Megger

FRAX-series

Sweep frequency analyser

User guide

FRAX-series · User guide

NOTICE OF COPYRIGHT & PROPRIETARY RIGHTS

2008-2022, Megger Sweden AB. All rights reserved.

The contents of this manual are the property of Megger Sweden AB. no part of this work may be reproduced or transmitted in any form or by any means, except as permitted in written license agreement with Megger Sweden AB. Megger Sweden AB has made every reasonable attempt to ensure the completeness and accuracy of this document. However, the information contained in this manual is subject to change without notice, and does not represent a commitment on the part of Megger Sweden AB. Any attached hardware schematics and technical descriptions, or software listings that disclose source code, are for informational purposes only. Reproduction in whole or in part to create working hardware or software for other than Megger Sweden AB products is strictly prohibited, except as permitted by written license agreement with Megger Sweden AB.

TRADEMARK NOTICES

Megger® and Programma® are trademarks registered in the U.S. and other countries. All other brand and product names mentioned in thisdocument are trademarks or registered trademarks of their respective companies.

Megger Sweden AB is certified according to ISO 9001 and 14001.

Postal address	Visiting address
Megger Sweden AB Box 724 SE-182 17 Danderyd Sweden	Megger Sweden AB Rinkebyvägen 19 SE-182 36 Danderyd Sweden
T: +46 8 510 195 00 E: seinfo@megger.com W: www.megger.com	

Table of Contents

1. Introduction 5
1.1. Product description, FRAX 5
1.2. Company website 5
1.3. Receiving Instructions 5
1.4. Support, service & repair 5
1.5. Calibration 6
1.6. Warranty 6
1.7. Contact information 7
1.8. Shipping with battery 7

2. General safety 8
2.1. Symbols on the instrument 8
2.2. Warning and caution notices 8
2.3. Accessories 8
2.4. Cables 8
2.5. Placement 9
2.6. Cleaning 9
2.7. Damaged product 9
2.8. Inputs and outputs 9
2.9. Lightning 10
2.10. Servicing 10
2.11. Safety instructions 11
2.12. Battery inside 12

3. Instrument description 13
3.1. Front panel FRAX 99/101 13
3.2. Front panel FRAX 150 14
3.3. Bluetooth Communication (only FRAX 101) 14
3.4. Built-in battery pack and charger 16
3.5. Ground loop detector 17
3.6. Sweep frequency response 17

4. Quick start tutorial 19
4.1. Preparatory procedures 19
4.2. Ground loop control 19
4.3. Start FRAX and establish communication 19
4.4. Create a new test 20
4.5. Test lead connection 21
4.6. Start Measurement 24

5. FRAX Software 26
5.1. Installing FRAX Software 26
5.2. Overview 26
5.3. Edit menu 27
5.4. Configuration menu 27
5.5. Windows menu 37
5.6. Action buttons 37
5.7. Legend 39
5.8. Usage overview 40
5.9. File description 40
5.10. Test description 40
5.11. Measurement settings 41
5.12. Views 41
5.13. Legend action button description 42
5.14. Correlation analysis 42
5.15. Exit (Alt+F4) 43
5.16. Select Test... (Ctrl+F) 43
5.17. Connect 43

6. Specifications **44**

7. Appendix **46**

7.1. Appendix A. Calibration instruction 46

7.2. Appendix B. Adjusting output voltage 49

7.3. Appendix C. Test name settings 50

7.4. Appendix D. Cables and clamps 53

8. Index **56**

1. Introduction

Thank you for your trust in Megger.

We have the goal to always offer you a pleasant purchasing experience. The FRAX-series is developed and manufactured in Sweden by knowledgeable and committed employees. Every day, our team does its best to offer best in class products and services.

This document contains information regarding the correct use and handling of FRAX-series. Keep this document at hand when using the product. Please ensure to consult the chapter 'Safety'. This chapter contains important information for your personal safety. Read the safety regulations attentively before using this device.

1.1. Product description, FRAX

Most dielectric and mechanical failures in large power transformers are preceded by mechanical changes in the winding structure. These displacements in the winding structure may be the result of transportation damage, short circuit forces, or natural aging effects on the insulating structures used to support the windings. Detection of these displacements before dielectric failure reduces maintenance costs and improves system reliability.

FRAX Sweep Frequency Response Analyser (SFRA) is designed to detect winding displacements in power transformers or faults in the magnetic core. The system provides attenuation signature curves that can easily be compared for deviations which indicate:

- Core movements
- Winding deformations and displacements
- Faulty core grounds
- Partial winding collapse
- Hoop buckling
- Broken or loosened clamping structures
- Shorted turns and open windings

1.2. Company website

Occasionally an information bulletin may be issued via the Megger website. This may concern new accessories, new usage instructions or a software update. Please occasionally check on the Megger web site for anything applicable to your Megger instruments.

www.megger.com

1.3. Receiving Instructions

This instrument has been thoroughly tested and inspected to meet rigid specifications before being shipped. It is ready for use when set up as indicated in this user manual.

- Check the equipment received against the packing list to ensure that all materials are present. Notify Megger of any shortage.
- Examine the instrument for damage received in transit. If damage is discovered, file a claim with the carrier at once and notify Megger, giving a detailed description of the damage.

1.4. Support, service & repair

Technical support

For technical assistance please contact your local representative or direct your request to Megger in Sweden.

E-mail: support-sweden@megger.com

Service, repair & calibration

Megger has a wide network of authorized service centers. Please consult your local representative or the webpage for an up-to date listing.

Service, repair and calibration is also available at the service center at the manufacturing site in Sweden.

E-mail: service-sweden@megger.com

When sending the instrument, please use either the original packaging or one of equivalent strength. Add the return authorization number to the address label of the shipping container for proper identification and quicker handling.

For the service center in Sweden we recommend filling out and packing a service information sheet with the product. This document can be requested via email (service-sweden@megger.com) or downloaded via this link: https://se.megger.com/getattachment/Support/Service-information-form-2022-PDF.pdf?lang=sv-SE

1.5. Calibration

Megger operates fully traceable calibration and repair facilities to make sure your instrument continues to provide the high standard of performance and workmanship that is expected. These facilities are complemented by a worldwide network of approved repair and calibration companies, which offer excellent in-service care for your Megger products.

Calibration of FRAX

The instrument is calibrated before leaving the factory. Calibration should be performed minimum every third year, but yearly calibration is a general recommendation for test instruments.

It is also recommended to perform regular tests to verify the integrity of the complete test system, including cables and connectors.

The following tests can be performed:	
Open test	cables attached to FRAX but not connected to any device
Short test	cables connected to FRAX and connected to each other in the clamp end
FTB test	one measurement with the Field Test Box (FTB101), which will give a smooth “hockey stick” shaped curve from -100 dB to 0 dB.

The instrument can be calibrated by Megger or any calibration institute that follows the calibration instruction given in Appendix A, Calibration Instructions.

1.6. Warranty

Products supplied by Megger are warranted against defects in material and workmanship for a period of 18 monts following shipment. Our liability is specifically limited to replacing or repairing, at our option, defective equipment.

This warranty does not include batteries, lamps, or other expendable items, where the original manufacturer’s warranty shall apply. We make no other warranty.

The warranty is void in the event of negligence abuse (failure to follow recommended operating procedures) or failure by the customer to perform specific maintenance as indicated in this manual.

Equipment returned to the factory for repair must be shipped prepaid and insured. Contact nearest Megger representative for instructions and a return authorization (RA) number. Please indicate all pertinent information, including problem symptoms. Also specify the serial number and the part number of the unit.

Checklist before calling/emailing for support:

- Check for power supply/battery of the unit
- Restart the unit and the computer
- Try to repeat the operation
- If any error messages, make a print screen (or a note) and attach to your email
- When reporting an error please include also the serial number of the unit and software version. If related to a computer, also include the version of Windows used.

1.7. Contact information

Web page: www.megger.com

Email: seinfo@megger.com

Telephone: +46 8 510 195 00

1.8. Shipping with battery

IMPORTANT

The FRAX-series contains batteries, so make sure that current Dangerous Goods Regulations are complied with. If the battery is suspected to be faulty - do not ship it, either separately or inside an instrument. Contact Megger in need of support. Consult your shipment supplier or Megger for advice concerning your specific shipment.

2. General safety

- All safety and operating instructions must be read before using the FRAX-series.
- All safety and operating instructions for the FRAX-series must be followed.
- All safety and operating instructions must be retained for future reference.

2.1. Symbols on the instrument

Symbol	Description
	Caution, refer to accompanying documents.
	Protective conductor terminal.
	WEEE, Waste Electronic Equipment. Please utilize your local WEEE collection facilities in the disposition of this product and otherwise observe all applicable requirements.The unit can also be returned to Megger at any time at no charge for the disposal.

2.2. Warning and caution notices

Warning and caution notices are used throughout this user guide where applicable and should be strictly observed and followed. These notices appear in the format shown below and are defined as follows:

WARNING

Warning, as used in this manual, is defined as a condition or practice which could result in personal injury or loss of life.

