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ISX-3 / ISX-3mini

certified in accordance with
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ISO 13485:2016

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1 Which products are covered by this manual

This manual is valid for:

- single channel impedance analyzer ISX-3
- miniature impedance analyzer ISX-3mini
- single channel impedance measurement module for ISX-5 and MSX-8 platform (refer to ISX-5 or MSX-8 platform manuals for technical details and use of this module within these systems)

2 General

Please pay attention to the comment.

Please pay attention to the note/warning.

Please pay attention to the warning.

2.1 Warranty

This product is warranted against defects in material and workmanship for a period of one year. During the warranty period any parts or services that show defects with a cause that was present before the transfer of risk shall – at the option of Sciospec – be replaced, reworked or re-performed free of charge (rectification).

For warranty service or repair, this product must be returned to a service facility designated by Sciospec. The buyer shall pay all shipping charges, duties, and taxes for products returned to Sciospec from another country.

Sciospec warrants that its software and firmware designated by Sciospec for use with an instrument will execute its programming instruction when properly installed on that instrument. Sciospec does not warrant that the operation of the instrument, or software, or firmware will be uninterrupted or error free.

Further details on the warranty and transfer of risk are described in the general terms and conditions of Sciospec. No other warranty is expressed or implied. Sciospec specifically disclaims the implied warranties of merchantability and fitness for a particular purpose. Further and/or divergent regulations require contractual agreements in written form.

The foregoing warranty shall not apply to defects resulting from improper or inadequate maintenance by the buyer, operation or service through unauthorized personnel, the buyer-supplied software or interfacing, unauthorized modification or misuse, operation outside the environmental specifications for the product, or improper site preparation or maintenance.

2.2 Intended (normal/contractual) use

The product is intended for indoor use in qualified technical environments and laboratories with all necessary safety measures for electric installations and cabling in place. In order to fulfill the requirements towards electrical safety and electromagnetic compatibility the system is to be installed in a safe environment with electrical connections (especially power supply) according to general safety regulations. In addition to general safety regulations all safety measures and precautions noted in this document are to be followed.

For outdoor use separate precautions and safety measures are required. Specifically it might be required to mount the system into a protective housing according to the ambient/environmental conditions.

2.3 Non-intended use

Any form of use deviating from the intended use qualifies as non-intended use/misuse/maloperation. Other applications, modes of operations, modifications or types of installations can impair safety and functionality and are thus for safety reasons not permitted for the user or third parties.

2.4 Authorized personnel

In general different levels of qualification of operating and maintenance personnel have to be distinguished.

> Danger through insufficient qualification of operating/service personnel.

The instrument may only be operated, functionally tested and serviced by sufficiently qualified personnel. Work reserved for professional technical personnel may only be done by staff authorized through Sciospec.

2.4.1 Users

Users are all personnel older than 18 years that have been instructed in the operation of the instrument by Sciospec or an authorized representative. They have to have read and understood this manual completely.

User may be tasked with the following:

- General operation of the system through externally accessible interfaces
- Operation of external controls on the instrument
- functional tests through externally accessible interfaces
- to some extent elimination of malfunctions or initiation of measures to eliminate malfunctions through externally accessible interfaces

2.4.2 Professional technical personnel

Professional technical personnel are all persons who in accordance to their professional education, professional experience and contemporary professional occupation

- posses respective knowledge of electrical impedance analyzers
- have been trained, authorized and instructed by Sciospec for maintenance, installation and service tasks on/for the instrument

Further the professional technical personnel have to be qualified for those tasks through their professional education, experience and technical knowledge on electrical impedance analyzers.

In addition to the authorization of users professional technical personnel may be tasked with

- Elimination of malfunctions exceeding the measures permissible for a user
- installations
- maintenance and service work as instructed by Sciospec

2.4.3 Unauthorized personnel

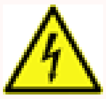
> Through operation and service procedures executed by unauthorized personnel substantial danger up to danger to life may arise.

Defects and damage caused by measures performed by unauthorized personnel are not covered by warranty and Sciospec will not be made liable for these.

2.5 Danger and risks

Even with proper professional installation and proper condition of the instrument not all dangers can be covered. Following some of the remaining risks are described.

2.5.1 Electrical currents

> **Danger to life through electrical currents**
>
> 
>
> - operation and maintenance only to be done by trained personnel
> - no access to the instrument for other than authorized personnel
> - never bypass fuses or protective parts
> - maintenance and installation only in volt-free state
> - keep moisture and excessive heat away from the instrument

2.5.2 Risk for danger to personnel

Increased risk for danger to the user exists

- when minors, elderly or disabled persons are allowed to operate the instrument
- when proper instruction, training and monitoring of the user is not possible
- when no authorized personnel exist
- when the number of users to the instrument are very high
- when modifications to the instrument or its installation are done

Modifications, extensions/additions to the instrument are not permissible without prior authorization through Sciospec. Any unauthorized technical or procedural modification voids the permission for operation and the warranty.

2.6 Safety information and precautions

When you notice any of the unusual conditions listed below, immediately terminate operation and disconnect the power cable. Contact Sciospec Scientific Instruments for repair of the instrument. If you continue to operate without repairing the instrument, there is a potential fire or shock hazard for the operator.

- Instrument operates abnormally.

- Instrument emits abnormal noise, smell, smoke or a spark-like light during the operation.
- Instrument generates high temperature or electrical shock during operation.
- Power cable, plug, or receptacle on instrument is damaged.
- Foreign substance or liquid has fallen into the instrument.

The following measures help assuring safe instrument operation and are to be followed in order to comply with intended use specifications.

> Technical expertise is required. Risk of damage to the instrument exists through unintended use and wrong cabling/installation.

- Do not operate the instrument in the presence of inflammable gasses or fumes. Operation of any electrical instrument in such an environment clearly constitutes a safety hazard.

> **Electro static discharge warning**
>
> 
>
> This product, like all electronic products, uses semiconductors that can be damaged by electrostatic discharge (ESD). Use care when handling the devices to prevent damage. Damage due to inappropriate handling is not covered by the warranty.
> ESD damage is most likely to occur as the test fixtures are being connected or disconnected. Protect them from ESD damage by wearing a grounding strap that provides a high resistance path to ground. Alternatively, ground yourself to discharge any static charge built-up by touching the outer shell of any grounded instrument chassis before touching the test port connectors.
> Do not exceed the operating input power, voltage, and current level and signal type appropriate for the instrument being used, refer to technical specifications sections in this manual.

2.7 Replacement parts and equipment

Obtain replacement parts only through Sciospec, authorized customer support services or authorized distributors.

> **Danger of injury through use of wrong or faulty replacement parts!**
>
> The use of wrong, faulty or unauthorized/unintended replacement parts can lead to danger of injury to the operating/service personnel, malfunction or complete failure of the instrument.

Use of unauthorized replacement parts voids the instruments warranty.

3 Technical Specifications

3.1 General overview

- single channel impedance measurement module
- multiplexed second channel (optional)
- impedance measurement capability
  - 100mHz…10MHz
  - mOhm...GOhm
  - connection for 4, 3 or 2 electrode configurations (software configurable)
  - one high resolution signal generator with selectable current or voltage excitation mode
- high resolution DC bias/offset generation (± 1 V)
- ExtensionPort for application specific frontends including highly flexible digital IO functions through the Sciospec ***InterfacePort*** standard
- high isolation, ultra-low parasitic reed relay switches for channel connect/disconnect with superior performance compared to semiconductor switches
  - >10 TΩ || 0.4 pF isolation at power off or software selected cell disconnect
  - extremely low parasitic capacitance < 0.7 pF offers close to no cell loading
  - max. series resistance 200 mΩ in connected state
  - zero leakage current in on state
  - zero charge injection, no distortion, no noise contributions beyond thermal noise
- additional peripherals (optional)
  - IOport (digital IOs with highly flexible digital IO functions through the Sciospec ***InterfacePort*** standard) + 2 NTC temperature measurement ports
  - Ultra-fast hardware synchronization through sync in/out ports (e.g. through low level isolated interface or optional isolated sync module)
  - 3 analog voltage measurement ports 0…12V
  - 1 additional NTC temperature sensor port
  - 3 low side switches (e.g. for fan or external switch control)
- interfaces:
  - isolated USB 2.0 (FS, 12 Mbits/s) with ESD protection (±12kV IEC 61000-4-2 contact ESD, clamp voltage 13V (min), break-down voltage 5.5V (min))
  - 10/100 Base-T Ethernet

All specifications are stated for a operating at temperatures of 0°C to 40°C unless specified otherwise.
Warm-up time must be greater than or equal to 30 minutes after power on to comply with all specifications.

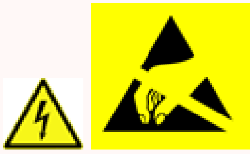
Maximum Ratings

Stresses above the listed absolute maximum or maximum ratings may cause permanent damage to the device. This is a stress rating only; functional operation of the device at these or any other conditions above those indicated in the operational section of this specification is not implied. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.

3.2 Measurement specifications

All ports (C, R, WS, W) of channels 1 and 2 are available through BNC coaxial connectors.

measurement port protection



Be aware that the measurement terminals (Counter, Reference, Working Sense and Work Electrode Terminals, including the measurement terminals of the *ExtensionPort*) are very sensitive to electrostatic discharge, over-current and over-voltage. Protection of the terminals of the instrument and strict adherence to the specified maximum ratings has to be ensured by the user. For further information on how to connect specific device under test to the instrument contact Sciospec or an authorized representative directly.

3.2.1 Set point & excitation signal generator (C port)

- software selectable current or voltage source for excitation signal generation
- low distortion single sine signal and superimposed high resolution DC offset

- compliance voltage ±4.9 V (@ 10kΩ load)
- compliance current
  - 200% of selected current range
  - abs. max. ±50mA (continuous)
  - short circuit current max. 65 mA
- Voltage Excitation Mode:
  - Abs. max. applied potential range ± 5 V

  - DC potential set-point resolution 0.0001% of applied voltage range (~19.5bit @2ms settling time)
  - DC potential set-point accuracy ≤ 0.1% || ±100 µV
  - maximum uncalibrated DC offset error: ±40 mV

- Current excitation mode
  - Abs max. applied current range ± 50 mA
  - DC current set-point resolution 0.0001% of applied voltage range (~19.5bit @2ms settling time)
  - DC current set-point accuracy ≤ 0.1% || ±1 µA
  - maximum uncalibrated DC offset error: ±40 µA

- AC Excitation Signal Range
  - 1 mV … 1 V (peak amplitude), resolution 0.1 mV in voltage excitation mode
  - 10 µA … 10 mA (peak amplitude) in current excitation mode
  - EIS Excitation Amplitude Error (uncalibrated): ±1% typ. (±8% max.)
  - Excitation Signal Resolution 0.1% of range
  - Frequency Range 100mHz to 10MHz
  - Frequency Resolution <120mHz
  - Frequency Precision
    - ±100ppm (@25°C)
    - additional ±10ppm over temperature range
    - additional ±5ppm during first year
- Number of Frequency Points per Sweep: 1 to 2048

3.2.2 potential measurement (R & WS ports)

- potential measurement ranges
  - ± 1 V
  - AC voltage measurement range equals selected potential measurement range
  - measured potential resolution < 0.008% of potential range
  - measured potential accuracy:
    - max uncalibrated gain error 1%
    - max uncalibrated offset error 2% of potential measurement range
  - electrometer amplifier input
    - input impedance ≈ 1 TΩ, 2.3 pF
    - ±1.5 pA input bias current typ. (50 pA max.)

3.2.3 Current measurement (W port)

- 4 current measurement ranges
  - ± 10 mA (100 Ohm range)
  - ± 100 µA (10 kOhm range)
  - ± 1 µA (1 MOhm range)
  - ± 10 nA (100 MOhm range)
- AC current measurement range equals selected current range
- measured current resolution < 0.008% of current range
- max uncalibrated gain error
  - 0.1% for ±10 mA range
  - 0.1% for ±100 µA range

  - 1% for ±1 µA range
  - 5% for ± 10 nA range
- max uncalibrated offset error 2% of current measurement range ± input bias current
- current amplifier input bias current ±10 pA typ. (max. ±1nA)

3.2.4 timing

- max. acquisition rate < 10000 points/s (> 100 µs per frequency)
- DC set point interval > 150 µs ("ramp time resolution")

3.2.5 impedance spectroscopy

- Impedance Measurement Range: mΩ…GΩ
- Impedance Accuracy (for details refer to respective section)
  - |Z|/Z: 0.1%
  - |Phi|: 0.1°

3.3 Master interfaces

3.3.1 isolated Full Speed USB Interface

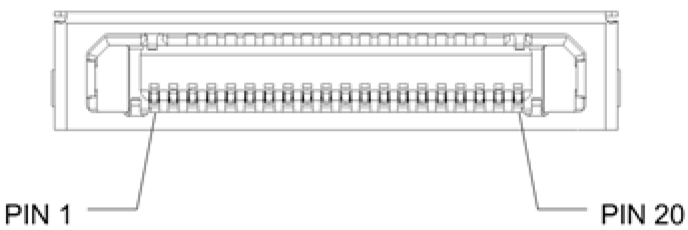
standard conformity	USB 2.0, FS (12 Mbits/s)
connector	Mini USB Type B
Protocol	High Speed USB 2.0
ESD Protection	Class 3A contact ESD performance per ANSI/ESD STM5.1-2007
isolation	2500 V rms for 1 minute per UL 1577 IEC 60950-1: 600 V rms (basic) DIN V VDE V 0884-10 (VDE V 0884-10):2006-12 VIORM = 560 V peak

3.3.2 Ethernet

standard conformity	10/100 Base-T, RJ45
protocol	TCP/IP

3.4 Sciospec ExtensionPort

connector type	Samtec FCS8 20 Pin

signal level standard	LVCMOS 3V
maximum input voltage[1]	3.6V
minimum input voltage	-0.3V
high level input voltage	≥1.7V
low level input voltage	0.8V
high level output voltage	≥2.8V
maximum output current	12mA
ESD protection of IOs	±12kV IEC 61000-4-2 contact ESD ±15kV IEC 61000-4-2 air-gap ESD clamp voltage 10.5V (min) break-down voltage 7V (min)
Digital IOs	8 software defined function digital input/output pins (IO1…8) with flexible configuration options through the Sciospec ***InterfacePort*** Standard (e.g. digital Inputs, digital Outputs, SPI Master, UART, I^{2}C)
measurement terminals	four (counter *C*, reference *R*, work *W*, working sense *WS*)
power terminals	+5V maximum current 500mA +5V maximum current 500mA
connector Layout	
pin assignment	C, R, WS, W: measurement terminals of the impedance analyzer module +5V, -5V: supply voltage terminals for use at external module IO1…IO8: digital input/output pins shielding is connected to board GND

PIN	1	2	3	4	5	6	7	8	9	10
function	W	+5V	+5V	+5V	+5V	WS	IO1	IO2	IO3	IO4
PIN	11	12	13	14	15	16	17	18	19	20
function	IO5	IO6	IO7	IO8	R	-5V	-5V	-5V	-5V	C

[1] Inputs are internally biased to 3V by a 1MOhm pull up resistor

3.5 Relation between the precision setting and the measurement time and measurement accuracy

The precision settings enables the user to adjust the trade off between measurement stability and measurement speed. For more information see chapter Functional Description.

The figure "*Accuracy over Precision Parameter*" shows the influence of the precision settings on the accuracy and time for the measurement of an impedance value at the specified frequency.

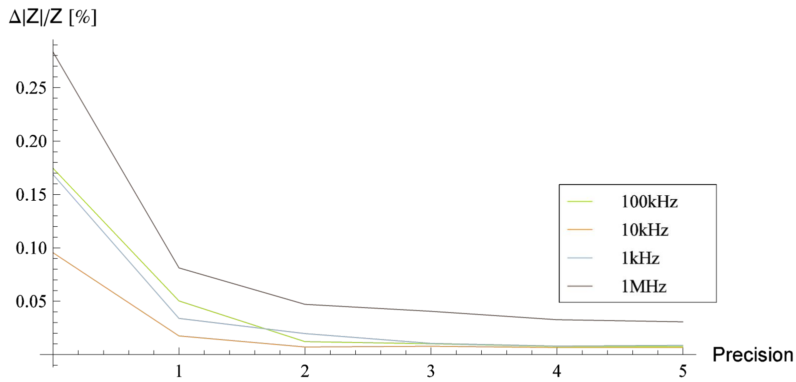


Fig: Accuracy over Precision Parameter

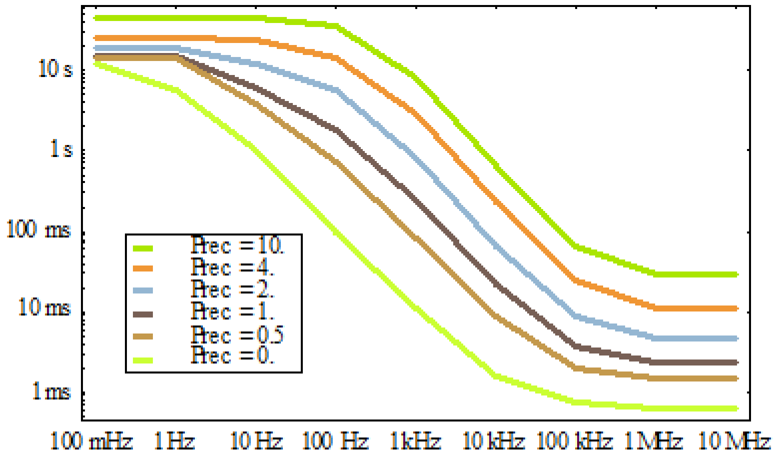


Fig: Measurement Time over Precision Parameter

3.6 Accuracy contour plot

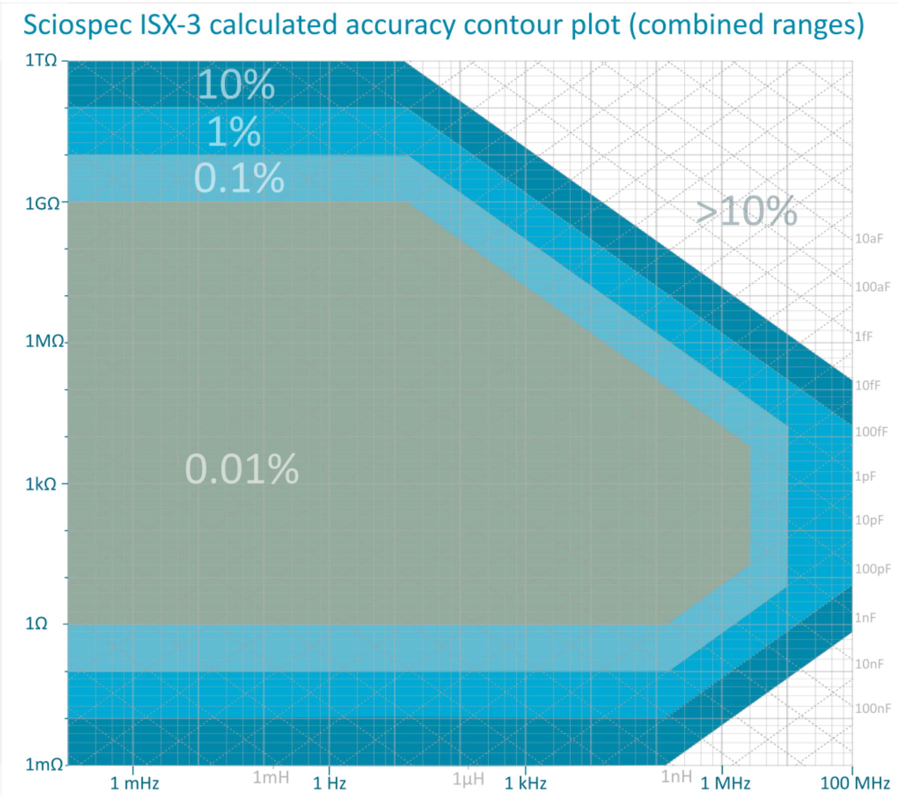


Fig: accuracy contour plot

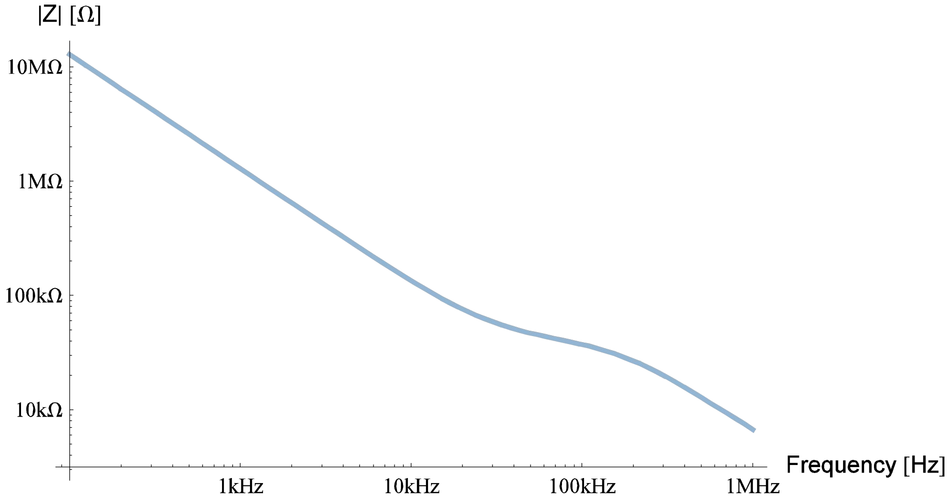
Note: The accuracy contour plot was determined under lab conditions and should be used for reference purposes. Please note that the true limits of an impedance measurement are influenced by all components in the system, like cables, cell, and the instrument.

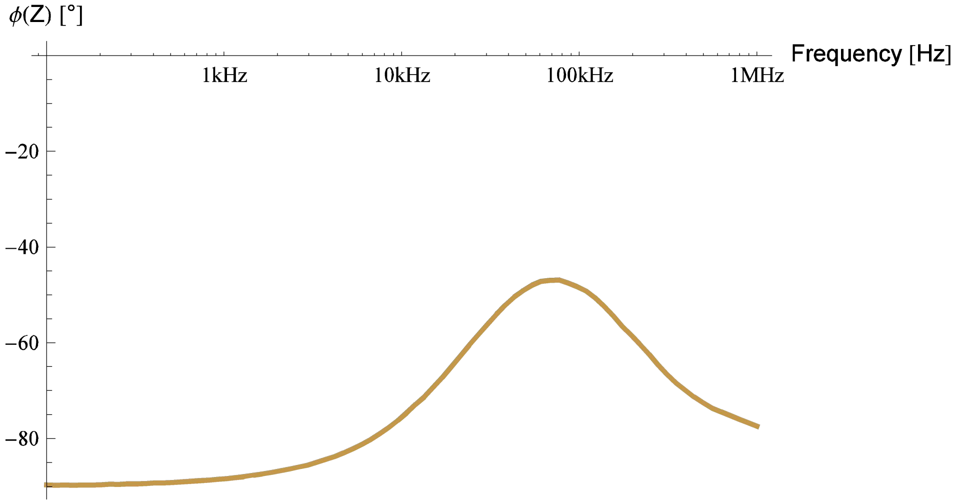
3.7 Example Measurement

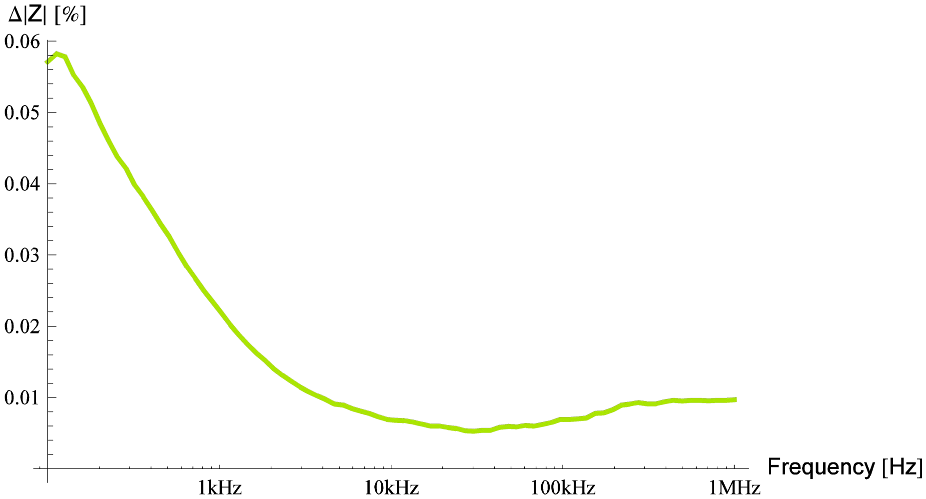
Frequency sweep: 100Hz - 1MHz, 80 logarithmic Frequency steps, precision 1, amplitude 100mV, measurement range MΩ

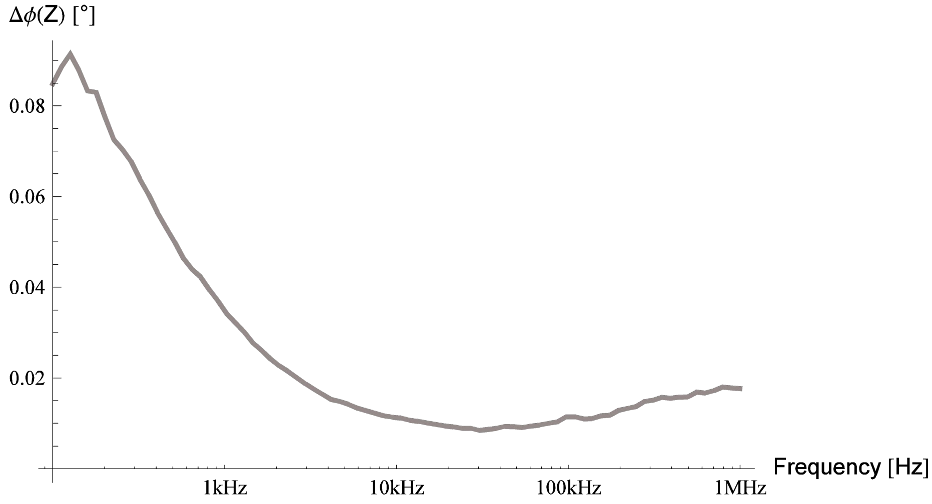
Measurement instrument: Sciospec ISX-3 with connected Sciospec MEArack

DUT: multi electrode array, 40µm electrodes, 200µm apart, platinum PBS buffer solution


|Z| [Ω]
10MΩ
1MΩ
100kΩ
10kΩ
1kHz
10kHz
100kHz
1MHz
Frequency [Hz]

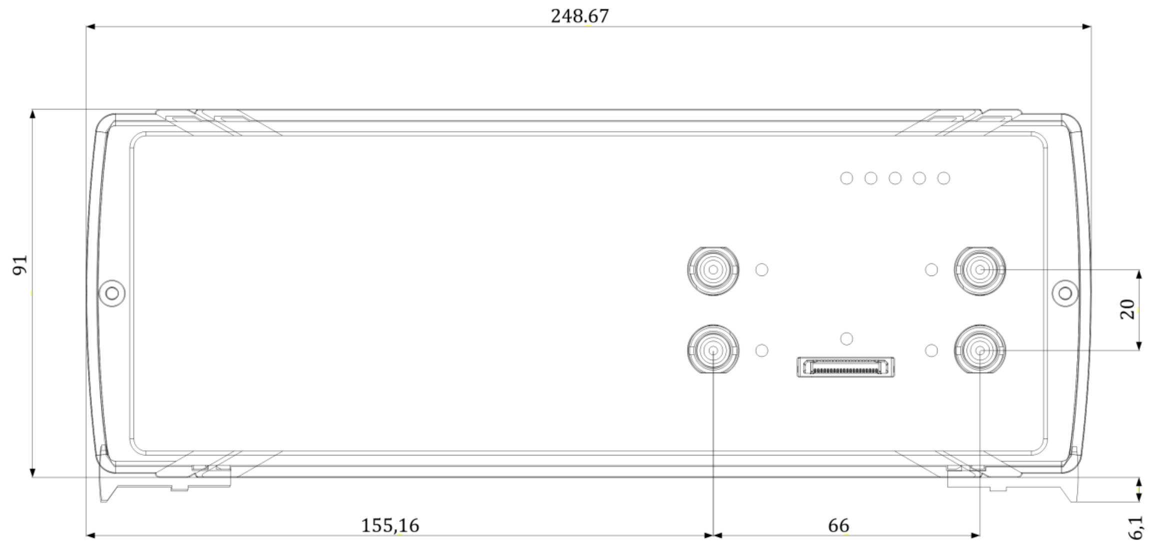

ϕ(Z) [°]
1kHz
10kHz
100kHz
1MHz
Frequency [Hz]
−20
−40
−60
−80


Δ|Z| [%]
0.06
0.05
0.04
0.03
0.02
0.01
1kHz
10kHz
100kHz
1MHz
Frequency [Hz]



3.8 General Specifications ISX-3

power requirements	100-240V AC (typ.), 50/60Hz, 60W (max)
Input fuse	Miniature Fuse, 5 x 20 mm, 1A, 250V, Fast Blow
Timing accuracy	1% accuracy over the full temperature range
dimensions	248.67mm x 97.1mmx 193.2mm (width x height x depth) see *Fig: ISX-3 front/side view*
weight	2.5kg (typical)
operating conditions	0°C to 40°C, <80% relative humidity non condensing, 0...3000m altitude
non-operating conditions	-25°C to 80°C, <80% relative humidity non condensing The temperature gradient should not exceed 1K/min to reach operating conditions.


