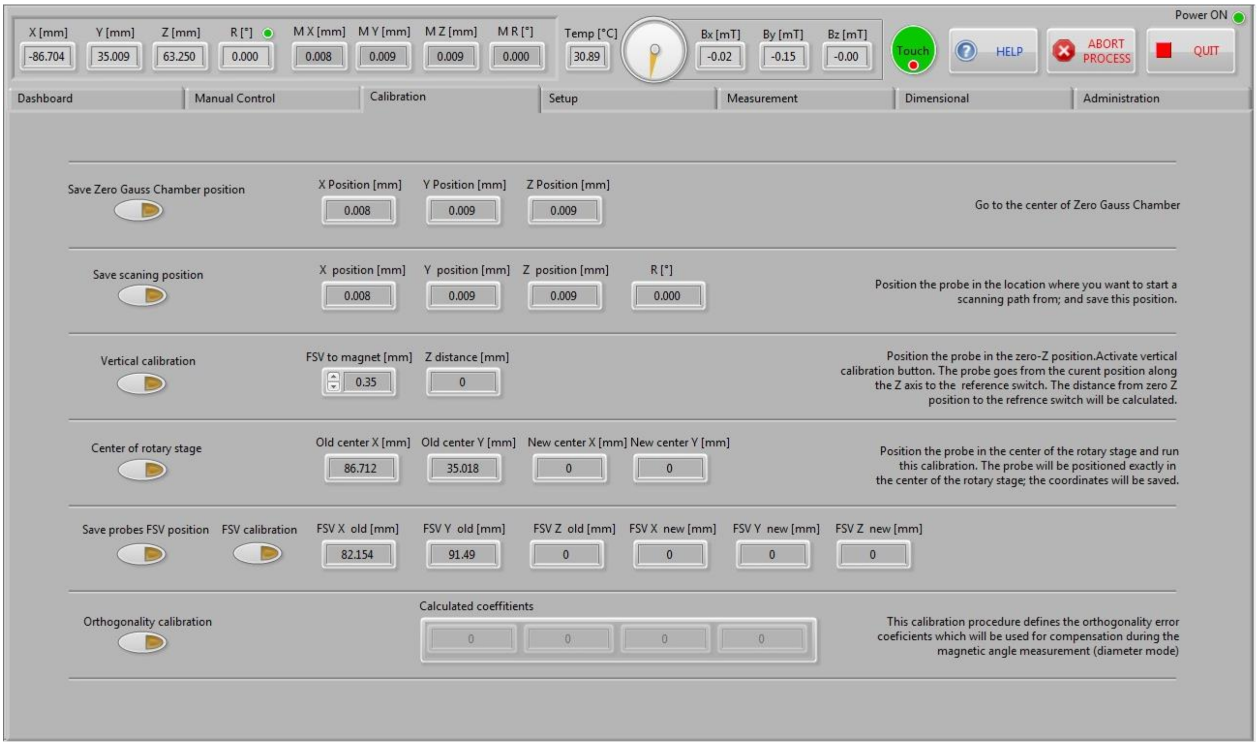



*Fig. 87 – Calibration procedures are launched from the Calibration tab*

The *Calibration Tab* is self-explanatory. It contains the following calibration procedures/options:

1. **Save Zero Gaus Chamber position** – Operator can position the probe at any point in the space (should be in the Zero Gauss Chamber) and start this command. The current probe position will be stored and used for the "Go Home" comand – positioning in the Zero Gauss Chamber

2. **Save scanning position** – with this command, the current position of the probe will be stored and used as the user defined scanning start position (in the *Manual Tab*) or as the command for setting the scanning paths in the *Setup Tab*. The start position will be saved in the customer's named file under C:\\Senis\Start position.

3. **Vertical Calibration** –This calibration algorithm is partly described in the chapter 3.5.2 of this document. For each new magnet type that shall be scanned, the vertical distance needs to be referenced, since the reference surface vertical position was changed. Manually drive the probe toward the magnet surface using the commands in the *Manual Tab*. When you come near to the magnet surface use step by step moving (slow) or ˝Move for˝ button (zero value for X and Y and -0.005mm (5um) for Z control). Minus sign for Z axis drives the probe toward the surface, while the plus sign moves the probe away from the magnet surface. Move the probe until it gently touches the magnet surface and then click on the "Vertical Calibration" in the *Calibration Tab*. The current Z-coordinate will be stored as the Zero-Z position.

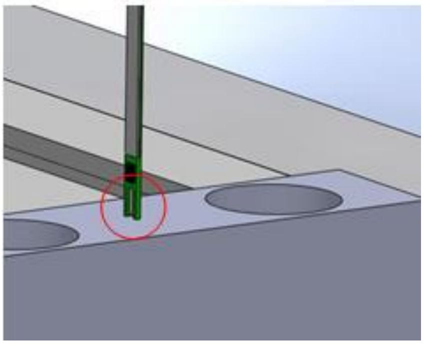


*Fig. 88 – Probe touches the surface*

 Please note that the calibration of vertical distance (Z-axis) in the older versions of Magnetic Field Mapper software was differently executed (touching the surface and providing the distance between the FSV and probe-tip). This procedure required the information of the FSV position in the Hall probe.

4. **Center of rotarty stage** – the probe position is always defined by tree position coordinates X, Y and Z. This coordinates are given in millimeters at the top left of the screen. The right reference coordinate system can be aligned exactly in the center of the rotation table. When X=0 and Y=0 the probe is in the axis of rotation of the rotation table. Z coordinate displays distance between the probe's FSV (Field Sensitive Volume) and the reference surface. The surface of the magnet under test should be taken as reference surface. User can define the desirable reference surface which will be described later. This calibration algorithm is described in the chapter 3.5.3 of this document. Place the tool for the determination of the rotation axis on the rotary stage of the mapper and in Manual Tab, position the probe close in the center of the tool (approximatively) and at the vertical distance of 4-5mm from the tool surface. Then start the calibration. The rotary stage will turn several time, the probe will move in X and Y directions and the magnetic field zero-crossings will be measured during these turns. At the procedure end, the "Completed" message will appear on the screen and the coordinates (center of rotation will be stored).

*Fig. 89 - Tool for the axis of rotation determination*

5. **Set probe FSV position** – The position for FSV calibration shall be the center of the FSV tool (FSV = magnetic **F**ield **S**ensitive **V**olume). If this tool vas dispositioned or the Hall probe was replaced, it might be needed to position the probe in the center of the FSV tool and to store its coordinates for the FSV Calibration procedure.

⚠ This command shall be executed only if necessary. Storing the wrong coordinates might cause the FSV Calibration not to work properly.

6. **FSV Calibration** – This calibration algorithm is described in the chapter 3.5.2 of this document. On activating this procedure, the probe will be navigated over the PCBs in X-, Y- and Z-direction and the position of the magnetic field sensitive volume will be obtained and the corresponding fields (X,Y,Z; old and new values) will be updated. The procedure ends with a "Completed" message on the screen.

   The old and new values can be then compared. A large difference (e.g. >0.1mm) indicates either a probe displacement in the probe holder or a need for Hall probe recalibration at SENIS.

7. **Orthogonality Calibration (Optional)** – This calibration algorithm is described in chapter 3.5.3 and of this document. Fix the tool for the determination of the rotation axis on the rotary stage of the mapper and start this Calibration procedure. It will turn the rotary stage several times, calculate the homogeneity, obtain the optimal values and store them accordingly. At the procedure end, the "Completed" message will appear on the screen.

⚠ All calibrated values are stored in the appropriate calibration files in the Calibration folder (as per Figure 23). Once the system is properly calibrated, the Calibration folder has to be backuped. In case of a wrong calibration procedure, the good calibration data might be overwritten and lost. In this case restore the Calibration folder or a part of it from the good backup. In this case a good initial state will be established again (NOTE: the vertical distance might not match the current magnet type).

⚠ Turning the wheels on the linear modules, a mechanical rework on the mapper or a displacement of the probe or its holder can unset the coordinate system of the probe. Reference the probe position each time you use these wheels to prevent possible damage on the probe. In this case a backup/restore procedure is not fully applicable.

⚠ Vertical Calibration shall be executed every time a new magnet type has to be scanned, since it surface might be on a different vertical distance.

### 4.2.4 Setup Tab

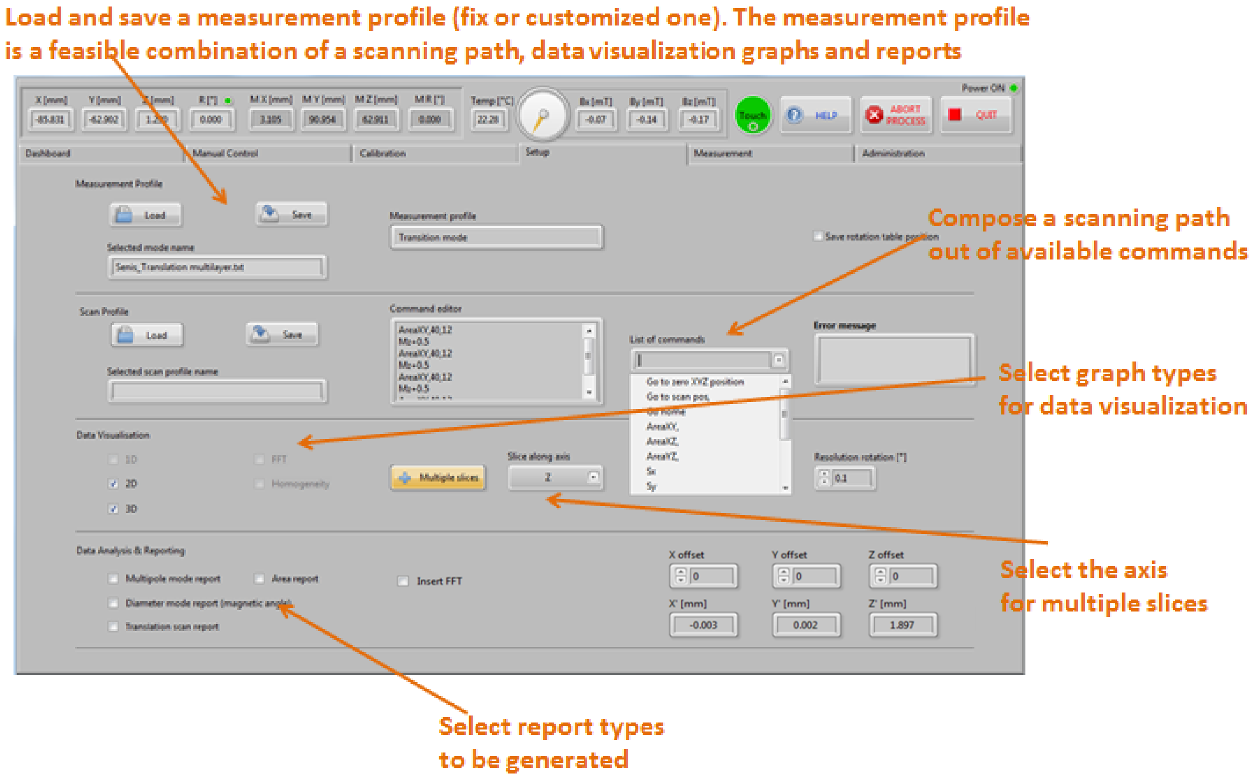



*Fig. 90 – Setup Tab for Measurement Profile definition*

The *Setup Tab* allows user to define a measurement profile, which consists of a feasible combination of the scanning path, the data visualization type (measured data display) and the PDF report type.

Scanning paths can be loaded, modified and stored. There are system defined (SENIS) scanning paths that cannot be modified and should be used for a standard measurement profile or as a template for user-defined measurement profiles. The system defines profiles are stored in the Measurement mode folder.

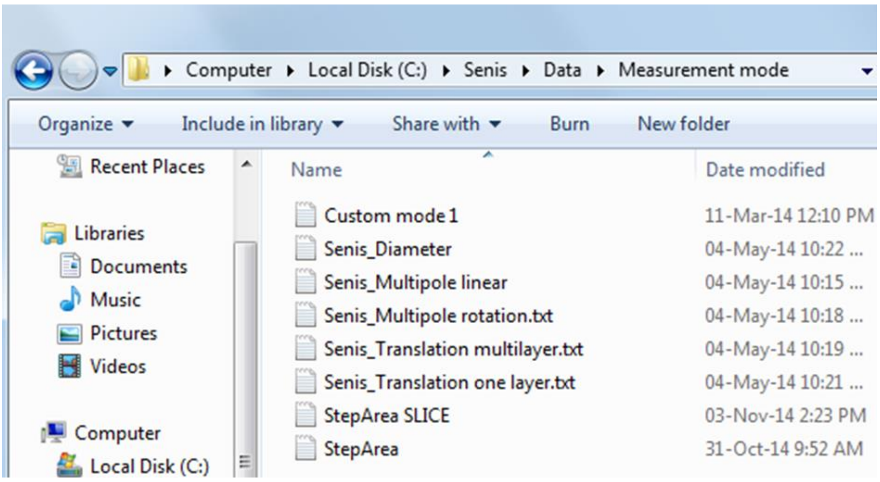



*Fig. 91 – System-defined Measurement Profile files*

The scanning path can be created or modified using the command editor. It provides a list of the available commands, which can be used for setting up a scanning path.