CAUTION

Caution, as used in this manual, is defined as a condition or practice which could result in damage to or destruction of the equipment or apparatus under test.

2.3. Accessories

Only use accessories that are recommended by Megger.

2.4. Cables

Only use the approved main detachable cable set with the FRAX-series. Main supply cable shall be rated for the maximum current for the equipment and the cable shall meet the requirements of IEC 60227 or IEC 60245. Main supply cables certified or approved by a recognised testing authority are regarded as meeting this requirement.

Connecting cables must be routed so that they are not likely to be walked on nor pinched by items placed upon or against them. Do not pull on or tie them together. Pay particular attention to the connectors.

To disconnect a cable:

1. Unlock the retainer, in case of an XLR conector.
2. Grasp the connector firmly and pull.

If an input or output cable becomes damaged, stop using it. Use of a damaged cable may result in fire or electric shock.

2.5. Placement

The FRAX-series must be situated away from any heat sources such as radiators, heat registers, stoves, or other products that produce heat. Do not place the FRAX-series in areas with excessive dust, mechanical vibration or shock.

Do not use the FRAX-series near water.

Do not expose the FRAX-series to rain or moisture with open lid.

Do not touch the plug with wet hands. Doing so may result in electric shock.

2.6. Cleaning

Unplug the FRAX-seriesbefore cleaning

Do not use liquid cleaners or aerosol cleaners.

Only use a damp cloth for cleaning.

Stubborn stains may be removed with a cloth lightly dampened with a mild detergent solution.

2.7. Damaged product

Do not use the FRAX-series if the test leads appear damaged.

Do not continue using a damaged FRAX-series. Using a damaged FRAX-series may result in fire or electric shock.

Do not touch a damaged LCD panel directly with bare hands. The liquid crystal, which leaks from the panel, is poisonous if it enters the eyes or mouth. If any part of the skin or body comes in direct contact with the panel, please wash thoroughly. If some physical symptoms result, please consult your doctor.

Damage requiring service

Unplug the FRAX-series from all connections and entrust servicing to qualified service personnel under the following conditions:

- If any connector is damaged, including main plug.
- If liquid has been spilled into the FRAX-series.
- If the FRAX-series has been exposed to rain or moisture.
- If the FRAX-series does not operate normally (following the operating instructions).
- If the FRAX-series has been dropped or damaged in any way.
- If the FRAX-series exhibits a distinct change in performance.
- If the FRAX-series begins to emit smoke, smell, or make strange noises, disconnect all power connections immediately and contact your dealer for advice.

2.8. Inputs and outputs

- Do not exceed the specified input voltage limit on any of the FRAX-series inputs.
- Do not apply voltage to the outputs.
- Polarity must be red to + and black to −, Timing AUX channels excluded.

2.9. Lightning

For added protection of the FRAX-series during a lightning storm, unplug it from the AC outlet and from all cables connected to the inputs. This will prevent damage to the FRAX-series due to lightning and power supply surges.

Never touch the plug and power cord if it begins to thunder. Touching them may result in electric shock.

2.10. Servicing

Do not attempt to service the FRAX-series yourself. Opening or removing covers can expose you to dangerous voltage and other hazards.

Please entrust all servicing to qualified service personnel.

If you attempt to service the FRAX-series yourself, the warranty will no longer be valid.

In case of return for service, please use either the original transport box or one of equivalent strength.

2.11. Safety instructions

WARNING

1. It is not possible to eliminate all potential hazards from, and in using, electrical test equipment. For this reason, every effort has been made to point out in this instruction manual the proper procedures and precautions to be followed by the user in operating this equipment and to mark the equipment itself with precautionary warnings where appropriate. It is not possible to foresee every hazard which may occur in the various applications of this equipment. It is therefore essential that the user, in addition to following the safety rules in this manual, also carefully consider all safety aspects of the test before proceeding.
2. The test set and the specimen to which it is connected are a possible source of high-voltage electrical energy and all persons making or assisting in tests must use all safety practice precautions to prevent contact with energized parts of the test equipment and related circuits.
3. Persons engaged in the test must stand clear of all parts of the complete high-voltage circuit, including all connections, unless the test set is de-energized, and all parts of the test circuit are grounded. Persons not directly involved with the work must be kept away from test activities by suitable barriers, barricades, or warnings.
4. Treat all terminals of high-voltage power equipment as a potential electric shock hazard. There is always the potential of voltages being induced at these terminals because of proximity to energized high-voltage lines or equipment.
5. Always ground connection points of the test specimen before connecting any leads from the test set. Whenever possible, always keep one side of the test specimen grounded at all times. Always use a safety ground stick to ground any high-voltage conductor.
6. The ground connection on the test set must be the first made and the last removed. Any interruption of the grounding connection can create an electric shock hazard.
7. Make sure that the instrument is properly grounded, both through its AC power cord and through the ground connector. The AC power cord is the disconnecting device.
8. Always disconnect test leads from test specimen before attempting to disconnect them at the test set.
9. High-voltage discharges and other sources of strong electric or magnetic fields may interfere with the proper functioning of heart pacemakers. Persons with heart pacemakers should obtain expert advice on the possible risks before operating this equipment or being close to the equipment during operation.
10. All persons making or assisting in tests must use all practical safety precautions to prevent contact with energized parts of the test equipment and related circuits. Also follow all local and company safety requirements.
11. Safety is the responsibility of the user.
12. Misuse of this high-voltage equipment can be extremely dangerous.
13. The purpose of this equipment is limited to use as described in this manual. Do not use the equipment or its accessories with any device other than specifically described.
14. Before making any connections, make sure that the instrument is de-energized and that all parts of the test circuit are properly grounded.
15. Never connect more than one output at the time. All outputs are energized by the same amplifier and therefore all outputs are energized simultaneously.
16. Operation is prohibited in rain or snow.
17. Do not use the test set in an explosive atmosphere.
18. Refer all servicing to qualified personnel.
19. A qualified operator should attend all times while the test equipment is in operation.
20. Observe all safety warnings marked on the equipment.
21. Corrective maintenance must only be performed by qualified personnel who are familiar with the design and operation of the test set and the hazards involved.

Maintenance

IMPORTANT

1. DISCONNECT the power adapter before any cleaning or maintenance.
2. Maintenance should be performed only by qualified personnel familiar with the hazards involved with high-voltage test equipment.
3. Refer all servicing to qualified personnel.
4. Routine maintenance is all that is required for these test sets. The cables and connector panel should be inspected frequently to be sure all connections are tight and all ground connections intact.
5. The appearance of the test set can be maintained by occasional cleaning of the case, panel, and cable assemblies. The outside of the carrying case can be cleaned with detergent and water. Dry with a clean, dry cloth. The control panel can be cleaned with a cloth dampened with detergent and water. Do not allow water to penetrate panel holes, because damage to components on the underside may occur. A household all-purpose spray cleaner can be used to clean the panel. Polish with a soft, dry cloth, taking care not to scratch the display screen cover. The cables and mating panel receptacles can be cleaned with isopropyl or denatured alcohol applied with a clean cloth.

2.12. Battery inside

- This product is not intrinsically safe. Do not use in an explosive atmosphere
- This instrument contains a lithium battery.
- Do not pierce, damage, disassemble or modify the battery.
- The battery contains safety and protection devices, which if tampered with may cause the battery to generate heat, rupture or ignite.
- If the battery is suspected to be faulty – do not ship it, either separately or inside an instrument.
- The instrument must be powered off and securely packaged before shipping.
- Do not heat or dispose of the battery in a fire.
- Do not subject the battery to strong impact, mechanical shock or excessive heat.
- Do not short-circuit or reverse the polarity of the battery.

3. Instrument description

3.1. Front panel FRAX 99/101

1. **On / Off** To turn the instrument on/off
2. **DC-input** To connect the AC/DC adapter
3. **USB** USB-connector type B, to connect a USB cable to PC
4. **Antenna** (only FRAX101) Bluetooth module, enables Bluetooth communication
5. **GLD Test** Ground loop continuity check
6. **Generator (Yellow)** Generator output connected to Reference at Red Clip
7. **Refereence (Red)** Reference input connected to Generator at Red Clip
8. **Measure (Black)** Measure input Connected to Black Clip
9. ⏚ **Protective Earth/Ground connector** Always connect the instrument to station earth/ ground using the separate earth/ground cable.The separate earth/ground wire should be the first connection made and the last removed.

WARNING

All test objects must be grounded at one end at all times to minimize risks for high voltage interference entering the instrument.

3.2. Front panel FRAX 150

1. ⏚ **Ground (Protective earth) connector** Always connect the instrument to station earth/ ground using the separate earth/ground cable. The separate earth/ground wire should be the first connection made and the last removed.
2. **Screen backlight control**
3. **Mains input** With fuse 2 A
4. **On/Off button**
5. **Network** For connecting the FRAX-150 to LAN
6. **USB port** Four USB ports for accessories such as keyboard, mouse and USB flash drive
7. **INT / EXT** Switch for internal or external PC
8. **USB port** For connection of external computer
9. **Generator (Yellow)** Generator output connected to Reference at Red Clip
10. **Reference (Red)** Reference input connected to Generator at Red Clip
11. **Measure (Black)** Measure input Connected to Black Clip
12. **GLD Test indicator**
13. **GLD Test button**
14. **Touchscreen** With built-in software keyboard

3.3. Bluetooth Communication (only FRAX 101)

Bluetooth is a standard for wireless serial communication. Simply speaking, Bluetooth replaces a serial cable between laptop and FRAX instrument.