248.67
91
20
6,1
155,16
66

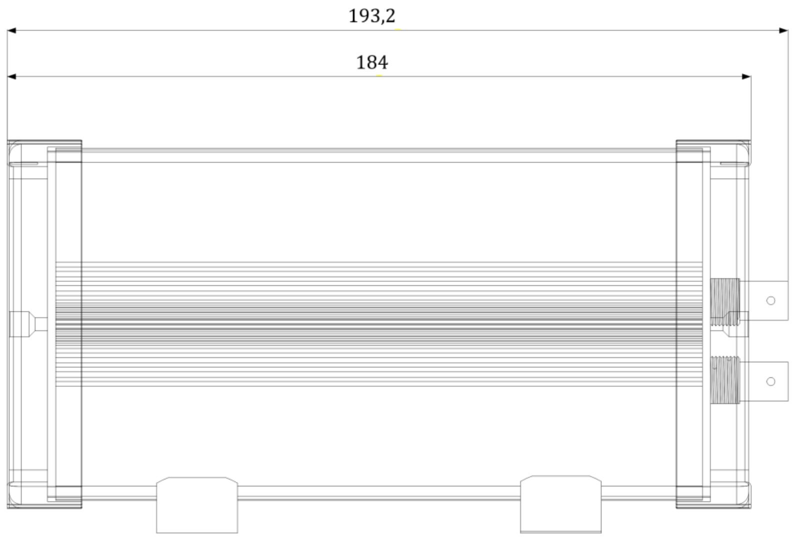

193,2
184

Fig: ISX-3 front/side view

3.9 General Specifications ISX-3mini

power requirements	12VDC (typ.), 15W (max), Connector DC Jack (Type: Switchcraft PN: 712A)
Timing accuracy	1% accuracy over the full temperature range
dimensions	184.0mm x 54.8mmx 113.1mm (width x height x depth) see *Fig: ISX-3mini front/side view*
weight	1.0kg (typical)
operating conditions	0°C to 40°C, <80% relative humidity non condensing, 0...3000m altitude
non-operating conditions	-25°C to 80°C, <80% relative humidity non condensing The temperature gradient should not exceed 1K/min to reach operating conditions.

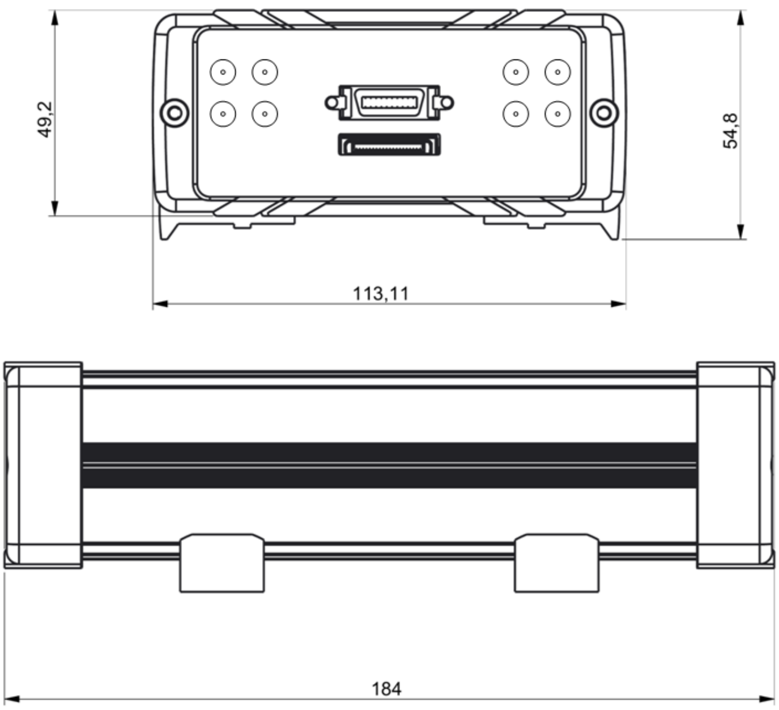


Fig: ISX-3mini front/side view

4 Functional Description

4.1 Master Interfaces

4.1.1 Full Speed USB

The device creates a virtual COM port named "serial USB device", which can be used like a serial port.

Any COM port obtains a unique number by the operating system. (i.e. "COM6") Which number is assigned to a certain port is decided by the operating system and can not be altered.

The port can be used either to connect the Sciospec Software or any terminal program to the device. There is no need to configure the general settings for the serial port (e.g. baud rate, stop bit count, etc.). Any setting of your terminal program will work.

To connect the Sciospec Software to the virtual COM port, choose "serial" in the connection dialog and then choose the desired port.

Driver installation

For Microsoft Windows 8 or more recent versions, there is no need to install any driver to connect to the device. After establishing a USB connection between the device and a PC, the new serial COM port will be available.

For Microsoft Windows 7 or XP, the driver named "Sciospec FS USB driver" provided in the Sciospec Software package, has to be installed before connecting the device to the PC. If you encounter a compatibility or verification warning during installation, choose to continue and install the driver anyway. When the installation has finished, you can connect the device to your PC. The new serial COM port will then be available.

Finding the correct COM port

If more than one COM is active on the PC, you have to determine which one belongs to the Sciospec device. An overview of known COM ports is given by the Windows device manager (Shortcut for Windows 8 or more recent: 'WIN + X') under "Ports (COM & LPT1)". Plugging in the USB cable while observing the port list shows which number is assigned to it.

Example: C-Code for establishing a connection

```
Handle hSerial = CreateFile(  "\\\\.\\COM6",
                              GENERIC_READ|GENERIC_WRITE,
                              0,
                              NULL,
                              OPEN_EXISTING,
                              FILE_ATTRIBUTE_NORMAL,
                              NULL );
          if (hSerial == INVALID_HANDLE_VALUE)
          {
                  fprintf(stderr, "Error\n");
                  return 0;
```

```
        }
          return 1;
```

Ethernet

The Sciospec device uses a bidirectional socket communication in which it implements the socket server and the connected PC the socket client. It is delivered with a ready to use ethernet configuration. It supports DHCP to receive an IP address from a DHCP server. Since DHCP is enabled by default, the device will obtain an IP address if you connect it to your ethernet router and can instantly be operated via this interface. This is the default setting but can be deactivated using the software or the “set Ethernet configuration” command. When DHCP is deactivated a static IP address must be set by the user. All Sciospec devices use the following port.

port	5000

The Sciospec device also can identify itself in a local area network by answering a UDP broadcast call. It answers with its device id. From this answer you may obtain the IP address by checking the UDP package. The broadcast message to be send is the "Get Device ID" command and needs to be send on the following port

port	8888

Example: Establishing a connection using the COMinterface

1. Connect the device Ethernet network and via USB to your computer.
2. Open terminal program and connect to the USB port of the device. (see "Setting up a connection to the device via USB")
3. Send the "get IP address" command **[BE] [01] [01] [BE]**.
4. The device will return the IP address, which it received from the DHCP server. (See command description for return syntax or disabling DHCP.)
5. Disconnect the terminal programm.
6. Use the obtained IP address and the port to establish a socket connection from your software to the device.
7. From now on the device can be controlled by regular COMinterface commands.

Example: C-Code for establishing a connection

```
    int sock;

/**This block is needed only if using WinSocket (Windows) to initialize the socket*/
    printf("\nInitialising Winsock...\n\n");
    WSADATA wsa;
    if (WSAStartup(MAKEWORD(2,2),&wsa) != 0){
        printf("Failed. Error Code : %d",WSAGetLastError());
        return 1;
    }
/** End of WinSocket initializing*/
```

```
    if( (sock = socket(AF_INET, SOCK_STREAM , 0)) == INVALID_SOCKET ){
         printf("Could not create socket");
         return -1;
    }

    /*Initialize address of device
     * IP address needs to be adapted, depending on local network and Ethernet
settings of the device*/
    struct sockaddr_in server;
    server.sin_addr.s_addr = inet_addr("192.168.100.115");
    server.sin_family = AF_INET;
    server.sin_port = htons( 5000 );

    //Connect to remote server
    if (connect(sock , (struct sockaddr *)&server , sizeof(server)) < 0){
        printf("connect error");
        return -1;
    }
```

Example: Java-Code for UDP broadcast call

```
String host = "255.255.255.255";    //Broadcast address
int port = 8888;                    //the destination port of the broadcast
char data[] = {0xD1, 0, 0xD1};      //bc char is unsigned
String message = new String(data);

try{
    InetAddress adds = InetAddress.getByName(host);
    DatagramSocket ds = new DatagramSocket();
    DatagramPacket dp = new DatagramPacket(message.getBytes(), message.length(),
adds, port);
    ds.send(dp);
    ds.close();
}
catch (UnknownHostException e){
    e.printStackTrace();
} catch (SocketException e) {
    e.printStackTrace();
} catch (IOException e){
    e.printStackTrace();
}

byte[] buf = new byte[1024];    //store the message sent

try {
    //Bind port
    DatagramSocket ds = null;
    DatagramPacket dp = null;
```

```
    ds = new DatagramSocket(port);
    dp = new DatagramPacket(buf, buf.length);

    System.out.println("The listening broadcast port is open:"+port);

    ds.receive(dp);
    ds.close();

    System.out.print("Recieved Msg:");

    for(int j=0;j<dp.getLength();j++) {
         System.out.print(" "+String.format("%02X", buf[j]));
    }

    System.out.println("");
    System.out.print("Received from:"+dp.getAddress());
}
catch (SocketException e) {
    e.printStackTrace();
} catch (IOException e){
    e.printStackTrace();
}
```

4.2 Impedance Spectroscopy

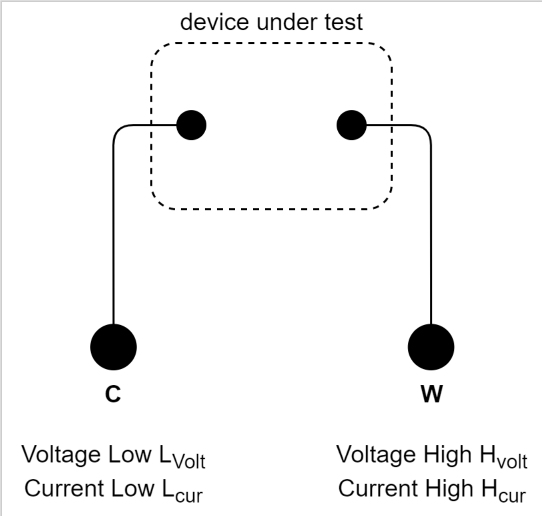
The impedance of an object depends on its resistance, capacitance and inductance. It is measured by applying a sinusoidal AC excitation signal and capturing the voltage and current values at the object for a certain time. An impedance spectrum is obtained by varying the frequency of the excitation signal over a given range. The frequency is normally increased in discrete steps, where the impedance of every step represents a singe point in the impedance spectrum.

There are three typical topologies used to measure the impedance:

- 2-Point-Configuration
- 3-Point-Configuration
- 4-Point-Configuration

4.2.1 2-Point-Configuration

The system topology in 2 point configuration includes one current injecting COUNTER electrode port (C-port) and one WORK port (W-port). Voltage measurement and excitation of the device under test is both done with the same wires.

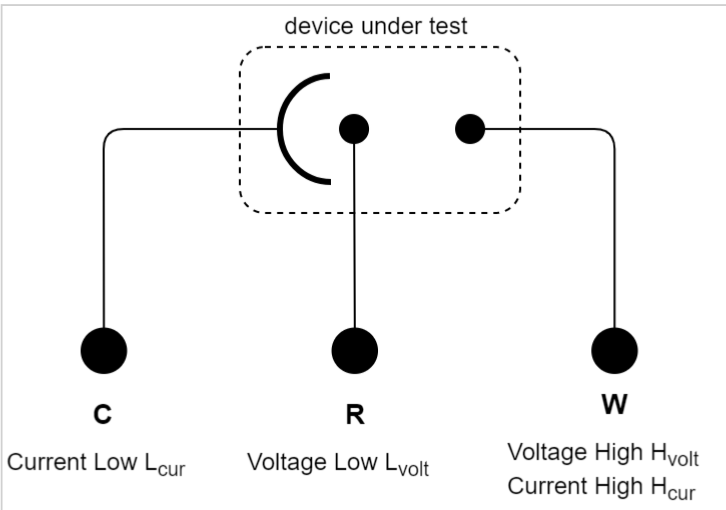


On devices with separate C, R, W and WS ports a common C port is established by shorting C and R and a common W port is established by shorting W and WS.

Possible issues include than in some cases the potential drop of the wires, caused by the excitation signal, may reduce the accuracy of the measurement as well as a build up of a resistive layer on top of one of the electrodes will be also part of the measurement result. On the other hand the number of wire need is greatly reduced compared to a 3 point or 4 point technique. This is especially important for massive multichannel configurations.

4.2.2 3-Point-Configuration

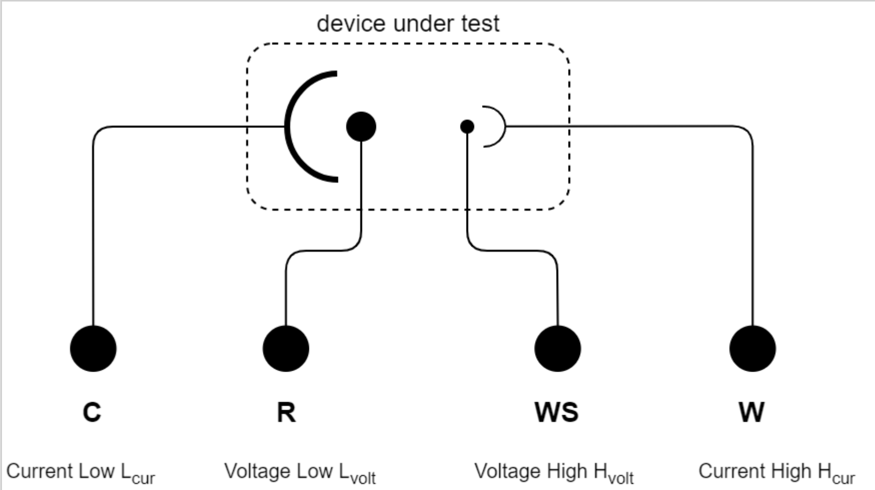
The system topology in 3 point configuration includes one current injecting COUNTER electrode port (C-port), one high impedance REFERENCE (R) port and one WORK port. Voltage measurement is performed by measuring the R-port potential against potential of the W port giving in result the potential drop/difference from REFERENCE to WORK.



On devices with separate W and WS ports a common W port is established by shorting W and WS.

4.2.3 4-Point-Configuration

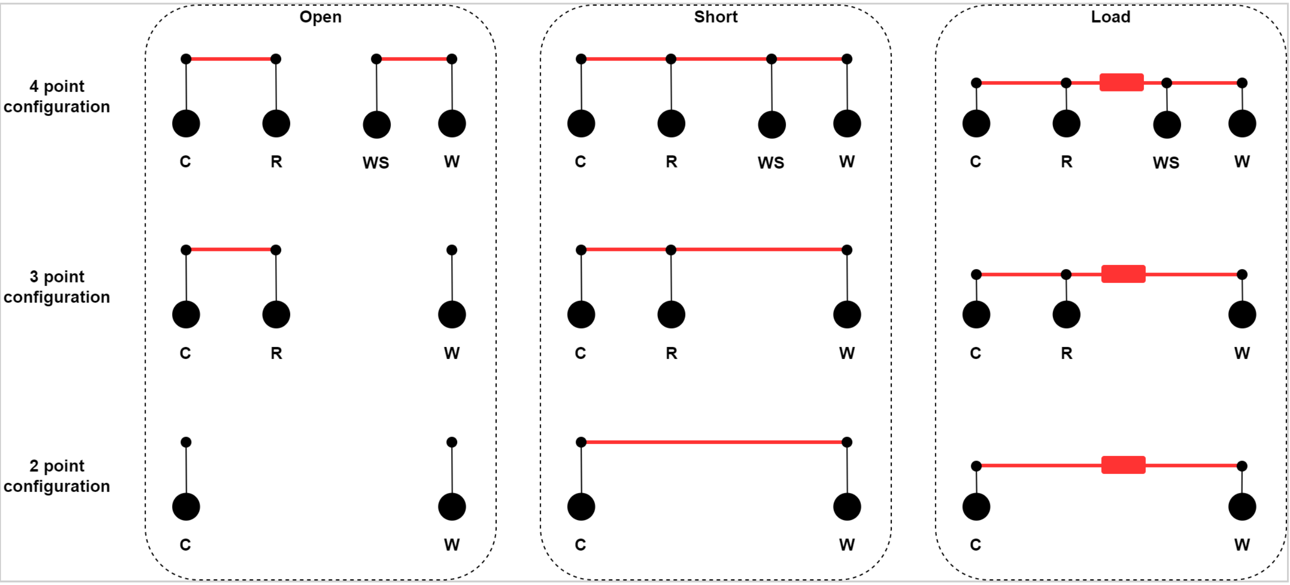
The system topology in 4 point configuration includes one current injecting COUNTER electrode port (C-port), one high impedance REFERENCE (R) port, one high impedance WORKING SENSE (WS) port and one WORK port. Voltage measurement is performed by measuring the R-port potential against potential of the WS port giving in result the potential drop/difference from REFERENCE to WORKING SENSE.



Usually this configuration gives the most accurate results, because the error introduced by the wires is reduced to a minimum due to the high impedance characteristic of the voltage measurement path.

4.3 Compensation

It is possible to perform an impedance compensation to account for parasitic effects. Once a new setup for impedance measurement is configured, it is recommended to do the compensation routine prior to first measurement. Compensation is done by performing an open-short-load compensation routine. This is done for every configured frequency point. Thus, changing the frequencies of impedance settings (or any other parameter in the setup) will require a new compensation. A drawing of the principle connections for 4 point, 3 point and 2 point configuration is shown below.



4.4 Overcurrent / Overvoltage Detection

The device will send a system message (see Acknowledge messages in COMInterface documentation) if a overcurrent or overvoltage event was detected during a measurement.

- ⚠ Overcurrent Detected: Value of DC current on W-ports exceeds capability of configured current range
- ⚠ Overvoltage Detected: Value of DC voltage difference between R and WS port exceeds capability of configured voltage range

4.5 Settings description

4.5.1 DC Bias

The "DC Bias" functionality allows to adjust the DC-offset-voltage across the measuring object. More precisely, the offset voltage between the R (reference) an Ws (work sense) ports will be adjusted. The DC Bias can be activated/ deactivated and the desired value set from the software or using the Sciospec COMInterface. When the DC Bias is activated, the system regulates the DC Bias to the set value one single time. If the measuring section or the measuring object changes, this procedure has to be repeated to regulate the system to the new conditions. The DC Bias can be set between + 1 V and - 1 V.

ⓘ **Prerequirements for DC Bias adjustment**

- The measurement object must be connected to the device before DC Bias adjustment is performed.
- A measurement setup must be set.
- No measurement may be active.
- Current direction: C = + , W = -

DC Bias is only available on the measurement port 1 (BNC). It is not available for the ExtensionPort.

The absolute value of excitation amplitude + DC Bias does not exceed 1V (limit of voltage measurement). |excitation amplitude + DC Bias| ≤ 1 V.

4.5.2 Precision

The precision settings enables the user to adjust the trade off between measurement stability (low standard deviation of measured impedance values) compared to high measurement speed. A low precision settings correspond to fast measurements with lower stability. High precision setting corresponds to greater stability at longer measurement times. The precision setting is directly correlated to the relative bandwidth of the measurement. The setting can be found in the measurement setup config panel in the software or alternatively in the set setup command (0xB6) of the Sciospec ComInterface.

For relation between the precision setting, accuracy, measurement timing and the range setting see Technical Specification chapter.

4.5.3 Measurement delay options and phase synchronization

There are different options to define delays during a measurement. Basically there are two possibilities. Either way the measurement pauses after a full sweep is completed (sweep delay, synchronization time) or after a specific frequency point has been measured (point delay). In the case of a none zero point delay, the next frequency excitation will be used and before the actual measurement starts the defined time will elapse. Both parameters can be set in the software or by a corresponding command via USB or Ethernet (see Command description command 0xB9 and command 0xB6).

The optional phase synchronization feature ensures that change of frequency in the excitation signal, which is exerted on the device under test, with no change in phase and without any glitches. This is for example needed for precise measurements of the impedance of resonant devices under test. The disadvantage of this option is that a longer time for the measurement is needed (see Command description command 0xB6).

4.6 Sciospec Extension Port

At present the Sciospec ExtensionPort is only usable to connect an extension module to the device. It makes use of the Sciospec Interface Port standard. If you need access to one of the features described in the *Sciospec Interface Port standard* section or you would like to see some other functionality available, just get in contact with Sciospec customer service.

4.7 Sciospec *InterfacePort* standard

The *Sciospec InterfacePort* standard provides up to 32 I/Os per bank, which can be freely configured to serve as a number of different interface types. These particular interface functionalities are described below. However, in some applications just a subset of these functions may be available and some parameter borders can vary too and may differ from standard values. Thus all these variable parameters are described in the particular application documentation.

Multiple independent *InterfacePort* instances may exist in a project. Each instance can be addressed by its bank address and the command code.

4.7.1 Interfaces

Digital Inputs

- This is the default configuration of every I/O, if no other interface is configurated on it.
- A weak pull up resistor (25kΩ) to VDD is connected to each I/O.
- The logic stack of all I/Os can be read out by command ("get IO state register"). The command provides a bit vector, where every bit represents the actual logic state of one certain I/O, even if it is configured as "digital output".

Digital Outputs

- The logic state of each pin can be set independently, using the "set output register" command.
- Default state of this register ist 0 for every I/O.

SPI Master

- Type: 4-wire (MOSI as well as MISO can be left unused).
- The polarity of the SPI (CPOL) is configurable by command ("set SPI polarity").
- CPHA = 0
- The SCLK-frequency is configurable within the range (mSPI_f_SCLK_source ÷ 2) ≥ f_SCLK ≥ mSPI_f_SCLK_min
- Word length = 8 Bit
- Send and receive a maximum of "mSPI_max_byte" Byte in a single communication process framed by #CS = '0'.
- Data, read from MOSI, always will be transmitted to the master interface where the command came from, which initialized the communication process.
- Application dependend parameters:
    - mSPI_f_SCLK_source
    - mSPI_f_SCLK_min
    - mSPI_max_byte

UART

- Parameters:
    - Baud is rate configurable from BaudrateMin to BaudrateMax (Baudrate = BaudrateMax/ BaudrateDivider).
    - Parity configurable (odd, even, no parity)
    - Startbit = 1
    - Stopbit = 1
    - Idle state = high
    - Receive timeout always is 10 word durations.

    - Send and receive a maximum of 128 Bytes in one continuous transmission.
- Fully asynchronous reception
- Configurable output interface for received data (any of the master interfaces)

I^{2}C

- SCK and SCL line open drain
- Parameters:
    - fSCK = 100kBaud
    - Send and Receive a maximum 15 Bytes

5 Measurement Software Description

5.1 Use of measurement module within ISX-5 / MSX-8

For use of the impedance measurement module within a ISX-5/MSX-8 platform system refer to the respective system manual for guidance on general software use (setting up connection, handling data, etc.). The measurement module specific dialogs (configuration of setups) are equivalent to the here described software (e.g. refer to Configuring a measurement setup in the Advanced Mode and sections Handling setups and spectra to Saving and loading of a PlotterGrid).

5.2 Installation

5.2.1 System requirements

- Windows® 7 or more recent

ⓘ Attach all required extension modules to your device before turn on the device.