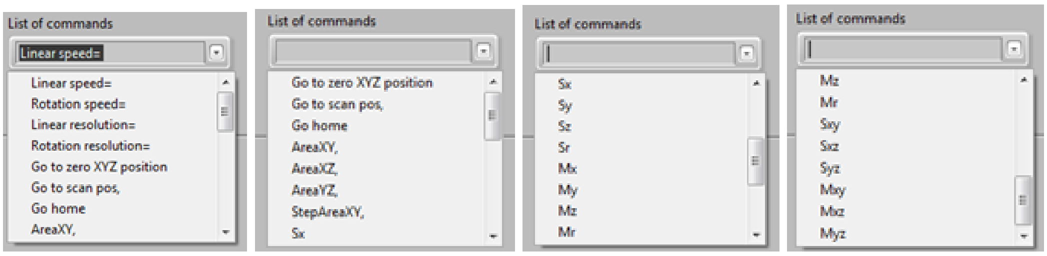



*Fig. 92 – Available commands in the comand editor*
*(an example – it might differ based on the software version)*

**Linear speed=** – this command sets the speed of linear modules
Example: **Linear speed=50**

**Rotation speed=** – this command sets the speed of the rotary stage
Example: **Linear speed=50**

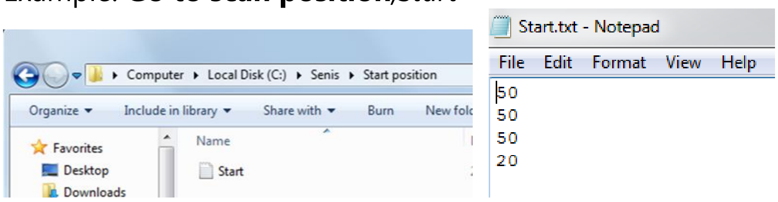
**Linear resolution=** – this command sets the resolution (in µm) of linear modules
Example: **Linear resolution=100**

**Rotation resolution=** – this command sets the resolution (in °) of the rotary stage
Example: **Rotation resolution=0.2**

⚠ Do not use this command with Diameter mode (scanning profile)

**Go to zero XYZ position** – this command will position the probe in the mapper zero coordinates and rotary stage at 0°

**Go to scan position** – providing the start position file path, this command will position the probe in the desired start position. This file must be saved under C:\\Senis\Start position. The data are entered in the customized-named file (XYZR)
Example: **Go to scan position**,*Start*




**Go home** – this command will position the robe in the Zero Gauss Chamber

**AreaXY,** – providing the X,Y distance in mm the probe will move along area
Example: **AreaXY**,*4,4*

**AreaXZ,** – providing the X,Z distance in mm the probe will move along area
Example: **AreaXZ**,*4,4*

**AreaYZ,** – providing the Y,Z distance in mm the probe will move along area
Example: **AreaYZ**,*4,4*

**StepAreaXY** - providing the X,Y distance the probe will move along area with the delay between the points (delay is given in ms). This command implements the step-by-step measurement,

where a high resolution measurement of small magnetic field is required.
Example: **AreaXZ**,*4*,*4*,100

**Sx** – providing the direction (+/-) and a number in mm, this command will move the probe by given number of mm and in the given direction along the X axis wile measuring magnetic field
Example: **Sx**,*4*

**Sy** – the same as Sx, only in Y axis
Example: **Sy**,*4*

**Sz** – the same as Sx, only in Z axis
Example: **Sz**,*4*

**Sr** – providing the direction (+/-) and a number in degrees, this command will move the rotary stage by given number of degrees and in the given direction (clockwise or counterclockwise) wile measuring the magnetic field
Example: **Sr**,*180*

**Mx** – the same as Sx, only without scanning (without data acquisition)
Example: **Mx**,*4*

**My** – the same as Sy, only without scanning (without data acquisition)
Example: **My**,*4*

**Mz** – the same as Sz, only without scanning (without data acquisition)
Example: **Mz**,*4*

**Mr** – the same as Sr, only without scanning (without data acquisition)
Example: **Mr**,*4*

**Marc** – Moving along an arc in degrees without data acquisition
Example: **Marc**,*180*

**//** – Command comment separator
Example: **Marc//***This is a comment*

**etc. (the list is not completed)**

The command editor allows user to define the path of the probe during the scans. The commands will be written in a txt file. To load the file, click on the browse icon and select the file. If the syntax in the file is not correct, the user will get the error message. Each command needs to be written in the new line.

The general syntax for defining the scanning path is as follows:

**Ab±distance**

A - Represents the type of desired operation and can be M for Move and S for Scan - only capital letters can be used. If the entered letter is "M", the probe will move but will not scan. If the entered letter is "S", the probe will scan while moving.
b – This shows along which axis the probe should move. It can be "x", "y", "z", or "r" for rotation.
± - Shows the direction in which the probe should be moved along the given axis. The direction applies to right coordinate system, and the rotation table rotates clockwise for "+" sign, and counterclockwise for "-"sign.
Distance – Shows how many millimeters the probe should move in the given direction, or how many degrees the rotation table should rotate in given direction. For example, if the text file contains a command Sx+100, the probe will scan 100mm along the x-axis.

The data visualization selection defines the way the measured data will be displayed on the screen:

- 1D – X-Y representation of the data (e.g., Magnet Feld Amplitude vs Time or vs Angle)
- 2D – Magnet Field Color representation in the X-Y plane
- 3D – Magnet Field Color representation in 3D
- FFT – Fast Furrier Transformation – Analysis of the signal harmonics
- Homogeneity – Measurement of magnetic field homogeneity (Angle error vs rotation angle; Angle error = Measured magnetic field angle – rotary stage angle)

In the "Number of slices" control, user can enter the desired number of slices to be scanned. Since there is three dimensions that the user can choose: X, Y and Z, two dimensions define the scanning area and the third number defines the distance between two scanning planes. If the number of slices is one, third dimension is ignored.

For example, if X-Y plain is chosen, and X=3, Y=5, Z=1, X and Y controls define the scanning area (3 mm x 5 mm). Further, if chosen number of slices is two, the probe will scan the area 3 mm x 5 mm in the X-Y plane, move back to the starting point and then move up from the magnet surface for 1 mm in the Z axis direction, and scan another 3 mm x 5 mm. In this way the probe has scanned the area 3 mm x 5 mm in the two parallel planes with 1 mm distance between these planes. The graphical display of the results will appear from left to right for each new plane. After the scan is finished, the probe will always move back to the starting point for the first plane. In this way one can repeat the measurements, or put another magnet for testing, without adjusting the probe position.

Scanning resolution is also user selectable. Keep in mind that better resolution means longer scanning time. It is not recommended to use better scanning resolution than 0.1 mm since it would take too much time to finish (except for the very small scanning area).

Diameter mode always scans with the 0.1° resolution.

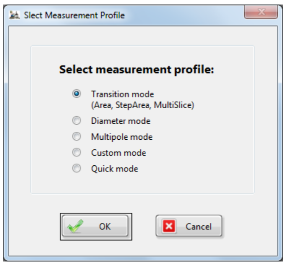
Typical predefined measurement profiles with feasible combinations of data visualization and reports are listed below. All measurement modes can be processed in a number of slices (distance in the Z-axis) and presented on the multiple diagrams. Please note that not all of measurement profiles are necessarily included in the delivery scope.

1. Custom Mode – allows user to define the custom measurement profile setting and store it for further use. The reports and visualization can be modified (all combinations).
2. Quick mode - allows user to define the custom measurement profile setting. The reports and visualization can be modified (all combinations).
3. Diameter mode – In this mode the probe is fixed on a desired distance from the center of a ring-magnet and the rotary stage turns, typically 360°. The magnetic field is measured and the results are presented on 1D plot (Amplitude vs rotation angle). The FFT (Angle harmonics) and homogeneity visualization is also enabled.
4. Multi-pole rotation mode – In this mode the probe is fixed on a desired distance from the center of a ring-magnet and the rotary stage turns, typically 360°. The magnetic field is measured and the results are presented on 1D plot (Amplitude vs rotation angle) for several slices. The FFT ("angle harmonics+) visualization is also enabled.

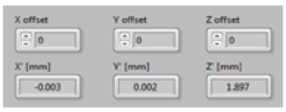
5. Multi-pole Linear mode – During this measurement, the probe moves above the magnet, while the magnet is fixed. The probe starts measuring from a starting point, continues for the defined distance. After the distance is reached, the probe moves back to the starting point. The magnetic field is measured and the results are presented on 1D plot (Amplitude vs distance). The FFT ("distance" harmonics) visualization is also enabled.
6. Translation one layer mode – During this measurement, the probe moves above the magnet, while the magnet is fixed. The probe starts measuring from a starting point, continues for the defined grid in X-Y plane. After the grid is scanned, the probe moves back to the starting point. The magnetic field is measured and the results are presented on 2D and 3D color graphs.
7. Translation multi-layer mode – During this measurement, the probe moves above the magnet, while the magnet is fixed. The probe starts measuring from a starting point, continues for the defined grid in X-Y plane in the defined number of slices (Z distances). After the grid is scanned, the probe moves back to the starting point. The magnetic field is measured and the results are presented on 2D and 3D color graphs for several slices.
8. StepArea – During this measurement, the probe moves above the magnet step-by-step, while the magnet is fixed. The probe starts measuring from a starting point, continues for the defined grid in X-Y plane with a defined time interval between each step, which is defined by the scanning resolution. After the grid is scanned, the probe moves back to the starting point. The magnetic field is measured and the results are presented on 2D and 3D color graphs for several slices.
9. StepArea SLICE – During this measurement, the probe moves above the magnet, while the magnet is fixed. The probe starts measuring from a starting point on continues for the defined grid in X-Y plane with a defined time interval between each step, which is defined by the scanning resolution. The scanning is done in the defined number of slices (Z distances). After the grid is scanned, the probe moves back to the starting point. The magnetic field is measured and the results are presented on 2D and 3D color graphs for several slices.

⚠ If the probe is not in the correct starting position, there is a risk of damaging it.

The user can modify any measurement profile and save it with another file name at any customer's folder. When saving the profile, a profile type shall be selected:




The fields X-offset, Y-offset and Z-offset allow users to change the coordinates that will be written in the output file. In other words, it is used to define a new coordinate system for the measurement reports.



### 4.2.5 Measurement Tab

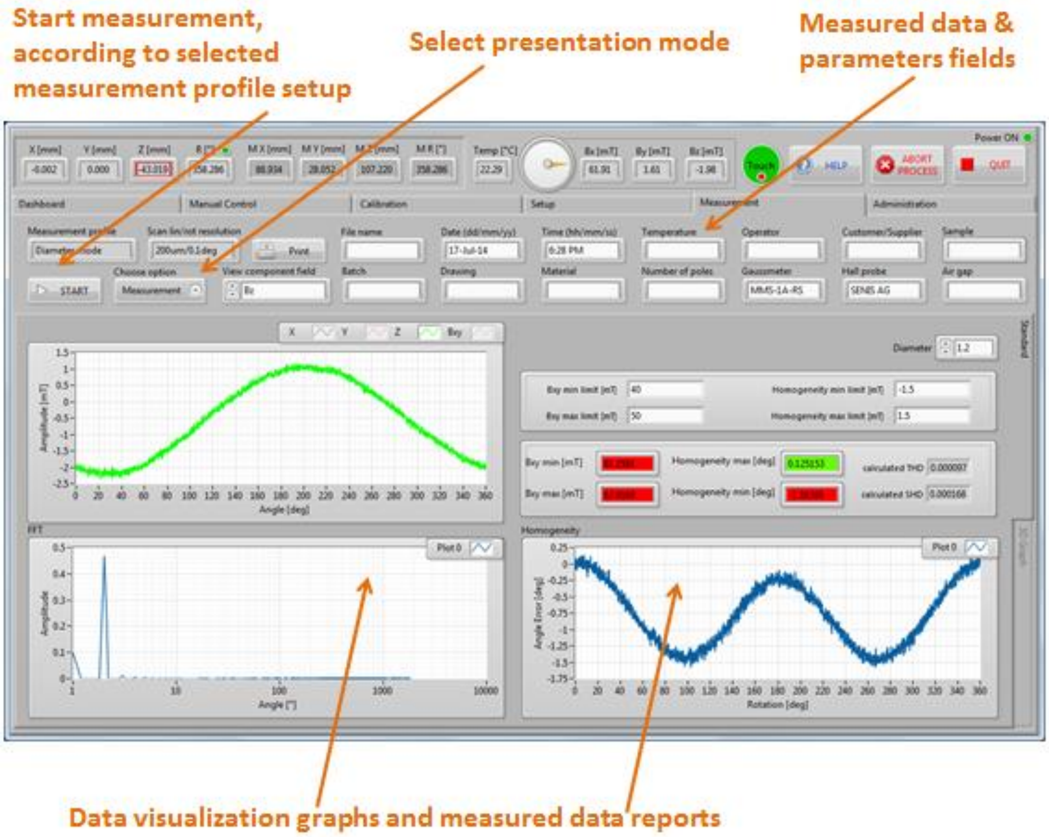



*Fig. 93 – Measurement Tab for measured data visualization*

After the measurement profile is setup in the *Setup Tab*, the user can start the measurement in the *Measurement Tab*.

There are fields for labeling magnets, including magnet type, drawing, lot, magnet sample and operator. Before a measurement, the operator enters these values for each magnet under test. All this data are provided in the report, generated along with measured data for the corresponding magnet.