The output power of Bluetooth module is divided into three classes:

Power class	Max output power	Expected range
Class 1	100 mW	100 m / 330 ft
Class2	2.5 mW	10 m/33 ft
Class 3	1 mW	1 m /3.3 ft

The Bluetooth module used in FRAX 101 is class 1. Also, the Bluetooth USB Adapter that comes as a standard accessory with FRAX is class 1. Using this adapter communicating with FRAX, class 1 communication will be established.

Many laptops of today have in-built Bluetooth capability, most common is class 2. Since the Bluetooth module used in FRAX 101 has excellent receiving properties, a built-in Bluetooth device may be suitable in many situations. However, in field/substation environments Bluetooth class 1 is recommended.

To configure a built-in Bluetooth device, please follow the manufacturers instruction. To configure the Bluetooth USB Adapter that comes with the FRAX, install the included Bluetooth software before the adapter is inserted into the USB-port.

NOTE

It is reported that in some cases an activated built-in Bluetooth and using an external USB Bluetooth Adapter can create some conflicts in Windows. If this happens, uninstallation both adapters and reinstallation only the one which is intended to be used can solve this issue.

Bluetooth communication must be established first before attempting to connect the FRAX Software to the FRAX instrument.

The following steps show how to add a connection between the FRAX instrument and the computer using built-in Bluetooth functionality. Please note that the procedure is managed by operating system directly. Thus, the procedure necessary on a particular computer may differ from the following steps, and it should be regarded as an example.

1. Form Windows start menu open “Devices and Printers” and click on “Add a device”. Computer will list all available devices.
2. Find device named “Megger FRAX 101” select it and click “Next”. Computer will connect to device.

3. Click on option “*Enter the device’s pairing code”.*

4. *Enter pairing code “0000”* and click “Next”

5. Now connection to FRAX unit from the FRAX software can be established.

NOTE

The procedure described above only needs to be done once. Next time the computer is started simply insert the USB adapter using same USB port or use built-in Bluetooth.

NOTE

If external USB dongle is installed in a different USB port of the computer, then the serial COM port assigned to that USB port may be different.

Either connect to other USB port or change the COM port in the FRAX communication setting.

Then start FRAX software and press connect.

TIP

It may be a good idea to remove unused Bluetooth connections from settings as each connection is checked when FRAX unit is connected. This can be done in the Bluetooth settings in the Windows Control Panel.

6. It is possible to also set the port to use as a default in the settings file. It is located in C:\Users\...\AppData\Roaming\FRAX and named UserAppData.xml.

   Open it in Notepad and look for the tag:

```
<Communication>
     <Config name="RS232Port">COM5</Config>
</Communication>
```

Set the port to be used there.

3.4. Built-in battery pack and charger

As an option, FRAX-101 is delivered with a built-in battery pack and charger.

The battery is of Li-Ion type, 4.8 Ah, 11.1 V.

The charger is powered from the standard AC/DC adapter that is delivered with the instrument.

FRAX-101 automatically enters low power consumption mode when waiting for a measurement and because a typical sweep takes approximately 1 minute, the battery lasts for at least 3 hours of measuring or more than 12 hours idle.

Charging is performed automatically when the AC/DC adapter is connected. The FRAX-101 does not have to be turned on. To ensure long battery life, batteries will not be charged if the battery charge is higher than 90 % or if the temperature is above 40 °C. A complete charge takes approximately 8 hours.

The blue LED gives indication of charging status:	
LED not lit	FRAX turned off, or FRAX is switched on, battery empty.
LED blinking	Charging
LED lit	FRAX connected to AC/DC adapter, Battery is fully charged (or charging disabled of other reason see above)
LED lit	FRAX runs on batteries (AC/DC adapter not connected)

3.5. Ground loop detector

Embedded 'Ground Loop Detector' in FRAX checks the test setup and assures that all connections including the grounding braids are properly connected. After pressing GLD button on FRAX the green/ red ("Pass/ Fail") LED shows user status of the ground loop. In case of "Fail" signal (red LED), the connections must be checked. "Pass" signal (green LED) guarantees that the measurement results can be reproducible.

NOTE

Ground loop detector is not available in FRAX 99.

3.6. Sweep frequency response

FRAX "Generator" (Gen.) output generates sinusoidal voltage at a selected frequency. Two separate input channels, "Reference" (Ref.) and "Measure" (Meas.) measure both the generated voltage and the response voltage with respect to amplitude and phase.

The instrument stores "Amplitude" and "Phase" data for both "Reference" channel and "Measure" channel as well as the ratio "Measure" divided by "Reference". The values can be plotted and exported as Magnitude, Phase, Impedance, Impedance-Phase, Admittance and more.

The Custom models function make it possible to calculate almost any parameter based on the measured/ stored data.

FRAX uses the sine correlation technique. This means that the input voltages are multiplied by a sine and a cosine, and then averaged over an integer multiple of the interval of time. The sine, cosine and the voltage applied have exactly the same frequency. The sine correlation technique is well known and is suitable for Sweep Frequency Response Analysis (SFRA) measurements. Since the signals on the two input channels are treated the same way, the phase resolution between these two channels is extremely high. The rejection of DC offset and harmonics - referred to as the applied voltage - are in theory infinite. By increasing the integration cycles, the rejection gradually improves.

The IF bandwidth is commonly used as a parameter defining the bandwidth around the applied signal analyzed. An IF bandwidth of 10 % of active frequency is equivalent to 12 cycles of integration.

4. Quick start tutorial

4.1. Preparatory procedures

This tutorial provides an introduction on how to use FRAX and FRAX software. They are intentionally kept brief so that user can start using the instrument and software as quickly as possible. The objective is not to teach user every single detail but to familiarize with the basic principles.

IMPORTANT

Always follow the safety instructions in this manual. Always comply with local safety regulations.

1. The transformer must be disconnected from the net, which means that any connection to the transformer bushings including neutral(s) must be disconnected.
2. The transformer tank must be properly grounded.
   A. If the transformer is equipped with a Load Tap Changer (LTC), the position of the LTC will influence the SFRA measurement. The recommendation is to put the LTC in the position to include all tap windings in circuit ("Extreme Raise" position) and note that this LTC position is used. When making measurements at several tap positions, make sure to note each tap position.
   B. If the transformer is equipped with a De-Energized Tap Changer (DETC), the position of the DETC will influence the SFRA measurement. The recommendation is to leave it at the nominal tap position unless otherwise specified. Make sure to note the DETC position in the Nameplate section of the software.
3. Connect the FRAX instrument to station earth/ground near the power transformer to be measured using the separate earth/ ground wire (at bottom of transformer if instrument is operated beside the transformer, at another good connection to transformer at top of transformer if instrument is used on top of transformer). The separate earth/ ground wire should be the first connection made and the last removed.
4. Connect the test lead BNC connectors to the FRAX instrument, Generator (yellow), Reference (red) and Measure (black).
5. Connect the AC/DC Adapter to the FRAX and a power source that meets local safety regulations and the AC/DC Adapter specifications or use optional in-built battery supply.
6. If not using Bluetooth communication, connect the USB cable to the FRAX and computer.
7. Turn on the FRAX.

4.2. Ground loop control

1. Press GLD button to verify ground loop continuity.

   If LED is red, check ground connections at transformer and bushings.
2. Start FRAX-software on PC and establish communication, see Establish Communication

4.3. Start FRAX and establish communication

- If using Bluetooth communication: Establish Bluetooth communication, see also detailed description Bluetooth Wireless Communication. Usually, a serial port number will be assigned, e.g., 8, that should be used when FRAX establish connection. Note that FRAX Software remembers the last used port.
- If using US communication: Connect the USB cable to the computer and to the FRAX. The computer should display a message that it found new hardware

1. Start FRAX software
2. Connect to FRAX by selecting "Connect" from menu File, by clicking "Connect" button on the right hand side of software window or by using F7 key.

- If connections are set-up properly the window name will change from “FRAX (Disconnected)” to FRAX (Connected).
- If the connection does not work, an error message will appear suggesting what to do, normally selecting the suggested port number with a green symbol next to it.

4.4. Create a new test

A test starts by creating a sequence of sweeps and decide where to save data by use of “New Test”.

1. Use the command “New Test” from the File menu or use of Ctrl+N or use of the button “New Test”.
2. The “Measurement type” window will appear. In “Measurement type” window, select the tab of choice:

Quick Test	Makes a test with single sweep and the test label of choice
Multiple Test	Makes it possible to select apre-defined test template design from “Test groups”
Use Measurement as Template	Makes it possible to use an earlier measurement as template for a new measurement

A. If “Multiple tests” tab is selected there will be given a choice of different pre-defined templates for different transformer designs. Select desired tests to make and press OK. Note that it is always possible to add new sets of tests with different names.