5.2.2 Software Installation

- start the downloaded installation file (Sciospec_[device name]_[date].exe) by double click
- follow the instructions

5.2.3 Run the installation for full speed USB devices

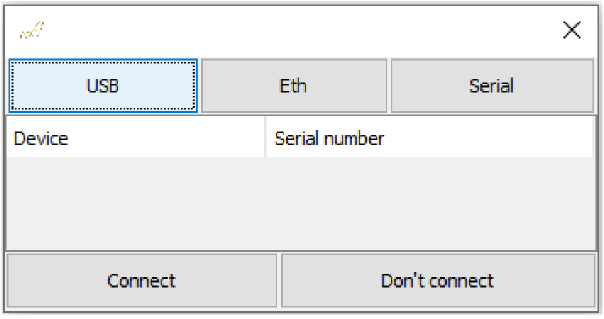
- driver for full speed USB devices are standard drivers for standard operating system (Windows, Linux, macOS)
- no additional installation needed

ⓘ Logfiles are stored at the user directory "%APPDATA%\SciospecSoftware"

5.3 Establishing connection

Once the software is started the connection dialog appears. Please make sure, that the device is powered and connected to the computer by one of the available connection interfaces.

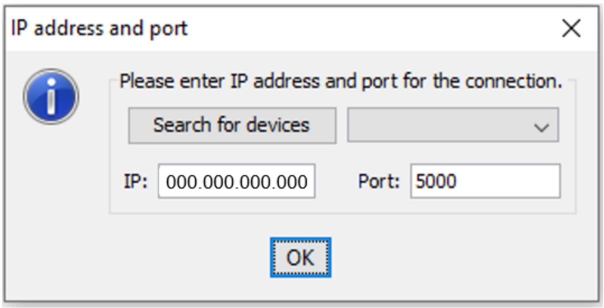
The connection dialog is shown below. You may establish a connection by clicking on the buttons representing the interface.



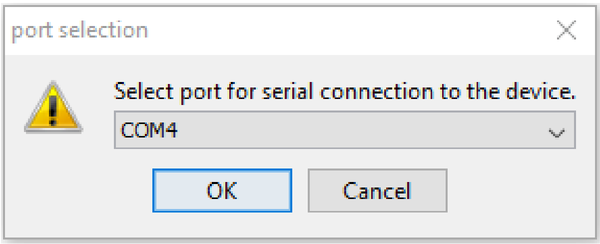
Clicking on [USB] a query for Sciospec devices connected via high speed USB interface is started. All available devices are listed with their respective serial number in the devices list of the connection dialog.

To connect to a device via Ethernet, click the [Eth] button of the connection dialog. A new dialog window will open.

Sciospec devices can identify themselves in a local area network to the software by answering on a broadcast message. To call for available devices, click the [Search for devices] button. If one or more devices answered to the broadcast message, they will be listed with their respective serial number in the drop down menu next to the search button. Selecting a device will automatically set the correct IP address of the device. Alternatively you may enter the IP of the device manually. All devices use port number 5000. If a correct IP address and port have been entered click [OK]. The device will be listed with its respective serial number in the devices list of the connection dialog.

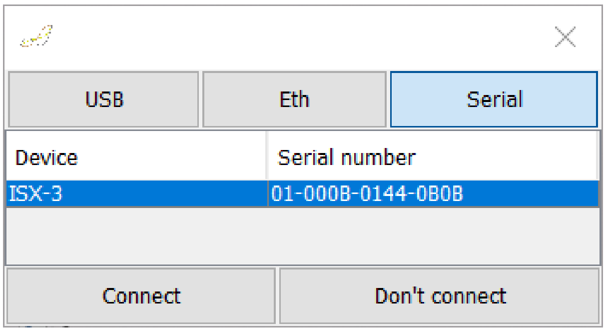


By clicking on [Serial] all devices connected to the USB serial ports (aka. full speed USB) of the PC are listed in a new dialog window.



Select the port of the Sciospec device. You may identify the correct port by opening the device manager. Click [OK] and afterwards the device will be listed with its respective serial number in the devices list of the connection dialog.

If a connection has been established successfully with the chosen connection interface, the device with its respective serial number will be shown in the devices list of the connection dialog.



If more than one device is listed in connection dialog, highlight the device you want to connect to by selecting it with a left mouse button click.

> ⚠ In case no device is detected, close the software and retry establishing a connection

After highlighting a device you may press the [connect] button. The main window of the software will open up.

> ⓘ **Don't connect**
>
> You also can run the software without an actively connected device. This way, you may visualize and analyze previously recorded data. To do so, click the [Don't connect] button.

5.4 General software window description

The software will be opened in the main window, see Figure 1.

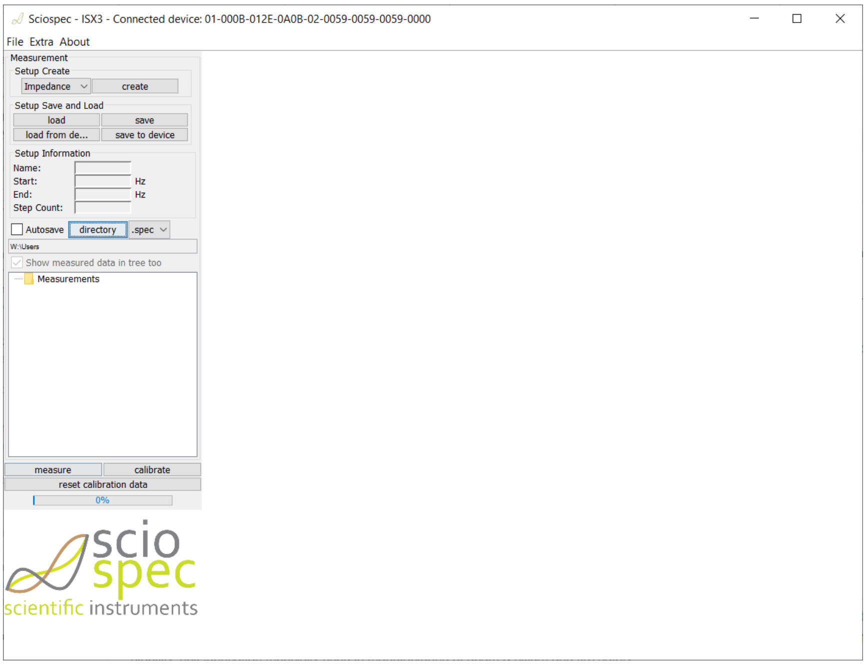


Figure 1: Main Window

In the software the user has options for configuring a measurement, displaying, editing and saving of measured impedance spectra.

The main window is broadly separated into two parts. On the left side is the control panel of the software. On the right side (blank space) windows will show up displaying status information of measurements as well as plotter windows displaying data, both of live data and already acquired data. In the control panel every device interaction and data saving interaction is handled. In the top part of the control panel are the interaction activities concerning setting up a measurement, loading and saving measurement setups. Below everything concerning measurements is displayed, including the measurement tree, the autosave feature, setup information as well as a section handling device interaction, i.e. start and stop a measurement and perform or reset a calibration.

In the menu bar there are multiple menu items displayed. In the "File" menu, the user can disconnect and reconnect the software from the device. To reconnect the software to the device the connection dialog will be opened again. Furthermore there is an option to close the software and the option to "set Synctime". Please refer to the Synctime chapter for more information.

The "Extra" menu includes a dialog to show configuration for ethernet connection. Here the IP address as well as the MAC address are displayed. Additionally the user can enable/disable DHCP.

Moreover the "Extra" menu provides a dialog to configure the DC Bias, refer to DC Bias.

Depending on the features of the device, the "Extra" menu provides for example dialogues for Wifi Configuration, IO Configuration or Battery Mode.

Clicking the "About" menu item will open a new window, showing information of the connected device. This includes the device ID, its firmware version and the software version.

> ⓘ In the right click menu of the "About" the device information can be copied to the clipboard.

5.5 Configuring a measurement setup

A new configuration of the system can be created by choosing the desired mode and pressing the [create] button, as shown in Figure 2. Following modes are available:

- **Impedance:** for standard impedance spectroscopy measurements
- **Kinetic:** The Kinetic-Mode is an easy-to-use tool to track the impedance measured at multiple frequencies points over a period of time. It can be configured for one or for multiple channels.
- **Conductivity:** for conductivity measurements using a conductivity sensor
- **Impedance Tomography:** electrical impedance tomography, only available for ISX-3 with EIT, refer to the chapter EIT for ISX-3 for more information.

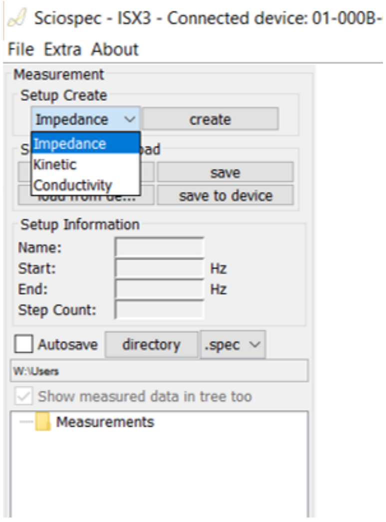


Figure 2: Measurement mode selection

The setup is divided into three parts: Frequency settings, Excitation settings, Channels settings

Frequency Setting

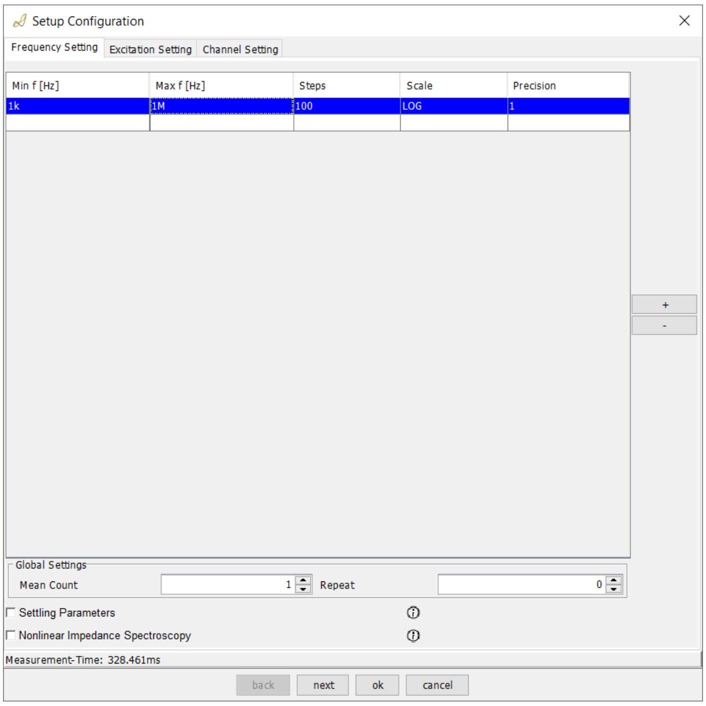


Figure 3: Setup Configuration Dialog - Frequency Setting

In this tab the frequency of the measurement and a few other parameters have to be selected. The selection of the frequency list can be configured block wise, which enables a very freely distribution of the selected frequency points.

The following settings have to be made for each frequency block (one line in the setup represents one frequency block). It is possible to combine as many frequency blocks as needed. The total number of frequency points is limited to 2048 (Impedance, Conductivity and EIT Mode) or to 16 for Kinetic Mode. Duplicated frequencies are eliminated automatically.

- Choosing the minimal [Min f], maximal [Max f] frequency and the number of points in between called [Steps]
- Selection of the type of scale [Scale] (logarithmic or linear distribution, short cut for selection: F2)
- Setting of the precision value [Precision] (0 ≤ precision ≥ 10):
  - 1 → Standard configuration (max relative Deviation < 0.1%)
  - < 1 faster measurement but less precise
  - > 1 more precise but slower measurements

Global Settings:

- Mean Count:
  - user defined averaging over n data sets
  - n = 1 → no averaging
- Repeat:
  - number of repetition of the measurement using this setup
  - 0 → never ending measurement, measurement has to be ended manually by pressing the measure button again

Settling Parameters:

- Introduces a hold time (settling time) between start of excitation and start of acquisition of the impedance data and the option to use phase synchronous change of excitation frequency. Boths can be used to compensate for settling effects of devices under test like seen in resonante objects.
- Setting the point delay in µs. (Time between two consecutive frequency measurements)
  - Minimum 0 µs (default)
  - Maximum 180E6 µs (= 3 min)
- Configuring the Phase Synchronization
  - Disabled: Standard
  - Enabled: Use for resonant sensors only

Nonlinear Impedance Spectroscopy:

- Allows to set multiple different excitation amplitudes for individual frequency blocks. The measurement range plot is not available, if Nonlinear Impedance Spectroscopy is activated.

Specific for the Conductivity mode:

- Cell Constant
  - cell constant of the used sensor in [1/cm]
- Alpha
  - temperature coefficient in [%/K] at 25 °C

Switch to the Excitation Setting panel by selecting [next].

Excitation Setting

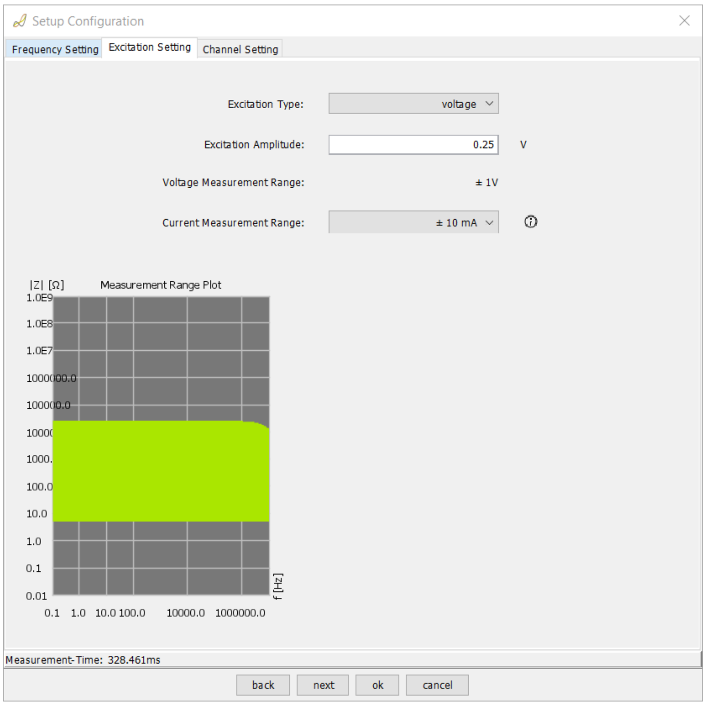


Figure 4: Setup Configuration Dialog - Excitation Setting

Excitation Type:

- Selection between voltage and current excitation

Excitation Amplitude:

- enter the amplitude of the excitation signal
- 10 mV to 1000 mV for voltage excitation (peak amplitude = half of peak-peak value)
- 10 µA to 10 mA for current excitation (peak amplitude = half of peak-peak value)

Voltage Measurement Range:

- fixed to ± 1V

Current Measurement Range:

current measurement range	old range nomenclature
± 10 mA	100
± 100 µA	10k
± 1 µA	1M
± 10 nA	100M

Measurement Range Plot

- shows the possible impedance measurement range (green) for the current selected excitation settings.

Channel Setting

Switch to the channel settings panel by selecting [next]

- Select the measurement channel (ExtensionPort Modules have a specific setup dialog)
  - MAIN PORT – Standard Configuration
    - PORT 1
    - PORT 2
  - MUX32
  - MeaModule
  - EXT2 (for InternalModules like InternalMUX32)
- Setting the configuration to 2, 3 or 4 point. Options depends on the device and Extension- / InternalModule.

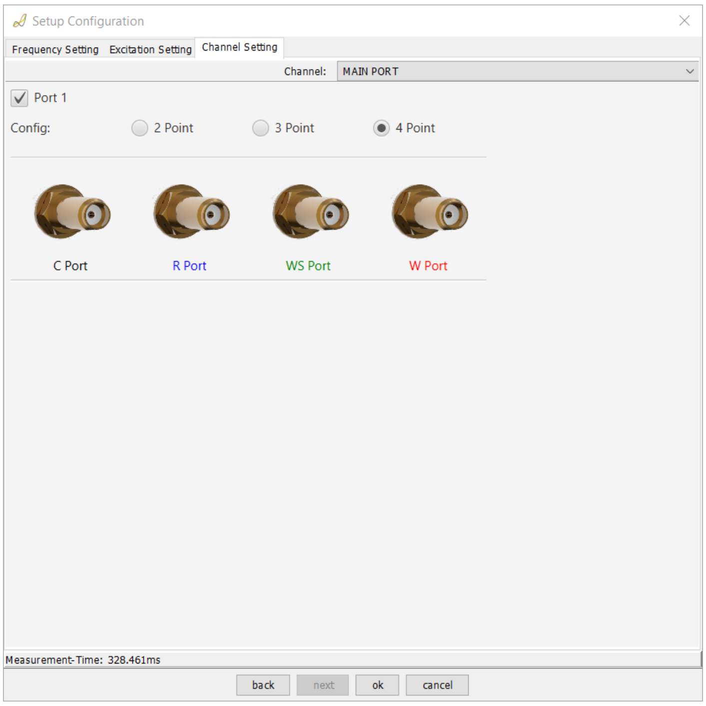


Figure 5: Setup Configuration Dialog - Channel Setting

Confirm the parameters by pressing [Ok].

Unit Prefix

All Parameters can be entered with a unit prefix. Following unit prefixes are valid:

Prefix	Symbol	Factor
tera	T	10^{12}
giga	G	10^{9}
mega	M	10^{6}
kilo	k	10^{3}

Prefix	Symbol	Factor
milli	m	10^{-3}
micro	µ / u	10^{-6}
nano	n	10^{-9}

5.6 Running a measurement

- Select the desired setup in the measurement data tree
- Choose [measure] to start the measurement
- To stop the measurement press [measure] again
- It is possible to start multiple setups at once. Select them by holding the control key while clicking on each one. Now press [measure]. A measurement option window opens.
    - "Loop setups": Once the measurement has been started with the option loop setup each setup will run one after another. A selection of a repeat count of 0 in one of the setups will result in never reaching the next setup, therefore this is not possible. Select a number of 1 or higher for repeat in the setups. The Repeat counter in the Measurement option window defines how many times a loop of the setups is done. A loop repeat of 0 results in a never ending measurement.
    - The option stitch spectra creates an additional stitched spectra.

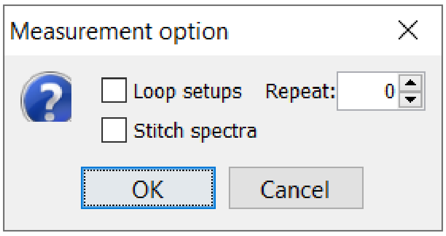


Figure 6: Measurement Option Window

5.7 Performing a calibration routine for a setup

To compensate for parasitic impedance effects induced by the cabling it is possible to calibrate the system with an easy open-short-load compensation. The calibration procedure has to be done for each setup used, but can be stored with the setup to the device and reloaded for later use.

The calibration requires arranging three different cabling connections. The configuration of "OPEN", "SHORT" and "LOAD" are shown in the Functional Description chapter compensation.

The calibration routine can be started in the software by selecting the setup configuration and click on calibrate. The software then prompts to set the open arrangement as described above and showed below. Followed by short and load arrangement.

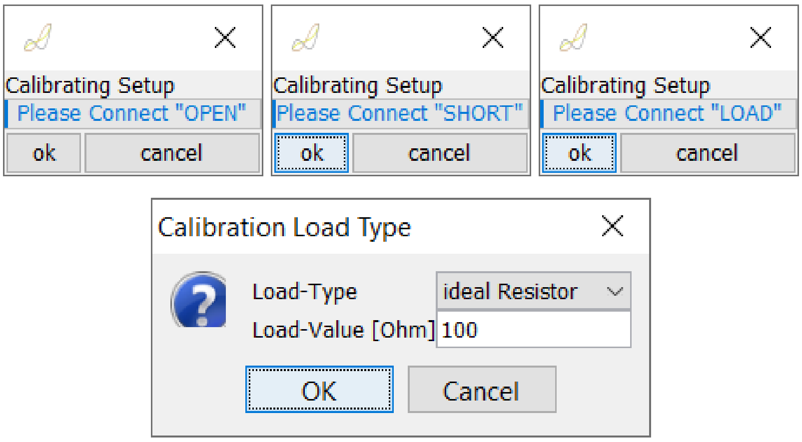


Fig: Calibration Dialog

Choose a load device in the impedance range of your device under test. It is possible to use an ideal resistor or a capacitor as a standard load device.

5.8 "Autosave" feature

The [Autosave] Option allows to automatically saving the measured data to a previously selected folder.

- Select the path of the folder by clicking on [directory]. (By default is the folder “Data” in the Sciospec ISX-3 folder selected)
- Following file extensions are possible (drop down menu): .spec / .xls / .dat
- If the checkbox [Show measured data in tree too] is checked, the data will be displayed in the data tree too.
- If the checkbox [Show measured data in tree too] is unchecked, the data will not be displayed in the data tree, to reduce the amount of memory needed by the software.
- Once a measurement is started a subfolder with the name of the setup configuration will be created and all data will be saved there.
- The saved data can be displayed by loading them into the software.
- It is also possible to display the current data by creating a PlotterGrid as described above.
- The major advantage of this feature is that the required program memory will not increase significantly over the runtime of the experiment and all measured data is stored to the hard drive. A fault condition will not compromise the already measured spectra. In case the “Autosave” feature is not active the measured data will only be held in the program memory.

ⓘ It is highly recommended to use the “Autosave” feature when performing long experiments.

5.9 Overcurrent / Overvoltage Detection

The device will send a system message if a overcurrent or overvoltage event was detected during a measurement.

- ⚠ Overcurrent Detected: Value of DC current on W-ports exceeds capability of configured current range

- Overvoltage Detected: Value of DC voltage difference between R and WS port exceeds capability of configured voltage range

The software will display a warning icon in the right upper corner of the software window while the measurement is running and an overcurrent or overvoltage event is detected. This icon can be seen in Figure 7. If an overcurrent or overvoltage event was detected, the affected data set will be marked with the warning icon in the data tree. In addition the event will be noted in the saved spec file as shown in Figure 8.

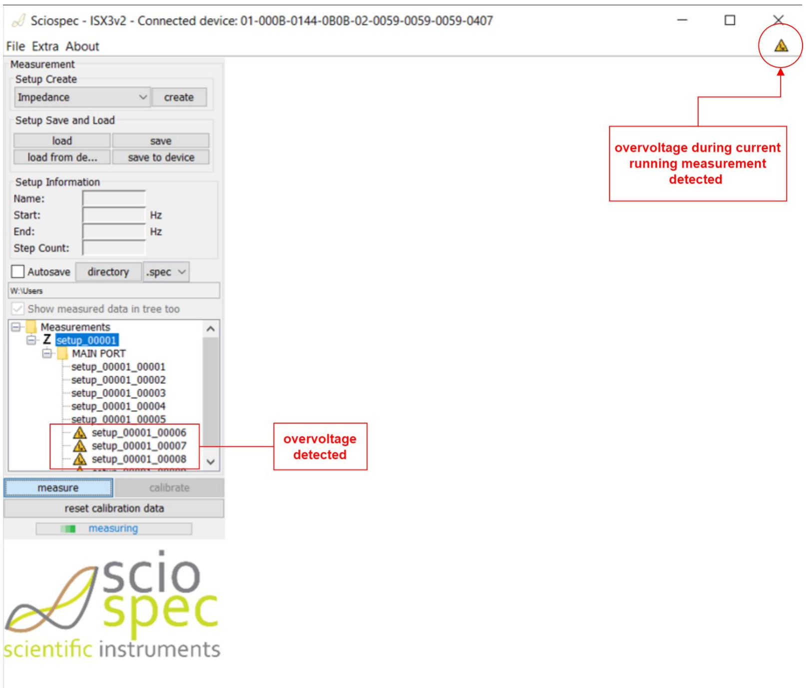


Figure 7: Overcurrent detection

```
7
setup_00001_00006
Offset: 0.0V
Overcurrent detected
Channel: MAIN PORT
13-Dec-2021 01:34:43:616 PM
frequency[Hz],Re[Ohm],Im[Ohm]
100.000761449337,1939.794189453125,0.07167129963636398
200.001522898674,1939.5330810546875,0.0270648505538702
300.002284348011,1939.7750244140625,0.030577857047319412
399.9972250312567,1939.5931396484375,-0.05213436856865883
499.9979864805937,1939.712158203125,-0.02468254044651985
599.9987479299307,1939.771484375,-0.007970315404236317
699.9995093792677,1939.585693359375,0.097711481153965
800.0002708286047,1939.725341796875,0.16763891279697418
900.0010322779417,1939.7349853515625,0.15093041956424713
1000.0017937272787,1939.606201171875,0.2718646228313446
```

Figure 8: Overcurrent detected in saved .spec file

5.10 DC Bias

The "Extra" menu provides a dialog to configure the DC Bias, as shown in Figure 9. Please refer to the functional description of this functionality for functional description and prerequirements!

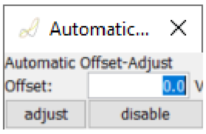


Figure 9: DC-bias dialog

If the system detects a out of current or out of voltage event during the adjustment of the DC Bias, the software will display an error message shown in Figure 10

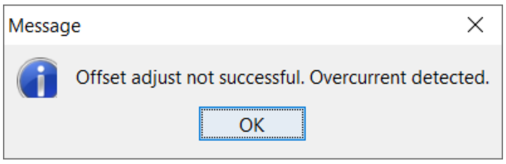


Figure 10: DC Bias error message

5.11 Synctime

The Sync time is the time between the measurement of two spectra. Maximum value is 180s. It is described in the functional description of this document.

If a Synctime > 0s is set, the Synctime icon will be displayed in the right upper corner of the Main Window, as shown in Figure 11.

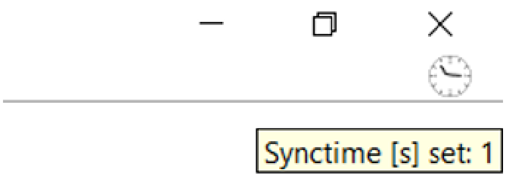


Figure 11: Synctime Icon

5.12 Handling setups and spectra

Setup and spectrum datasets can be renamed by pressing F2.

5.12.1 Spectra

- Saving spectra
    - Select the datasets you want to save
    - Press [save]
    - The files will be stored in the selected directory including a number and with the file extension “spec” (see File description ".spec")

- Loading spectra
    - Press [load]
    - Select the datasets you want to load and confirm by pressing [Open]
    - You can also “Drag and Drop” the data files into the software
- The [Autosave] option allows for automatic saving of files to the hard drive.
- By selecting [show Info] from the right click drop down menu from a dataset additional information can be stored with a dataset

5.12.2 File description ".spec"

Basically the files can be interpreted as a plain text comma separated (csv) file with a header and a main part.