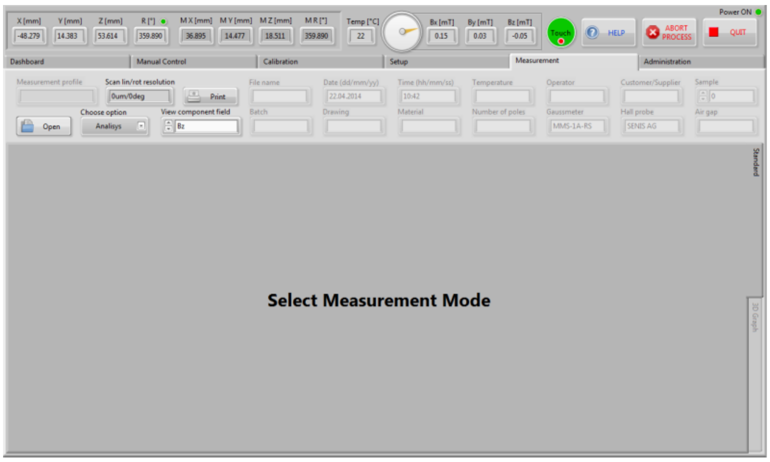



*Fig. 94* – Measurement Tab prior to setting a measurement profile

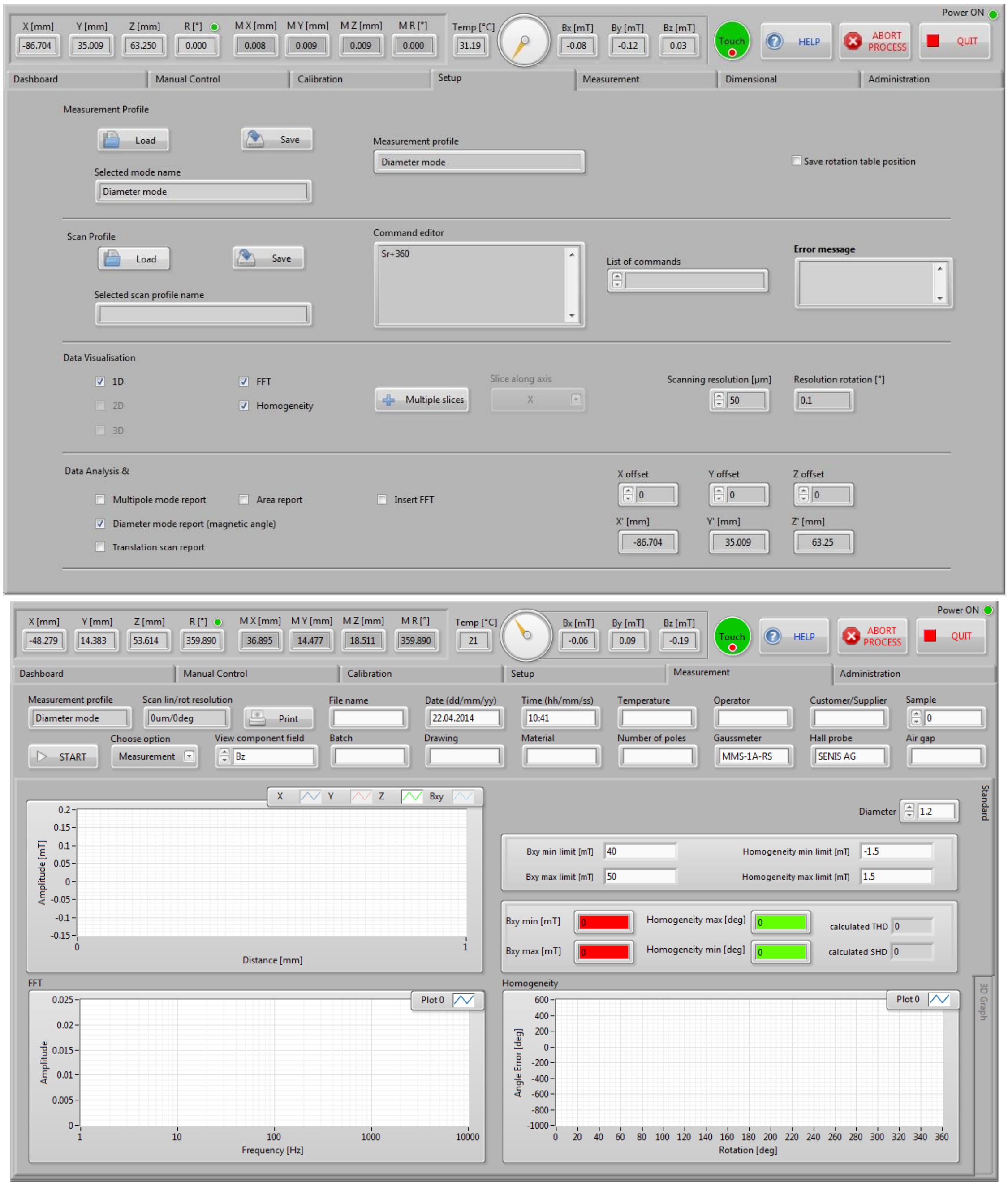



*Fig. 95 – Measurement Tab after setting a measurement profile – Diameter Mode*

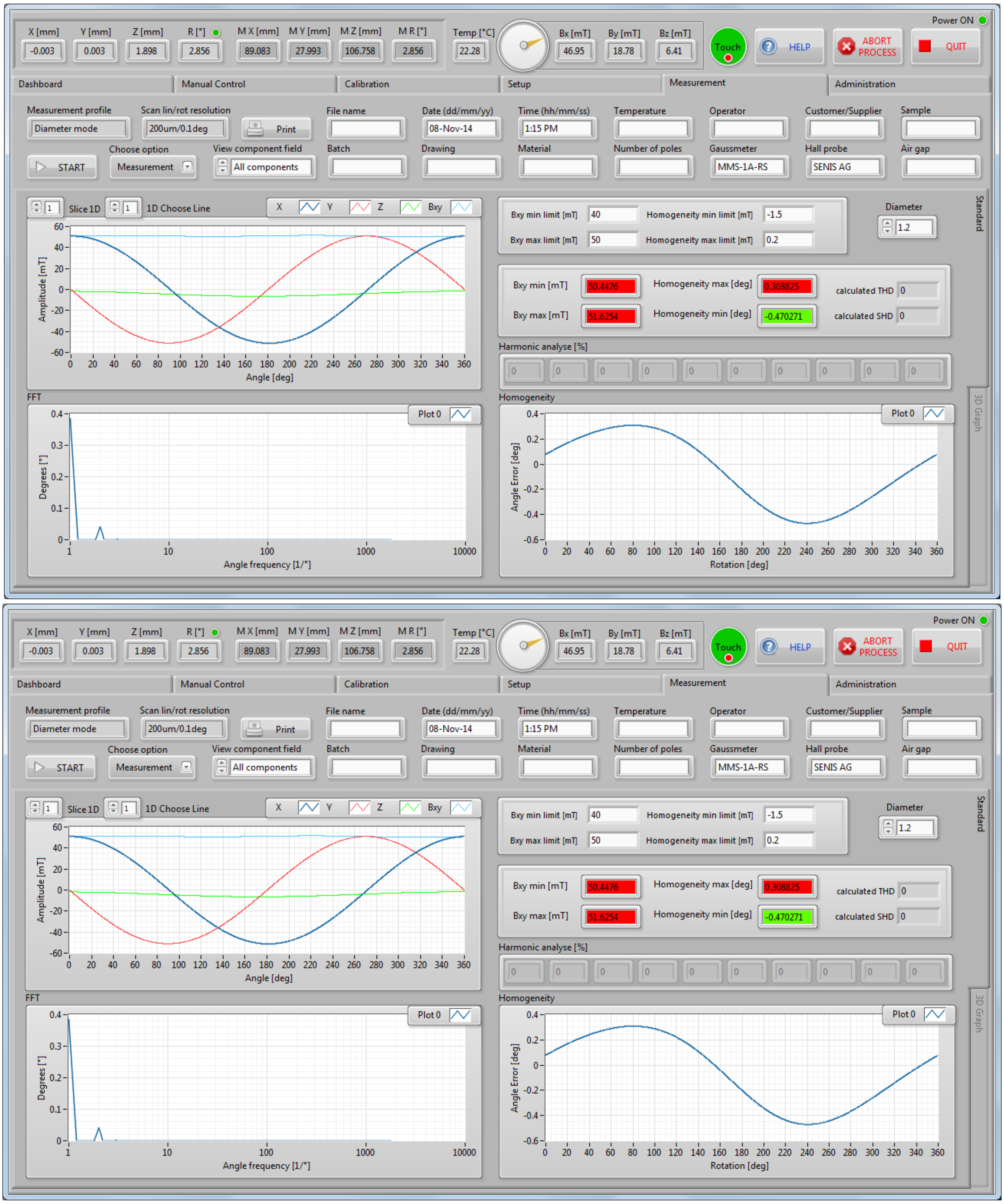



*Fig. 96* – Measurement Tab *after a completed measurement process* – Diameter Mode.
The bottom screen shows the case when the tolerances were exceeded (fields are red-colored).


*Fig. 97 – Measurement Tab after setting a measurement profile – Multipole Mode*

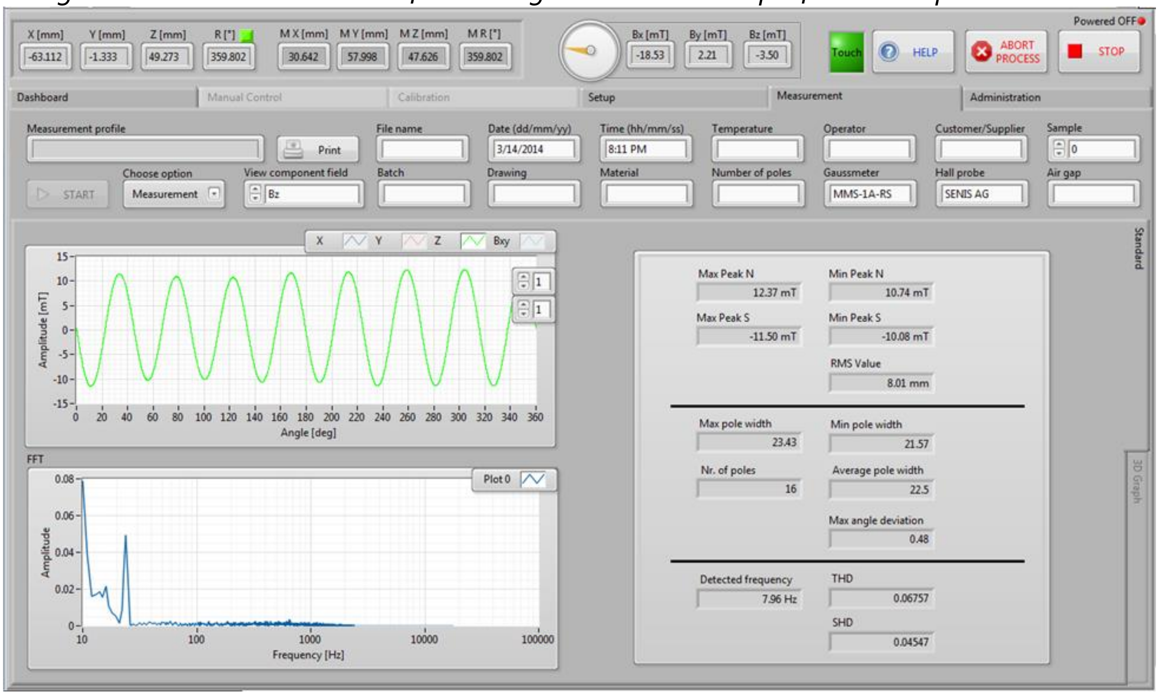
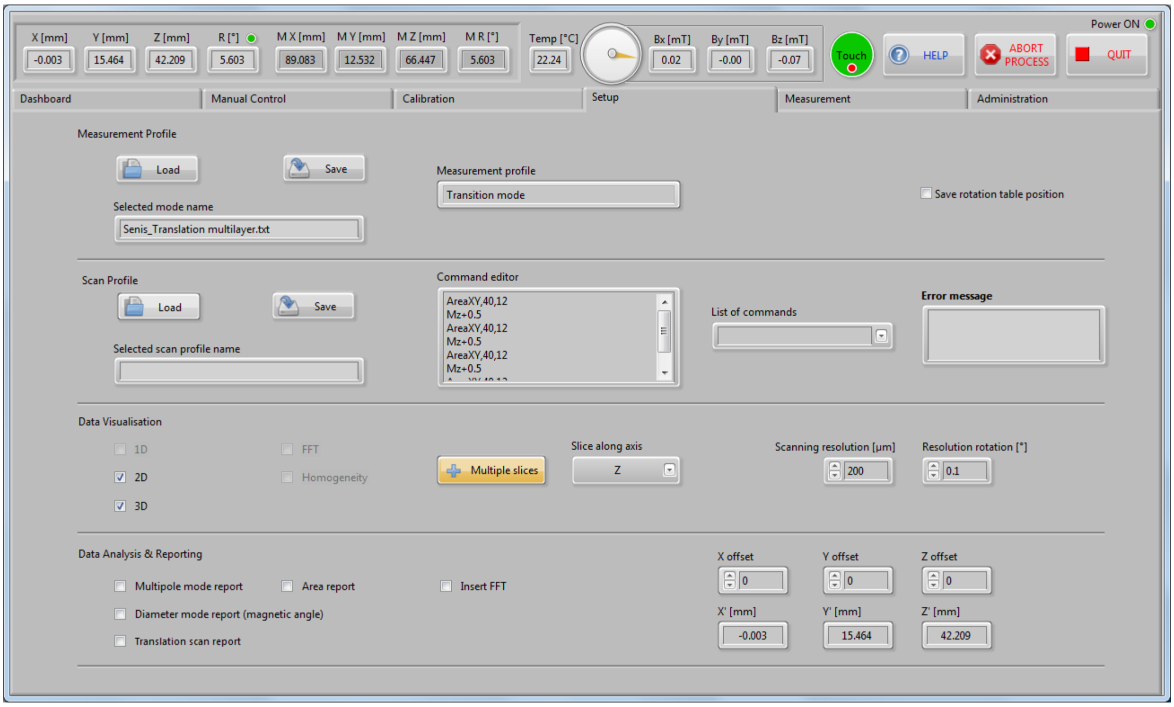
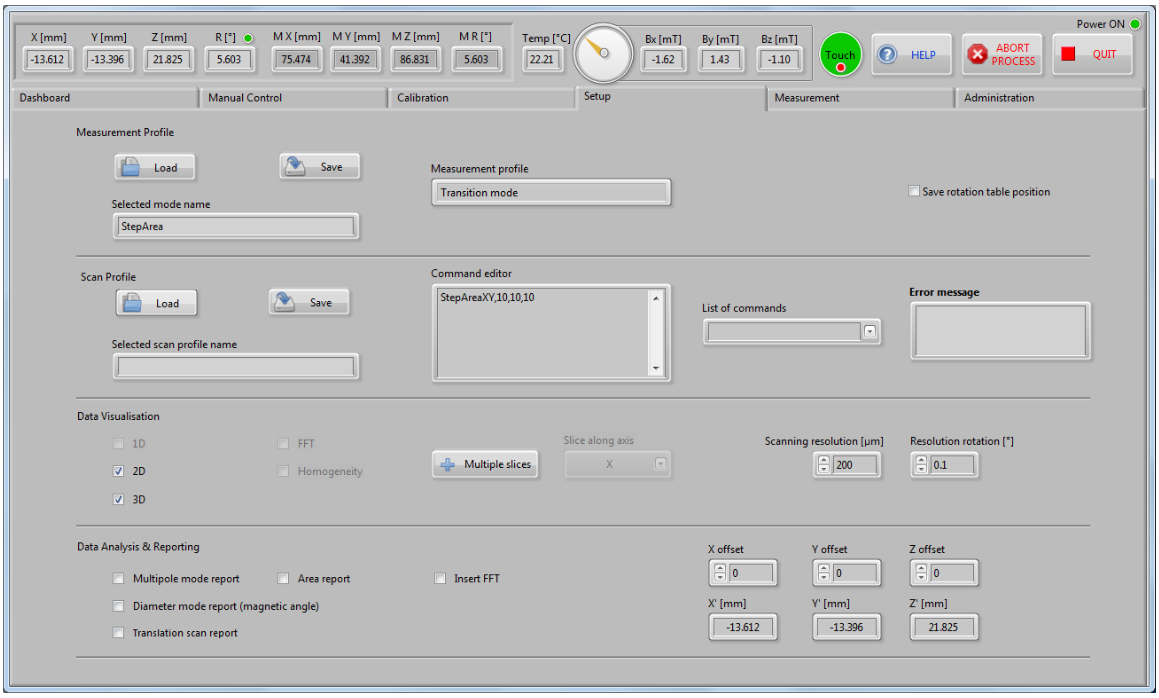
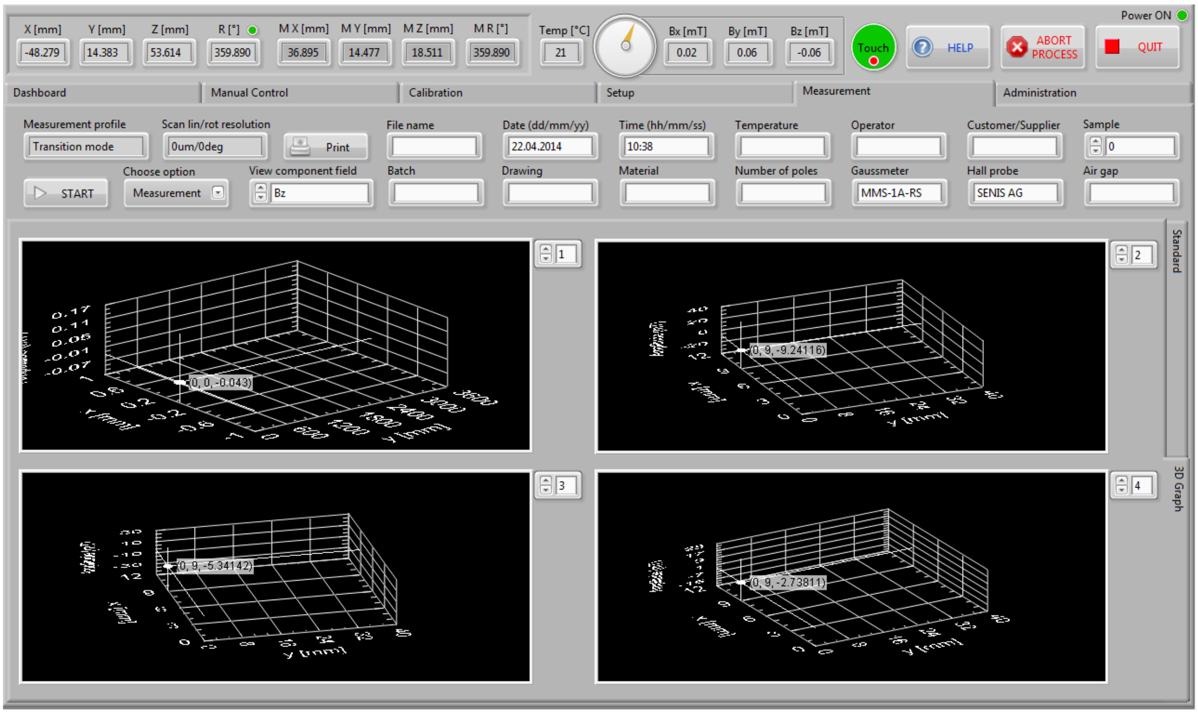