B. If “Quick Test” or “Multiple Tests” in the “Measurement type” dialog is selected, an almost empty nameplate will appear. The “Test date:” is automatically added from PC system date. Please fill in the Nameplate data (no field is required) and press “OK”. The selected measurement sweeps are visible in the in the Test Browser.

C. If the “Measurement type” “Use Measurement as Template” is used the Nameplate contains the Template Nameplate as default, except the “Test Date” that is automatically added from PC system.

3. Enter Nameplate information and press “OK”. A “Save As...” dialog appears where the file structure and a name of choice can be selected. The default directory will be My Documents\FRAX on first start and then the directory used last time. The file name will be formatted as selected in default filename settings. Click “Save” to save the file.

NOTE

Information can always be added to the “Nameplate” at any time. This feature makes it possible to add notes during the measurement.

For more details see New Test in chapter FRAX Software, File menu.

4.5. Test lead connection

The FRAX clamp helps to connect and achieve repeatable test results. It handles both round and flat connectors and is easy to attach to any bushing. The firm grip allows heavy cables and accessories to be mounted near the bushing without any risk of the falling off. The clamp offers all necessary connectors (BNC, ground braid, cable strain relief) in one clamp. See Appendix D: FRAX cables and clamps.

WARNING

Make sure to use strain reliefs for all FRAX cables. If not used there is high probability that BNC connectors will be pulled partially or completely off the cable. Such a cable may still visually look intact but the conductor or shield inside may be broken. Measurements with broken cables are meaningless.

IMPORTANT

Make sure to follow local safety regulations. Local safety regulations most certainly prescribe all bushing connections to be earthed/grounded when working on the transformer e.g., connecting the FRAX test leads.

Connect the ground braid. It shall go from the top clamp the shortest way to the bottom of the bushing. Good ground connection is essential.

NOTE

The test connection polarity is important since reversed polarity will produce different results. The user must establish a polarity convention. In this software it is assumed, and recommended, that H1-H0 imply the red/ yellow connectors (source and reference) is connected to H1 and the black (measure) is connected to H0.

Connect FRAX test leads

Good grounding practice.

Poor grounding practice.

1. Make sure to remove paint and or rust from the nuts or bolts used on the flange for proper measurement ground connections.
2. Connect the red and yellow (generator and reference) to the clamp at the top of a bushing and corresponding ground braid to the base of bushing. Make sure that the braid does not touch any conducting part at top of bushing.
3. Connect the black (measure) lead to the clamp at the top of the other bushing and the corresponding ground braid to the base of bushing. Make sure that the braid does not touch any conducting part at top of bushing.
4. Following local safety regulations, remove possible ground connections from top of the bushings.
5. Using an easy repeatable cable setup is crucial to ensure reliable SFRA results.

TIP

A good idea is to take photos of the connections to ensure repeatability.

Good connection.

Bad connection can affect the curve at higher frequencies.

Verification of system and leads

Test leads should be checked for continuity and integrity before use. The best means for checking lead integrity and correct operation of the equipment is to perform the SFRA self-check using a standard test object. This check is especially valuable for checking SFRA test equipment since there is generally no intuitive way of knowing if the test equipment is giving correct results when making field measurements.

The results of test measurements showing short circuit measurement (black), open circuit measurement using FRAX-101 (green) and FTB-101 measurement (red).

A short circuit test

This is a test to check the integrity of test leads.

Connect the “Source”/”Reference” and “Measure” clips together and connect the respective measurement earth/ground together.

The result should be an almost straight line around 0 dB (black).

An open circuit measurement

This should in theory provide a 0-response, i.e., a minus infinity dB-response. However, all measurement systems have internal noise, and the test leads will also add some response from open clips ends.

Separate the “Source”/”Reference” clip from the “Measure” clip. The clips themselves will give some influence at highest frequencies, if the “Measure” coaxial cable from the FRAX unit is disconnected the graph shows the noise in the measurement system (green).

Field test box, FTB-101

FTB-101 is a field test box that is intended to be used to verify the leads and the equipment as recommended by CIGRE and several others.

Connect the “Source”/”Reference” clip to the left-hand side connector and the braid from the clip to the bottom connector. Connect “Measure” clip to the right-hand side connector and the braid from the clip to the bottom connector. Also connect the bottom connector to ground/earth (otherwise the system will face some interference at 50/60 Hz).

If the hook-up and the equipment is in good working order the sweep should look like in the picture below.

The results can be compared with the file “FTB-101.frax” that is shipped with the FRAX software. Available from the installation folder:

C:\Program Files(x86)\Megger\FRAX\Measurement examples.

More information in Appendix D about connections.

4.6. Start Measurement

1. Execute measurement by selecting a measurement in the Legend at the left side. In the picture below the blue color shows that H2-H1 (Open) is selected.
2. Start the measurement by pressing the “Start” button, (F9)-key or by selecting “Start” in the “File” menu.

View Data

Allows for viewing data in the FRAX Software. For more details see chapter “FRAX Software”.

Export Data

If the data needs to be used in other software it is possible to use data files directly or export the data of choice, see Export... in chapter “FRAX Software”, “File menu”.

5. FRAX Software

5.1. Installing FRAX Software

PC Requirements

- Operating system Windows 2000/XP/7/10/11
- Processor Pentium 500 MHz or higher.
- Memory 256 MB RAM or more.
- Hard drive Minimum 30 MB free.
- Bluetooth (FRAX-101 only) and USB.

Welcome Screen

Welcomes to Megger Installer for FRAX. To install FRAX Software press Next which will bring up License Agreement.

License Agreement

Read the license and check the "I accept the terms in the License Agreement" checkbox.

This will enable the Next button.

To continue the installation press Next. In this dialog an Installation Location can be chosen.

Already Installed

If the FRAX software is previously installed user is asked to uninstall the older version or not.

It is recommended that the previously installed version is uninstalled before installing a new version. If the old version is decided to be kept a different directory for the new version must be specified.

Installation Location

Select the location to which the FRAX Software will be installed. Make sure there is enough space available on the hard drive. To continue the installation press Next to come to the Shortcuts Screen.

Shortcuts Screen

This is where installed shortcuts can be selected. The software is now ready to be installed. Press Install to proceed and invoke the Installation Progress popup.

Installation Progress

The application executables and registry items are being installed. The window Installation Complete automatically appears when all files are installed.

Installation Complete

Congratulations! The installation is now complete. Now the FRAX Software can be started.

NOTE

FRAX 150 is supplied with FRAX and its calibration software FraxCal already installed.

5.2. Overview

In this section it is assumed that the FRAX software is installed and has started up properly. (For issues regarding installation of FRAX Software, see section: Installing FRAX Software).

The FRAX Main Window is shown below.

The FRAX Software Main Window is divided into three sections:

- The test browser or Legend to the left (empty in screen shot below) with four arrow buttons for selecting Measurement File or Test in the test browser. Also, the buttons Add Test and Delete Test are included in this section of the window.
- The large area in the middle presents the Nameplate, and the selected graph options in different tabs.
- The action buttons to the right can be used with touch screen, or mouse click. They are also assigned to specific keyboard shortcuts and all buttons except Graph 1 to Graph 4 can be selected in the File or Configuration menus.

Between the legend and the rest of the window is a splitter bar that can be used to adjust the relative size of the two parts of the window. Just drag it into the desired position and release it there. The resizing is limited to ensure that the program is always usable.

5.3. Edit menu

Copy View

Copies the current view into the clipboard. It can then be pasted into another program.

Copy Legend

Copies the Legend into the clipboard.

Copy View + Legend (Alt+C)

Copies the current View and the Legend into the clipboard. For more information check Copy View and Copy Legend.

Change Display Options... (Alt+O)

This dialog allows for changing the color and line width of the selected curve and change the thickness of the line.

The thickness of the line can either be set as the default or a custom width. It is also possible to set a new default curve for all lines by pressing the “Default” button.

5.4. Configuration menu

Change Language...

Selecting one of the available languages will change language in menus and dialogs in the FRAX software. A software restart is required to activate the changes after the new language is selected.

Change Standards...

SFRA measurement can be done according to standartised practices, which regulates connection of reference and response terminals, tap changer positions as well as terminal abbreviations. Available standards are IEC and IEEE. A software restart is required to activate the changes after the new standard is selected.

Connection Settings...

The PC uses a COM-port to communicate with the FRAX instrument. It will use different COM-ports for USB and Bluetooth communication. The FRAX software will try to find the active COM-port and provide suggestions if no FRAX instrument was found.

COM-ports marked with green indicate that a FRAX instrument was found on that COM-port. Red means that no FRAX instrument was found.

Measurement Settings... (Ctrl+M)

The default measurement settings are specified in this dialog. All new measurement sweeps except sweeps based on “Use Measurement as Template” will have these settings initially.