Row	Content
1	Number of header rows N (including this one)
2	Name of file
3 to N-3	Comment
N-2	Channel
N-1	Time of the measurement
N	Column labels
N+ to End	Data according to the column labels

5.12.3 Setups

- Saving setup configurations
    - Right click a setup or press on [save] after a setup is selected.
    - You can automatically save all data obtained with this setup by selecting “include sub data”
    - The file extension is „setUp“.
- Loading setup configurations
    - Press [load]
    - Select the file extension „setUp“ from the file filter drop down menu
    - Select the setup file you want to load and confirm by pressing [Open]
    - Or „Drag and Drop“ a setup file into the software

Setups and spectra can also be handled using the right click menu, as shown in Figure 12. All possible opportunities will be displayed as saving, renaming, opening in new window...

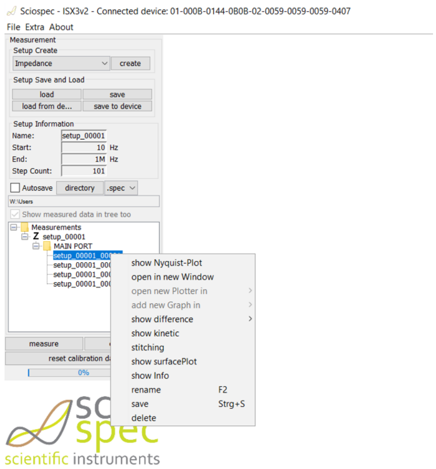


Figure 12: Main Window with right click menu

ⓘ Exported .spec files can be directly imported into analysis software like **ZView®** or **RelaxIS**

5.13 Visualization of the data

5.13.1 Plotter

There are multiple options to visualize previously recorded data in a static plotter:

- Show a **Bode plot** (absolute value vs. frequency and phase value vs. frequency) by
  - double clicking on the measured dataset in the data tree
  - right click on one or multiple datasets and select "open in new Window"
  - dragging one or multiple datasets into the display area
- Show a **phase plot** by
  - double clicking on the measured dataset while pressing the [Control] key
  - dragging one dataset into the display area while pressing the [Control] key
- Show an **absolute value plot** by
  - double clicking on the measured dataset while pressing the [Shift] key
  - dragging one dataset into the display area while pressing the [Shift] key.
- Show a **Nyquist plot** (negative imaginary part vs. real part) by
  - double clicking on the measured dataset while pressing the [Alt] key
  - dragging one dataset into the display area while pressing the [Alt] key.
  - right click on the data and select "open Nyquist-Plot"
- Show **absolute or relative differences** of spectra of either absolute value or phase value by right click on a selection of datasets in the datatree and clicking "show difference"
- Show **kinetic** of spectra recorded at different times by right click on a selection of datasets in the datatree and clicking "show kinetic"

Quick-access plotter configuration

Quickly adjusting diagram and visalization configurations can be done with the help of right click pop-up menus.

Right click on the drawing area will enable you to quickly

- set axis scalings
  - Lin-lin
  - Log-lin
  - Lin-Log
  - Log-Log
- set, copy or paste zoom settings
- set labels

Furthermore you can access the detailed plotter configurations by clicking "Diagram configuration".

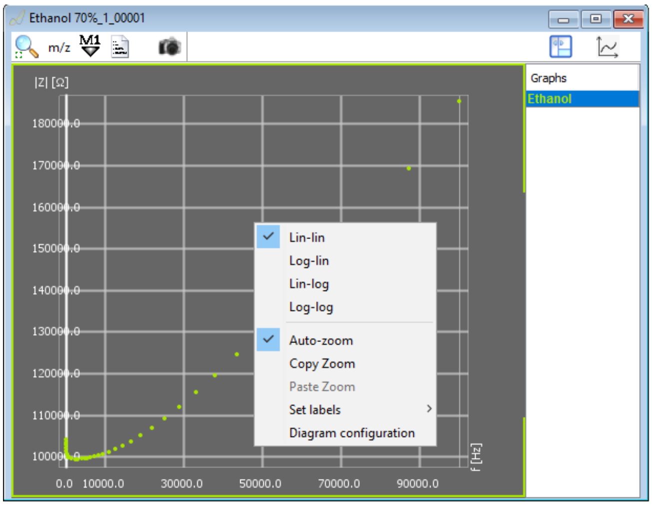


Fig: Drawing area pop-up menu

Right click on a signal listed in the graphs panel will enable you to quickly change appearance of the signal, f.e. conecting and/or showing points of the signal. Furthermore you can access the detailed signal settings by clicking "Change signal settings".

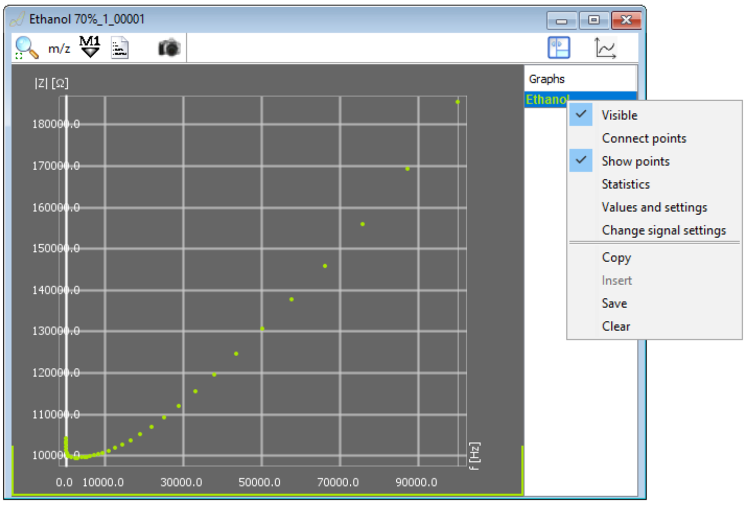


Fig: Graphs panel pop-up menu

Detailed diagram configuration

The diagram configuration dialog can be opened by right click in the plotter area and select "Diagram configuration". The diagram configuration dialog enables the user to customize the axes settings and signal settings of the plotter in detail. For example scale, labels, colors, intervals as well as signal names and signal appearances and much more. The diagram configuration dialogue is displayed in below.

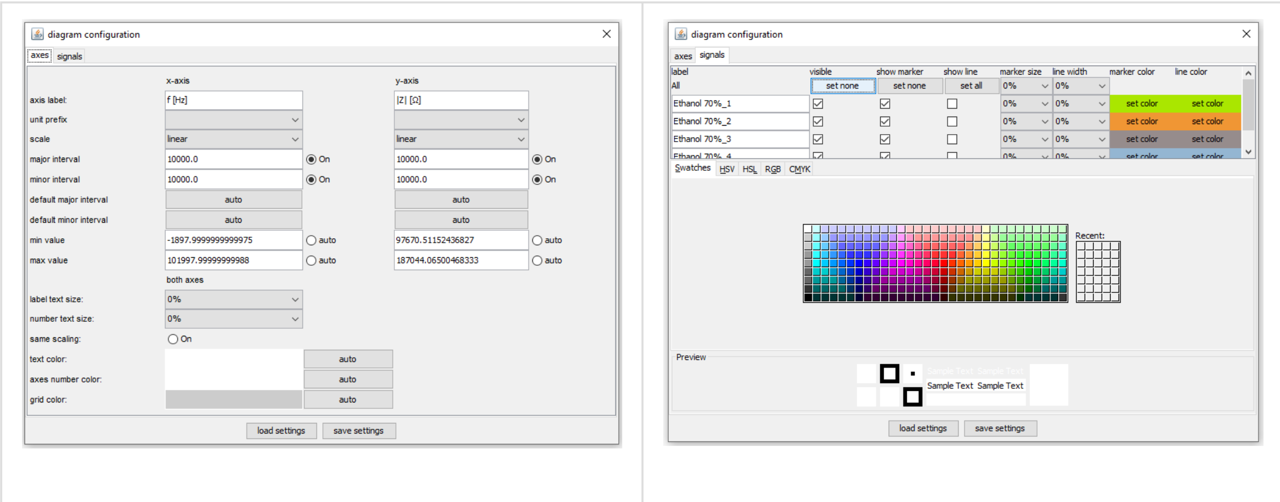


Fig: Diagram configuration dialog

The general diagram configurations such as diagram background color, caption, height and width can be customize in the general diagram configuration panel. It can be opened by click on the button  at the top right corner of the plotter. It is possible to access the diagram configuration dialog by clicking the [>>] button. The diagram configuration panel will open as shown below.

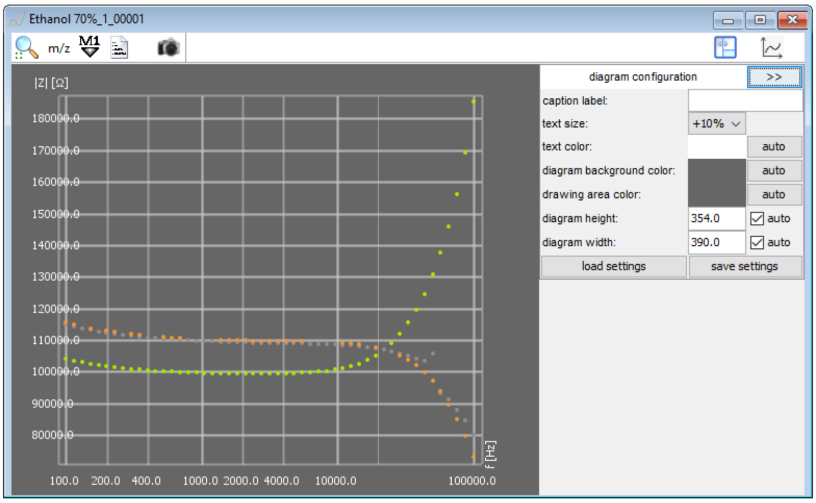


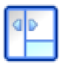
Fig: Plotter window with diagram configuration panel

Plotter functions

Action to perform	Function / Result
Middle mouse button, Right click pop-up menu and "Auto zoom" or 	Auto zoom
Mouse Wheel or  / 	Zoom
Left mouse button or  and drag	Zooms into selected rectangle
	open diagram configuration panel
Right mouse button and drag	Moving the displayed area
Right click pop-up menu and "Copy zoom" or 	Copy the current zoom setting
Right click pop-up menu and "Paste zoom" or 	Paste a copied zoom setting
	Saving the displayed data to a ".csv" file
	Creating a new marker
	Taking a snapshot as a „png" file
Double click on a dataset	The absolute value and the phase will be displayed
Holding [shift] while opening data	Only the absolute value will be displayed
Holding [ctrl] while opening data	Only the phase value will be displayed
Holding [ctrl] while operating mouse wheel	Zoom with a lower magnification
Dragging a dataset into an active Plotter	The absolute value and the phase value will be added to the plotter
Double click on the plotter	Full screen mode (Escape to exit full screen)

Graphs panel

Right click on the data	Disabling or enabling the visualization and computing methods of the data

	Hiding the graphs panel

5.13.2 PlotterGrid

The PlotterGrid gives more options for displaying of measured data.

Setting up a live PlotterGrid

- Right click on desired setup opens a drop down menu.
- Select one of the "add new PlotterGrid" options.
- A PlotterGrid with the currently measured data will be displayed.

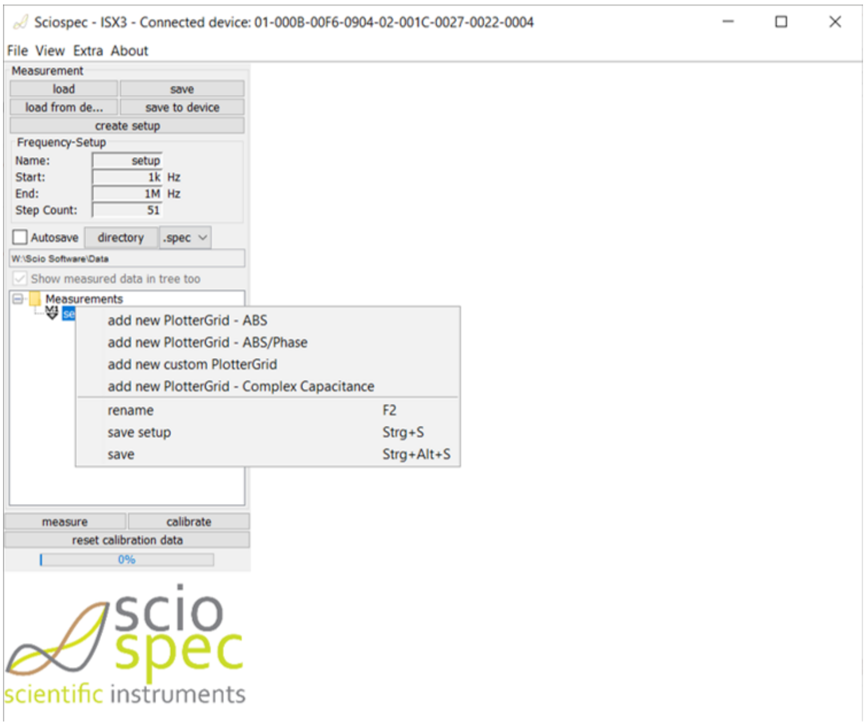


Fig: Setting up a live PlotterGrid

Setting up a PlotterGrid

- Right click in the white empty area of the software
- Select [new PlotterGrid] or [default PlotterGrid]

Fig: Setting up a PlotterGrid

- State the number and the arrangement of the desired Plotters (maximal 8 rows and 8 columns)
    - for example: row 1 → 2 columns, row 2 → 1 columns

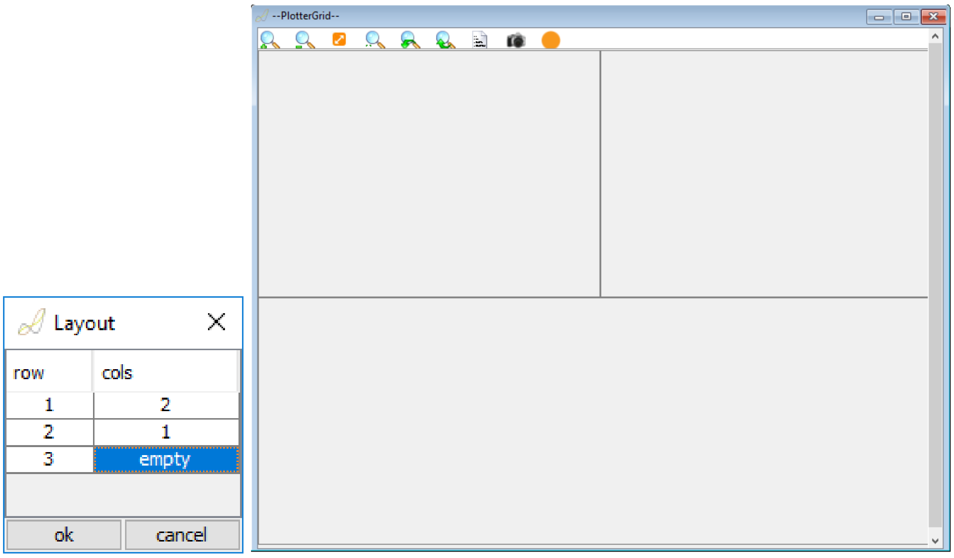


Fig: PlotterGrid layout

Every created part can now be filled with data. Configure each one by right clicking it and selecting [configure]. The following dialog appears.

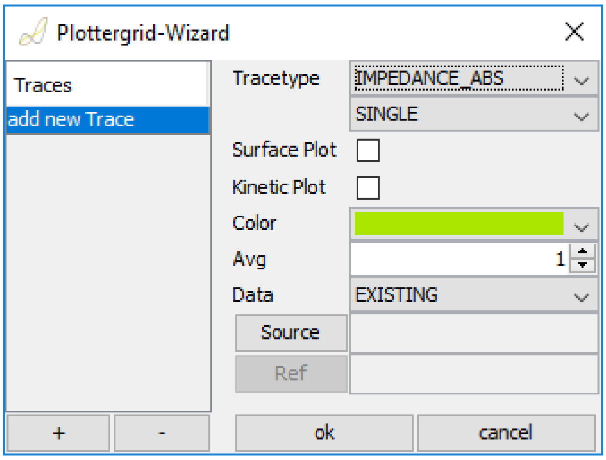


Fig: PlotterGrid Wizard

Trace type	Type of the data to be visualized. Real part, imaginary part, absolute value or phase over frequency can be selected. Additionally a Nyquist plot (negative imaginary over real part) is possible. „Single“, „Difference“ and „Relative Difference“ gives you the ability to track changes in the impedance. A reference spectrum has to be selected.
Color	Color of the plotted points
Avg	Number of Points used for a moving average.
Data	Selection of existing or currently .measured data to be displayed
Source	Select the data to be visualized. For existing data select the datasets from the data tree. For currently measured data select the channel of interest.
Ref	Select the reference spectrum for the “Difference” and “Relative Difference” modes.

Saving and loading of a PlotterGrid

It is possible to save a PlotterGrid to a file and load it again later.

- To save press the button in the active PlotterGrid. State the save path of the file. The file extension is “.grid”
- To load a PlotterGrid right click into the empty display area a select [load PlotterGrid] from the drop down menu

5.13.3 Surface Plot

The Surface Plot gives more options for displaying the measured, time dependence data.

- Select the datasets you want to show in the surfacePlot and right click on it
- Select [surfacePlot]

- Choose one of the available surface types, which are shown in *Fig: Select surface type window* and confirm by pressing [OK]

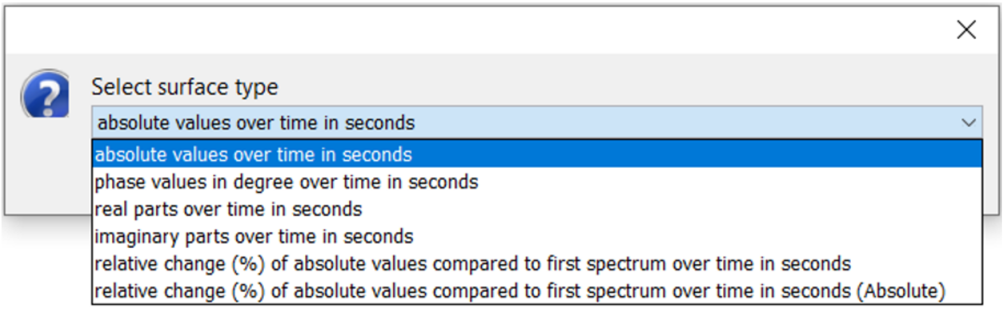


Fig: Select surface type window

- The surfacePlot will open as shown in *Fig: Surface Plot Example - visualization options*
- Right click on the surface plot area opens possible options to change the visualization, as shown in *Fig: Surface Plot Example - visualization options*
- Zoom functionality is available as described in Plotter functions

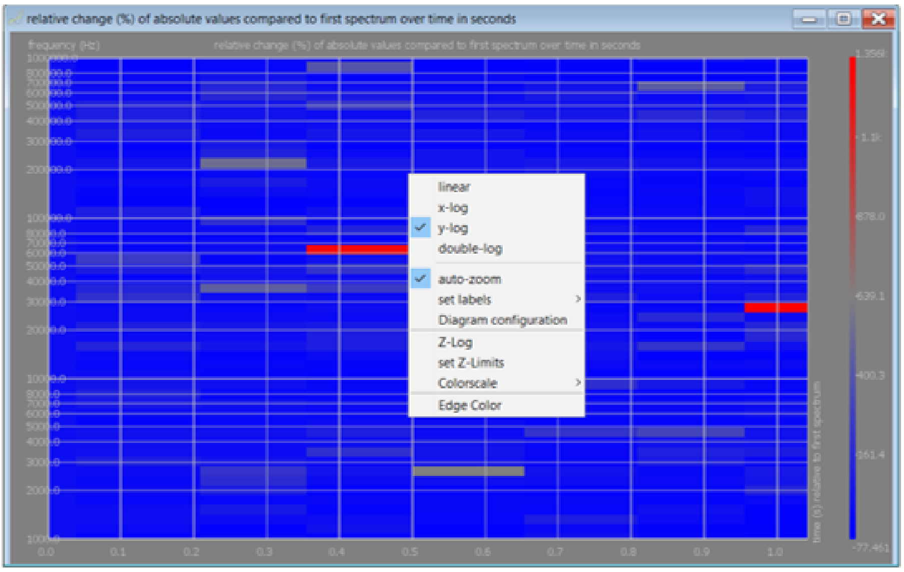


Fig: Surface Plot Example - visualization options

5.13.4 Conductivity Plot

If the conductivity measurement mode was used the corresponding data will be shown in the conductivity plot as shown in Figure 13

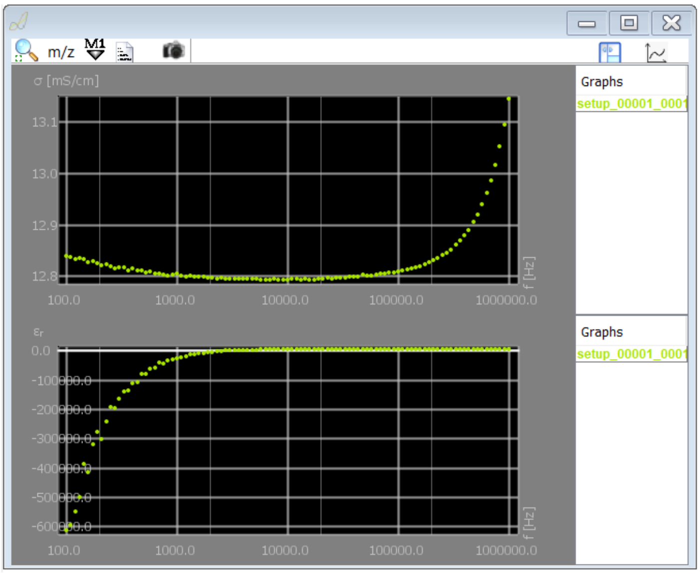


Figure 13: conductivity plot

5.14 Error Messages

When the software encounters a problem, a message window appears, which shows the respective error code and the failed command. The complete list of error codes can be found in subsequent table. For detailed description of the relevant command see Sciospec COMInterface section of the device.

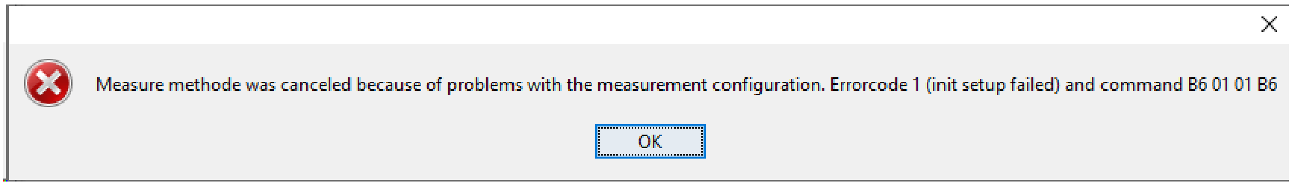


Fig: Error Message window

error code	description
1	init setup failed
2	add frequency block failed
3	set parasitic parameters failed
4	set acceleration settings failed
5	set sync time failed
6	set channel settings failed
7	set calibration data failed

error code	description
8	set timestamp failed
9	start measurement failed
34	set amplitude failed
46	get frequency list from device failed

6 Sciospec Communication Interface

The Sciospec Communication Interface (COMinterface) enables the user to access all functions of the device by using any of the available master interfaces. The actual command structure is identical in all connection types.

6.1 Syntax

The general structure of each communication with a Sciospec device:

- The communication is done by frames
- Each communication frame is constructed as follows

- 1 byte command-Tag (Frame-Start)
- 1 byte number of data-bytes (0...255)
- 0...255 data-bytes
- 1 byte Command-Tag (Frame-End)

- The command-tag identifies the command (see Command list)
- Frame-Start and –End must be identical

Example: "System-Ready-Message"

CMD-Tag	Number of bytes	Data	CMD-Tag
0x18	0x01	0x84	0x18

6.2 Acknowledge messages

- Communication-frames with incorrect syntax will cause a “Frame-Not-Acknowledge” message
- If the transmission of a communication-frame is interrupted for more than 10 ms a “Timeout” message is send
- Every invalid command-tag will cause a “Not-Acknowledge” message
- Every valid command is acknowledged with an acknowledge command [ACK]
- For commands with a return value the returning frame comes before the acknowledge message
- When commands are sent during the current measurements, measurement data can be transmitted between the command and the following returning frame and the acknowledge-message (commands are handled asynchronously)
- Before sending a new command, the resulting acknowledge or not acknowledge of the previous command has to be awaited.

The ACK-Frame:

0x18	0x01	[ACK]	0x18

General System Messages	
0x01	Frame-Not-Acknowledge: Incorrect syntax

General System Messages	
0x02	Timeout: Communication-timeout (less data than expected)
0x04	Wake-Up Message: System boot ready
0x11	TCP-Socket: Valid TCP client-socket connection
0x81	Not-Acknowledge: Command has not been executed
0x82	Not-Acknowledge: Command could not be recognized
0x83	Command-Acknowledge: Command has been executed successfully
0x84	System-Ready Message: System is operational and ready to receive data

Device Specific System Messages	
0x90	Overcurrent Detected Value of DC current on W-ports exceeds capability of configured current range
0x91	Overvoltage Detected Value of DC voltage difference between R and WS port exceeds capability of configured voltage range

ⓘ For use of the impedance measurement module within a ISX-5/MSX-8 platform system refer to the respective system manual for guidance on specific communication within those systems. Commands and functionality are the same as described here, but additional framing and setup commands will be required due to the multi slot system structure within ISX-5/MSX-8.

6.3 Abbreviations

abbreviation	full name
[CT]	command tag
[LE]	length
[OB]	option byte
[CD]	command data

6.4 Command list

The leading hex code of each command heading represents the [command code] of the respective function.

- 0x90 - Save Settings

6.5 Command description

6.5.1 0x90 - Save Settings

General Syntax

[CT] 00 [CT]

Return

ACK

Description

Saves the following parameters permanently into the flash memory of the ISX-3:

- NTC Parameters 1 and 2
- Parameter stack synchronization time

This command can only be used if no measurement is currently running.

6.5.2 0x97 - Set Options

General Syntax

[CT] [LE] **[OB] [CD]** [CT]

Return

ACK

[OB]

Function	code
Activate time stamp	0x01

Active time stamp

Configuration of the Instrument. Activate time stamp of measured data.

Syntax

- Syntax set: **[CT] 02 01 [CD] [CT]**

[CD]

- 0x01 Enable Time Stamp
- 0x00 Disable Time Stamp

Depending on this setting the return frame of the measured data changes (see command B8)

Remarks:
It is not possible to change this setting while a measurement is running. This setting cannot be saved persistently.