*Fig. 98 – Measurement Tab after a completed measurement process – Multipole Mode*


X [mm] -0.003
Y [mm] 15.464
Z [mm] 42.209
R [°] 5.603
M X [mm] 89.083
M Y [mm] 12.532
M Z [mm] 66.447
M R [°] 5.603
Temp [°C] 22.24
Bx [mT] 0.02
By [mT] -0.00
Bz [mT] -0.07
Touch
HELP
ABORT PROCESS
QUIT
Power ON
Dashboard
Manual Control
Calibration
Setup
Measurement
Administration
Measurement Profile
Load
Save
Selected mode name
Senis_Translation multilayer.txt
Measurement profile
Transition mode
Save rotation table position
Scan Profile
Selected scan profile name
Command editor
AreaXY,40,12
Mz+0.5
AreaXY,40,12
Mz+0.5
AreaXY,40,12
Mz+0.5
List of commands
Error message
Data Visualisation
1D
2D
3D
FFT
Homogeneity
Multiple slices
Slice along axis
Z
Scanning resolution [µm]
200
Resolution rotation [°]
0.1
Data Analysis & Reporting
Multipole mode report
Area report
Insert FFT
Diameter mode report (magnetic angle)
Translation scan report
X offset
Y offset
Z offset
X' [mm] -0.003
Y' [mm] 15.464
Z' [mm] 42.209


X [mm] -13.612
Y [mm] -13.396
Z [mm] 21.825
R [°] 5.603
M X [mm] 75.474
M Y [mm] 41.392
M Z [mm] 86.831
M R [°] 5.603
Temp [°C] 22.21
Bx [mT] -1.62
By [mT] 1.43
Bz [mT] -1.10
Touch
HELP
ABORT PROCESS
QUIT
Power ON
Dashboard
Manual Control
Calibration
Setup
Measurement
Administration
Measurement Profile
Load
Save
Selected mode name
StepArea
Measurement profile
Transition mode
Save rotation table position
Scan Profile
Selected scan profile name
Command editor
StepAreaXY,10,10,10
List of commands
Error message
Data Visualisation
1D
2D
3D
FFT
Homogeneity
Multiple slices
Slice along axis
X
Scanning resolution [µm]
200
Resolution rotation [°]
0.1
Data Analysis & Reporting
Multipole mode report
Area report
Insert FFT
Diameter mode report (magnetic angle)
Translation scan report
X offset
Y offset
Z offset
X' [mm] -13.612
Y' [mm] -13.396
Z' [mm] 21.825



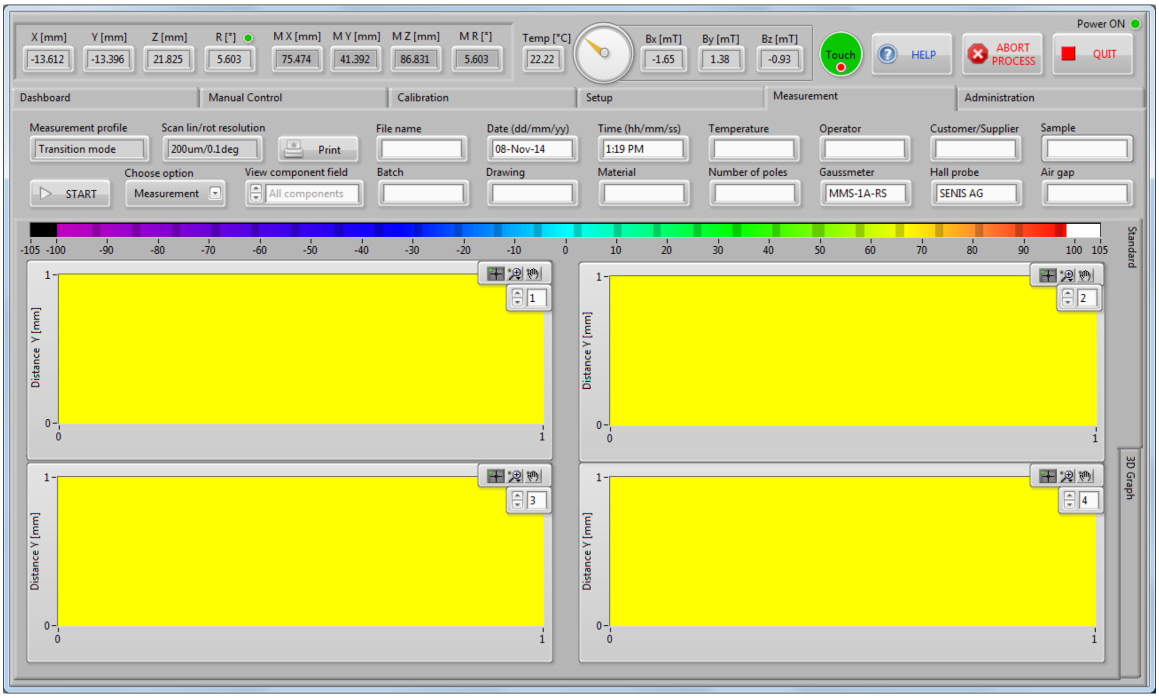




*Fig. 99 – Measurement Tab after setting a measurement profile (Area and StepArea commands) – Translation Mode*

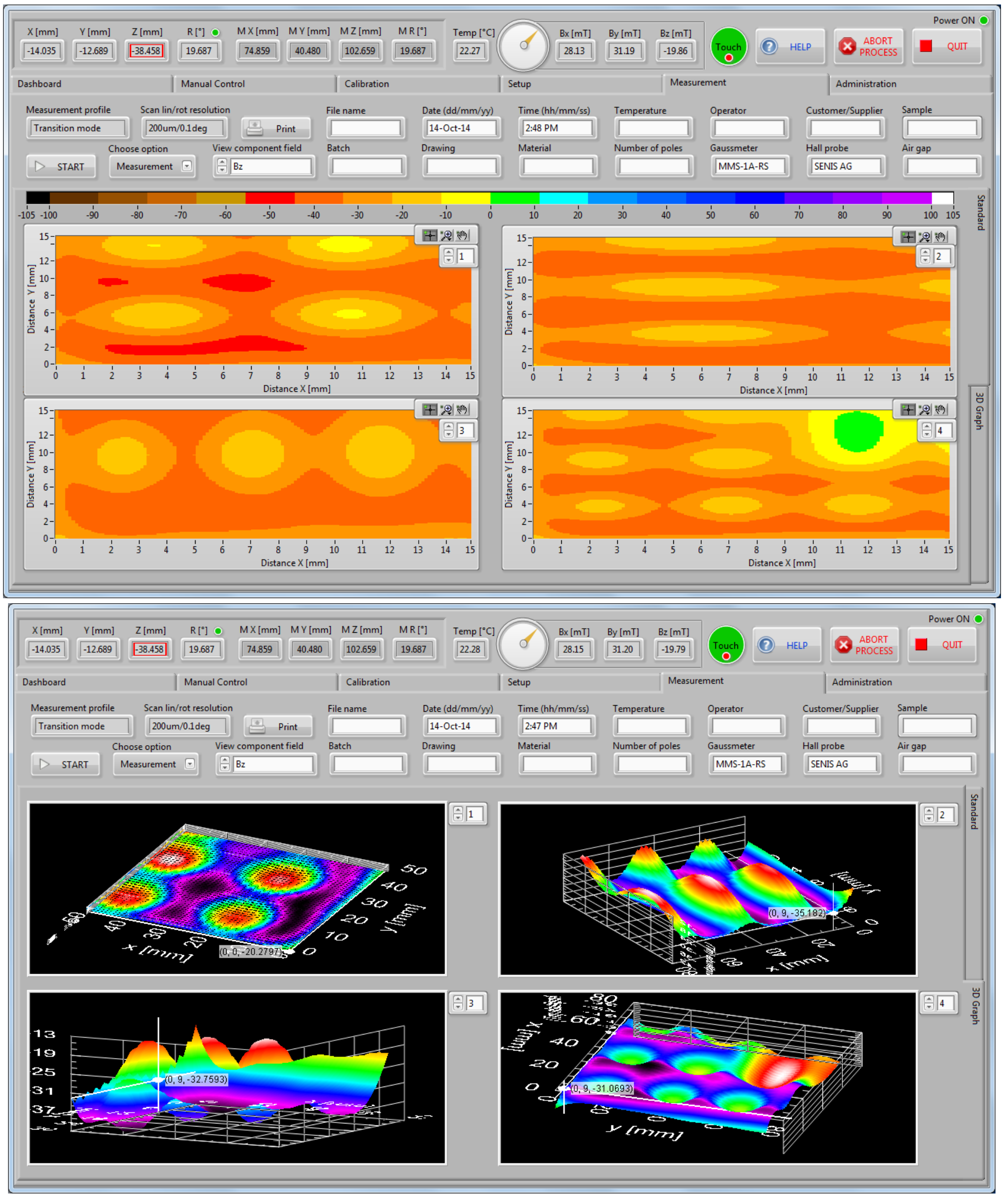



*Fig. 100 – Measurement Tab after a completed measurement process – Translation Mode (Area and StepArea commands)*