A measurement sweep can consist of one or more (max 15) measurement bands with different settings. Normally the frequency settings are set in such a way that the next band continues the previous band. The screen shot below shows the default settings.

1. “Start Freq” and “Stop Freq” are limits of the given band.
2. “P / D” are points per decade. This is the number of measurement points, equally spaced in a logarithmic or linear scale, per decade. For example, in logarithmic scale 200 “P/D” between 10 Hz and 1000 Hz results in 400 measurement points logarithmically distributed between 10 Hz to 1000 Hz (two decades). In a linear scale, “P / D” is the total number of measurement points, linearly distributed. For example: 200 P / D from 10 Hz to 1000 Hz results in 200 measurement points linearly distributed. Using less than 10 P / D is not recommended.
3. “Min time” and Min cycles” define the time and the number of cycles in measurement. Depending on the current frequency either one is used to start measurement at next frequency.
4. “Min skip time” and “Min skip cycles” define the time and the number of cycles applied before measurement starts at given frequency.

Example: *A measurement is performed at 100 Hz, “Min time” = 0.1s and “Min cycles” = 12. Since 12 cycles is greater than 10 cycles = 0.1s the system measures at 100 Hz using 12 cycles. Same settings at 1000 Hz means that the system measures 100 cycles since 0.1s = 100 cycles is greater than 12 cycles. Note! Min Cycles = 12 equals an IF Bandwidth of 10%.*

If necessary to perform the measurement faster, the low frequency range can be modified by decreased number of measurement points and/or lower the integration time (“Min Cycles”). Below are examples of various sweeps.

	P/D	Freq bands (Hz)	Meas points	Approx. meas. time (s)
Default	50	20-200	50	
	100	200-2k	100	
	200	2-20k	200	
	300	20-200k	300	
	400	200k-2M	400	
			Total: 1050	64
Fast	40	20-200	40	
	60	200-2k	60	
	80	2-20k	80	
	100	20-200k	100	
	160	200k-2M	160	
			Total: 440	37
Fixed P/D set-tings				
Example	100	20-2M	500	
Omicron default	160	20-2M	800	76
Doble default	200	20-2M	1000	93
Omicron max	320	20-2M	1600	145
Double max	360	20-2M	1800	163
Frax max	6400	20-2M	32000	

On FRAX-101 and 150 the test can be set to be performed in reverse frequency order, i.e., to measure from the highest frequency to the lowest. This is a single setting for all bands.

Output Voltage...

The voltage output of FRAX can be adjusted within range of 0,1 to 12$V_{peak.}$

The default value of output voltage is 10V_{peak}. The changes made during measurement session will be reset back to default 10V_{peak} when the software is terminated.

Graph Settings... (Ctrl+G)

In the Graph settings dialog auto scale or range and spacing for the axis can be set. The Dialog has one tab for Magnitude and one tab Phase, as well as a tab for the combination of both Magnitude and Phase. At the bottom there is a check box that makes changes that affect all graphs.

Graph Views...

In the Graph Views dialog, it is possible to configure which graphs are accessible as separate tabs. The default selections include Magnitude, Phase, and Magnitude / Phase, as shown below.

1. To select a graph, check or uncheck the box to the left of its name.

2. To edit or delete a custom graph, select the graph in the list and then click the Delete or Edit... buttons. To add a custom graph, click the Add... button, and the following dialog is shown.
3. To add a graph type, type a name and a description in the box, and click the Add button.
4. Enter a description and a number in the Graph Type box. The number is used as a unique id for this particular graph. It is also possible to use pre-defined types via the Get... button.

Models...

In the Models dialog, it is possible to select which models to use when a graph is plotted. When using an active probe (not available anymore), the model for the probe should be used. No other models should be used together with a probe model. In the dialog below, the SFRA (dB) model is selected. This is the most used model.

Selected models are shown below the graphs in the main window and can be selected and deselected by clicking the small check box.

If "Reference" voltage is Ch0 and Measure voltage is Ch1, the following equations are used in calculations.

NOTE

All standard models display phase in degrees, but in custom models defined below phases are in radians (1 radians = 180/Pi degrees)

SFRA (dB)

Magnitude = 20 x $\log_{10}$ (Ch1 / Ch0)

Phase = Phase(Ch1/Ch0) = Phase(Ch1) – Phase(Ch0)

SFRA (Linear)

Magnitude Ch1/Ch0

Phase = Phase(Ch1/Ch0) = Phase(Ch1) – Phase(Ch0)

Impedance

Z = U/I = (Ch0- Ch1)/I = 50 x (Ch0- Ch1)/Ch1

Phase = Phase(Z)

Admittance

Y = 1/Z = Ch1/(50 x (Ch0- Ch1))

Phase = Phase(Y) = - Phase(Z)

Two additional models are available and that is R and L model that plots its results in Impedance view. The R and L models are very useful evaluate why curve deviates at low frequencies in short-circuit measurements, increase of R at lowest frequencies may be a poor contact, whereas change of L may be a winding movement. Also comparing R when frequency increase, typically in the range 50-400 Hz may give valuable information; this is also called FRSL (Frequency Response of Stray Losses).

1. To create a custom model, check “Custom Model” in the “Models” dialog as shown above.
2. Click “OK”
3. Then, click the button named “...” in the “Custom Model” frame in the main window. This brings up a window called “Model Options”.

The screenshot above, the custom model designed by Megger for the Active Voltage probe AVP-101, illustrates some of the features of Custom Models. Type 0 represents the SFRA(dB) Magnitude graph and since the AVP-101 has a ratio of 10, the equation becomes 20*log10 ((ch1*ratio)/ch0). The phase is just the phase, but since all phase variables (Vars...) come in radians and we want to plot in degrees we multiply the phase by 360/(2*Pi), ph2 = ph1-ph0).

The buttons Units, Vars, Func, and Graph Types pro- vide lists with available units, variables, mathematical functions, and graph types that can be used within formulas.

NOTE

A formula only affects one graph type. That is, a type must be unique for each formula, and two or more formulas cannot share the same type.

4. Click the Save button to save the model. The model is listed as “User defined” in the Models dialog for later use.

Analysers...

Two analysers are available for evaluation of the measurement results and can be invoked from Configuration menu:

- Correlation analysis
- DL/911-2004 Analyser

Correlation analysis includes three separate statistical techniques:

1. Cross-correlation
2. DL/T 911-2004 (Rxy) approach
3. NCEPRI evaluation

These techniques can be selected under “Settings...” button. The frequency regions and limits for all these techniques can be adjusted in “Correlation analysis” dialog window.

Analyzing data will only very briefly be described in this manual. Please refer to relevant guides and standards such as:

- IEC 60076-18
- IEEE PC57.149
- CIGRE Brochure 342
- Chinese standard DL/T 911-2004
- NCEPRI algorithm

Detailed interpretation of results is not covered in this manual. Analysers built in FRAX software can be used to help understanding the data.

Using DL/T 911-2004 Analyzer

Use the test browser to select the two sweeps to be compared.

The results for the combinations of the first three selected sweeps is displayed in a table at the top.

If more than three sweeps are selected, the analyzer will only display the first three. The calculations are performed automatically, and the “Conclusion” is presented in the table. To see the curves and details of a certain combination, select it in the table.

The DL/T 911-2004 Analyzer computes the relative factor Rxy function for the three different frequency ranges (1kHz-100kHz, 100kHz-600kHz and 600kHz- 1MHz) according to equations in A1, A2, A3 and A4.

The value for each frequency range is assigned as a “Winding Deformation degree” and finally the Conclusion is set as the worst “Winding Deformation degree”. Note that RHF<0.6 is not assigned to any “Winding deformation degree”.

1. **A.1 Calculate the standard variance of these two sequences**

$$D_X = \frac{1}{N}\sum_{k=0}^{N-1}\left[X(k) - \frac{1}{N}\sum_{k=0}^{N-1}X(k)\right]^2$$

$$D_Y = \frac{1}{N}\sum_{k=0}^{N-1}\left[Y(k) - \frac{1}{N}\sum_{k=0}^{N-1}Y(k)\right]^2$$

2. **A.2 Calculate the covariance of these two sequences**

$$C_{XY} = \frac{1}{N}\sum_{k=0}^{N-1}\left[X(k) - \frac{1}{N}\sum_{k=0}^{N-1}X(k)\right] \times \left[Y(k) - \frac{1}{N}\sum_{k=0}^{N-1}Y(k)\right]$$

3. **A.3 Calculate the normalization covariance factor of these two sequences**

$$LR_{XY} = C_{XY}/\sqrt{D_X D_Y}$$

4. **A.4 Calculate the relative factor Rxy meeting the project requirements as per the following formula**

$$R_{XY} = \begin{cases} 10 & 1 - LR_{XY} < 10^{-10} \\ -\log(1 - LR_{XY}) & others \end{cases}$$

5. **A.5 Judge the degree of deformation of transformer winding as per Table A.1**

Table A.1 Relation between relative factors and degree of transformer winding deformation (only for reference)

Winding deformation degree	Relative factors R
Severe deformation	RLF < 0.6
Obvious deformation	1.0> RLF 0.6 or RMF < 0.6
Slight deformation	2.0> RLF 1.0 or 0.6 RMF < 1.0
Normal winding	RLF 2.0, RMF 1.0 and RHF 0.6
RLF represents the relative factor when the curve is in low frequency band (1kHz~100kHz) RMF represents the relative factor when the curve is in medium frequency band (100kHz~600kHz) RHF represents the relative factor when the curve is in high frequency band (600kHz~1000kHz).	