6.5.3 0x98 - Get Options

General Syntax

[CT] [LE] **[OB]** [CT]

Return

[CT] [LE] **[OB] [CD]** [CT]

ACK

[OB]

Function	code
Time stamp	0x01

Time stamp

Returns the currently configured options of the instruments.

Syntax

- Syntax get: **[CT] 01 01 [CT]**
    - Return: **[CT] 02 01 [CD] [CT]**

[CD]

- Currently configured option depending on option byte

6.5.4 0xA1 - Reset System

complete restart of the system

General Syntax

[CT] 00 [CT]

Return

ACK
Wake-Up Message
System-Ready-Message

6.5.5 0xB0 - Set FE Settings

Frontend configuration

The device has a stack length of 1 (ISX-3) or 2 (ISX-3 mini or ISX-3 with second channel option or InternalMux). So only 1 (or 2) FE settings can be stored. Sending the set FE settings command more than 1 (or 2) times results in a NACK return. Send following command to empty the stack: **B0 03 FF FF FF B0**

General Syntax

[CT] 03 **[measurement mode] [measurement channel] [range settings]** [CT]

Return

ACK

[measurement mode]

Function	code
4 point configuration	0x02
3 point configuration	0x03
2 point configuration	0x01

[measurement channel]

Function	code
BNC Port (ISX-3mini: Port 1)	0x01
ExtensionPort	0x02
ExtensionPort2 (ISX-3mini: Port 2, ISX-3: optional, *InternalMux*)	0x03

[range settings]

current measurement range	old range nomenclature	code
± 10 mA	100	0x01
± 100 µA	10k	0x02

current measurement range	old range nomenclature	code
± 1 µA	1M	0x04
± 10 nA	100M	0x06

6.5.6 0xB1 - Get FE Settings

Returns the currently selected frontend configuration

General Syntax

[CT] 00 [CT]

Return

[CT] 03 **[measurement mode] [measurement channel] [range settings]** [CT]

ACK

[measurement mode]

Function	code
4 point configuration	0x02
3 point configuration	0x03
2 point configuration	0x01

[measurement channel]

Function	code
BNC Port (ISX-3mini: Port 1)	0x01
ExtensionPort	0x02
ExtensionPort2 (ISX-3mini: Port 2, ISX-3: optional, *InternalMux*)	0x03

[range settings]

current measurement range	formally	code
± 10 mA	100	0x01
± 100 µA	10k	0x02
± 1 µA	1M	0x04
± 10 nA	100M	0x06

6.5.7 0xB2 - Set ExtensionPort Channel

Set the ExtensionPort channel settings.

General syntax

[CT] 04 **[CP] [RP] [WS] [WP]** [CT]

Return

ACK

ExtensionPort- channel settings

[CP]	(C-Port): Counter - Port Selection
[RP]	(R-Port): Reference - Port Selection
[WS]	(WS-Port): Working Sense - Port Selection
[WP]	(W-Port): Work - Port Selection

See documentation of the connected extension module for detailed information.

6.5.8 0xB3 - Get ExtensionPort Channel

Read the currently set ExtensionPort configuration.

General syntax

[CT] 00 [CT]

Return

[CT] 04 **[CP] [RP] [WS] [WP]** [CT]
ACK

ExtensionPort- channel settings

CP	(C-Port): Counter - Port Selection
RP	(R-Port): Reference - Port Selection
WS	(WS-Port): Working Sense - Port Selection
WP	(W-Port): Work - Port Selection

See documentation of the connected extension module for detailed information.

6.5.9 0xB5 - Get ExtensionPort Module

Read the type of the currently connected extension module.

General syntax

[CT] 00 [CT]

Return

Optional channelCount is only valid in case of module = Mux32any2any2202

[CT] [LE] **[ExtensionModule] [InternalModule] [optional ChannelCount Ext*] [optional ChannelCount Int*]**
[CT]
ACK

[LE]

- 2 byte, unsigned integer
- 4 byte, unsigned integer if ExtensionModule = Mux32any2any2202
- 4 byte, unsigned integer if InternalModule = Mux32any2any2202
- 6 byte, unsigned integer if ExtensionModule = Mux32any2any2202 and InternalModule = Mux32any2any2202

[ExtensionModule]

This code represents the connected extension module.

Function	code
no module connected	0x00
MEArack	0x01
MuxModule32	0x02
ECIS Adapter	0x03
ExtensionPortAdapter	0x05
SlideChipAdapter	0x06
Mux32any2any (external)	0x07
DaQEisMux	0x08
Mux32any2any2202 (external)	0x09

[InternalModule]

This code represents the internal module.

Function	code
no module connected	0x00
MuxModule16x4	0x01

Function	code
MuxModule32x2	0x02
Mux32any2any (internal)	0x07
Mux32any2any2202	0x09

[optional ChannelCount*]: 2byte unsigned integer

6.5.10 0xB6 - Set Setup

General syntax

[CT] [LE] **[OB] [CD]** [CT]

Return

ACK

[OP]

	Function	code
Initialization and Configuration Commands	Init	0x01
	Add single frequency point	0x02
	Add frequency list	0x03
	Set amplitude	0x05
Calibration Commands	start calibration	0x10
	calibration acknowledge	0x11
	calibration not-acknowledge	0x12
	calibration-interaction-request Open	0x13
	calibration-interaction-request Short	0x14
	calibration-interaction-request Load	0x15
	calibration-interaction-request Load value	0x16
	set calibration data	0x17
Saving to Slot	saving to slot	0x20
DC Bias	DC Bias	0x30

	DC Bias not-acknowledge	0x32
	DC Bias set value	0x33

Init

This option resets the currently configured setup and an empty setup is initialized.

Syntax:

- Syntax set: **[CT] 01 01 [CT]**

Add single frequency point

This command is used to add a single frequency point to the currently configured setup.

Syntax

- Syntax set: **[CT] [LE] 02 [CD] [CT]**

[CD]

- [LE] = 13 (frequency, precision, amplitude)

frequency			precision			amplitude		
MSB	...	LSB	MSB	...	LSB	MSB	...	LSB

In this case the point delay (= 0 ms) and phase sync is not used.

- [LE] = 13 **+** extended options length

frequency			precision			amplitude			point delay				use phase sync				excitation type			
MSB	...	LSB	MSB	...	LSB	MSB	...	LSB	EOP =01	MSB	...	LSB	EOP =02	MSB	...	LSB	EOP =03	MSB	...	LSB
obligatory									optional				optional				optional			

Frequency: frequency in Hz (4Byte float)

Precision: precision value (4Byte float)

Amplitude: amplitude in V (peek value, 4Byte float)

Extended Options EOP:

- For each optional additional setting an EOP identifier needs to be send before the actual setting. Therefore any of the following options or multiple can be send.
- Point delay (EOP=01): delay between this frequency and the next frequency in µs (4Byte unsigned integer)
- Use phase sync (EOP=02): phase synchronous switch between this and the next frequency
  - Use: 0x0000001
  - Don't use: 0x00000000
- excitation type (EOP=03): Defines weather the excitation amplitude is in Volt or in Ampere

- voltage excitation: 0x00000001 (default)
- current excitation: 0x00000002

Examples

- B6 0D 02 46 FA 00 00 3F 80 00 00 3E 80 00 00 B6
  - Frequency = 32 kHz
  - precision = 1.0
  - amplitude = 0.25 V
  - NO extended options have been used
- B6 12 02 46 FA 00 00 3F 80 00 00 3E 80 00 00 **02** 00 00 00 01 B6
  - Frequency = 32 kHz
  - precision = 1.0
  - amplitude = 0.25 V
  - phase synchronization = used
  - One extended option has been used

Add frequency list

This command is used to add multiple frequencies to the currently configured setup.

Syntax

- Syntax set: **[CT] [LE] 03 [CD] [CT]**

[CD]

- [LE] = 22

start-frequency			stop-frequency			count			scale	precision			amplitude		
MSB	...	LSB	MSB	...	LSB	MSB	...	LSB	MSB	MSB	...	LSB	MSB	...	LSB

In this case the point delay (= 0 ms) and phase sync is not used.

- [LE] = 22 + extended options length

start-frequency			stop-frequency			count			scale	precision			amplitude			point delay				use phase sync				excitation type			
MSB	...	LSB	MSB	...	LSB	MSB	...	LSB	MSB	MSB	...	LSB	MSB	...	LSB	EOP = 01	MSB	..	LSB	EOP = 02	MSB	..	LSB	EOP = 03	MSB	..	LSB
obligatory																optional				optional				optional			

- Start-Frequency: start-frequency of the frequency block in Hz (4Byte float)
- Stop-Frequency: stop-frequency of the frequency block in Hz (4Byte float)
- Count: number of frequency steps used (4Byte float, rounded to the next smaller integer)

- Scale: linear or logarithmic scale (1Byte integer)
  → linear: 0
  → logarithmic: 1
- Precision: precision value (4Byte float)
- Amplitude: amplitude in V (peek value, 4Byte float)

Extended Options EOP:

- For each optional additional setting an EOP identifier needs to be send before the actual setting. Therefor any of the following options or multiple can be send.
- Point delay: delay between this frequency and the next frequency in µs (4Byte unsigned integer)
- Use phase sync: phase synchronous switch between this and the next frequency
  - Use: 0x0000001
  - Don't use: 0x00000000
- excitation type (EOP=03): Defines weather the excitation amplitude is in Volt or in Ampere
  - voltage excitation: 0x00000001 (default)
  - current excitation: 0x00000002

Example

- B6 20 03 44 7A 00 00 4B 18 96 80 41 20 00 00 01 3F 80 00 00 3E 80 00 00 **01** 00 00 03 E8 02 00 00 00 00 B6
- start frequency = 1 kHz
- stop frequency = 10 MHz
- count = 10
- scale = logarithmic
- precision = 1.0
- amplitude = 0.25 V
- point delay = 1000 µs
- phase sync = disable

Set amplitude

This command sets the amplitude.

Syntax

Two options are available:

- Syntax set all amplitudes with one command: **[CT] 06 05 [ExcitationType] [Amplitude] [CT]**
- Syntax set amplitudes row-wise: **[CT] 08 05 [Row] [ExcitationType] [Amplitude] [CT]**

[ExcitationType]

- Length: 1 byte
- 0x01 - voltage
- 0x02 - current

[Amplitude]

- Length: 4 byte
- Data format: float

[Row]

- Length: 2 byte
- 0 ≤ row ≤ maximum row count

start calibration

A detailed example of the required communication necessary to calibrate a setup can be found in Example of impedance calibration procedure.

This command starts the calibration of the setup.

Syntax

- Syntax set: **[CT] 01 10 [CT]**

calibration acknowledge

The calibration acknowledge (CACK) is used to answer a “Calibration-Interaction-Request”

Syntax

- Syntax: **[CT] 01 11 [CT]**

calibration not-acknowledge

The calibration acknowledge (CNACK) is used to answer a “Calibration-Interaction-Request”

Syntax

- Syntax: **[CT] 01 12 [CT]**

calibration-interaction-request Open

This is a message from the ISX-3 to request an open configuration on the measurement channel. This request must be answered with a CACK to continue the calibration or with a CNACK to abort the calibration.

calibration-interaction-request Short

This is a message from the ISX-3 to request a short configuration on the measurement channel. This request must be answered with a CACK to continue the calibration or with a CNACK to abort the calibration.

calibration-interaction-request Load

This is a message from the ISX-3 to request a load configuration on the measurement channel. This request must be answered with a CACK to continue the calibration or with a CNACK to abort the calibration.

Before the answer to this request is send the load value and type must have been send to the device (Option 0x16).

calibration-interaction-request Load value

The connected load value must have been send in the command data part [CD] of the command.

Syntax

- Syntax set: **[CT] 06 16 [LoadType] [Value] [CT]**

[LoadType]

- Length: 1 byte
- 0x01 - resistance

- 0x02 - capacitor

[Value]

- Length: 4 byte
- Data format: float
- Unit: Ohm for [LoadType] = resistance, Farad for [LoadType] = capacitor

Example

- [CT] 06 16 01 44 7A 00 00 [CT] → resistance = 1000 Ohm

set calibration data

This command configures the calibration data of the configured setup.

Syntax

- Syntax reset calibration data: **[CT] 02 17 01 [CT]**
- Syntax set data: **[CT] [LE] 17 02 [Channel] [Row] [Open Re] [Open Im] [Short Re] [Short Im] [Load Re] [Load Im] [CT]**

[Channel]	[Row]	[Open Re]	[Open Im]	[Short Re]	[Short Im]	[Load Re]	[Load Im]
1 byte	2 byte	4 byte float	4 byte float	4 byte float	4 byte float	4 byte float	4 byte float

saving to slot

It is possible to load all information required for a measurement from the internal storage of the impedance analyzer. The system holds up to 255 setup configurations including any calibration data. For addressing, the configurations are numerated from slot 1 to slot 255.

Syntax

- Syntax saving to slot: **[CT] 02 20 [Slot] [CT]**

[Slot]

- Length: 1 byte

Example

- [CT] 02 20 05 [CT] → load configuration from slot 5

DC Bias

This command activates or deactivates the DC Bias on the configured channel. When the DC Bias is activated DC Bias is set to 0V and then regulated towards the selected value. This process can be aborted by sending the "DC Bias-Not-Acknowledge".

If the DC Bias is reached a "DC Bias-Acknowledge" is send from the ISX-3 / ISX-3 mini.

If the DC Bias could not reached "DC Bias-Not-Acknowledge" is send from the ISX-3 / ISX-3 mini.

Syntax

- Syntax set: **[CT] 02 30 [CD] [CT]**

[CD]

- Length: 1 byte
- 0x00 - deactivate
- 0x01 - activate

DC Bias not-acknowledge

This command is to abort the DC Bias regulation.

Syntax

- Syntax: **[CT] 01 32 [CT]**

DC Bias set value

This command sets the value for the DC Bias.

Syntax

- Syntax set: **[CT] 05 33 [bias value] [CT]**

[bias value]

- Length: 4 byte
- Data format: float
- Unit: V (volt)
- range: + 1 V to - 1 V

Example

- [CT] 05 33 3F 80 00 00 [CT] → Sets the bias value to 1 V.

How to regulated the DC Bias after the measuring section or the measuring object changed:

- send the **DC Bias set value** command (Syntax set: [CT] 05 33 [bias value] [CT]) → not necessary if the set value doesn't change
- send the **DC Bias** command (Syntax: [CT] 02 30 [CD] [CT])

6.5.11 0xB7 - Get Setup

General syntax

[CT] [LE] **[OB] [CD]** [CT]

Return

[CT] [LE] **[OB] [CD]** [CT]

ACK

[OP]

Function	code
Get total number of frequencies	0x01

Function	code
Get information of frequency point	0x02
Get frequency list	0x04
calibration-interaction-request Open	0x13
calibration-interaction-request Short	0x14
calibration-interaction-request Load	0x15
save setup to slot	0x20
Get DC Bias	0x33

Get total number of frequencies

This command reads the total number of frequencies configured in the setup.

Syntax

- Syntax get: **[CT] 01 01 [CT]**
    - Return: **[CT] 03 01 [CD] [CT]**

[CD]

- number of rows configured
- Length: 2 byte
- Data format: unsigned integer

Get information of frequency point

This command gets information of a configured point of the setup.

Syntax

- Syntax get: **[CT] 03 02 [CD] [CT]**
    - Return: **[CT] 0D 02 [Frequency] [Precision] [Signal amplitude] [CT]**

[CD]

- row number
- Length: 2 byte
- Data format: unsigned integer

[Frequency]

- Length: 4 byte
- Data format: float
- Unit: Hz

[Precision]

- Length: 4 byte
- Data format: float

[Signal amplitude]

- Length: 4 byte
- Data format: float

Get frequency list

This command gets a list of frequencies configured in this setup.

Syntax

- Syntax get: **[CT] 01 04 [CT]**
    - Return: **[CT] [LE] 04 [4 Byte float frequency$_1$] [...] [4 Byte float frequency$_N$] [CT]**

[4 Byte float frequency$_1$] [...] [4 Byte float frequency$_N$]

- *Since one data frame is limited to a total of 255 bytes of data the returning command will be split into multiple separate frames. For example if the setup contains 64 frequency points the first 63 will be transmitted in a frame containing 253 bytes (=63*4+1) and in a separate frame containing 5 bytes (=1*4+1) bytes of data.*

calibration-interaction-request Open

This is a message send by the ISX-3 to request an open configuration on the measurement channel. This request must be answered with a CACK to continue the calibration or with a CNACK to abort the calibration.

calibration-interaction-request Short

This is a message send by the ISX-3 to request a short configuration on the measurement channel. This request must be answered with a CACK to continue the calibration or with a CNACK to abort the calibration.

calibration-interaction-request Load

This is a message send by the ISX-3 to request a load configuration on the measurement channel. This request must be answered with a CACK to continue the calibration or with a CNACK to abort the calibration.

Before the answer to this request is send the load value and type must have been send to the device (Option 0x16).

save setup to slot

This command saves the setup-configuration.

Syntax

- Syntax: **[CT] 02 20 [Slot] [CT]**

[Slot]

- Slot number
- Length: 1 byte

Get DC Bias

This command reads the currently configured DC Bias from the device.

Syntax

- Syntax get: **[CT] 01 33 [CT]**
    - Return: **[CT] 05 33 [DC Bias] [CT]**

[DC Bias]

- Length: 4 byte
- Data format: float
- Unit: V

6.5.12 0xB8 - Start Measure

Starts the measurement.

General syntax

[CT] [LE] **[OB] [CD]** [CT]

Return

If time stamp is disabled (see command 0x97 and 0x98)

[CT] 0A **[ID] [Real part] [Imaginary part]** [CT]
ACK

Else

[CT] 0E **[ID] [Time stamp] [Real part] [Imaginary part]** [CT]
ACK

[ID]

- ID number of the frequency point
- Length: 2 byte
- Data format: integer

[Time stamp]

- time stamp of the frequency point
- Length: 4 byte
- Data format: integer
- Unit: ms

[Real part]

- real part of impedance
- Length: 4 byte
- Data format: float

[Imaginary part]

- imaginary part of impedance
- Length: 4 byte
- Data format: float

ⓘ Please refer to the Appendix for a description of the data format.

[OP]

Function	code
Stop measurement	0x00
Start measurement	0x01

Stop measurement

Stops the measurement.

Syntax

- Syntax: **[CT] 01 00 [CT]**

Start measurement

Starts the measurement.

Syntax

- Syntax: **[CT] 03 01 [CD] [CT]**

[CD]

- number of spectra to be measured
- Length: 2byte
- Data format: integer value
- The setting 0 starts a continuous measurement. Send the command (B8 01 00 B8) to stop the continuous run.
- example: B8 03 00 01 B8 - to start a measurement and stop it automatically after one measurement spectra per channel configuration.

ⓘ If the measurement has been started with a repeat greater than 0 no stop command is required. The data will be transmitted as soon as each frequency point has been measured. The system therefore **does not** wait for the spectrum to be completed before it will send the data.

0xB9 - Set Sync Time

Set the synchronization time in µs. (Time between the measurement of two spectra)

ⓘ This is also the time the SyncOut signal is in its low state between two measurements. Use save settings command (0x90) to save this parameter persistent.

General syntax

[CT] [LE] **[Sync time]** [CT]

Return

ACK

[Sync time]

- Length: 4 byte
- Data format: integer value
- Unit: µs
- Default: 0µs
- Min: 0µs
- Max 180s = 180E6 µs (0x0ABA9500)

6.5.13 0xBA - Get Sync Time

Reads the currently configured synchronization time.

General syntax

[CT] 00 [CT]

Return

[CT] 04 **[Sync time]** [CT]

ACK

[Sync time]

- Length: 4 byte
- Data format: integer value
- Unit: µs

6.5.14 0xBD - Set Ethernet Configuration

Configure DHCP setting and IP address.

General Syntax

[CT] **[LE] [OB] [CD]** [CT]

Return

ACK

[LE]

- Represents the byte count of the command frame and varies with the amount [data] bytes. [length] is always the amount of [data]-bytes + 1.

[CD]

- Command data whose syntax and content depends on the used [option byte].

[OB]

Function	code
IP address	0x01

Function	code
DHCP on/of	0x03

IP address

- Set static IPv4 address of the device.
- This address will only be used, when DHCP is disabled.
- The default setting is 0.0.0.0
- Syntax: **[CT] [05] [01] [address] [CT]**
- [address]
  - Desired address.
  - Length: 4 byte
  - Data format: byte-wise unsigned integer
  - Value range of each byte: 0 ... 255

DHCP on/off

- Activate/deactivate DHCP usage.
- To apply this setting, a system reboot is required.
- Syntax: **[CT] [02] [03] [switch] [CT]**
- [switch]
  - Length: 1 byte
  - Values:
    - 0x00 - off
    - 0x01 - on (default)

> To save these settings persistently, the "save settings" command must be sent before powering off the device.

6.5.15 0xBE - Get Ethernet Configuration

Read out parameters like DHCP setting, MAC and IP address.

General Syntax

[CT] **[LE] [OB]** [CT]

Return

[CT] **[LE] [OB] [CD]** [CT]
ACK

[LE]

- Represents the byte count of the command frame and varies with the amount [data] bytes. [length] is always the amount of [data]-bytes + 1.

[CD]

- Command data whose syntax and content depends on the used [option byte].

[OB]

Function	get
IP address	0x01
MAC address	0x02
DHCP on/off	0x03

IP address

- Read out currently allocated IPv4 address of the device. This is the actual address the device
- Get syntax: **[CT] [01] [01] [CT]**
- Return syntax: **[CT] [05] [01] [address] [CT]**
- [address]
  - Current address.
  - Length: 4 byte
  - Data format: byte-wise unsigned integer

MAC address

- Read out currently allocated MAC address of the device. This is the actual address the device
- Get syntax: **[CT] [01] [02] [CT]**
- Return syntax: **[CT] [07] [02] [address] [CT]**
- [address]
  - MAC address.
  - Length: 6 byte
  - Data format: byte-wise unsigned integer

DHCP on/off

- Read out the current DHCP setting.
- Get syntax: **[CT] [01] [03] [CT]**
- Return Syntax: **[CT] [02] [03] [switch] [CT]**
- [switch]
  - Length: 1 byte
  - Values:
    - 0x00 - off
    - 0x01 - on

6.5.16 0xCF - TCP connection watchdog

General Syntax

[CT] **05 00 [interval]** [CT]

Return

ACK

Description

The device checks periodically if the connection from the TCP socket to the client is still active. This is done by the device by periodically sending the TCP socket acknowledge command (see chapter "Acknowledge messages"). If the command cannot be send, i.e. because of a lost client connection, the socket server state will be reset to "listening". Thus, a new socket-client connection can be established.

This command provides access to setting the interval for sending the TCP socket acknowledge command.

[interval]

- Set the interval for TCP communication watchdog
- Length: 4 Byte
- Data format: unsigned integer
- Values:
    - Minimum: 1 s
    - Maximum: 600 s
    - Increment: 1 s
    - Default: 60 s

> ⚠ To save these settings persistently, the "save settings" command must be sent before powering off the device.

6.5.17 0xD0 - Get ARM firmware ID

Syntax

D0 00 D0

Return

D0 06 [developer information] **[revision number] [build number]** D0
ACK

Description

- Reads out version number of ARM firmware.

[developer information]

- This information is for internal development purposes only.
- Length: 2 Byte

[revision number]

- Length: 2 Byte
- Data format: unsigned integer

[build number]

- Length: 2 Byte

- Data format: unsigned integer

6.5.18 0xD1 - Get Device ID

Syntax

[CT] 00 [CT]

Return

[CT] [LE] **[general information]** [developer information] [CT]
ACK

Description

- Read out device information
- Includes all information necessary to identify a Sciospec device.

[general information]
This information can also be found on the serial number label on the case of the device.

Byte	Description	Comments
1	version of the general information part	• Defines the format of the following items. There is only version 1 so far. • data format: unsigned integer
2-3	device identifier	• Unique number, which identifies the device types. • data format: unsigned integer
4-5	serial number	• Unique identifying number for all Sciospec devices. • data format: unsigned integer
6-7	date of delivery	• Byte 6: Year since 2010 (0x00 = 2010, ..., 0xFF = 2265) • Byte 7: Month (0x01 = january, ..., 0x0C = december)

[developer information]

This information is for internal development purposes only.

6.5.19 0xD2 - Get FPGA firmware ID

Syntax

D2 00 D2

Return

D2 09 [developer information] **[revision number] [build number]** D2
ACK

Description

- Reads out version number of ARM firmware.

[developer information]

- This information is for internal development purposes only.
- Length: 5 Byte

[revision number]

- Length: 2 Byte
- Data format: unsigned integer

[build number]

- Length: 2 Byte
- Data format: unsigned integer

6.5.20 Example of impedance calibration procedure

This example demonstrates the communication required to calibrate an already configured setup.