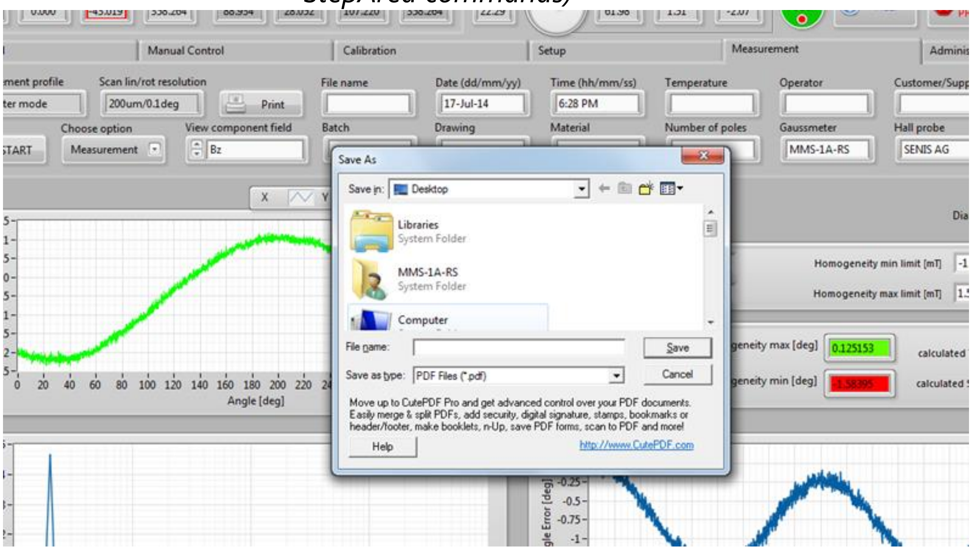



*Fig. 101 – In case of a report being selected in the Setup Tab, the browser will apear for entering the PDF report file name*

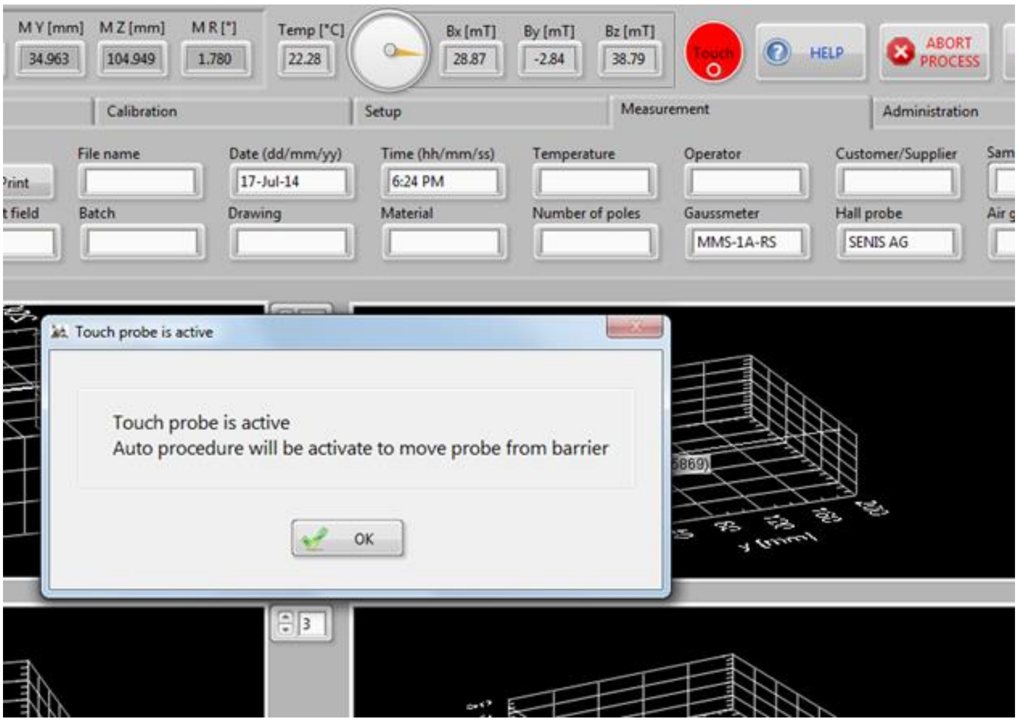
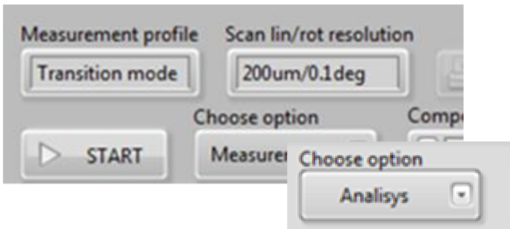
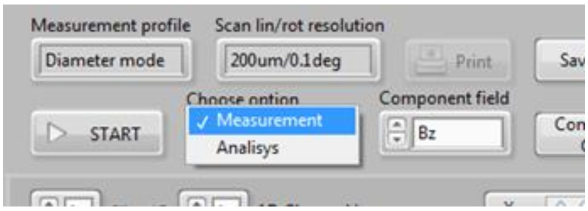



*Fig. 102 – In case the probe touches an object during the measurement, the probe movement will be stopped and an appropriate warning message will appear on the screen*

**Visualization modes**

There are two data visualization modes available in the *Measurement Tab*:



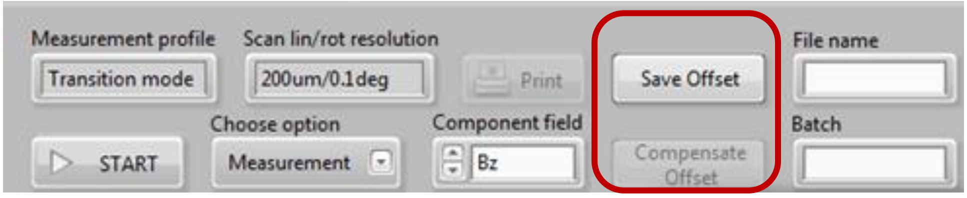




Measurement – Standard Mode for performing and visualization of measurements

Analysis – provides the off-line analysis of already completed measurements

**Offset Compensation**

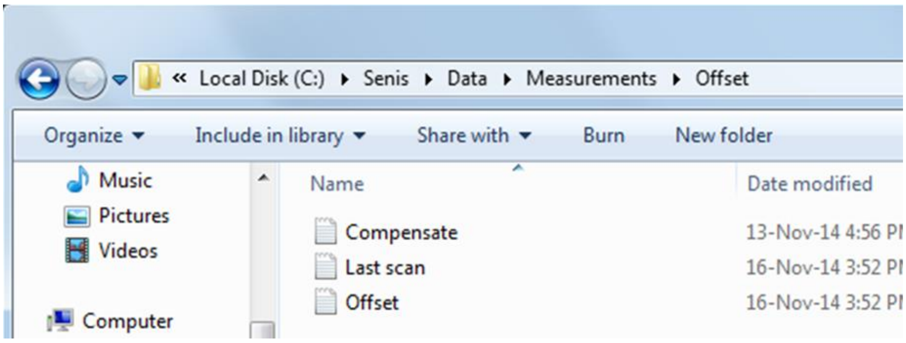
In the *Measurement Tab* the User can decide to scan an area without magnet positioned on the mapper table. These scanned results can be used as Offset compensation for the next measurement with the object under test. With the *Save Offset* button the scan result is saved in the *Offset.txt* file for the future Offset compensation. If the scan results are saved for Offset compensation, the user can scan now the same area with the magnet. After the magnet was canned, with the *Offset Compensation* button the saved scan results will be subtracted from the later scanned results (*Last scan.txt* file) and the offset compensated results will be saved in the *Compensate*.txt file and presented on the screen.




=>


The saved scan results for Offset compensation (Offset saved) are deleted as soon as the measurement tab is left in order to ensure the compatible data for Offset compensation. For Offset compensation in the measurement tab, please do not leave the measurement tab during between the scanning without magnet, *Save Offset* button, scanning with magnet and *Offset Compensation* button.

All three scan results are saved in the ...\\Measured data\Offset folder and can be off-line analyzed in the Analyze mode (files *Compensate.txt, Last scan.txt and Offset.txt*).



### 4.2.6 Administration Tab

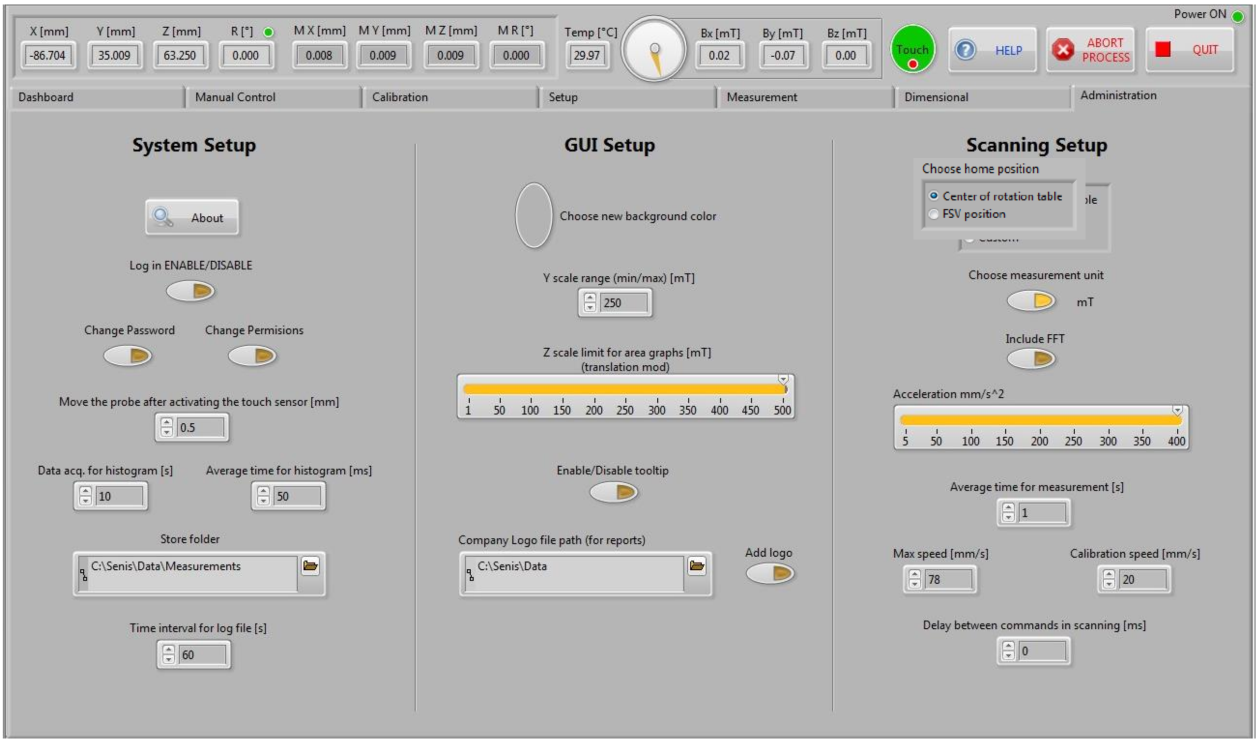



*Fig. 103* – Admin Tab for system settings

The follwing settings area are provided in the *Admin Tab*:

1. **System Setup** – User Settings
   a. About Window with Mapper Software information (required for tech support)

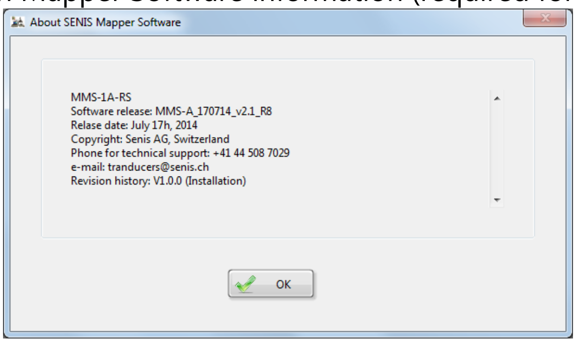
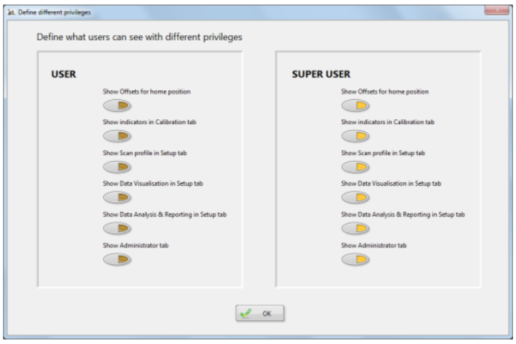



*Fig. 104 – About window for Mapper Software*

   b. Enable/Disable the log in at the Mapper software start
   c. Login Password
   d. Permisson setup for User/Administrator




e. Data acquisition and data avaraging time for hystogram (probe noise) obtained at the program start
f. Store folder setup for measurement results
g. Saving interval for data log file

2. **GUI Setup**

a. Background Color setup
b. Y-axis scaling in the manual tab
c. Z-axis scaling in the measurement tab
d. Instructional Tooltips enable/disable
e. Customer's Logo in PDF reports

3. **Scanning Setup**

a. Selection of the refernce coordinate system
b. Enabling FFT during the scanning
c. Probe motion acceleration setting
d. Maximal speed setup during scanning
e. Maximal speed setup during calibration
f. Delay (in ms) between commands in the scanning profile (to avoid the probe vibrations during the scanning)