Using Correlation Analysis

The Correlation analyzer is by default a copy of the DL/T 911-2004 analyzer. It uses the same calculations to get the values. The difference is that it is possible to create and change limits and frequency ranges to create a custom analyzer.

1. Use the test browser to select the curves to be compared.

If more than three curves are selected, the analyzer will only display the first three curves selected. The calculations are performed automatically, and the “Conclusion” is present ed below the table.

2. To change the settings for the analysis, click the “Settings” button in the analyzer selection dialog.

This brings up a dialog where the settings can be adjusted. In bottom right corner it is possible to select if the evaluation variable is the correlation coefficient (LRxy), the Rxy-factor according to DL7T 911 or analysis using NCEPRI algorithm.

It is possible to add or remove frequency ranges; as well as modify the frequency settings and interpretation criteria.

Magnetisation impedance

In the low frequency region, the End-to-End open measurement reflect the magnetisation impedance, deviation in this area may indicate shorted turns or core related problems.

NOTE

Residual magnetism that is NOT a failure mode, also affect this region.

Magnitude difference parameter

End-to End (Short) measurement in the low frequency region reflects the leakage impedance, where even small deviation in this area (>0.25 dB) may indicate severe winding deformation. This parameter displays result of an automatic analysis of the magnitude difference between phases. Frequency range for analysis is 110 Hz to 2 kHz.

Default Filename Settings

1. Specify the default filename settings that will be used in the New File Save As dialog.

- Data time format (YYYY-MM-DD hh.mm.ss) is used to generate a file name in format “YYYY-MM-DD hh.mm.ss.txt” based on the system time in PC

- Choice “According to nameplate” generates a file name based on data entered into the nameplate in the format “substation_designation_date time.frax”
- Number format (Dxxxxxxx) option generates a file name starting with the number entered in the edit field. Once a new file has been created, the number will be incremented. Starting number can be selected arbitrary

5.5. Windows menu

Menu command description

Output window (Ctrl+O) Toggle shows/hides the output window.

Output window (Ctrl+O)

Opens a small window that displays all communication between PC and FRAX instrument.

1] Click on the “Last row” button to see new lines when they become available during the continuous communication.

5.6. Action buttons

Action buttons for faster access to common functions.

Graph settings

Same as the menu item “Graph settings”... (Ctrl+G).

Graph view settings

These five buttons control the graph settings specified in “Graph Settings” dialog.

New File

Same as the menu item “New File... (Ctrl+N)".

Select File

Same as the menu item “Select File... (Ctrl+F)".

Edit Nameplate

Same as the menu item "Edit Nameplate... (Ctrl+E)". This button is only enabled when a file is selected in the Legend.

Connect

Same as the menu item Connect (F7).

Start

The start button is a multi-functional button. Action suggestions can be obtained by pressing the button.

Button icon	Description
	This icon means that FRAX is not connected to the system.
	▪ No file is selected in the Legend. ▪ No sweep is selected in the Legend. ▪ The selected sweep is already measured.
	Measurement in progress.
	Ready to start measurement.

Start button can be pressed at any time. The application provides suggestions in case unsure of what action to take.

5.7. Legend

The legend or Test Browser is where most of the time is spent. Here the measurement settings can be changed, and the Graphs controlled. Below a typical legend view.

5.8. Usage overview

The legend can be navigated by using the arrow buttons at the bottom of the legend or Alt+arrow keys Up and Alt+arrow key Down to navigate between tests. Using Alt+Page Up or Alt+Page Down the File can be changed.

If there are many tests or several files open at the same time a scroll bar will be shown to the right of the legend making it possible to scroll up and down to see all tests.

It is also possible to change the order of the tests in a file. Click and hold on a test and then drag it to the desired position and then let go to drop it in place.

5.9. File description

The file header contains 3 function buttons and the name of the file.

File function button	Description
or	Hide / Show inactive tests in the file
or	Enable / Disable tests in the file
	Close the file

5.10. Test description

The test contains two function buttons and the name of the test. Below is a list of different tests with different attributes.

Test function button	Description
or	Enable / Disable the test. The color and line width can be set for each test. Color and line width can be changed by right clicking on the icon.
or	Measured / Empty test. Clicking on this icon change the measurement settings for the test.

5.11. Measurement settings

This window allows for changing the settings for the test. It is possible to change only the settings for "empty" tests (containing no measurement data).

Press Ctrl+M to change the default measurement settings for new tests.

5.12. Views

There are several views available. The Nameplate view is always present and the "Magnitude (Alt-M), Phase (Alt+P) and Magnitude / Phase (Alt+B) are also present when software is started first time. The view can easily be changed by clicking the view-tab above the view. It is also possible to change views and create custom views, see further Graph views...

Below the Magnitude view with one measurement loaded is shown.

5.13. Legend action button description

Below is a typical measurement file. A file is a container of the tests.

5.14. Correlation analysis

Correlation analysis is based on cross-correlation between two curves. Three options are available:

1. Cross-correlation

The Correlation analysis uses same calculations as DL/T 911-2004 Analyzer (see below for more details) but it is possible to modify, if analysis is based on LRxy or Rxy variable for calculations, number of frequency ranges analyzed, frequency limits and interpretation limits.

2. Analysis based on DL/T 911-2004 standard (see below for more details)
3. NCEPRI algorithm and criteria

The NCEPRI algorithm estimates the correspondence of frequency responses by calculating the effective deviation (ED) of two transfer functions TF_1 and TF_2 according to the formulae:

$$ED_{12} = \frac{1}{N}\sum_{i=1}^{N}(TF_{1i} - TF_{2i})^2$$

where TF_1 and TF_2 are the reference and compared transfer functions or frequency responses.

The DL/T 911-2004 Analyzer is based on the Electric Power Industry Standard of People's Republic of China, DL/T 911-2004.

The analyzer calculates the relative factor Rxy from the correlation LRxy and implementation is only possible using SFRA Magnitude in dB-scale.

NOTE

Calculations of LRxy and LRxy is based on discrete mathematics described under the DL/T 911-2004 Analyzer section below. Therefore, same traces measured with logarithmic or linearly spaced measurement points will give slightly different result. Mathematics describing a continuous trace is best approximated using linear spaced measurement points.Furthermore, the DL/T 911-2004 standard also assumes linearly spaced measurement points.

5.15. Exit (Alt+F4)

Terminates the FRAX software.

5.16. Select Test... (Ctrl+F)

Find a previously performed test in the test database and load it into the graph view.

A dialog showing the files in the database will be shown.

1. By clicking on the column headings (Substation, Designation and so on) it is possible to sort the list alphabetically according to that entry.
2. User can change the order of the columns by dragging the column header to the desired position or drag them away to remove them. To add more headings, click on the Customize button for a list.
3. To see the full nameplate of a test, click the Nameplate button.
4. To group the tests according to any heading by dragging it into the gray area at the top.

The FRAX indexer works in the background and checks all monitored directories for new or changed files. When a file is opened from a directory that is not indexed the question is presented if this directory shall be indexed. If it's a directory with valid measurements, user should answer “Yes” if those files are supposed to show up in the Select Test database.

5.17. Connect

Same as the menu item Connect (F7).