Direction of communication:

PC to ISX-3 / ISX-3mini
ISX-3 / ISX-3mini to PC

↓	#	Command	Communication			
	1	Initiating the calibration routine	B6	01	10	B6
	2	Acknowledge	18	01	83	18
	3	Request to leave the terminals open	B7	01	13	B7
	4	Calibration acknowledge	B6	01	11	B6
	5	Acknowledge	18	01	83	18
	Calibration measurement on open terminal is performed					
	6	Request to short all terminals	B7	01	14	B7
	7	Calibration acknowledge	B6	01	11	B6
	8	Acknowledge	18	01	83	18
	Calibration measurement of shorted terminals is performed					

	9	Request to connect a known load impedance to the device	B7	01	15	B7					
	10	Set known value of the load impedance (e.g. 100Ohms)	B6	06	16	01	42	C8	00	00	B6
	11	Acknowledge	18	01	83	18					
	12	Calibration acknowledge	B6	01	11	B6					
	13	Acknowledge	18	01	83	18					
	Calibration measurement of load terminals is performed										
	14	Calibration done	B7	01	10	B7					

6.5.21 Example of dc bias calibration procedure

This example demonstrates the communication required to calibrate an already configured setup. It is essential the frontend settings (channel, measurement mode and range) are correctly initialized before starting the dc bias calibration routine

Direction of communication:

PC to ISX-3 / ISX-3mini
ISX-3 / ISX-3mini to PC

↓	#	Command	Communication							
	1	Setting the dc bias voltage	B6	05	33	3F	00	00	00	B6
	2	Acknowledge	18	01	83	18				
	3	Init the dc bias calibration	B6	01	30	B6				
	4	Acknowledge	18	01	83	18				
	Calibration measurement is performed									
	5	Calibrate DC Bias acknowledge	B7	01	31	B7				

	6	Getting the dc bias voltage	B7 01 33 B7
	7	DC Bias	B7 05 33 3E FF FE B0 B7
	8	Acknowledge	18 01 83 B18

6.6 Code Example (ANSI C)

```c
/*
============================================================================
 Name        : ISX-3_C-Code.c
 Author      : Sciospec
 Version     : Revision 1
 Copyright   : Sciospec 2022
 Description: ISX-3 Communication Demo in C, Ansi-style
============================================================================
 */


#include <stdio.h>
#include <stdlib.h>

byte connectToDevice(HANDLE* handle);
byte readAck(HANDLE handle);
void readData(HANDLE handle, byte* buffer, int bytesToRead);
void writeDataToDevice(HANDLE handle, byte* data, DWORD dataCount);

int main(void) {

    HANDLE handle;
    if(!connectToDevice(&handle))
        return -1;

    //This will force stdout to be unbuffered.
    setvbuf (stdout, NULL, _IONBF, 0);

    printf("Connection established\n");
    byte *cmd, *readBuffer;



    /* **************************** *
     *                              *
     *     Initialize Setup         *
```

```
     *                              *
     * ************************** */
    printf("Initialize Setup.\n");
    int numberOfBytes = 4;
    cmd = (byte*)malloc(sizeof(byte)*numberOfBytes);
        cmd[0] = 0xB6;  cmd[1] = 0x01; cmd[2] = 0x01; cmd[3] = 0xB6;
        writeDataToDevice(handle, cmd, numberOfBytes);
    free(cmd);
    readAck(handle);
    printf("\n");


    /* *************************** *
     *                             *
     *     Initialize Freq.Block   *
     *                             *
     * *************************** */

    float startFrequency    = 100;      //100Hz
    float stopFrequency     = 100e3;    //100kHz
    float frequencyCount    = 80;
    float precision         = 1;
    float amplitude         = 0.1;  //V
    byte  scale             = 1;    //log
    printf("Set Setup-config: Frequency-block (%fHz .. %fHz, scale=%i, prec=%f, amplitude=%fV)\n", startFrequency, stopFrequency, scale, precision, amplitude);
    numberOfBytes = 0x16 + 3;
    cmd = (byte*)malloc(sizeof(byte)*numberOfBytes);
        cmd[0] = 0xB6;  cmd[1] = numberOfBytes-3; cmd[2] = 0x03;

        unsigned long tmp = *(unsigned long*)&startFrequency;
        byte counter = 3;
        cmd[counter++] = (tmp>>24)&0xFF;
        cmd[counter++] = (tmp>>16)&0xFF;
        cmd[counter++] = (tmp>>8)&0xFF;
        cmd[counter++] = (tmp)&0xFF;

        tmp = *(unsigned long*)&stopFrequency;
        cmd[counter++] = (tmp>>24)&0xFF;
        cmd[counter++] = (tmp>>16)&0xFF;
        cmd[counter++] = (tmp>>8)&0xFF;
        cmd[counter++] = (tmp)&0xFF;

        tmp = *(unsigned long*)&frequencyCount;
        cmd[counter++] = (tmp>>24)&0xFF;
        cmd[counter++] = (tmp>>16)&0xFF;
        cmd[counter++] = (tmp>>8)&0xFF;
        cmd[counter++] = (tmp)&0xFF;

        cmd[counter++] = scale;

        tmp = *(unsigned long*)&precision;
        cmd[counter++] = (tmp>>24)&0xFF;
```

```
        cmd[counter++] = (tmp>>16)&0xFF;
        cmd[counter++] = (tmp>>8)&0xFF;
        cmd[counter++] = (tmp)&0xFF;

        tmp = *(unsigned long*)&litude;
        cmd[counter++] = (tmp>>24)&0xFF;
        cmd[counter++] = (tmp>>16)&0xFF;
        cmd[counter++] = (tmp>>8)&0xFF;
        cmd[counter++] = (tmp)&0xFF;

        cmd[numberOfBytes-1] = 0xB6;
        writeDataToDevice(handle, cmd, numberOfBytes);
    free(cmd);

    readAck(handle);
    printf("\n");


    /* *************************** *
     *                             *
     *     Set FrontEnd Settings   *
     *                             *
     * *************************** */
    printf("Clear Channel Stack\n");
    numberOfBytes = 6;
    cmd = (byte*)malloc(sizeof(byte)*numberOfBytes);
    cmd[0] = 0xB0;    cmd[1] = 0x03;    cmd[numberOfBytes-1] = cmd[0];
    cmd[2] = 0xFF;    cmd[3] = 0xFF;    cmd[4] = 0xFF; //Delete channel stack
    writeDataToDevice(handle, cmd, numberOfBytes);
    readAck(handle);

    printf("\n");    printf("Set Channel Stack: to channel 1\n");
    cmd[3] = 0x02;    //mode = 4Pt measurement
    cmd[4] = 0x01;    //add channel: Channel 1 (BNC),
    cmd[5] = 0x01;    //100Ohm Range,
    writeDataToDevice(handle, cmd, numberOfBytes);
    readAck(handle);
    printf("\n");

    free(cmd);

    /* *************************** *
     *                             *
     *     Start Measurement       *
     *                             *
     * *************************** */
    byte numberOfSpecs = 1;
    printf("Start Measurement\n");
    numberOfBytes = 6;
    cmd = (byte*)malloc(sizeof(byte)*numberOfBytes);
    cmd[0] = 0xB8;  cmd[1] = 0x03;
    cmd[2] = 0x01;
    cmd[3] = 0;
```

```
    cmd[4] = 0;
    cmd[numberOfBytes-1] = 0xB8;
    writeDataToDevice(handle, cmd, numberOfBytes);
    free(cmd);
    readAck(handle);
    printf("\n");


    /* ******************* *
     *                     *
     *     Receive Specs   *
     *                     *
     * ******************* */
    readBuffer = malloc(14);    //3Byte Framing, 2Byte idNumber, 4Byte RE, 4Byte Im
    byte j;
    byte i;
    UINT8 ch;
    UINT16 id;
    UINT32 tmp32;
    float re, im;
    for(j=0; j<numberOfSpecs; j++){
        printf("Spec#%i:\n", j+1);
        printf("ch\tid\tre\tim\n");
        for(i=0; i<frequencyCount;i++){

            readData(handle, readBuffer, 14);

            ch = readBuffer[2];
            id = (readBuffer[3]<<8) + readBuffer[4];
            tmp32 = (readBuffer[5]<<24) + (readBuffer[6]<<16) + (readBuffer[7]<<8) + (readBuffer[8]);
            re = *(float*)&tmp32;
            tmp32 = (readBuffer[9]<<24) + (readBuffer[10]<<16) + (readBuffer[11]<<8) + (readBuffer[12]);
            im = *(float*)&tmp32;

            printf("%i\t%i\t%f\t%f\n", ch, id, re, im);
        }
        printf("\n");
    }

    printf("Stop Measurement");
    numberOfBytes = 6;
    cmd = (byte*)malloc(sizeof(byte)*numberOfBytes);
    cmd[0] = 0xB8;  cmd[1] = 0x03;
    cmd[2] = 0x00;
    cmd[3] = 0;
    cmd[4] = 0;
    cmd[numberOfBytes-1] = 0xB8;
    writeDataToDevice(handle, cmd, numberOfBytes);
    free(cmd);
    readAck(handle);
    printf("\n");
```

```

    CloseHandle(handle);//Closing the Serial Port

//  sprintf();

    return 1;
}

/*
 * Connect to COM6 if available
 * @param handle - the pointer to USB-Conection-Handle
 * @return True if connection was successfull else false
 */
byte connectToDevice(HANDLE* hSerial){
    *hSerial = CreateFile(  "\\\\.\\COM6",
                            GENERIC_READ|GENERIC_WRITE,
                            0,
                            NULL,
                            OPEN_EXISTING,
                            FILE_ATTRIBUTE_NORMAL,
                            NULL );
        if (hSerial == INVALID_HANDLE_VALUE)
        {
                fprintf(stderr, "Error\n");
                return 0;
        }

        return 1;
}

void writeDataToDevice(HANDLE handle, byte* cmd, DWORD dataCount){

    byte i;
    for(i=0; i<dataCount;i++)
        printf("%.2X ", cmd[i]);
    printf("\n");

    WriteFile(handle, cmd, dataCount, NULL, NULL);


}

/** Tries to Read ACK Frame
 *
 * @return true if ACK is received, else false
 */
byte readAck(HANDLE handle){

    int i = 0;
    byte* readBuffer;
    readBuffer = (byte*)malloc(sizeof(byte)*4);

    readData(handle, readBuffer, 4);

```

```
    printf("ACK-Frame: ");
    for(i=0; i<4;i++){
        printf("%.2X ", readBuffer[i]);
    }
    printf("\n");

    if(readBuffer[2] == 0x83){
        free(readBuffer);
        return TRUE;    //ACK
    }else{
        free(readBuffer);
        return FALSE;   //NOT ACK
    }
}

void readData(HANDLE handle, byte* buffer, int bytesToRead){
    int i;
    for (i = 0; i < bytesToRead; i++) {
        unsigned char ch = 0;
        DWORD read = 0;

        /* Wait for characters */
        while(!read) {
            ReadFile(handle, &ch, 1, &read, NULL);
            if (read) {
                buffer[i] = ch;
            }
        }
    }
}
```

7 Options

The Sciospec ISX-3 and partially the ISX-3mini can be equipped with a variety of different additional Hard- and Software options. The Sciospec ISX-3mini is already equipped with the SecondChannelOption and the IOPort option.

- IOPort
- SecondChannelOption
- AcCoupling internal
- MUX32 (Internal or External)
- Synchronization Ports

7.1 IOPort

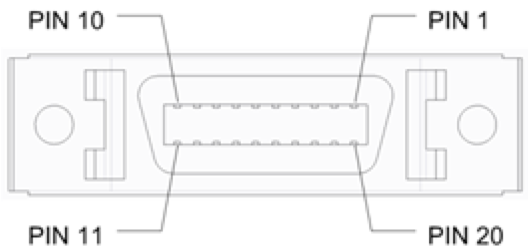
7.1.1 Technical Specifications

The Sciospec IOPort provides 8 individually controllable general purpose digital inputs / outputs (GPIO) and additionally two connections for temperature sensors of type NTC. The GPIOs may serve as input, output, I^2C, UART or SPI serial interface.

Revision	1
connector type	D-Sub-Mikro-D 20Pin
signal level standard	LVCMOS 3V
absolute maximum input voltagei	3.6V
absolute minimum input voltage	-0.3V
high level input voltage	≥1.7V
low level input voltage	≤0.8V
high level output voltage	≥2.8V
low level output voltage	≤0.2V
maximum output current	12mA
ESD Protection of IOs	±12kV IEC 61000-4-2 contact ESD ±15kV IEC 61000-4-2 air-gap ESD clamp voltage 10.5V (min) break-down voltage 7V (min)
number of GPIOs	eight (freely distributable)
number of IOs	eight (freely distributable between input and output)

IO configuration	GPIO, SPI, UART, I^2C
UART configuration	115.2kBaud, 1 start bit, 8 data bits, 1 stop bit, even parity, idle high
I^2C configuration	100kbit, 7bit address, standard mode, device behaves as master, max. 15 data bytes
SPI configuration	SPI master, type: SPI 4-wire, data valid on rising SCLK edge, SCLK frequency = 60MHz ... 1kHz, SCLK frequency default = 20MHz, 8 bit wide words, send and receive a maximum of 2^16 byte in one continuous sending
number of temperature sensors	2
temperature sensor type	Negative temperature coefficient (NTC) configurable: Reference resistance, reference temperature, Beta value

IOPort Connector Layout



IOPort pin assignment

PIN	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Funktion	GND	NTC1	GND	NTC2	GND	GPIO1	GND	GPIO2	GND	GPIO3	GND	GPIO4	GND	GPIO5	GND	GPIO6	GND	GPIO7	GND	GPIO8

7.1.2 Functional Description

At present the Sciospec IOPort can only be used to control the GPIO pins of the port. It makes use of the Sciospec Interface Port standard. If you need access to one of the features described in the *Sciospec Interface Port standard* section, the NTC ports or you would like to see some other functionality available, just get in contact with Sciospec customer service.

7.1.3 Measurement software description

The IOport configuration window can be found in the software under [Extra] → [IO Config]

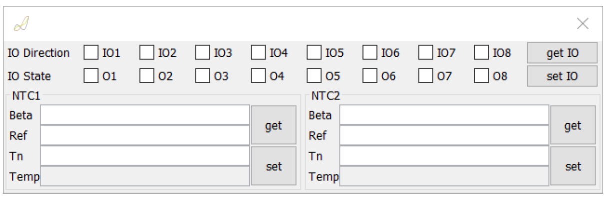


Figure 14: IO Config window

In this window the direction (checked: output | not checked: input) and the state (checked: high | not checked: low) of the IOs can be set or read out. In the lower part of the window the NTC parameter can be set or read out.

7.1.4 Sciospec COMInterface

0x99 - Set IOPort Configuration

General Syntax

[CT] [LE] **[OB]** [CT]

Return

ACK

[OB]

Function	code
GPIO direction	0x01
Port state	0x02

GPIO direction

Configure GPIOs independently as input or output port.

Syntax

- Syntax set: **[CT] [02] [01] [IO vector] [CT]**

[IO vector]

- Hot bit vector for all 8 IOs
- Length: 1 Byte
- Order: MSB first ([[IO8] [IO7]] [IO6] [IO5]] [[IO4] [IO3]] [[IO2] [IO1]])
- Hot bit interpretation:
  - 0 - IO is configured as input (Default)
  - 1 - IO is configured as output

Port state

Set state of output ports for every IO separately.

Syntax

- Syntax set: **[CT] [02] [02] [IO vector] [CT]**

[IO vector]

- Hot bit vector for all 8 IOs
- Length: 1 Byte
- Order: MSB first ([[IO8] [IO7]] [IO6] [IO5]] [[IO4] [IO3]] [[IO2] [IO1]])
- Hot bit interpretation:
  - 0 - output is set to logic low (Default)
  - 1 - output is set to logic high

0x9A - Get IOPort Configuration

Read the configuration data of the IOPort.

General Syntax

[CT] [LE] **[OB]** [CT]

Return

[CT] [LE] **[OB] [CD]** [CT]
ACK

[OB]

Function	code
GPIO direction	0x01
Port state	0x02

GPIO direction

Configure GPIOs independently as input or output port.

Syntax

- Syntax get: **[CT] 01 01 [CT]**
  - Return: **[CT] 02 01 [IO vector] [CT]**

[IO vector]

- Hot bit vector for all 8 IOs
- Length: 1 Byte
- Order: MSB first ([[IO8] [IO7]] [IO6] [IO5]] [[IO4] [IO3]] [[IO2] [IO1]])
- Hot bit interpretation:
  - 0 - IO is configured as input (Default)
  - 1 - IO is configured as output

Port state

Set state of output ports for every IO separately.

Syntax

- Syntax get: **[CT] 01 02 [CT]**

- Return: **[CT] 02 02 [IO vector] [CT]**

[IO vector]

- Hot bit vector for all 8 IOs
- Length: 1 Byte
- Order: MSB first ([[IO8] [IO7]] [IO6] [IO5]] [[IO4] [IO3]] [[IO2] [IO1]])
- Hot bit interpretation:
    - 0 - output is set to logic low (Default)
    - 1 - output is set to logic high

0x9B - Set NTC Parameter 1

General Syntax

[CT] [LE] **[OB] [CD]** [CT]

Return

ACK

[OB]

Function	code
beta parameter [K]	0x01
nominal resistance at T_N [Ω]	0x02
operating temperature T_N [K]	0x03

For standard NTC parameters see Appendix.

beta parameter [K]

Syntax

- Syntax set: **[CT] 05 01 [CD] [CT]**

[CD]

- 32Bit Fload value

nominal resistance at T_N [Ω]

Syntax

- Syntax set: **[CT] 05 02 [CD] [CT]**

[CD]

- 32Bit Fload value

operating temperature T_N [K]

Syntax

- Syntax set: **[CT] 05 03 [CD] [CT]**

[CD]

- 32Bit Fload value

0x9C - Get NTC Parameter 1

Returns the currently configured NTC-parameters 1.

General Syntax

[CT] [LE] **[OB]** [CT]

Return

[CT] [LE] **[OB] [CD]** [CT]

ACK

[OB]

Function	code
beta parameter [K]	0x01
nominal resistance at T_N [Ω]	0x02
operating temperature T_N [K]	0x03
current temperature [°C]	0x04

For standard NTC parameters see Appendix.

beta parameter [K]

Syntax

- Syntax get: **[CT] 01 01 [CT]**
    - Return: **[CT] 05 01 [CD] [CT]**

[CD]

- 4 byte float value

nominal resistance at T_N [Ω]

Syntax

- Syntax get: **[CT] 01 02 [CT]**
    - Return: **[CT] 05 02 [CD] [CT]**

[CD]

- 4 byte float value

operating temperature T_N [K]

Syntax

- Syntax get: **[CT] 01 03 [CT]**

  - Return: **[CT] 05 03 [CD] [CT]**

[CD]

- 4 byte float value

current temperature [°C]

Syntax

- Syntax get: **[CT] 01 04 [CT]**
  - Return: **[CT] 05 04 [CD] [CT]**

[CD]

- 4 byte float value

0x9D - Set NTC Parameter 2

General Syntax

[CT] [LE] **[OB] [CD]** [CT]

Return

ACK

[OB]

Function	code
beta parameter [K]	0x01
nominal resistance at T_N [Ω]	0x02
operating temperature T_N [K]	0x03

For standard NTC parameters see Appendix.

beta parameter [K]

Syntax

- Syntax set: **[CT] 05 01 [CD] [CT]**

[CD]

- 32Bit Fload value

nominal resistance at T_N [Ω]

Syntax

- Syntax set: **[CT] 05 02 [CD] [CT]**

[CD]

- 32Bit Fload value

operating temperature T_N [K]

Syntax

- Syntax set: **[CT] 05 03 [CD] [CT]**

[CD]

- 32Bit Fload value

0x9E - Get NTC Parameter 2

Returns the currently configured NTC-parameters 2.

General Syntax

[CT] [LE] **[OB]** [CT]

Return

[CT] [LE] **[OB] [CD]** [CT]

ACK

[OB]

Function	code
beta parameter [K]	0x01
nominal resistance at T_N [Ω]	0x02
operating temperature T_N [K]	0x03
current temperature [°C]	0x04

For standard NTC parameters see Appendix.

beta parameter [K]

Syntax

- Syntax get: **[CT] 01 01 [CT]**
    - Return: **[CT] 05 01 [CD] [CT]**

[CD]

- 4 byte float value

nominal resistance at T_N [Ω]

Syntax

- Syntax get: **[CT] 01 02 [CT]**
    - Return: **[CT] 05 02 [CD] [CT]**

[CD]

- 4 byte float value

operating temperature T_N [K]

Syntax

- Syntax get: **[CT] 01 03 [CT]**
    - Return: **[CT] 05 03 [CD] [CT]**

[CD]

- 4 byte float value

current temperature [°C]

Syntax

- Syntax get: **[CT] 01 04 [CT]**
    - Return: **[CT] 05 04 [CD] [CT]**

[CD]

- 4 byte float value

7.2 SecondChannelOption

The Sciospec ISX-3 can be equipped with an additional multiplexed measurement channel, which can be used for an additional experiment. The second channel can be equipped with almost any type of connector. By default BNC, SMA and MCX are available. Connect Sciospec for further details.

7.3 AcCoupling internal

The AC coupling interface **-** Internal adds a fully galvanic isolated interface to the measurement channel of the ISX-3. The circuit is shown in *Fig: Circuit - AcCouplingOption.*,

> ⓘ The AC coupling interface should only be used for measurements between 100 Hz to 100 MHz!

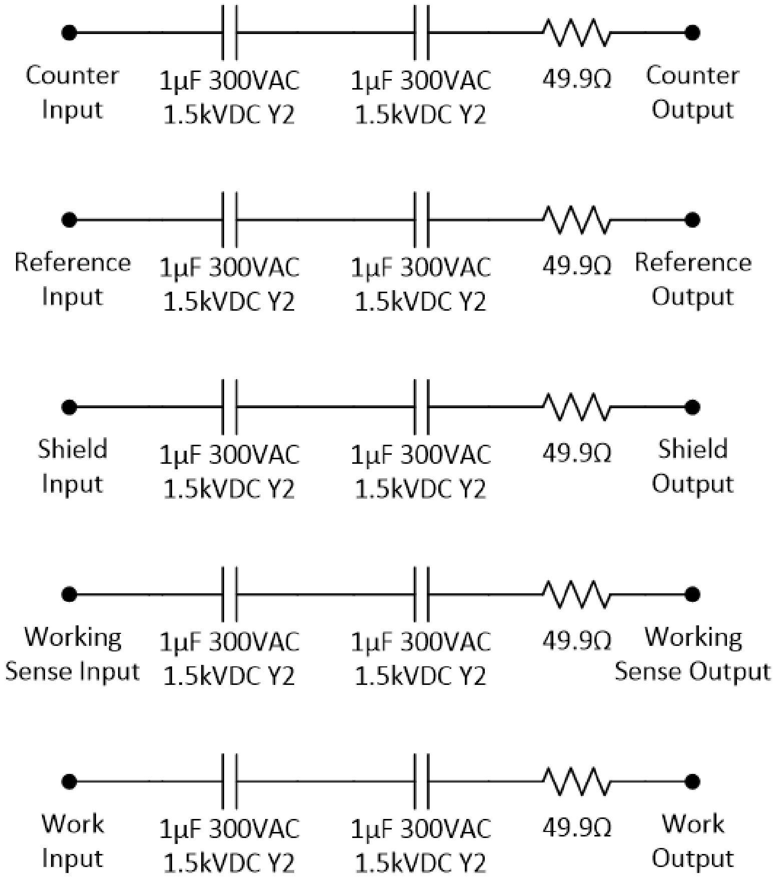


Fig: Circuit – AcCouplingOption (additional each input terminal is connected with a 1MOhm resistor to the cable shield of the input cable.)

7.4 MUX32 (Internal or External)

The Sciospec ISX-3 can be equipped with a 32 channel any to any multiplexer module.

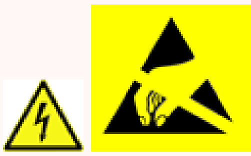
7.4.1 Technical Specifications

General Overview

The MUX32 / MUX64 is a multiplexer module which offers 32 channels or 64 channels. Every channel can be any of the functions: Counter, Reference, Working Sense or Work in 2, 3 or 4 point configuration. Measurements can be configured from any to any other channel(s). Measurements are acquired sequentially (multiplexed).

- 32 /64 channel multiplexer module with any to any functional multiplexing for 2, 3 and 4 electrode configurations
- high isolation, ultra-low parasitic reed relay switches with superior performance compared to semiconductor switches
  - >10 TΩ || 0.4 pF isolation at power off or software selected cell disconnect
  - extremely low parasitic capacitance < 0.7 pF offers close to no cell loading
  - max. series resistance 200 mΩ in connected state
  - zero leakage current in on state
  - zero charge injection, no distortion, no noise contributions beyond thermal noise
- 4 IOs (digital IOs with highly flexible digital IO functions through the Sciospec ***InterfacePort*** standard)
- available frontpanel connectors: edge-card connector (MEC1-150-02-F-D-EM2), MDR40 connector (10240-1210PE). The mating connectors for the MDR40 connector are the 10140-3000PE (solder lugs) or the 10140-6000EC (IDC wire mount).

> All specifications are stated for a operating at temperatures of 0°C to 40°C unless specified otherwise.
> Warm-up time must be greater than or equal to 30 minutes after power on to comply with all specifications.

> **measurement port protection**
>
> 
>
> Be aware that the measurement terminals are very sensitive to electrostatic discharge, over-current and over-voltage. Protection of the terminals of the instrument and strict adherence to the specified maximum ratings has to be ensured by the user. For further information on how to connect specific device under test to the instrument contact Sciospec or an authorized representative directly.

7.4.2 General Specifications

operating conditions	0°C to 40°C, <80% relative humidity non condensing, 0...3000m altitude

non-operating conditions	-25°C to 80°C, <80% relative humidity non condensing The temperature gradient should not exceed 1K/min to reach operating conditions.

7.4.3 Channel Selection

Pinout - Edge-card connector (MEC1-150-02-F-D-EM2)

Pin (MEC1, bottom side)	Function		Pin (MEC1, top side)	Function
1	1		2	2
3	3		4	4
5	5		6	6
7	7		8	8
9	d.n.c.		10	d.n.c.
11	9		12	10
13	11		14	12
15	13		16	14
17	15		18	16
19	d.n.c.		20	d.n.c.
21	17		22	18
23	19		24	20
25	21		26	22
27	23		28	24
29	d.n.c.		30	d.n.c.
31	25		32	26
33	27		34	28
35	29		36	30
37	31		38	32

Pin (MEC1, bottom side)	Function		Pin (MEC1, top side)	Function
39	d.n.c.		40	d.n.c.
41, 43, 45, 47, 49, 53, 55	GND		remaining pins	d.n.c.
50	IO1		51	IO2
52	IO3		54	IO4

ⓘ The Edge-card connector can be used to connect any customized sensor chip or adapter card. Please contact Sciospec for any customized chip. Sciospec also provides on request needed information (DXF-data, PDF-file) so customers can build their own chips, sensors etc.

Pinout - MDR40 connector (10240-1210PE)

Pin MDR40	Function		Pin MDR40	Function
1	GND		21	IO4
2	IO3		22	IO2
3	IO1		23	d.n.c.
4	GND		24	GND
5	32		25	31
6	30		26	29
7	28		27	27
8	26		28	25
9	24		29	23
10	22		30	21
11	20		31	19
12	18		32	17
13	16		33	15
14	14		34	13

Pin MDR40	Function		Pin MDR40	Function
15	12		35	11
16	10		36	9
17	8		37	7
18	6		38	5
19	4		39	3
20	2		40	1

Configuring the Measurement Port of the *MUX32 or MUX64 (internal or external)* in the Software

The configuration of the setup has to be done accordingly to the manual of the corresponding impedance analyzer Sciospec ISX-3, Sciospec ISX-3mini or Sciospec ISX-5.

The measurement channel of the *MUX32* / MUX64 is done in the Channel-Settings dialog by selecting **MUX32/64 (Int)** for Internal MUX or **MUX32/64 (Ext)** for external MUX as the primary channel, see Figure 15. Now the 2/3 or 4 point configuration and channel selection can be configured.