### 4.2.7 Dimensional Measurement Tab (Option)

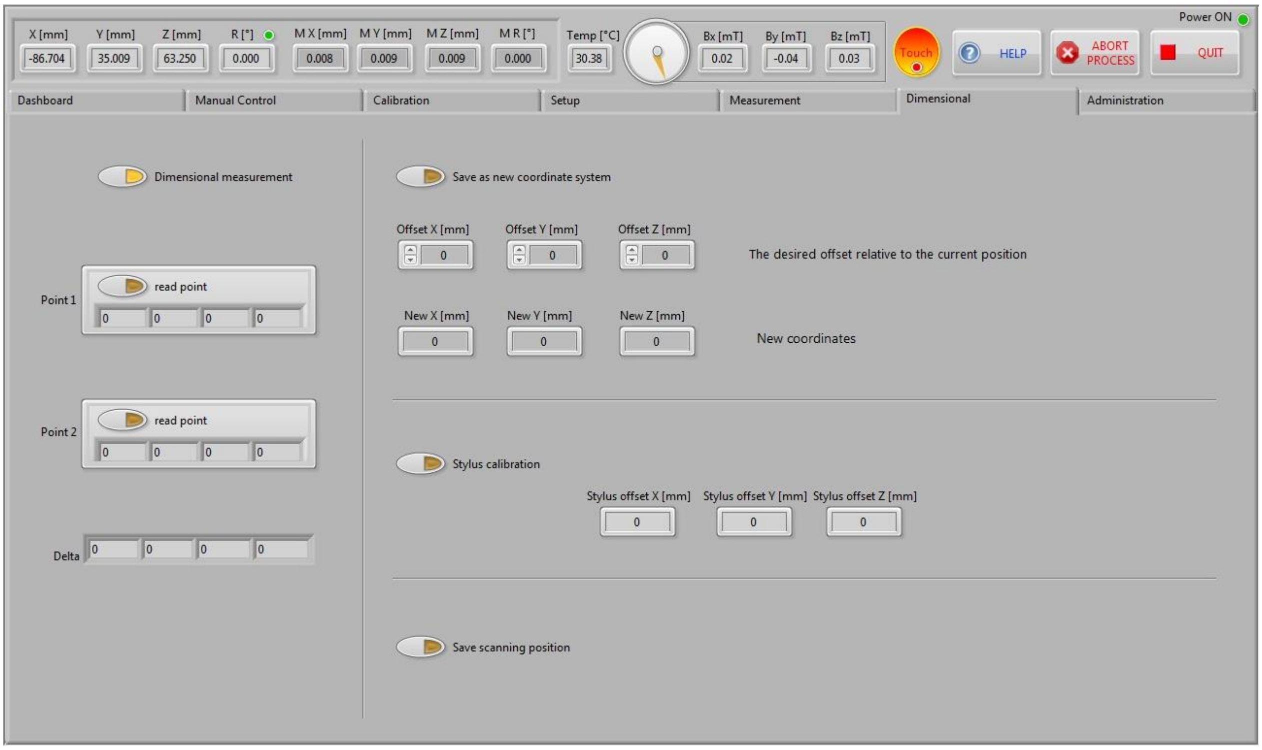



*Fig. 105* – Dimensional Tab

If the Dimensional Measurement Option was ordered, a dedicated software module is delivered to be used for the dimensional measurement.

Due to application of linear and rotary encoders, the probe position coordinates can be accuratelly measured. The coordinates are stadilly calculated and shown in the mapper software. By moving the probe (manualy or within a scanning profile) these coordinates change.

In the *Dimensional Tab* user can setup its customized coordinate system, i.e. zero coordinates for absolute magnet positioning.

The dimensinal measurements and the absolute magnet positioning is performed using the touch stylus. The calibration of the touch stylus and the Hall probe field sensitive area can be performed in this tab. During the calibration, the relation between the position of the stylus sapphire ball (used for dimensional measurements) and the field sensitive spot of the probe (used for magnetic field measurements). All this with regard to the mapper coordinate system that is defined by reference markers on linear encoders.

The Touch-trigger sensor is a mechanical device that has the ability to return the stylus ball to the same repeatable position following any deflection. For the touch-trigger function, the probe is moved in the direction of the object under test, until it is touched. The touch sensor is connected to the controller of the Mapper so that the exact probe position (X-, Y-, and Z-coordinates) is saved and the movement is stopped when the probe touches an object under test.

The Hall probe is mounted (mechanically connected) to the touch-trigger sensor, which is fixed on the Mapper moving console. During the magnetic field mapping, the touch-trigger sensor is used to prevent probe damage. As soon as the Hall probe touches an object, the touch-trigger sensor will react and the probe movement will be stopped.

For the dimensional measurement of an object under test (e.g. a permanent magnet), the touch-stylus has to be mounted on the touch-trigger sensor, so it replaces the Hall probe.

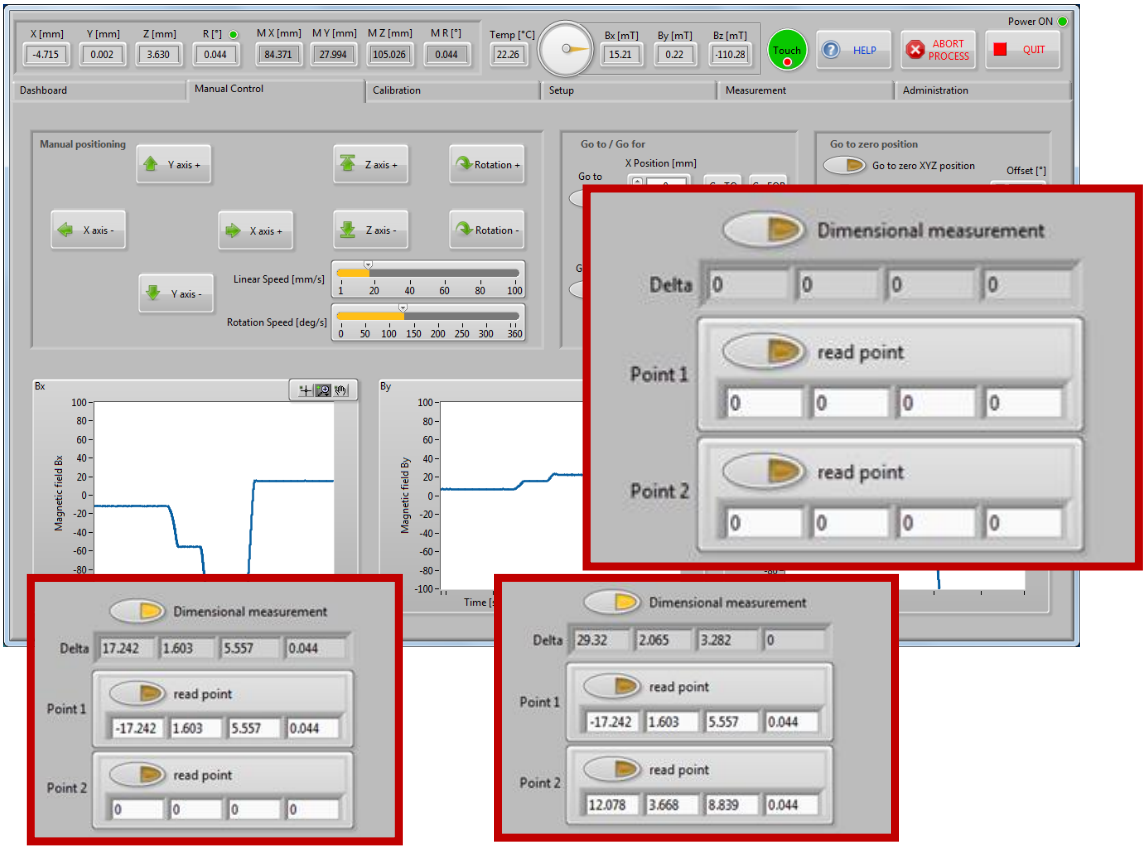
The idea is not to compete with the commercially available CMMs. A mapper does not need to create a couture or 3D object out of the dimensional measurement that shall be validated against an e.g. CAD drawing.

It can be well used for simple measurement of the magnets under test (radius of a ring or disc magnet), length and height of a square magnet etc.

By touching the surface of a magnet under test the probe can be accurately positioned on a defined distance from the magnet surface. It is important for magnet inspection in the quality control or for magnet characterization during the R&D. As an object is touched by the stylus, the coordinates of the touched point (P1) will be stored. By touching the next point on the object (P2), the coordinates of the second touched point will be stored and the delta (distance) between the coordinates of these two points will be calculated as

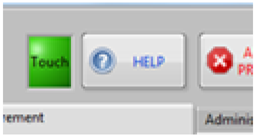
$$\boldsymbol{\Delta(x,y,z)} = \boldsymbol{P2_{(x2,y2,z2)}} - \boldsymbol{P1_{(x1,y1,z1)}}$$

,where **Δ** denotes "delta array" (distances in x-, y- and z-axis); ***P1*** denotes the first touch point; and ***P2*** denotes the second touched point.



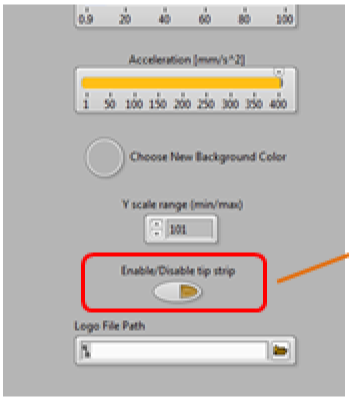
### 4.2.8 Help & Instructions

There are different possibilities to obtain the information and instructions on operating the MMS-1A-RS magnetic field mapper:

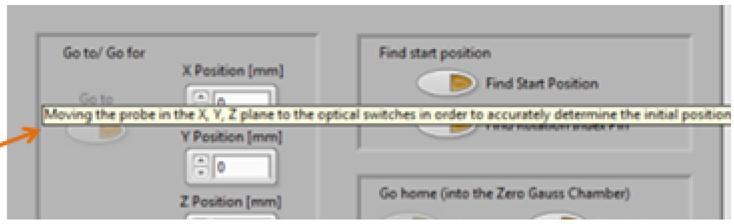



**Help** button starts the User Manual

**Descriptive texts** provide detailed instructions or algorithm descriptions

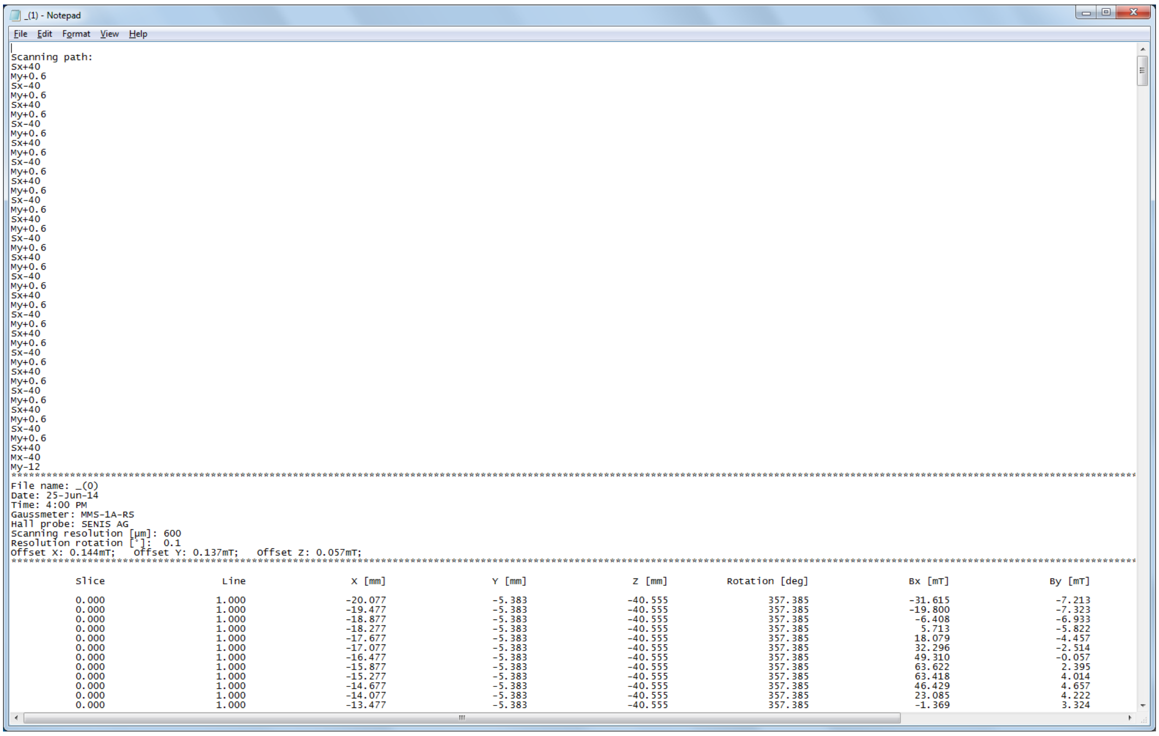

**Tooltips** provide operators instructions



### 4.2.9 Reports

After each measurement, the program will save the measured data in the ASCI file and save the graphs in the PDF file (if reporting was selected). The dialog box will appear asking the user to choose the file name for the PDF report. There are also Area reportsavailable.