6. Specifications

FRAX Series
Sweep frequency response analysers

SPECIFICATIONS	FRAX 99	FRAX 101	FRAX 150
Specifications are valid at nominal input voltage and an ambient temperature of +25°C ±5°, (77°F). Specifications are subject to change without notice.			
Environment			
Application field	The instrument is intended for use in medium and high-voltage substations and industrial environments.		
Ambient temperature			
Operating	-20°C to +55°C (-4°F to +131°F)	-20°C to +55°C (-4°F to +131°F)	-5°C to +50°C (23°F to +122°F)
Storage	-30°C to 70°C (-22°F to +158°F)		
Humidity	< 95% RH, non-condensing		
CE-marking			
EMC	2004/108/EC		
LVD	2006/95/EC		
General			
DC power supply	11-16 V DC		-
AC power supply	-	-	90 – 264 V AC, 47 – 63 Hz
Internal battery	24 Wh/2.2 Ah (optional)	49 Wh/4.4 Ah (optional)	No
Dimensions			
Instrument	250 x 169 x 52 mm (9.84" x 6.65" x 2.05")		410 x 340 x 205 mm (16.1" x 13.4" x 8")
Transport case	520 x 460 x 220 mm (20.5" x 18.1" x 8.7")		No
Weight			
Instrument	1.4 kg (3.1 lbs) 1.8 kg (4 lbs) with battery		8.5 kg (18.7 lbs)
Case and accessories	12 kg (26 lbs)	15 kg (33 lbs)	Accessories 10kg (22 lbs)
Measurement section			
Test method	Sweep frequency (SFRA)		
Frequency range	0.1 Hz – 25 MHz, user selectable		
Frequency resolution	0.01%		
Frequency accuracy	0.01% (measurement error)		
Level resolution	0.001 dB		
Number of points	Default 1046, Up to 32 000 points, user selectable		
Measurement time	Default 64 s, fast setting, 37 s (20 Hz – 2 MHz)		
Points spacing	Log., linear or both		
Sweep settings	Individual settings for customer defined frequency bands. Linear and logarithmic scale or combination of both		
Internal noise level (average 20 Hz to 2 MHz)	< -120 dB	< -140 dB	< -140 dB
Dynamic range1)	>130 dB	>150 dB	>150 dB
Inaccuracy	±0.1 dB from +10 dB down to -40 dB ±1 dB down to -100 dB	±0.1 dB from +10 dB down to -40 dB ±0.5 dB down to -100 dB	
IF bandwidth	User selectable, default <10%		
USB	Yes	Yes	4 type A, 1 type B
Bluetooth	No	Yes	No
FRAX Software for Windows 7/8/10/11	Yes	Yes	Yes
Standards / guides	Fulfills requirements in IEC 60076-18, IEEE C57.149, DL/T 911, CIGRE TB 342 as well as other international standards and recommendations		
Ground loop detection	No	Yes	Yes

FRAX Series
Sweep frequency response analysers

Analog Output			
Channels	1	1	1
Compliance voltage	20 V p-p	0.20 – 24 V p-p	0.20 – 24 V p-p
Applied voltage at 50 Ω		0.1 – 12 V p-p	0.1 – 12 V p-p
Output impedance	50 Ω		
Protection	Short-circuit protected		
Frequency range	0.1 Hz – 25 MHz		
Sweep direction	Low to high or high to low		
Analog Input			
Channels	2		
Sampling	Simultaneous		
Frequency range	0.1 Hz – 25 MHz		
Input impedance	50 Ω		
Sampling rate	100 MS/s		
Analysis and data management			
Analysis	Cross correlation according to DL/T 911 and NCEPRI as well as fully customisable. Magnitude difference		
Data import:	Omicron (.fra, .tfra), Doble (.sfra, .sfrx), CIGRE TB342 .xfra, IEC 60076-18 .xml.		
Data export	CIGRE TB342 .xfra, IEC 60076-18 .xml, Doble sfra, .csv, .txt		
Built in PC	No	No	Yes
Operating system	–	–	Windows embedded
Touchscreen	–	–	12”
Memory	–	–	1000 records in internal memory External storage on USB stick

1) Dynamic range is defined from +10 dB to internal noise in the unit

7. Appendix

7.1. Appendix A. Calibration instruction

The calibration of a FRAX can be performed through an automated process by use of the FraxCal software. The FraxCal utilizes an Agilent 34401A or a Fluke 8845A/8846A DMM (digital multi meter) and a FRAX calibration adapter connected to the FRAX generator output and measuring input channels.

Preparing for calibration

To perform the automatic calibration the following equipment is necessary:

Agilent 34401 DMM or Fluke 8845A/8846A FRAX calibration set including the following:

- Calibration Adapter CAL-101
- FraxCal software
- 1 pc DB-9 standard serial cable
- 1 pc 2 x 4mm banana plug to BNC coaxial converter
- 3 pcs 50 ohm coaxial cables with BNC connectors, 0.5 meter length
- 1 pc 50 ohm coaxial cable with BNC connectors, 2 meter length

NOTE

The coaxial cables from the FRAX to the calibration box needs to be of equal length.

Connecting the equipment

1. Install the FraxCal software on the computer (FRAX 150 has software already installed).
2. Connect the FRAX AC/DC adapter and put the FRAX mains switch in the ON position (I)
3. Ground the FRAX using the ground screw.
4. Connect the FRAX with the USB cable to one of the USB ports on the computer.

NOTE

For FRAX 150 the switch **INT / EXT** should be in INT position

5. Connect the DMM to the computer, using the serial cable. If the computer lacks a serial interface, a serial/USB adapter can be used.
6. Connect the FRAX to the Calibration Adapter CAL-101 according to the figure below:

- 0.5 meter 50 ohm coaxial cable from FRAX Generator to CAL-101 IN
- 0.5 meter 50 ohm coaxial cable from FRAX Reference to BNC Y adapter
- 0.5 meter 50 ohm coaxial cable from FRAX Measure to BNC Y adapter
- BNC adapter to CAL-101 OUT
- 2 meter 50 ohm coaxial cable from CAL-101 DET to DMM using the BNC to banana adapter

7. Start the FraxCal software by double clicking the FraxCal icon on the desktop.

The start page of the software is presented in the figure below.

The software will automatically detect the serial number of the FRAX unit and the last calibration date. It will also automatically suggest current date to be the new calibration date. The date can be changed by the user. The software will also automatically detect the communication ports for the FRAX and the DMM.

8. To start the calibration, press “Start Calibration”.

During the calibration process, the software shows the information about the progress. The process takes approximately 12 minutes.

After successfully completed calibration, the following message will appear.

All calibration data is stored in the FRAX instrument. No written report can be obtained from the software, thus suggesting a separate calibration report to be created manually.

9. Apply the sticker on the FRAX back panel, informing the FRAX user about the last calibration date.

NOTE

Although the FRAX does not need to be calibrated more often than every two years, the recommendation is to calibrate the unit every year.

Verification

After a successful calibration, it is recommended to do a “short” measurement to verify that the FRAX performs as expected.

Connect as described in the figure below.

Measure from 10 Hz to 10 MHz and the measured data should be 0 dB with a maximum deviation of +/-0.1 dB.

Also make a verification using the built-in calibration reference.

1. Connect as explained in the figure below.
2. Run standard sweep from 20 Hz – 2 MHz.

When looking at standard view Magnitude Curve should be around -80 dB between 10 Hz – 100 kHz.

3. Unclick Magnitude, use model CAL-510k Curve should be 0 dB, +/-0.3 dB between 100 Hz – 10 kHz.
4. To add the 510k model: Insert the file CAL- 510k.model (on the attached USB stick) in the CustomModels directory, see below

5. To add model click:

   -Menu Configuration

   -Menu Models

   -Select CAL-510k

6. To activate model:

   -Uncheck “Magnitude”

   -Check “CAL-510k”

   On each CAL 101, there is a resistance value on the s/n label.

7. To ensure the best possible verification enter this resistance value here.

In this example, we have used 510 kilo Ohms.

7.2. Appendix B. Adjusting output voltage

FRAX software versions later than 2.6 allows for changing the output voltage from Configuration menu.

Earlier versions of software require manual changes as described below.

On the FRAX-101 and 150 the output voltage level may be adjusted from the standard/default 10 V up to 12 V and down to 0.1 V, by changing a file in the FRAX installation directory.

The file name is named “connectioncommands.txt” and it is in the directory where the FRAX software is installed, usually C:\Program Files (x86)\Megger\FRAX.

To use the file to adjust the output voltage add the command gen:gainx=k to the file.k is a factor for setting the output voltage.k=1 means output voltage is FRAX standard/default = 10 V output. By changing k, the voltage can be adjusted.

Examples:

- k = 0.2828 means output voltage = 0.2828*10V = 2.828 Vpeak = 2 V RMS (used by FRAnalyzer, Omicron)

- k = 0.05 means output voltage = 0.05*10 V = 0.5 V (= HP 4195 A output voltage).

Open/edit the file with Notepad. K must be a number between 1.2 and 0.01 and use point as decimal separator.

Save the changes. After k has been changed FRAX needs to be disconnected and connected again to activate the new setting.

NOTE

If using Windows Vista/7/10 a warning of insufficient rights to change/ save the file can appear. If so, right-clicking on the file, properties, selecting security and editing the user rights may help. Another possibility is to run Notepad as administrator and open the file from Notepad (not double click in the FRAX folder). In any other cases please check with system administrator.

IMPORTANT

Change back to original k = 1 after the measurement session!

7.3. Appendix C. Test name settings

There are two sets of predefined test plans – one based on the IEEE PC57.149 and other based on IEC 60076-18 and CIGRE Brochure 342, 2008.

All predefined test plans can be modified to suit particular use.

1. Use the buttons “Add” and “Delete”.
2. The names can be changed by selecting a “Test group” or “Test name” and enter a new name.
3. Select a “Test group” and select which tests should be included by setting a cross in front of the test name(s) and then hit “OK”.

The files containing the test plans are in the “MeasData” directory, e.g., for Windows 10 in C:\Program Files (x86)\Megger\FRAX 2.6\MeasData. The modified sweep groups can be found in X_Edit_DefaultTemplates.xml in respective folder - IEC or IEEE.

If new test groups are made and are to be distributed, it is possible to use the file UserTemplates.xml and rename it to a suitable name. When adding a test plan file just put it in the “MeasData” directory, at e.g., for Windows 10 at C:\Program Files (x86)\Megger\FRAX 2.6\MeasData and the FRAX software will read from it.