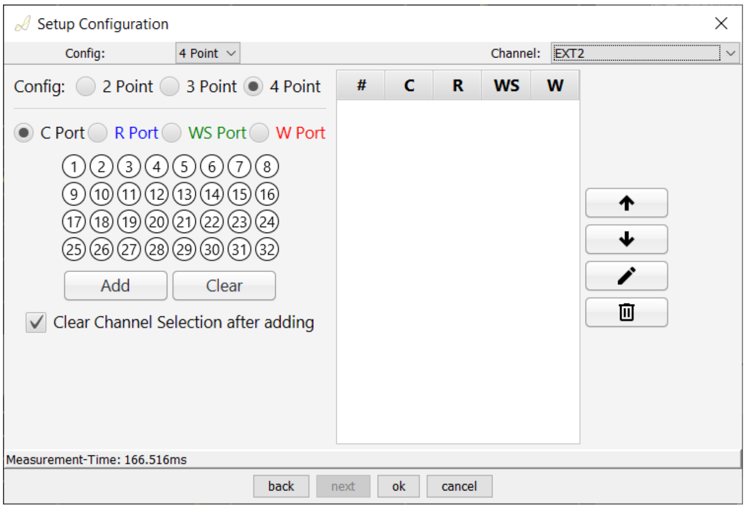
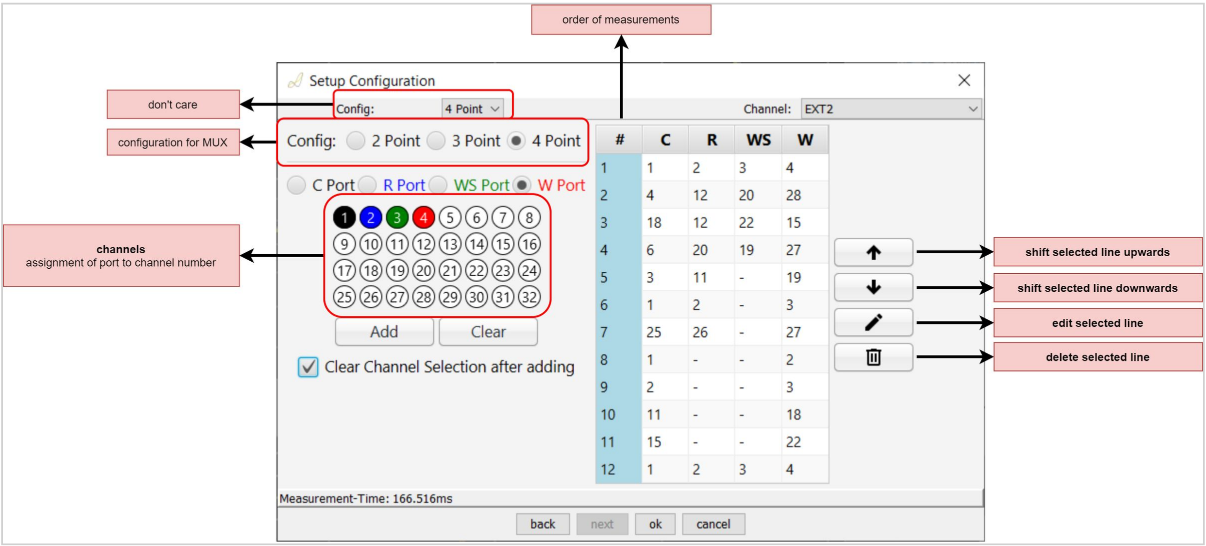


Figure 15: Channel configuration dialog



7.4.4 Sciospec COMInterface

Command list

The leading hex code of each command heading represents the [command code] of the respective function.

- 0xB2 - Add ExtensionPort Channel
- 0xB3 - Get ExtensionPort Channel
- 0xCB - FrontIOs

Command description

0xB2 - Add ExtensionPort Channel

Adding an ExtensionPort channel configuration to the stack.

> The device has a stack length of **128** (for InternalMux). So only 128 ExtensionPort Channel configurations can be stored. Sending the set ExtensionPort Channel command more than 128 times results in a NACK return. The stack will be emptied using the "empty FE settings" command: **B0 03 FF FF FF B0**

General syntax

[CT] 04 [CP] [RP] [WS] [WP] [CT]

Return

ACK

ExtensionPort- channel settings

[CP]	(C-Port): Counter - Port Selection
[RP]	(R-Port): Reference - Port Selection

[WS]	(WS-Port): Working Sense - Port Selection
[WP]	(W-Port): Work - Port Selection

All Ports numbers are send in integer straight binary numbers running from 1 to 32.

Example

- B2 04 **01 02 03 04** B2
  Adding the channel configuration C1, R2, WS3 and W4 for 4 point configuration
- B2 04 **01 02 03 03** B2
  Adding the channel configuration C1, R2 and W3 for 3 point configuration
- B2 04 **01 01 02 02** B2
  Adding the channel configuration C1 and W2 for 2 point configuration

0xB3 - Get ExtensionPort Channel

Read the currently set ExtensionPort configuration stack.

General syntax

[CT] 00 [CT]

Return

[CT] [LE] [channel config 1] [channel config 2] .... [channel config n] [CT] *

ACK

* O*ne data frame is limited to a total of 255 bytes of data. If the returned data exceed this amount of bytes, the returning command will be split into multiple separate frames.*

[LE]

- Length: 1 byte
- depends on the number of configuration currently set

[channel config #]

- # = 1, 2 ... n
- Length: 4 byte (for 2 /3 and 4 point configuration, not used ports are filled with 00)
- **[channel config #] = [CP] [RP] [WS] [WP]**

CP	(C-Port): Counter - Port Selection
RP	(R-Port): Reference - Port Selection
WS	(WS-Port): Working Sense - Port Selection
WP	(W-Port): Work - Port Selection

Example:

B3 0C 01 02 03 04 09 0A 0B 0C 11 00 00 14 B3

- 01 02 03 04 → C = 1, R = 2, Ws = 3, W = 4

- 09 0A 0B 0C → C = 9, R = 10, Ws = 11, W = 12
- 11 00 00 14 → C = 17, W = 20 - 2-point config

0xCB - FrontIOs

Configure and read the state of the available IOs.

General Syntax

[CT] **[LE] [OB] [CD]** [CT]

Return

[CT] [LE] [OB] [CD] [CT] *

ACK

* only for get-commands

[LE]

- Length: 1 byte
- depends on the number of configuration currently set

[OB]

description	set	get
IO direction	0x01	0x81
IO state	0x02	0x82

IO direction

Set/get the direction of an IO port

- Syntax set: **[CT] 03 01 [channel] [direction] [CT]**
    - Return: **ACK**
- Syntax get: **[CT] 02 81 [channel] [CT]**
    - Return: **[CT] 03 81 [channel] [direction] [CT]; ACK**

- Length: 1 byte
- Data format: unsigned integer

[channel]

- channel to set/get IO direction
- Length: 1 byte
- Data format: unsigned integer
- Interpretation:
    - 0x01 - IO 1
    - 0x02 - IO 2
    - 0x03 - IO 3
    - 0x04 - IO 4

[direction]

- direction of requested channel
- Length: 1 byte
- Data format: unsigned integer
- Interpretation:
    - 0x00 - input
    - 0x01 - output
- default: 0x00

IO state

Get / set the input/output state of an IO port

- Syntax set: **[CT] 03 02 [channel] [state] [CT]**
    - Return: **ACK**
- Syntax get: **[CT] 02 81 [channel] [CT]**
    - Return: **[CT] 03 82 [channel] [state] [CT]; ACK**

- Length: 1 byte
- Data format: unsigned integer

[channel]

- channel to set/get IO direction
- Length: 1 byte
- Data format: unsigned integer
- Interpretation:
    - 0x01 - IO 1
    - 0x02 - IO 2
    - 0x03 - IO 3
    - 0x04 - IO 4

[state]

- State of requested channel
- Length: 1 byte
- Data format: unsigned integer
- Interpretation:
    - 0x00 - low
    - 0x01 - high
- Default: 0x00

Example:

- Set IO direction for IO 1 to output
    - Send: CB 03 01 01 01 CB
    - Return: ACK
- Set IO state of IO 1 to low
    - Send: CB 03 02 01 00 CB
    - Return: ACK

- Get Input state of IO 1:
  - Send: CB 02 82 01 CB
  - Return: CB 03 82 01 01 CB
    ACK

7.5 EIT for ISX-3

7.5.1 Functional Description

This system can be used for measurements for electrical impedance tomography. For that purpose it contains:

- multiple dual role electrode connections, serving both as voltage measurement and current injection ports
- the number of available ports equals the number of channels of the MUX
- **sequential** sampling of all channels
- an ultra low leakage reed relay cross point switch matrix for assigning a positive and a negative injection port to a measurement channel (Any combination of ports is possible for every measurement channel.)

The measurement mode allows automatic sequential measurement of user configurable excitation settings. Each excitation setting contains a pair of electrode numbers. One to be used as positive current injection port and one as negative current injection port (current return). While one excitation setting is active:

- a single frequency sinusoidal test current will flow between the two selected ports (if a multi-frequency sweep is configured the configured frequency sweep is carried out on each excitation setting)
- the voltage will be measured on all measurement channels sequential

After the measurement phase is over, the next excitation setting which has been set by the user is configured and according to the timing specification, a new measurement period starts, again acquiring voltage signals for all measurement channels, but now with current flowing according to the new excitation setting. For multi-frequency measurements a measurement phase contains a whole sweep. Hence a frequency sweep is always completed before switching to the next excitation setting.

All measurement data is processed in real time by the Sciospec SineFit algorithm extracting real and imaginary parts of the acquired voltage signal.

Output data is organized in units called "EIT-frame". An EIT-frame contains the measurement results of all x channels (x depends on number of channels selected for the measurement).

Measurement Interface

For the measurement interface two options are available: MDR40 connector (10240-1210PE) or Edge-card connector (MEC1-150-02-F-D-EM2). Please refer to the chapter: "Channel Selection" of the MUX32 for the pinout of the connector types.

7.5.2 Measurement Software Description

Measurement setup

By right-click on [create setup] and choosing [EIT] a new EIT configuration of the system can be created. The selection of the frequency list can be configured block wise, which enables a very freely distribution of the selected frequency points. First organize the complete setup by selection of the frequency range, amplitude of the excitation signal, precision and number of repeats (called Burst count).

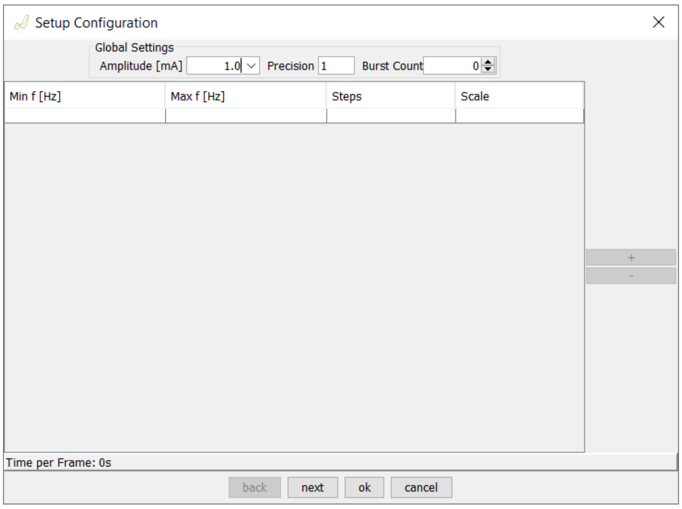


Figure 16: EIT Setup Configuration Dialog

- Amplitude:
  - Amplitude of the current excitation in milliampere
- Precision
  - The precision settings enables the user to adjust the trade off between measurement stability and measurement speed.
  - same as for EIS measurements, refer to Technical Specifications → Relation between the precision setting and the measurement time and measurement accuracy
- Burst Count (<256):
  - The number of measurements to be performed.
  - The measurement will stop automatically.
  - Burst count of 0 results in a never ending measurement. Measurement can be manually stopped by press [measure] again

The following settings have to be made for each frequency block. It is possible to combine as many frequency blocks as needed. The total number of frequency points is limited to 2048.

- Choosing the minimal [Min f], maximal [Max f] frequency and the number of points in between [Steps]
- Selection of the type of scale [Scale] (logarithmic or linear distribution)

Switch to the channel configuration panel by clicking on [next]

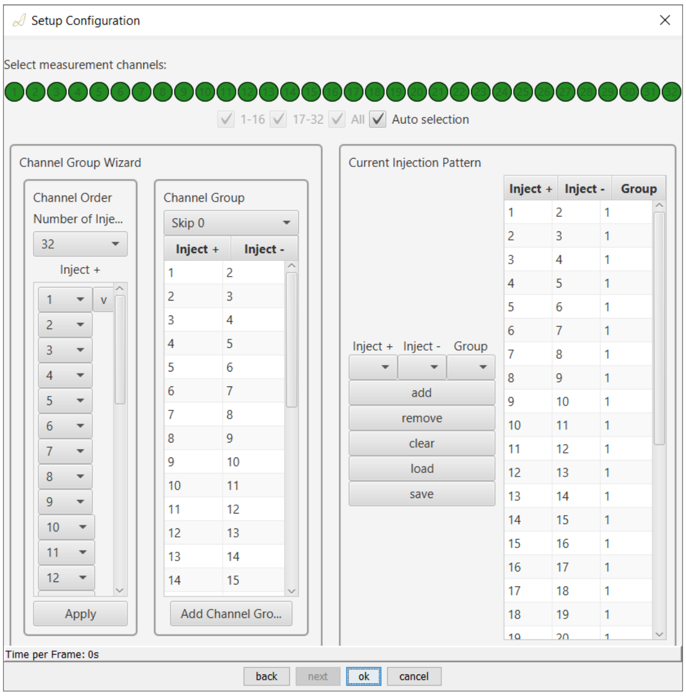


Figure 17: Channel configuration panel

- Select one of pre-configured current injection patterns
  - Skip 0 - Default setting
  - Skip 1
  - Skip 2
  - Skip 3
  - Skip 4
  - Skip 5
- User-defined - With the buttons on the right panel "Current Injection Pattern" the injection pattern can be modified freely. By pressing [clear], all inject rows can be removed. By pressing [clear], an injection row can be added up to 128. To remove a selected injection row, simply press delete key. The injection pattern can be saved or loaded by pressing [save], or [load]
- The pre-configured pattern is decided depending on the channel order. By default it is increasing order. It can be modified freely by selecting channel numbers with the combo boxes. Press [Apply] after modification.

Confirm the parameters by pressing [Ok].

Running a measurement

- Choose [measure] to start the measurement
- Options of visualization of the data:
  - In a data table by double clicking on the measured dataset in the data tree. For details, see **EIT Frame**
  - In a static plotter (with absolute value and phase) by right-clicking on a dataset and select [show voltage] and an injection pair. For details see **Voltage Spectrum Plot**
- To stop the measurement press [measure] again

- It is possible to start multiple setups at once. Select them by holding the control key while clicking on each one. Once the measurement has been started each setup will run one after another.

Every time a complete EIT frame is captured it will appear in the data tree

File description „.eit“

Basically the files can be interpreted as a plain text tab separated (tsv) file with a header and a main part.

- Header part:

Row	Content
1	Number of header rows N (including this one)
2	File Version number
3	Name of dataset
4	Timestamp (yyyy.mm.dd. hh:mm:ss.SSS)
5	Minimum frequency [Hz]
6	Maximum frequency [Hz]
7	Frequency scale (linear = 0, logarithmic = 1)
8	Frequency count
9	Amplitude [A]
10	Frame rate [Frames/s]
11	Phase correction parameter
12	1.0
13	1
14	0
15	0
16	0
17	MeasurementChannels
18	MeasurementChannelsIndependentfromInjectionPattern

- Main part

Row	Content
1	Injection setting: [Injection $_+$] [Injection $_-$]
2	Measurement values for 1st frequency Every value for every electrode is represented by its real part and its imaginary part. [re$_{E1}$] [im$_{E1}$] [re$_{E2}$] [im$_{E2}$] ... [re$_{E16}$] [im$_{E16}$]
3	Measurement values for 2nd frequency
...	...
N+1	Measurement values for Nth frequency

This block is repeated for every injection setting.

Setups

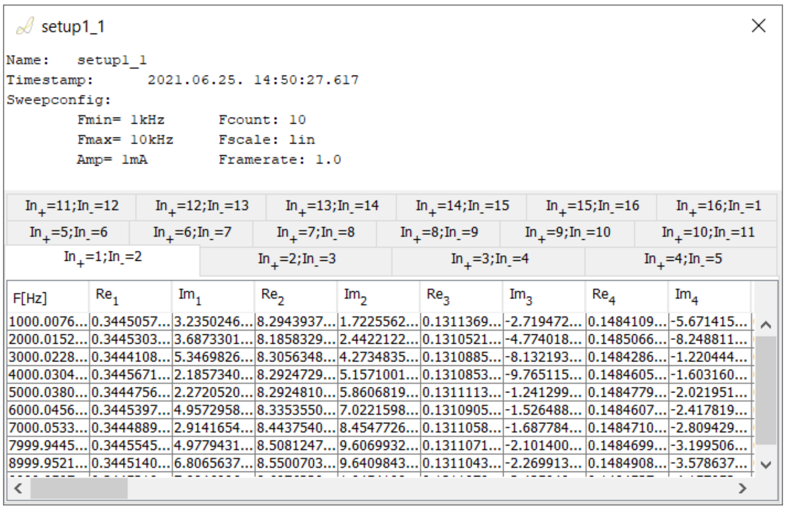
- Saving setup configurations
  - Right click a setup or press on [save] after a setup is selected.
  - You can automatically save all data obtained with this setup by selecting "include sub data"
  - The file extension is „setUp".
- Loading setup configurations
  - Press [load]
  - Select the file extension „setUp" from the file filter drop down menu
  - Select the setup file you want to load and confirm by pressing [Open]
  - Or „Drag and Drop" a setup file into the software

Data Visualization

- EIT Frame
- Voltage Spectrum Plot
- Voltage-Difference Spectrum Plot
- U-Shape Plot
- EIT Image Plotter

EIT Frame

Measured data which is in the *data tree* can be opened by double clicking on row in the list.



F[Hz]	Re_1	Im_1	Re_2	Im_2	Re_3	Im_3	Re_4	Im_4
1000.0076...	0.3445057...	3.2350246...	8.2943937...	1.7225562...	0.1311369...	-2.719472...	0.1484109...	-5.671415...
2000.0152...	0.3445303...	3.6873301...	8.1858329...	2.4422122...	0.1310521...	-4.774018...	0.1485066...	-8.248811...
3000.0228...	0.3444108...	5.3469826...	8.3056348...	4.2734835...	0.1310885...	-8.132193...	0.1484286...	-1.220444...
4000.0304...	0.3445671...	2.1857340...	8.2924729...	5.1571001...	0.1310853...	-9.765115...	0.1484605...	-1.603160...
5000.0380...	0.3444756...	2.2720520...	8.2924810...	5.8606819...	0.1311113...	-1.241299...	0.1484779...	-2.021951...
6000.0456...	0.3445397...	4.9572958...	8.3353550...	7.0221598...	0.1310905...	-1.526488...	0.1484607...	-2.417819...
7000.0533...	0.3444889...	2.9141654...	8.4437540...	8.4547726...	0.1311058...	-1.687784...	0.1484710...	-2.809429...
7999.9445...	0.3445545...	4.9779431...	8.5081247...	9.6069932...	0.1311071...	-2.101400...	0.1484699...	-3.199506...
8999.9521...	0.3445140...	6.8065637...	8.5500703...	9.6409843...	0.1311043...	-2.269913...	0.1484908...	-3.578637...

Figure 18: EIT frame window

This window shows all information saved for this measurement. The upper part of this window shows the name, the timestamp where the measurement took place the sweep settings configured for this measurement.

The lower part shows the measured data itself. Each injection setting is shown in a separate tap. The data in the table can be easily copied to the clipboard by selecting the data which should be copied and pressing CTRL + c. This data is compatible to Microsoft Excel and can also be pasted into an Excel worksheet.

Voltage Spectrum Plot

This plot shows a frequency spectrum of voltage of selected measured data set. To open this plot, select a data set in the data tree and do right-click. Then, a pop-up window will appear with a selection menu. Select [show voltage] and an injection pair. By default, the absolute value and phase are displayed. To display real and imaginary values, hold the control key while opening a plot. To display Nyquist plot, hold the shift key.

Voltage spectra of multiple data sets can be displayed. In this case, another selection menu for channel will be appear after the selection for inject pair.

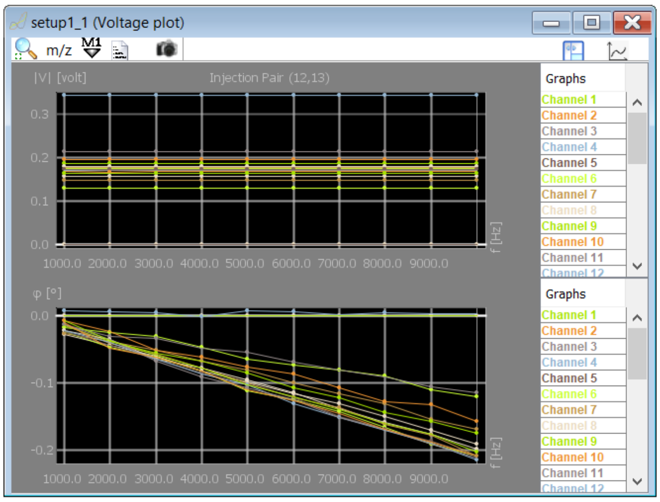


Figure 19: Display of measured data set on plotter

Voltage-Difference Spectrum Plot

This plot shows a frequency spectrum of a voltage-difference between two channels. Do right-click on a data set and select [show voltage-difference] in the selection menu and an injection pair. The channels for the difference are determined by the previously configured current injection pattern in **Measurement setup**. In the case that the current injection pattern is configured as User-defined, the plot shows voltage-difference between neighboring channels. By default, the absolute value and phase are displayed. To display real and imaginary values, hold the control key while opening a plot. To display Nyquist plot, hold the shift key.

U-Shape Plot

This plot shows all the voltage-differences in the same axis. to open this plot, select a data set in the data tree and do right-click. Then, a pop-up window will appear with a selection menu. Select [show U-shape Plot] or [show U-shape Plot (shifted & overlapped)]. U-shape plot is a good indicator for checking measurements when channels are configured in a certain order to a symmetrical object such as a circular phantom. The figure below shows the U-shape plot of a circular phantom with the adjacent current injection pattern. Due to the symmetry of the shape of the phantom, the voltage-differences have a certain pattern and its graph shows U shape for each injection pair as shown in the left plot in the figure. After shifting voltage-differences within in each injection pair and overlapping the voltage-differences for all injection pairs, its graphs become single U-shape. By default, the absolute value is displayed. To display real values, hold the control key while opening a plot. For displaying phase values, or imaginary value, use **EIT Image Plotter**.

EIT Image Plotter

This plotter performs **EIT image reconstructions** and plots EIT images. To open this plotter, go to [Extra] in the top menu bar and select [EIT Image Plotter]. Then, EIT image plotter will be appear as shown the figure below. To generate a EIT image, press [Show image] while measurement is running or a data set is selected in the data tree. While measuring, EIT image will be updated continuously for a newly measured data set. EIT image reconstruction is supported only for the adjacent current injection pattern with the circle as the imaging domain. U-shape plot can be monitored while measurement is running by pressing [Monitor data].

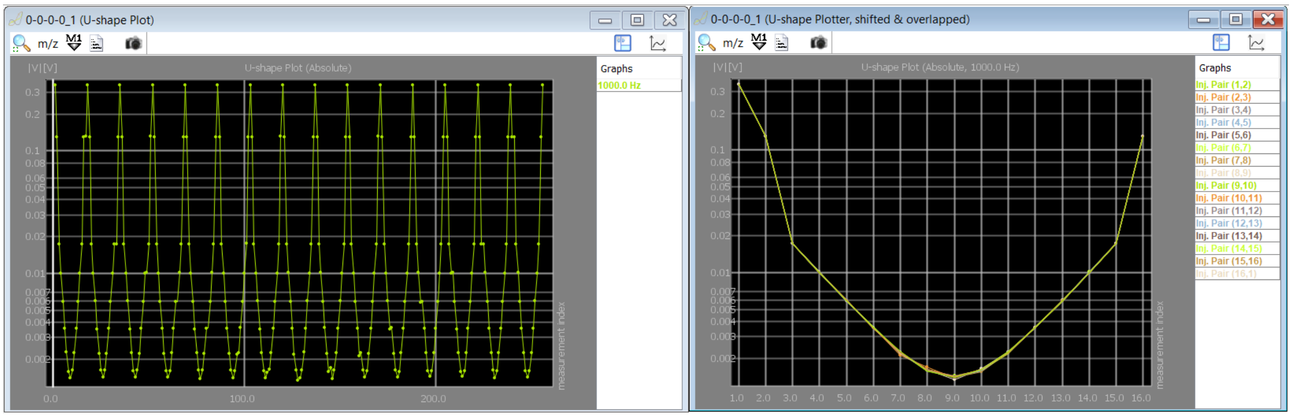


Figure 20: EIT Image Plotter Dialog

Imaging Mode

EIT Image Plotter supports the both time-difference and frequency-difference imaging. The time-difference imaging is set by default. The reference data is set as the first EIT frame measured after a measurement running. The reference data can be updated by pressing [Update Ref.]. For the frequency-difference imaging, the data set has to contain more than one frequency point.

Imaging Data

EIT image is generated using real part of voltage data by default. The imaginary, magnitude, or phase values can be used for generating EIT images. This setting also influences the display value type for U-shape plot. In this case, the absolute value of a selected display data type of voltage data can be shown by checking [Show absolute value]. This setting does not influence EIT image.

EIT Image

Whenever press [Show image] in EIT Image Plotter, new EIT Image window appears. Different EIT images for different settings can be displayed. The red and blue colors indicate positive and negative values, respectively. And the black color indicates zero.

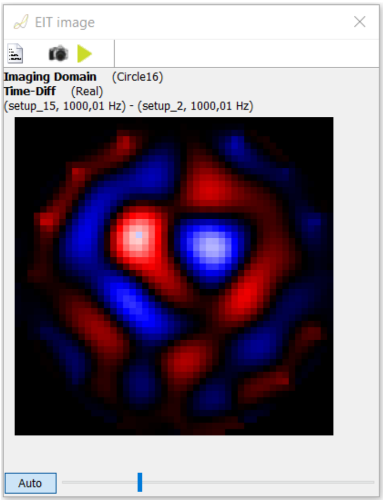


Figure 21: EIT Image Window

7.5.3 Sciospec COMInterface

0xC4 - Set EIT Setup

General Syntax

[CT] [LE] **[OB] [CD]** [CT]

Return

ACK

[OB]

Function	Code
Reset Setup	0x01
Burst Count	0x02
Precision	0x03

Function	Code
Excitation Frequencies	0x04
Excitation Amplitude	0x05
Excitation Setting	0x06
Measurement channels	0x08

Reset Setup

Resets the Setup.