The measured data are stored in the Measurements Folder.



```
_(1) - Notepad
File  Edit  Format  View  Help

Scanning path:
Sx+40
My+0.6
Sx-40
My+0.6
Sx+40
My+0.6
Sx-40
My+0.6
Sx+40
My+0.6
Sx-40
My+0.6
Sx+40
My+0.6
Sx-40
My+0.6
Sx+40
My+0.6
Sx-40
My+0.6
Sx+40
My+0.6
Sx-40
My+0.6
Sx+40
My+0.6
Sx-40
My+0.6
Sx+40
My+0.6
Sx-40
My+0.6
Sx+40
My+0.6
Sx-40
My+0.6
Sx+40
My+0.6
Sx-40
My+0.6
Sx+40
Mx-40
My-12
********************************************************************************
File name: _(0)
Date: 25-Jun-14
Time: 4:00 PM
Gaussmeter: MMS-1A-RS
Hall probe: SENIS AG
Scanning resolution [µm]: 600
Resolution rotation [°]:  0.1
Offset X: 0.144mT;   Offset Y: 0.137mT;   Offset Z: 0.057mT;
********************************************************************************

      Slice       Line       X [mm]      Y [mm]      Z [mm]   Rotation [deg]     Bx [mT]     By [mT]

      0.000      1.000      -20.077      -5.383     -40.555        357.385     -31.615      -7.213
      0.000      1.000      -19.477      -5.383     -40.555        357.385     -19.800      -7.323
      0.000      1.000      -18.877      -5.383     -40.555        357.385      -6.408      -6.933
      0.000      1.000      -18.277      -5.383     -40.555        357.385       5.713      -5.822
      0.000      1.000      -17.677      -5.383     -40.555        357.385      18.079      -4.457
      0.000      1.000      -17.077      -5.383     -40.555        357.385      32.296      -2.514
      0.000      1.000      -16.477      -5.383     -40.555        357.385      49.310      -0.057
      0.000      1.000      -15.877      -5.383     -40.555        357.385      63.622       2.395
      0.000      1.000      -15.277      -5.383     -40.555        357.385      63.418       4.014
      0.000      1.000      -14.677      -5.383     -40.555        357.385      46.429       4.657
      0.000      1.000      -14.077      -5.383     -40.555        357.385      23.085       4.222
      0.000      1.000      -13.477      -5.383     -40.555        357.385      -1.369       3.324
```

*Fig. 106 – Example of a measurement file (scanning path in the header and then Bx, By and Bz with the correponding spatial coordinates*

MMS-1A-RS can generate different PDF reports:

Date (dd-mm-year)...: 28-04-2014
Time (hh-mm-ss).......: 16:47:25
Sample.......................: 2
Gaussmeter................: MMS-1A-RS
Hall probe...................: SENIS AG

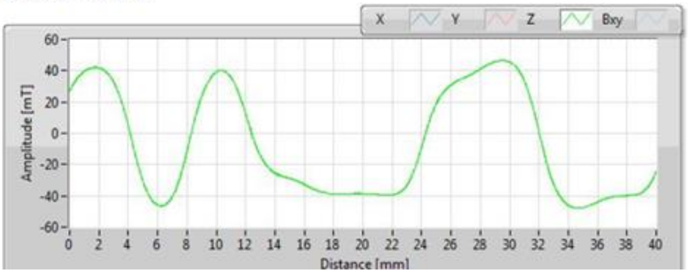
POLES

| N pole | B [mT] | Position [mm] | Position theor. [mm] | Diff. [mm] | Delta [mm] |
|---|---|---|---|---|---|
| 1 | 42.17 | 1.80 | 4.00 | -2.20 | 1.80 |
| 2 | -46.48 | 6.30 | 12.00 | -5.70 | 4.50 |
| 3 | 40.20 | 10.40 | 20.00 | -9.60 | 4.10 |
| 4 | -39.59 | 21.69 | 28.00 | -6.31 | 11.29 |
| 5 | 46.58 | 29.49 | 36.00 | -6.51 | 7.80 |

ZEROES

| N zero | Position [mm] | Position theor. [mm] | Diff. [mm] | Delta [mm] | Slope [mT/mm] | Slope theor. [mT/mm] |
|---|---|---|---|---|---|---|
| 1 | 4.12 | 4.12 | 0.00 | 4.12 | 50.00 | 13.14 |
| 2 | 8.28 | 12.12 | -3.84 | 4.16 | 19.70 | 13.14 |
| 3 | 12.39 | 20.12 | -7.73 | 4.11 | 21.14 | 13.14 |
| 4 | 24.26 | 28.12 | -3.86 | 11.87 | 7.07 | 13.14 |
| 5 | 32.02 | 36.12 | -4.10 | 7.76 | 11.05 | 13.14 |

RMS value= 34.67 mT




| N zero | Angle [deg] | Angle theor. [deg] | Diff. [deg] | Delta [deg] | Slope [mT/deg] | Slope theor. [mT/deg] |
|---|---|---|---|---|---|---|
| 107 | 317.75 | 334.74 | -16.99 | 2.69 | 3.36 | 7.03 |
| 108 | 321.81 | 337.89 | -16.08 | 4.06 | 3.43 | 7.03 |
| 109 | 323.28 | 341.05 | -17.77 | 1.47 | 4.09 | 7.03 |
| 110 | 326.67 | 344.21 | -17.54 | 3.39 | 8.15 | 7.03 |
| 111 | 335.45 | 347.37 | -11.92 | 8.78 | 2.35 | 7.03 |
| 112 | 346.37 | 350.53 | -4.16 | 10.92 | 2.97 | 7.03 |
| 113 | 351.22 | 353.68 | -2.46 | 4.85 | 0.08 | 7.03 |
| 114 | 353.94 | 356.84 | -2.90 | 2.72 | 3.51 | 7.03 |
| | | | | 3.07 | | 7.03 |

RMS value= 8.26 mT

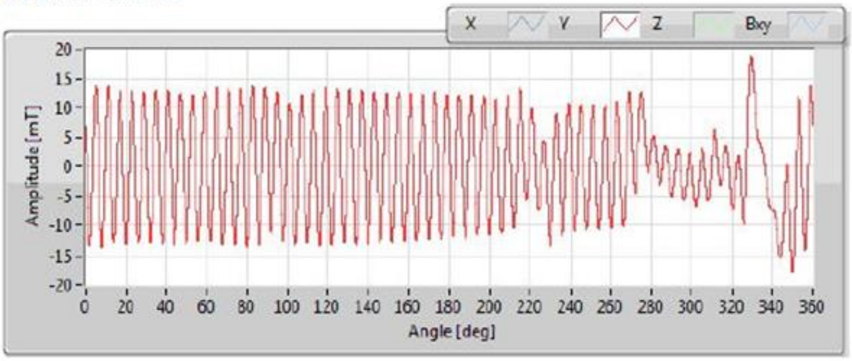



*Fig. 107 – Examples of Mapper Measurement Reports*

# 5. TECHNICAL SPECIFICATIONS

## 5.1 OVERVIEW

The magnetic field mapper performance strongly depends on the characteristics of the applied Hall probe, the measured electronic signal processing and on the positioning system (Cartesian Moving Platform and motion control).

## 5.2 HALL PROBE CHARACTERISTICS

All measurements of the magnetic field are performed with a 3-axis Hall probe. SENIS provides different Hall probe geometries, which can be applied in the MMS-1A-RS, depending on application requirements (robust probe, very thin probe for a measurement close to the magnet surface, etc.).

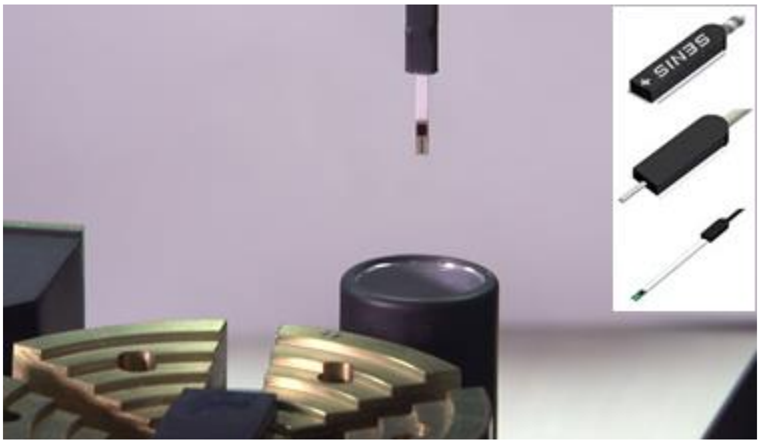


*Fig. 108 – SENIS Hall probes*

The Hall probe is based on the SENIS silicon integrated 3D Hall sensor, shown in Figure below. The sensor incorporates a compact array of horizontal (in the die plane) and vertical (perpendicular to the die plane) Hall elements and a temperature sensor.

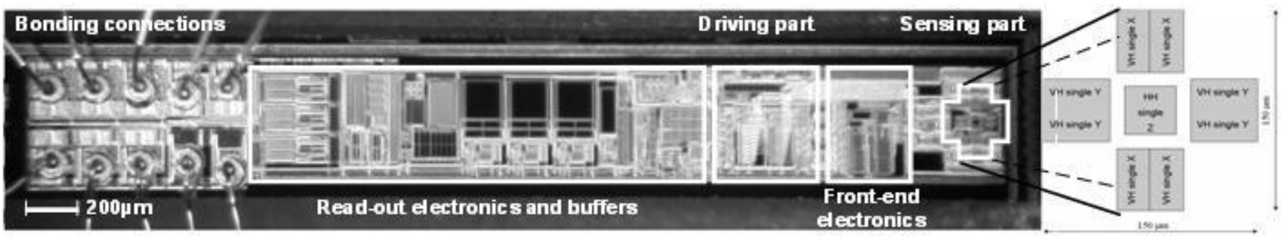



*Fig. 109 - Photograph of a fully integrated 3-axis Hall magnetic sensor*
*This is a CMOS integrated circuit which consists of: the magnetic sensing part, the signal processing part, and the connecting part. The magnetic sensing part is shown on the right-hand side.*

The SENIS magnetic-field-to-voltage Transducer (based on Hall-effect) is precisely calibrated with a NMR Teslameter from the 43mT and higher. The lower magnetic fields can be calibrated using the Helmholtz-coil equipment.

The Hall probe is stiff and assembled on a suitable assembling fixture having precisely machined 3 mutually orthogonal positioning planes. These positioning planes define the coordinate system of the Hall Probe. The position of the center of the MFSV of the Hall Probe with respect to the coordinate system of the Hall Probe is determined with the accuracy better than 50 µm. The dimensions of the Magnetic Field Sensitive Volume (MFSV) of the Hall Probe for all incorporated Hall elements (for all tree axes) is 140 x 10 x 140 µm3. The mutual orthogonally of the three sensitive axes of the Hall Probe is better than 0.1°.

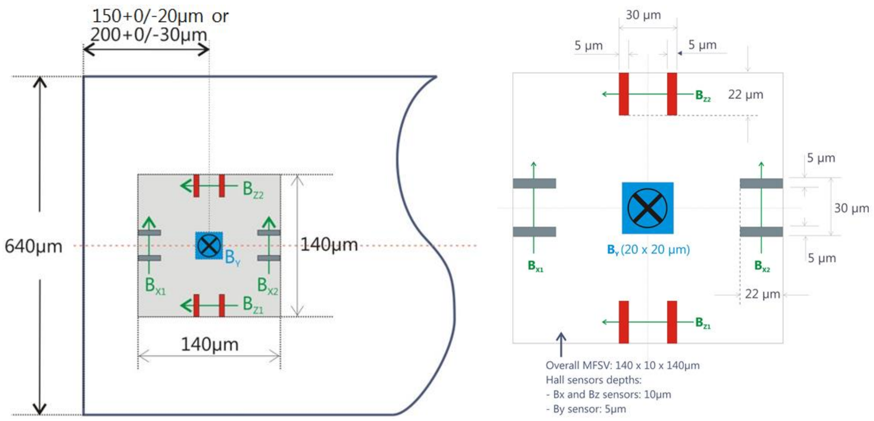



*Fig. 110 - A single horizontal Hall plate (HH) measures the magnetic field component perpendicular to the die plane and two pairs of vertical Hall de vices (VH) measure each of the two in-plane components of a magnetic field. All of these Hall elements are integrated on an area of about 140 mm x 140 mm and have a depth of less than 10 mm.*

The repeatability of the probes positioning is ensured by "calibrating" the probe utilizing the MFSV calibration tool. A further calibration software procedure (calibration tool) is applied to precisely determine the Hall probe position in respect to the angle displacement relative to the Mapper coordinate system and to referent point(s) on the probe (chapter 3.5).

The figure below provides the information on the field orientation measured by Hall probe.

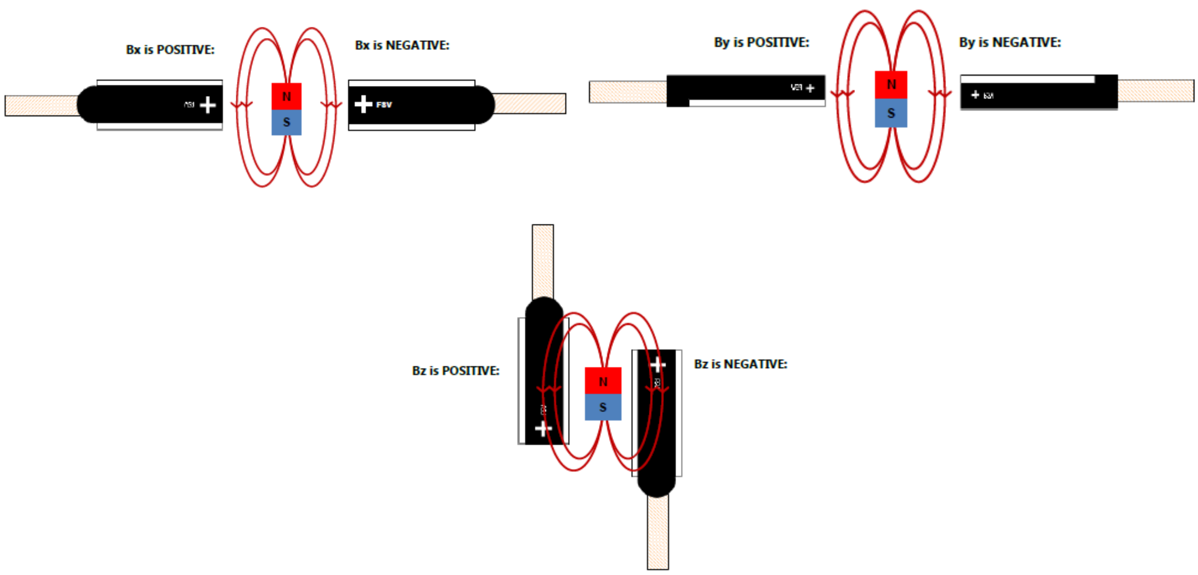
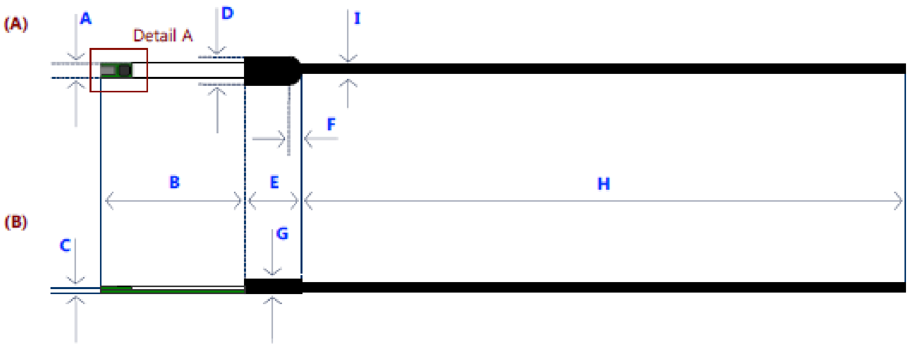
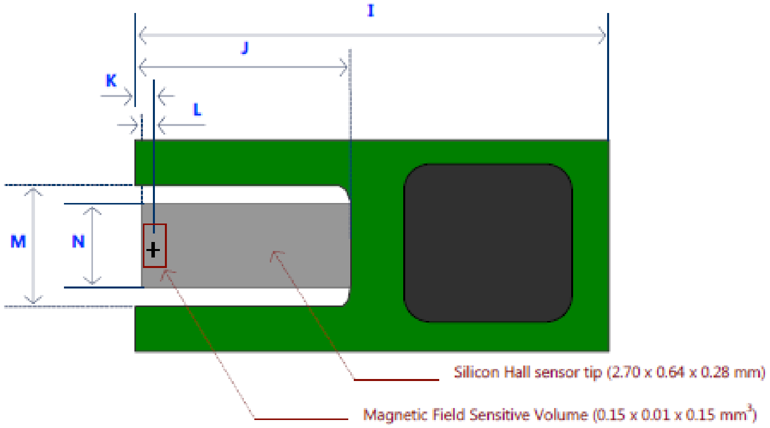