NOTE

The available test plans are displayed in alphabetical order based on the test plan file so to make sure custom test groups are displayed first rename the file to something like:1custom.xml or !!myfile.xml.

The basis of SFRA analysis is comparison with reference measurements; if reference measurements are available, it is strongly recommended to repeat those measurements exactly as the reference measurements were set up.For all new measurements IEC and IEEE test plans have some differences. Also, the phase labeling is different, note however, that it is always possible to change name in the template, e.g., change 1u, 1v and 1w to e.g., R, S and T.

NOTE

End-to End Short-circuit is optional. IEC also recommends measuring in the direction referring to bushing labeling, i.e., no modification is necessary to measure an YnYn6 compared to an YnYn4, and this is taken care of in the implementation.

In the IEEE PC57.149, it is recommended to follow the basic principle to measure windings from head-to-tail and consequently the recommended test connections will depend on winding configuration. The pre-defined templates in FRAX software covers the

out removing liquid or gas. Always make notes about actual set-up used in the notes section of nameplate.

Zig-zag connected windings shall be measured as star windings with a neutral connection (if accessible).

The standard measurement on a phase shifting transformers shall be from input terminal to output terminal on each phase and from the neutral of the shunt winding to the output terminal on each phase, each on neutral tap and on each extreme tap, a total of 18 measurements. If the phase shifting transformer is of the two-core type that has external interconnections that can be removed on site, then it shall be treated as two separate transformers.

Series reactors shall be measured from input terminal to output terminal on each phase, a total of three measurements for a three-phase reactor. Shunt reactors shall be treated as a star winding on a transformer, a total of three measurements for a three-phase reactor without taps and six for a reactor with taps.

Sample connections

IEC and ANSI/IEEE	Alternative ANSI/IEEE
End-to-End open	Open Circuit Self Admittance (oC)
End-to-End Short-Circuit	Short Circuit Self Admittance (SC)
Capacitive Inter-Winding (CIW)	Inter-Winding (IW)
Inductive Inter-Winding (IIW)	Transfer Admittance (TA)

IEC and ANSI/IEEE	Example IEC	Example ANSI/IEEE
End-to-End open	1u-1n [open]	H1-H0 [open]
End-to-End Short- Circuit	1u-1n [short]	H1-H0 [short]
Capacitive Inter- Winding (CIW)	1u-2u [CIW]	H1-X1 [IW]
Inductive Inter- Winding (IIW)	1u-2u [IIW, GND 1n, 2n]	H1-X1 [TA, GND H0,X0]

1. In the "End-to-End" (open Circuit Self Admittance, oC) the signal is applied to one end of each winding in turn, and the transmitted signal is measured at the other end. The low frequency range of this test is basically a low voltage measurement of the voltage dependent single-phase excitation current.

2. The "End-to-End Short-Circuit (Short Circuit Self Admittance, SC) is measured as the "End-to-End open" measurement but with one or more windings shorted. The low-frequency range of this test is basically a low voltage measurement of the single-phase impedance.

3. In the Capacitive Inter-Winding, CIW (Inter-Winding, IW) measurement, the signal is applied to one end of a winding and the response is measured at one end of another winding on the same phase (not connected to the first one). The lowest frequency range of this test is basically a capacitance and dissipation/ power factor measurement (e.g., CHL).

4. In the Inductive Inter-Winding, IIW (Transfer Admittance, TA) measurement, the signal is applied to a terminal on the HV side, and the response is measured on the corresponding terminal on the LV side, with the other end of both windings being grounded.

Example of labeling is “A-a1 [IIW, GND N,n1]” where GND N, n1 means ground terminal N (H0) and ground terminal n1 (X0). The low frequency range of this test is determined by the winding turns ratio (slightly affected by the 50 ohm load at the “Measure”-side.)

7.4. Appendix D. Cables and clamps

Appendix D: FRAX cables and clamps

The FRAX clamps and cables are field tested, rugged accessories ensuring repeatable and accurate measurements. Coaxial cables are covered with an extra protective cover and strain relief is fitted on all 9 and 18 meter cables to ensure a long and trouble free life of service.

Ground braids made of tin plated copper to ensure good contact, make them easy to work with and increase life of service compared to e.g. aluminium.

The FRAX clamps handles both round and flat connectors. Easy to attach and a firm grip avoids any risk of clamps falling off.

The C-clamp is used to connect the FRAX to the bushing. All necessary connectors (BNC, braid, ground, cable strain relief) are included in one clamp. The smaller G-clamp is used to connect the braids to ground. Both models are part of the standard cable set delivered with a FRAX.

Bushing connection

The C-clamp can be fastened on any type of bushing up to Ø 90 mm. The M12 screw ensures good electrical and mechanical contact. No risk of a clamp falling down due to heavy cables and braids.

The clamp is delivered with a M12 hat nut, which can be used when you want to avoid the screw making marks on a sensitive surface.

Generator cable connection (yellow/red)

Cable strain relief
Coaxial cables from FRAX
-Generator (Yellow)
-Reference (Red)
Ground braid
connected to ground. Keep the braid straight along the bushing and ground the braid at the base of the bushing. Ensure good connection.
The first 50 cm of the braid is insulated to avoid any electric connection to the bushing.

Measure Cable connection (black)

Ground braid practice

The ground braid shall go from the C-clamp the shortest way to the bottom of the bushing. Good ground connection is essential for reliable test results. Look at the next two pages for more information.

The braid cable set consists of 4 x 3 meter tin plated copper braids. Many transformers have bushings shorter than 3 m, which suggests two braids, one for each bushing, to be enough when it comes to length.

The C-clamp allows a two braid practice, not necessary when using FRAX, but useful if compatibility with previous two braid measurements is required.

The remaining braids can be used if bushings are taller than 3 m. See picture below how to joint two braids.

G-clamp connection to ground

The new, unique ground clamp handles both nuts and bolts as well as other round and flat connectors, making it the most easy-to-use and versatile ground connection available.

The G-clamp is easy to attach, easy to tighten the braid, which ensuring a quick and reliable procedure for shortest braid practice, which is essential to get repeatable measurements.

The sharp, adjustable M4 pin screw penetrates any paint or oxide, making it easy to get a good, solid ground connection on almost any surface.

Ground braid connection

The clamp can be attached to ground in many ways. See previous section.

To attach and tighten the braid: open up the braid plate by loosening the wing nuts.

Place the braid between the G-clamp and the braid plate. Tighten the braid to create a straight line from the C-clamp to the G-clamp. Tighten the wing nuts.

For extra flexibility when connecting the braids to ground, the short braid with clamp included in the ground braid set can be used.

Field Test Box FTB 101

1.	Connect the measure cable
2. 3.	Connect C-clamps to FTB101
4.	Connect the generator cables
5.	Attach the G-clamp to ground on the FTB101
6. 7.	Connect the braids to the G-clamp
8.	Connect the ground cable from FRAX to the G-clamp

8. Index

A
Action buttons, 37
Adjusting output voltage, 49
Antenna, 13

B
Battery pack, 16
Bluetooth Communication, 14

C
Cables and clamps, 53
Calibration, 6
Calibration instruction, 46
Connect FRAX test leads, 21
Create a test, 20

E
Export Data, 25

F
Front panel FRAX 150, 14
Front panel FRAX 99/101, 13

G
Ground loop control, 19
Ground loop detector, 17

Q
Quick start tutorial, 19

R
Repair, 5

S
Safety instructions, 11
Service, 5
Shipping, 7
Support, 5
Sweep frequency response, 17
Symbols on the instrument, 8

T
Test, 20
Test lead connection, 21

V
Verification of system and leads, 22

W
Warranty, 6

Local sales offices		
Visit us online: www.megger.com		
Manufacturing sites		
Megger Limited Archcliffe Road DoverKent CT17 9EN ENGLAND T. +44 (0)1 304 502101 F. +44 (0)1 304 20734	Megger GmbH Weststraße 59 52074 Aachen T. +49 (0) 241 91380 500 E. info@megger.de	Megger USA - Valley Forge Valley Forge Corporate Center 2621 Van Buren AvenueNorristown Pennsylvania, 19403USA T. +1 610 676 8500 F. +1 610 676 8610
Megger USA - Dallas 4545 West Davis Street Dallas TX 75237USA T. 800 723 2861 (USA only) T. +1 214 333 3201 F. +1 214 331 7399 E. USsales@megger.com	Megger AB Rinkebyvägen 19 Box 724 SE-182 17 DANDERYD SWEDEN T. +46 08 510 195 00 E. seinfo@megger.com	Megger USA - Fort Collins 4812 McMurry Avenue Suite 100 Fort Collins CO 80525USA T. +1 970 282 1200

This instrument is manufactured in Sweden.

Subject to change without notice. The company reserves the right to change the specification or design without prior notice.

Megger is a registered trademark. © Megger Limited 2022

Art. No. ZP-AC01E • Doc. AC033582GE • V06a • 2022