Syntax

- Syntax set: **[CT] 01 01 [CT]**

Burst Count

Number of frames generated before measurement stops automatically.

Syntax

- Syntax set: **[CT] 03 02 [burst count] [CT]**

[burst count]

- 2 Byte unsigned integer
- value range: 0 - 65535
- For continuous streaming set to 0.
- default: [CD] = 0

Precision

The precision settings enables the user to adjust the trade off between measurement stability and measurement speed.

Syntax

- Syntax set: **[CT] 05 03 [precision] [CT]**

[precision]

- 4 Byte float
- value range: 0 - 10
- default: precision = 0

Excitation Frequencies

Add excitation frequency block in Hz. To build a custom excitation frequency stack the command can be send multiple times. The frequencies are placed in the stack as they are configured. The total number of configured excitation frequencies must not exceed the excitation frequency stack length of 128.

Syntax

- Syntax set: **[CT] 0C 04 [f_{min}] [f_{max}] [f_{count}] [f_{type}] [CT]**

[f_{min}]

- minimum frequency f_{min}
- 4 Byte floating point single precision value
- range = 100 mHz - 10 MHz

[f_{max}]

- maximum frequency f_{max}
- 4 Byte floating point single precision value
- range = 100 mHz - 10 MHz

[f_{count}]

- frequency count f_{count}
- 2 Byte unsigned integer value
- range = 1 - 128
- minimum step size = 119mHz

[f_{type}]

- frequency type f_{type}
- 1 Byte unsigned integer value
- f_{type} = 0: linear frequency distribution | 1: logarithmic frequency distribution

Excitation Amplitude

Set the excitation amplitude.

Syntax

- Syntax set: **[CT] [LE] 05 [Amplitude] [CT]**

[Amplitude]

- could be either 32Bit float ([LE] = 05) or 64Bit float ([LE] = 09) (double)
- excitation amplitude in Ampere
- range 0.00001A - 0.01A

Excitation Setting

Add excitation setting to excitation sequence.

Syntax

- Syntax set: **[CT] 03 06 [CD_{out}] [CD_{in}] [CT]**

[CD_{out}]

- channel number of excitation out
- 1 byte unsigned integer

[CD_{in}]

- channel number of excitation in
- 1 byte unsigned integer

Each excitation setting must be added with a separate command. The excitation settings are placed in the excitation sequence in the same order as transmitted to the system. The maximum number of configured excitation setting must not exceed the total length of the excitation stack length of 64.

Measurement channels

Adds Channels that should be measured during an EIT-Measurement.

Syntax

- Syntax set: **[CT] [LE] 08 [CH$_1$] [CH$_2$] [...] [CH$_n$] [CT]**

[CH$_x$]

- length = 1 byte
- unsigned integer
- channel number

0xC5 - Get EIT Setup

General Syntax

[CT] [LE] **[OB] [CD]** [CT]

Return

ACK

[OB]

Function	Code
Burst Count	0x02
Precision	0x03
Excitation Frequencies	0x04
Excitation Amplitude	0x05
Excitation Setting	0x06

Burst Count

Returns the number of frames generated before measurement stops automatically.

Syntax

- Syntax get: **[CT] 01 02 [CT]**
  - Return: **[CT] 03 02 [burst count] [CT]**

[burst count]

- 2 Byte unsigned integer
- value range: 0 - 65535
- 0 for continuous streaming.

Precision

Return the precision settings.

Syntax

- Syntax get: **[CT] 01 03 [CT]**
  - Return: **[CT] 03 03 [precision] [CT]**

[precision]

- 4 Byte float
- value range: 0 - 10

Excitation Frequencies

Returns the list of configured excitation frequencies.

Syntax

- Syntax get: **[CT] 01 04 [CT]**
  - Return: **[CT] 0C 04 [f_{min}] [f_{max}] [f_{count}] [f_{type}] [CT]**

If more than 63 frequencies are configured, the answer is split into more than on frame.

[f_{min}]

- minimum frequency f_{min}
- 4 Byte floating point single precision value
- range = 100 mHz - 10 MHz

[f_{max}]

- maximum frequency f_{max}
- 4 Byte floating point single precision value
- range = 100 mHz - 10 MHz

[f_{count}]

- frequency count f_{count}
- 2 Byte unsigned integer value
- range = 1 - 128
- minimum step size = 119mHz

[f_{type}]

- frequency type f_{type}
- 1 Byte unsigned integer value
- f_{type} = 0: linear frequency distribution | 1: logarithmic frequency distribution

Excitation Amplitude

Returns the excitation amplitude.

Syntax

- Syntax get: **[CT] 01 05 [CT]**
  - Return: **[CT] 05 05 [Amplitude] [CT]**

[Amplitude]

- 32Bit float
- Amplitude in Ampere

Excitation Setting

Returns the configured excitation sequence stack.

Syntax

- Syntax get: **[CT] 01 06 [CT]**
    - Return: **[CT] XX 06 [CD_{out_1}] [CD_{in_1}] [CD_{out_2}] [CD_{in_2}] [...] [CD_{out_n}] [CD_{in_n}] [CT]**

[CD_{out_x}] / [CD_{in_x}]

- channel number of excitation out or in
- 1 byte unsigned integer

7.6 Synchronization Ports

The Sciospec ISX-3 can be equipped with the synchronization ports option for synchronization with other customer hardware. It enables ultra-fast hardware synchronization through sync in/out ports (e.g. through low level isolated interface or optional isolated sync module).

7.6.1 Technical Specifications

All specifications are stated for a operating at temperatures of 0°C to 40°C unless specified otherwise.
Warm-up time must be greater than or equal to 30 minutes after power on to comply with all specifications.

Maximum Ratings

Stresses above the listed absolute maximum or maximum ratings may cause permanent damage to the device. This is a stress rating only; functional operation of the device at these or any other conditions above those indicated in the operational section of this specification is not implied. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.

sync ports	two inputs, two outputs
sync input type	point hold off, sweep hold off, immediate stop
sync output type	sweep complete, point complete
connectors	four SMA (female, standard polarity)

absolute maximum input voltage	3.8 V for 3.3V logic (default) 5.5 V for 5V logic option
absolute minimum input voltage	-0.5 V
high level input voltage	≥2 V
low level input voltage	≤0.8 V
high level output voltage	≥2.9 V (typ. 3.1 V) for 3.3V logic (default) ≥4.6 V (typ. 4.8 V) for 5V logic option
low level output voltage	typ. 0.2 V
Output impedance	50 Ω
maximum output current	10 mA
Input leakage current	±10 µA
ESD protection	±12kV IEC 61000-4-2 contact ESD ±15kV IEC 61000-4-2 air-gap ESD clamp voltage 10.5V (min) break-down voltage 7V (min)
Isolation	Maximum Isolation (Input to Output) (1 sec) 4500 V RMS 60950-1: Up to 125 VRMS reinforced insulation working voltage; up to 250 VRMS basic insulation working voltage
Transient Immunity	50 kV/µs
Timing	Minimum Pulse Width 5 ns (max) Propagation Delay 8 ns (typ.) Output rise time 2.5 ns (typ. @C_L = 15 pF)

ⓘ Inputs are internally biased to 3.3V by a 10kΩ pull up resistor.

7.6.2 Functional Description

For synchronization with other customer hardware the Sciospec ISX-3 can be equipped with the Synchronization Module. It offers two “Sync Out” and two “Sync In” ports located at the back of the instrument. Use standard SMA cables to connect your hardware. Each port is equipped with an open drain buffer to allow different logic voltage levels.

ⓘ The outputs are equipped with a 10kΩ pull up resistor to 3.3V.
If you require different voltage levels please contact Sciospec directly for support.

The “Sync Out I” port gives information about the current state of the measurement.

- Logic high → Measurement is running
- Logic low → Measurement is paused between two measurement sweeps. This time can be configured by setting the sync time in the range 0s to 200s in 1µs steps. Default is 0 seconds.
- The setting 0 seconds results in no change of the signal between two measurements

If an average count higher than 1 is configured there will be a change in between one measured spectrum.

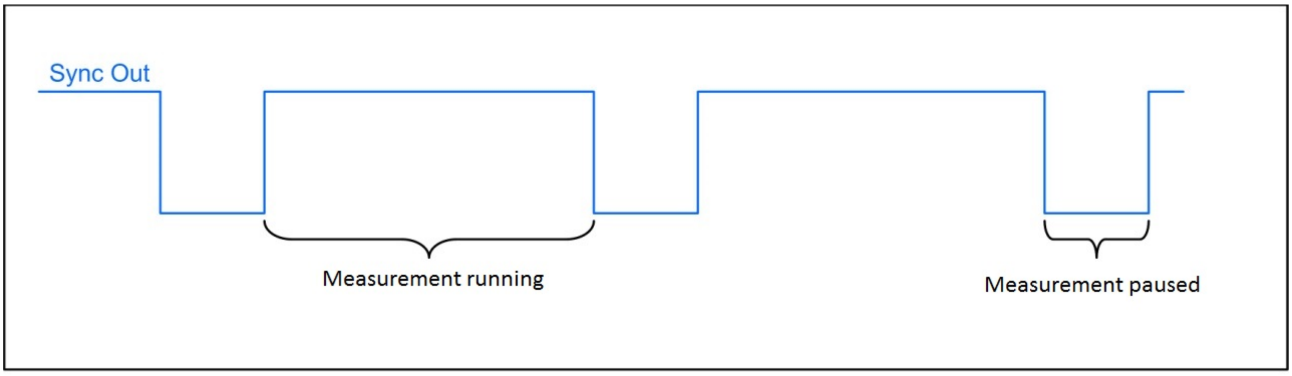


Fig: Sync Out Signal

- The “Sync In” port allows to control the measurement process
  - By default the signal is logic high, which allows for a continuous measurement.
  - By connecting this port to ground (logic low) the next measurement will be paused until the signal is released again.
  - An already running sweep will not be interrupted by the “Sync In 1” signal.
  - Do not apply any voltage source directly to the synchronization ports
- The ports “Sync In II” and “Sync Out II” are not used by default. Please contact Sciospec directly for further assistance when requiring different types of synchronization.

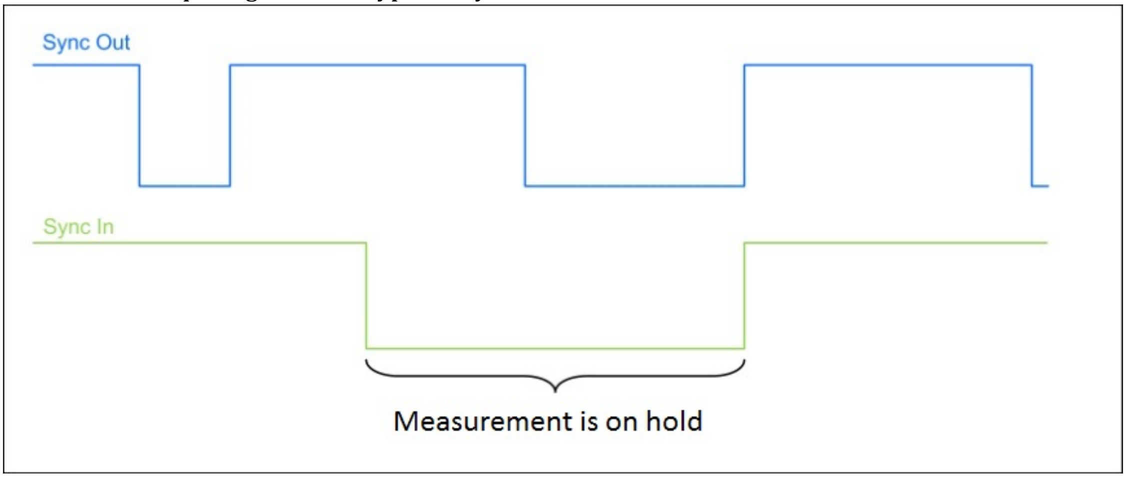


Fig: Sync In Signal

7.7 Battery Operation

The Sciospec ISX-3 and ISX-3mini can be equipped with an integrated battery pack for measurements up to 2-3 h. The Sciospec Medical Research ISX-3 is by default equipped with the integrated battery pack.

7.7.1 Technical Specifications

Battery Pack

- Lithium Ion battery pack
- no. of cells: 3 cells; 1S3P
- capacity nom. 10 Ah
- 36Wh according to UN38.3 TSR
- measurement time ~2-3h (determined under certain circumstances, not generally valid!)
- ambient temperature range

0°C to +45°C	charge
-20°C to +60°C	discharge
-20°C to +30°C	storage max. 1 year
-20°C to +45°C	storage max. 3 month

7.7.2 Functional Description

The Sciospec ISX-3 / ISX-3mini can be configurated to measure on battery operation or mains operation. The configuration can be done in the Sciospec software (see Measurement Software Description) or using the Sciospec COMInterface (see Sciospec COMInterface). If the device is measuring on battery operation a minimum capacity can be configured, where the device changes to mains operation but the measurement continuous. The minimum capacity can be changed between 5 % and 100 %. By default 10 % is configured.

ⓘ Please charge the device at 10% remaining capacity. Please do not fully discharge the battery.

7.7.3 Sciospec COMInterface

0xC2 - Set BatMod

General Syntax

[CT] [LE] **[OB] [CD]** [CT]

Return

ACK

[OB]

Function	set
Measure on Battery	0x02
Measure on Battery min capacity	0x03

Measure on Battery

Set the Battery Mode to measure on battery.

Syntax

- Syntax set: **[CT] 02 02 [CD] [CT]**

[CD]

- 0x00: Disable
- 0x01: Enable

Measure on Battery min capacity

Set the Battery Mode to change to external power supply when the battery min capacity is reached. Measurements will be continued.

Syntax

- Syntax set: **[CT] 02 03 [CD] [CT]**

[CD]

- minimum state of charge in percent (≤ 100)

0xC3 - Get BatMod

General Syntax

[CT] [LE] **[OB] [CD]** [CT]

Return

[CT] [LE] **[OB] [status] [remaining capacity]** [CT]

ACK

[OB]

Function	get
Status / remaining capacity	0x01

Status / remaining capacity

Gets Status of Battery Mode and remaining capacity of battery.

Syntax

- Syntax get: **[CT] 01 01 [CT]**
  - Return: **[CT] [LE] 01 [status] [remaining capacity] [CT]**

[status]

1 Byte bit coded

MsBit - Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	LsBit - Bit 0
d. c.	d. c.	d. c.	d. c.	d. c.	d. c.	powers source	charging

power source:

- 1 = battery
- 0 = external

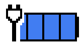
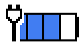
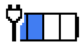
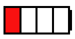
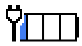
[remaining capacity]

- 1 byte hexadecimal remaining capacity in percent (≤ 100 percent)

7.7.4 Measurement Software Description

If the Sciospec ISX-3 or ISX-3mini contains a battery pack, the main window of the software will show the battery status at the right top, see *Fig: Main Window battery operation.* By hovering over the battery status symbol with the mouse pointer, the capacity left in % will be displayed. The possible battery statuses are shown in *Tab: Battery statuses*.

Fig: Main Window battery operation

symbol	status	remaining capacity		symbol	status	remaining capacity
	battery	100%-75%			charging	100%-75%
	battery	75%-50%			charging	75%-50%
	battery	50%-25%			charging	50%-25%
	battery	25%-0%			charging	25%-0%

Tab: Battery statuses

Battery Operation Configurations

Under [Extra] → [Battery Mode] a Battery Mode Configuration Window can be opened.

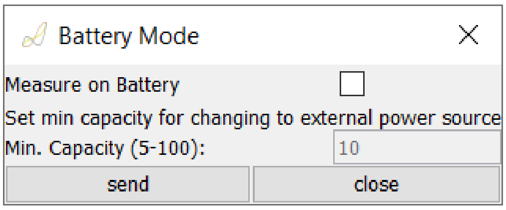


Fig: Battery Mode Configuration Window

Following configurations are available:

- Measure on Battery
- Set minimum capacity for changing to external power supply, **measurements will be continued**
  - selectable between 5-100%

8 Appendix

8.1 Data formats

All data sent to the device or sent from the device is either “Integer-Straight-Binary” or 32 Bit Float coded (according to IEEE 745). Either way the data is in Big-Endian format.

Big-Endian means that if a value consists of more than one byte the byte order is according to their value:

Example 4 byte Big-Endian Value: [MSByte] [MSByte-1] [LSByte-1] [LSByte]

The bit order is within one byte MSBit-first:

[MSBit] [MSBit-1] [MSBit-2] [MSBit-3] [LSBit+3][LSBit+2] [LSBit+1] [LSBit]

8.1.1 Float data format - single precision

<table>
<tr><td>Bits</td><td>31</td><td>30</td><td>29</td><td>28</td><td>27</td><td>26</td><td>25</td><td>24</td><td>23</td><td>22</td><td>21</td><td>20</td><td>19</td><td>18</td><td>17</td><td>16</td><td>15</td><td>14</td><td>13</td><td>12</td><td>11</td><td>10</td><td>9</td><td>8</td><td>7</td><td>6</td><td>5</td><td>4</td><td>3</td><td>2</td><td>1</td><td>0</td></tr>
<tr><td rowspan="2">Bytes</td><td colspan="8">MSByte</td><td colspan="8">MSB-1</td><td colspan="8">LSByte +1</td><td colspan="8">LSByte</td></tr>
<tr><td>S</td><td colspan="8">exponent [E]</td><td colspan="23">mantissa [M]</td></tr>
</table>

The float value is calculated as follows:

$$float = (-1)^S * (1 + M * 2^{-23}) * 2^{E-127}$$

8.1.2 Float data format - double precision

<table>
<tr><td>Bits</td><td>63</td><td>62</td><td>61</td><td>60</td><td>59</td><td>58</td><td>57</td><td>56</td><td>55</td><td>54</td><td>53</td><td>52</td><td>51</td><td>50</td><td>49</td><td>48</td><td>47</td><td>46</td><td>45</td><td></td><td>10</td><td>9</td><td>8</td><td>7</td><td>6</td><td>5</td><td>4</td><td>3</td><td>2</td><td>1</td><td>0</td></tr>
<tr><td rowspan="2">Bytes</td><td colspan="8">MSByte</td><td colspan="8">MSB-1</td><td colspan="3"></td><td>...</td><td colspan="3"></td><td colspan="8">LSByte</td></tr>
<tr><td>S</td><td colspan="11">exponent (E)</td><td colspan="19">mantissa (M)</td></tr>
</table>

The double precision value is calculated as follows:

$$float = (-1)^S * (1 + M * 2^{-52}) * 2^{E-1023}$$

8.1.3 Integer straight binary data format

<table>
<tr><td>Bits</td><td>15</td><td>14</td><td>13</td><td>12</td><td>11</td><td>10</td><td>9</td><td>8</td><td>7</td><td>6</td><td>5</td><td>4</td><td>3</td><td>2</td><td>1</td><td>0</td></tr>
<tr><td rowspan="2">Bytes</td><td colspan="8">MSByte</td><td colspan="8">LSByte</td></tr>
<tr><td>a_{n-1}</td><td>a_{n-2}</td><td colspan="13"></td><td>a_0</td></tr>
</table>

The numerical value is calculated as follows:

$$x_{ISB} = 2^{n-1} * a_{n-1} + 2^{n-2} * a_{n-2} + \cdots + 2^1 * a_1 + 2^0 * a_0$$

with

- n - bit width (in this example n=16)
- a_i - bit numbering i (a_{n-1}...most significant bit; a_0...least significant bit)

8.1.4 Two's complement data format

Example: 16bit two's complement

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Bytes	MSByte								LSByte							
	a_{n-1}	a_{n-2}														a_0

The numerical value is calculated as follows:

$$x_{twos} = -2^{n-1} * a_{n-1} + 2^{n-2} * a_{n-2} + \cdots + 2^1 * a_1 + 2^0 * a_0$$

with

- n - bit width (in this example n=16)
- a_i - bit numbering i (a_{n-1}...most significant bit; a_0...least significant bit)

8.2 Temperature Sensors - negative temperature coefficient (NTC) thermistor

The temperature measurement works by connecting a NTC thermistor to the specified port. The instruments needs to know the following characteristics of the connected thermistors to calculate the temperature correctly

name	symbol	description	unit	typical value
Beta parameter	β	material constant, refer to the datasheet of the thermistor	K	3800K
Reference temperature	T_N	operating temperature	K	298,15K (25°C)
resistance at T_N	R_N	Nominal resistance at the operating temperature	Ω	10kΩ

The conversion formula for the temperature ϑ is:

$$\vartheta = \frac{\beta * T_N}{\beta + \ln\left(\frac{R}{R_N}\right) * T_N} - 273{,}15$$

8.3 Declaration of Conformity

scio spec scientific instruments	Declaration of Conformity According to EN ISO/IEC 17050-1:2010	CE
Manufacturer's Name	Sciospec Scientific Instruments GmbH	
Manufacturer's Address	Leipziger Str. 43b, 04828 Bennewitz Germany	
Declares under sole responsibility that the product as originally delivered		
Product Name	Impedance Analyzer	
Model Number	ISX-3, ISX-3mini	
Product Options	This declaration covers all options, cables and accessories of the above products(s).	
Serial Number	Covers all products • 01-000B-XXXX-XXXX (ISX-3) • 01-000D-XXXX-XXXX (ISX-3mini)	
complies with the essential requirements of the following applicable European Directives, and carries the CE marking accordingly		
	Low Voltage Directive (LVD)	2014/35/EU
	Electromagnetic compatibility Directive (EMC)	2014/30/EU
	Restriction of Hazardous Substances Directive (RoHS2)	2011/65/EU
and confirms with the following product standards		
	EMC	DIN EN 61326-1:2013-07
	Safety	DIN EN 61010-1:2020-03
	RoHS	DIN EN IEC 63000:2019-05
The product is to be used for the intended purpose. This product were tested in a typical configuration with Sciospec test systems. When used under conditions other than the specified conditions appropriate protective measures by the user must be taken.		
This DoC applies to above-listed products placed on the EU market after		

scio spec scientific instruments	Declaration of Conformity According to EN ISO/IEC 17050-1:2010	CE
Date	April 15th, 2021	
Place	Bennewitz, Germany	
Name	Martin Bulst	
Signature	Martin Bulst	

9 Changelog

Revision 1.0

- Initial Release of this document

Revision 1.1

- Example code for establishing USB connection corrected
- Documentation of “add frequency block” corrected
- Added C-code example of a whole measurement

Revision 1.2

- Added Calibration Routines
- Added ability to store setup configurations in the device
- Added IP and MAC address commands for Ethernet communication

Revision 1.3

- Added point delay and phase synchronization options
- Updated set setup and get setup command description
- Updated Synchronization ports description
- Added Ethernet functionality

Revision 1.4

- Correction on "set Ethernet configuration" command

Revision 1.5

- Added ideal capacitor as possible load impedance
- Added description for use of measurement module within ISX-5/MSX-8

Revision 1.6

- Updated Kinetic Mode description

Revision 1.7

- Added Time Stamp Option (commands 0x97 & 0x98)
- Added External Temperature Control compatibility
- Minor Bugfixes
- More detailed description of the "Autosave" feature

Revision 1.8

- Changed Command "get ExtPort module" (0xB5)
- Minor Bugfixes

Revision 1.9

- Added Options section

Revision 1.10

- Added AcCoupleOption - External

Revision 1.11

- Updated description of B6 command regarding extent options (EOP)
- Update company contact details

Revision 1.12

- Fixed wrong order in of Ports in B2 and B3 command

Revision 53

- changed revision numbering system.
- Reworked whole document structure.
- Reworked Ethernet documentation. Added C-Code example to Appendix.
- Updated TechSpecs

Revision 72

- Added Error messages
- Added save directory of Logfiles
- Added the show measured data in tree too functionality
- Added stitch spectra option
- Added Full speed USB
- Updated Installation
- Added Surface Plot
- Excluded Synchronization Ports
- Updated photographs

Revision 74

- Updated measurement software description
- Changed position of section "Measurement delay options and phase synchronization"

Revision 80

- Changed formatting of commands in COMInterface section
- Added copy About screen functionality
- Updated Declaration of Conformity
- restructured documentation of optional Add-Ons
- Added section Battery Operation

Revision 81

- Added Details to Technical Specifications
- Added possible file extensions to autosave description
- Added General software window description
- Added firmware information readout functionality to COMInterface. (commands 0xD0 and 0xD2)
- Added additional data formats to appendix
- Updated installation section
- Excluded High Speed USB description
- Updated DC-Bias description
- Updated technical specifications Synchronization module
- Updated commands 0xB0, 0xB5, 0xB6 and 0xB7
- Shifted position of 0x99, 0x9A, 0x9B, 0x9C, 0x9D, 0x9E commands to Options IOport
- Updated IOPort description

- Excluded documentation of InternalMux

Revision 82

- Added documentation of InternalMux32
- Updated channel selection dialog in software description

Revision 83

- Corrected picture in measurement software description
- Added description of device specific ACK messages

Revision 86

- Updated page formatting
- Updated Documentation of 32any2anyMUX COMInterface

Revision 87

- Added EIT for ISX-3 option

Revision 93

- Added IO-Functionality to COM-Interface, technical description and channel selection of option Internal MUX32
- Added 0x11 ACK-Messages to COMInterface
- Changed product name in documentation from ISX-3v2 to ISX-3
- Fixed 1MHz to 10MHz in Add frequency list example
- Fixed 3D CC CC CD to 3E 80 00 00 in Add frequency list example
- Added 0x90 and 0x91 ACK-Messages to COMInterface
- Added a description of the compensation
- Updated DC Bias range
- Added command 0xCF "TCP connection watchdog" to COMInterface
- Changed the measurement software description
- Updated plotter description
- Added overcurrent and overvoltage detection
- Added conductivity plot to measurement software description
- Added Ethernet broadcast functionality to functional description
- Updated chapter "establishing connection" in measurement software description

Revision 94

- Updated accuracy contour plot
- Updated product pictures
- Updated command 0xB5 Get ExtensionPort Module
- Updated MUX section

Revision 95

- Updated length in command 0xB5 - Get ExtensionPort Module
- Updated measurement mode in command 0xB0 - Set FE Settings
- Updated section EIT for ISX-3
- Updated chapter software installation
- Updated C-code example in COM Interface

- Added COM Interface documentation to EIT option

Revision 96

- Added unit prefix to software description
- Updated software description
- Added intended frequency range for AC coupling interface