*Fig. 111 – Orientation of the magnetic field mweasured by the Hall probe*

Probe and Cable dimensions and characteristics




**Detail A (15:1): HALL Probe sensitive tip**




| Dimension | [mm] | Dimension | [mm] | Dimension | [mm] |
|---|---|---|---|---|---|
| A | 2.0 +0.1/-0.0 | G | 2.0 ± 0.1 | I | 6.0 ± 0.1 |
| B | 42.3 ± 0.2 | H | 250 ± 10 | J | 2.8 ± 0.1 |
| C | 0.5 +0.1/-0.0 | | | K | 0.35 ± 0.1 |
| D | 4.0 ± 0.1 | | | L | 0.15 |
| E | 12.0 ± 0.3 | | | M | 1.1 ± 0.1 |
| F | R 2.0 ± 0.2 | | | N | 0.64 |

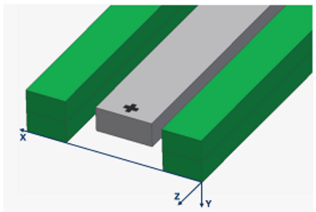



*Figure:* **The reference Cartesian coordinate system of the 03G Hall probe**

| Dimension | X [mm] | Y [mm] | Z [mm] |
|---|---|---|---|
| Magnetic field sensitive volume (MFSV) | 0.15 | 0.01 | 0.15 |
| Position of the centre of MFSV (corresponding to MFSP, see *Fig.2 and 3*) | 1.0 ± 0.1 | -0.4 ± 0.05 | -0.35 ± 0.1 |
| Total Probe external dimensions | • 2.0 +0.1/-0.0 - Longer, thinner part<br>• 4.0 ± 0.1 Shorter, thicker part of the probe | • 0.5 +0.1/-0.0 - Longer, thinner part<br>• 2.0 ± 0.1 - Shorter, thicker part of the probe | • 42.3 ± 0.2 - Longer, thinner part<br>• 12.0 ± 0.1 - Shorter, thicker part of the probe |
| Angular accuracy of the axes | ±0.5° with respect to the reference surface | | |
| CaH Cable | Shielded, with a flexible thin part near the probe | | |

*Fig. 112 – Thin Hall Probe Dimensions (Probe Type K)*

## 5.3 MAGNETIC FIELD TRANSDUCER CHARACTERISTICS

| Parameter | | Value | | | | Remarks |
|---|---|---|---|---|---|---|
| **Standard measurement ranges** | | ± 20mT | ± 0.2T | ± 3T | ± 20T | *No saturation of the outputs; Other meas. ranges available* |
| **Linear range of magnetic flux density (±$B_{LR}$)** | | ± 20mT | ± 0.2T | ± 2T | ± 2T | *Optimal, fully calibrated meas. range* |
| **Total measuring Accuracy (@ B < ±$B_{LR}$)** | high | 0.1% | 0.1% | 0.1% | 0.5% | |
| | low | 1.0% | 1.0% | 1.0% | 0.5% | |
| **Output voltages ($V_{out}$)** | | differential | | | | |
| **Sensitivity to DC magnetic field (S)** | | 500 V/T | 50 V/T | 5 V/T | 0.5 V/T | *Differential output;* |
| **Tolerance of sensitivity ($S_{err}$) (@ B < ± $B_{LR}$)** | high | 0.03% | 0.03% | 0.03% | 0.2% | |
| | low | 0.5% | 0.5% | 0.5% | 0.2% | |
| **Nonlinearity (NL) (@ B < ± $B_{LR}$)** | high | 0.01% | 0.05% | 0.05% | 0.2% | |
| | low | 0.1% | 0.1% | 0.5% | 0.2% | |
| **Planar Hall voltage ($V_{planar}$) (@ B < ± $B_{LR}$)** | | < 0.01 % of $V_{normal}$ | | | | |
| **Temperature coefficient of sensitivity** | | < ± 100 ppm/°C (± 0.01 %/°C) | | | | *@ Temperature range 23 °C ± 10 °C* |
| **Long-term instability of sensitivity** | | < 1% over 10 years | | | | |
| **Offset (@ B = 0T) ($B_{offs}$)** | | < ±40 µT | < ±60 µT | < ±0.6 mT | < ±4 mT | *@ Temperature range 23 °C ± 5 °C* |
| **Temperature coefficient of the offset** | | < ±2 µT/°C | < ±5 µT/°C | < ±50 µT/°C | < ±400 µT/°C | |
| **Offset fluctuation and drift (Δt = 0.05s, t = 100s)** | | < 30 µT | < 40 µT | < 100 µT | < 700 µT | *Peak-to-peak values;* |
| **Output noise** | | | | | | |
| **Noise Spectral Density @ f = 1 Hz ($NSD_1$)** | | 1 $\mu T/\sqrt{Hz}$ | 2 $\mu T/\sqrt{Hz}$ | 7 $\mu T/\sqrt{Hz}$ | 40 $\mu T/\sqrt{Hz}$ | *Region of 1/f – noise* |
| **Corner frequency ($f_C$)** | | 10 Hz | | | | *Where 1/f noise = white noise* |
| **Noise Spectral Density @ f > 10 Hz ($NSD_W$)** | | 0.7 $\mu T/\sqrt{Hz}$ | 0.8 $\mu T/\sqrt{Hz}$ | 2 $\mu T/\sqrt{Hz}$ | 16 $\mu T/\sqrt{Hz}$ | *Region of white noise* |
| **Broad-band Noise (10 Hz to $f_T$)** | | *depends on the customer's specified frequency bandwidth* | | | | *RMS noise;* |
| **Resolution** | | | | | | |
| **Typical frequency response** | | | | | | |
| **Frequency Bandwidth [$f_T$]** | | 0.5 kHz<br>2.5 kHz<br>10 kHz<br>max 25 kHz | 0.5 kHz<br>2.5 kHz<br>10 kHz<br>max 25 kHz | 0.5 kHz<br>2.5 kHz<br>10 kHz<br>max 25 kHz | max 0.5 kHz | *Other frequency bandwidths available;*<br>*Sensitivity decrease -3dB;* |
| **Output resistance** | | < 10 Ohms, short circuit proof | | | | |
| **Temperature output** | | | | | | |
| **Ground-referred voltage** | | $V_T$ [mV] = (T [°C] -23°C ± 1°C) x 500 [mV/°C]<br>$V_T$ [mV] = (T [°C] -23°C ± 3°C) x 100 [mV/°C] | | | | For temp. range: +5°C to +45°C<br>For temp. range up to: +100°C |

## 5.4 MAPPER CHARACTERISTICS

| Mechanical Specifications: | |
|---|---|
| **Parameter** | **Values** |
| The dimensions of the mechanical part of the scanner | 400 mm x 350 mm x 650 mm |
| Total system weight | • Mechanical part: 26 kg<br>• Electronic module: 7 kg<br>• Personal Computer: 2 kg |
| Maximal scanning volume (XxYxZ) | Standard: 135 x 135 x 135 mm³<br>Optional: 500 x 500 x 500 mm³ |
| Minimal distance of MFSV (Magnetic Field Sensitive Volume) from the magnet surface | 1.1 mm *(if the 03A Hall probe is applied)*<br>0.3 mm (if the 03G Hall probe is applied as an option) |
| Maximal scanning speed | Standard: 100 mm/s *in "SCANNING ON THE FLY" mode (continuous scanning)* |
| Minimal distance between two measurements (spatial resolution) | ±2µm; ±0.025° |
| Hall Probe positioning accuracy and repeatability | 3µm (linear), 0.05° (rotational) |
| Start-up time from cold start till availability for measurement | < 3 min |
| Shut down time | < 1 min |
| Recovery time from an emergency stop | < 1 min |
| **Magnetic Field Measurement Specifications:** | |
| **Parameter** | **Values** |
| Magnetic field measurement range<br>Standard:<br>one (fixed) measuring range<br>Optional:<br>Multiple selectable measuring ranges (up to 3) | • ± 20 mT<br>• ± 50 mT<br>• ± 100 mT<br>• ± 200 mT<br>• ± 500 mT<br>• ± 1'000 mT<br>• ± 2'000 mT |
| Magnetic measurement resolution | better than 0.02% for measurement range ≥200mT<br>better than 0.05% for measurement range ≤100mT<br>50µm at 100mm/s, 5µm at 10mm/s, 1µm at 2mm/s |
| Accuracy of the magnetic field measurement | better than 0.1% |
| Measurement sampling rate | > 30 kSamples/s, *for 3-channels acquisition*<br>> 200 kSamples/s, *for 1-channel acquisition* |
| Magnetic field Frequency Bandwidth | DC to 2.5 kHz (-3dB point)<br>Optional: DC to 25kHz for 3-axis, i.e. to 75kHz for 1-axis (-3dB) |
| Operating Conditions | Room Temperature (avoid strong temperature changes)<br>Not exposed to the strong electromagnetic disturbances or magnetic fields of the objects placed closed to the mapper |

## 5.5 SPARE PARTS & OPTIONS

- 3-axis Field Transducer with two selectable magnetic field ranges. Available ranges: 0.1T, 0.5T, 1T or 2T
- Second and third measurement range for the 3-axis Field Transducer
- Second, third and fourth measurement range for the 3-axis Field Transducer
- Spare H-Module (Hall probe of any type) of the 3-axis Field Transducer. This option is highly recommended for any application; it is mandatory for QA Mapper applications in the production lines
- Spare Module-H (Hall probe of any type) of the 3-axis Field Transducer with additional measurement range (up to four)
- Spare E-Module (Electronic Module of S type) of the 3-axis Field Transducer. Pre-calibrated E-Module, so that any H-Module can be connected
- Additional analog/digital inputs/outputs for integrating customer's probes and measurement units
- Non-magnetic multi-jaw scroll chuck, for a precise holding of magnet under test. It is especially convenient for ring- and cylindrical magnets.
- Calibration Tools for Hall probe field sensitive area calibration (current conducting Cu layer on PCB, constant current supply, SW module for automatic calibration process), including magnet frame for absolute positioning (especially convenient for the rectangular-formed magnets)
- Magnet Frame for absolute positioning (no calibration tool). It is especially convenient for the rectangular-formed magnets
- Spare Touch Sensor to prevent probe damage. It serves as an emergency stop, which is triggered whenever an object is touched by the probe during the measurement process
- Spare Zero Gauss Chamber
- Spare step motors for X, Y and Z linear axis
- Spare motor drive module for step motors
- Cables for connecting step motors and motor drives modules
- Protective Cabinet with Emergency Stop taster (to comply with European safety regulations - CE directives). This option is mandatory for QA Mapper applications in the production
- Dimensional measurement of the object under test and absolute magnet positioning utilizing 3D touch sensor. When touching with probe some characteristic reference points of the measured object, the mapper captures the object geometry and also calculates the absolute position of measured object relative to the mapper coordinate system.
- Defectoscope inspection system for cracks and inhomogeneity detection in magnetic materials (also non-magnetized)
- Customized software features

## 6. MAINTENANCE & TECH SUPPORT

SENIS Contact for all tech support issues:
e-mail: transducers@senis.ch
Phone: +41 44 508 7029

The MAGNETIC FIELD MAPPING SYSTEM (MMS) can be a low maintenance machine. However if neglected it can soon become irreparably damaged.

Please provide the following information when reporting an issue:

- Detailed description of the problem
- Object under test (geometry, magnetization, number of poles, etc.)
- Type of measurement (diameter, translation, inhomogeneity, etc.)
- Raw measured data and screenshots that explained the problem
- Mapper Software Version (About screenshot)
- What changed in the system (after the problem occurred)
- Environmental conditions (room temperature, strong magnetic field influences)

SENIS Technical Support includes:

- Transducer calibration at SENIS facilities (at additional costs). SENIS recommends a12-months Hall probe calibration period. The Hall probe has to be sent to SENIS calibration facility for the recalibration service.
- Mapper Software Upgrades (if required for issue corrections or enhancements; functional enhancements can be provided at additional costs)
- Up to 8 hours response time on an reported issue, within Swiss working hours (9am – 5pm).
  Within the response time, SENIS will answer any e-mail or phone call.
  As soon as the reported issue is evaluated by SENIS Tech Support group, SENIS will try to provide a solution, or at least send a troubleshooting plan to customer on how to approach/solve the reported issue (HW and SW)
- A weekend & Swiss public holidays service is not included. This can be provided on-demand, with a notice up to 5 days in advance