UHF User Manual

Zurich
Instruments

UHF User Manual

Zurich Instruments AG

Publication date Revision 28900

Revision History

Revision 28900, 18-Mar-2015:

Document update of all chapters to comply with the changes of the 15.01 product release.

Highlights of the changes and additions to the UHFLI product are:

- Specification change: typical input noise at 100 kHz is now 4 nV/√Hz (previously 5 nV/√Hz)
- Sweeper: Indicator for estimated sweep time
- PID: PID advisor with auto tune
- AU: Support of multiplication
- AU: Support of boxcar data
- Scope: Spectral Density for FFT of Scope Data
- Scope: Support of different FFT window functions
- NEW Option UHF-DIG Digitizer: Scope enhancement with continuous scope streaming, Scope trigger output on Trigger 1/2, Gated triggering, Hold-off specified as number of trigger events, Support of boxcar, demodulator, and pid data recording; Cross domain triggering for scope based on boxcar, demodulator, and pid data
- Boxcar: Reporting of the current data streaming rate

A more detailed list of all technical changes can be found in the LabOne release notes.

Revision 26210, 30-Sep-2014:

Document update of all chapters to comply with the changes of the 14.08 product release.

Highlights of the changes and additions to the UHFLI product are:

- Arithmetic Unit: a new tab that allows the control of 4 arithmetic units
- Sinc filter for Sweeper: increases speed of sweeps at low frequencies
- Scope: trigger performance, functionality and display have been further improved
- Scope: dual channel support (requires UHF-DIG Digitizer option)
- Scope: improved averaging and persistence refresh handling
- Sweeper: now supports data provided from the pid, boxcar and arithmetic unit
- Sweeper: simultaneous display of multiple traces
- Sweeper: additional application mode to support 3-omega measurements
- UHF-PID PID option: low pass filter for the D part now accessible in the user interface
- Auxiliary outputs can now output also the PID shift, e.g. frequency adjustment in a PLL
- UHF-MOD Modulation option: full access to phase, timeconstant, and filter order for the individual side bands
- UHF-BOX Boxcar option: averaging replaces the integration, provides better usability and more intuitive behavior
- New Harmonics Analyzer for UHF-BOX option: bar chart display for FFT of periodic waveform analyzer

A more detailed list of all technical changes can be found in the LabOne release notes.

Revision 23144, 22-Apr-2014:

Document overhaul and extension compliant to 14.02 product release. Updates include the getting started chapter, the ordering guide, added new tutorials, and updated the functional description. As of this release, the LabOne software contains installation files for both HF2 Series and UHF Series products. Also, as of this release, programming of the device by one of the supported APIS is described in a separated UHF Programmer's Manual.

Detailed changes and additions to the UHFLI product:

- Full support for UHF-10G Optical Ethernet option
- Boxcar option: support for baseline suppression
- PID option: added phase unwrap feature
- Periodic waveform analyzer (PWA): increased number of bins to 1024
- Periodic waveform analyzer (PWA): higher update rate
- UDP port assignment per device starting from port 8013
- Ethernet: improved reconnect after cable disconnect
- Start-up screen with device and setting selection: added support of multiple devices per server
- Improved Device connect/disconnect without server restart
- User interface: added cursor Math (with copy & paste of values)
- User interface: added relative cursor
- Lock-in: Vpk, Vrms, dBm support
- CSV transfer to other applications (Excel,...) via LiveLink
- Added histogram to oscilloscope
- Sweeper: Unbiased standard deviation
- Sweeper: Speed increase down to 6ms per sweep point
- Plotter: Support for PID and boxcar streaming data

Detailed changes and additions to the HF2LI/HF2IS products:

- HF2LI-MOD option: fixed calculation of index of modulation
- HF2LI-PID option: fixed calculation of MOD sidebands
- Sweeper: PID setpoint sweeper

Revision 20274, 22-Nov-2013:

Document overhaul and extension compliant to 13.10 product release. Updates include the getting started chapter, the ordering guide, added new tutorials, and updated the functional description. As of this release, the LabOne tooltips inside of the user interface correspond to the description of the functional elements in this user manual.

Detailed changes and additions to the product:

- Instrument back panel: former Trigger 1/2 on the back panel of the instrument have been renamed to Trigger 3/4.
- USB connectivity: USB high-speed 480 Mbit/s fully supported as interface alternative to LAN. Simpler connectivity
- NEW option UHF-BOX Boxcar Averager 1: boxcar and periodic waveform analyzer (PWA, jitter free averaging scope) on signal inputs (requires UHF-BOX option)
- NEW option UHF-BOX Boxcar Averager 2: multi-channel boxcar, periodic waveform analyzer (PWA) on boxcar outputs
- Linux support
- Scope: oscilloscope and FFT spectrum analyzer are now integrated on a single tab
- Scope: sampling rates down to 27 kSa/s
- Scope: dual edge trigger
- General User Interface: improved design and drag & drop functionality for all tabs
- Lock-in: integrated Tandem demodulation (full support demodulation of auxiliary input and auxiliary output signals as demodulator inputs)

- Lock-in: output amplitude setting in V and dBm
- Lock-in: support for edge and level triggers
- Lock-in: phase to zero adjustment
- PID: simultaneous operation of all 4 controllers at a rate of 14 MSa/s
- PLL: center point adjustment
- Plotter: multi-trace support and vertical axis groups
- Plotter: quick add trace feature
- Sweeper: additional sweep parameters
- Sweeper: much higher sweep speed and support for odd configurations
- Spectrum: new name of former ZoomFFT panel
- Spectrum: filter compensation and absolute frequency control
- Spectrum: windowing effect reduction
- Spectrum: calculation of spectral density and power on FFT spectrum
- Numeric: increase font size of numerical values
- SW Trigger: triggering on Ref / Trigger connectors
- SW Trigger: automatic trigger level adjustment
- SW Trigger: triggering on Ref / Trigger connectors
- Auxiliary: automatic adjustment of Preoffset and Offset to zero outputs
- Config: improved data streaming and unified directory to CSV and MATLAB
- API / Programming: LabVIEW 64-bit support
- API / Programming: timestamp support for some data types (API revision 4)

Revision 18265, 30-Jul-2013:

Large revision of the specification chapter compliant to 13.06 product release. Moved many parameters from minimum/maximum to typical when parameter is characterized but not specifically tested during production. Also updated the getting started section.

With 13.06 all tooltips of the user interface have been updated, providing a considerable increase of usability. The functional description chapter is still small. The user manual will be obverhauled with much more infomation with the next release.

Revision 17290, 23-May-2013:

Updated the connecting to the UHFLI section in the getting started chapter to reflect software usability improvements in software release 13.02.

Revision 15874, 11-Feb-2013:

Updated the getting started chapter with more detailed information on setup and several screenshots. Other minor edits in the whole document.

Revision 15785, 1-Feb-2013:

This is the first version of the UHFLI user manual related to software release 13.01. The main available sections are the getting started, the functional overview, a first tutorial of the user interface, and the specifications. Other sections will follow.

Table of Contents

Declaration of Conformity

The manufacturer

Zurich Instruments
Technoparkstrasse 1
8005 Zurich
Switzerland

declares that the product

UHFLI Lock-in Amplifier, 600 MHz, 1.8 GSamples/s

fulfils the requirements of the European guidelines

- 2004/108/EC Electromagnetic Compatibility
- 2006/95/EC Low Voltage

The assessment was performed using the directives according to Table 1 .

Table 1. Conformity table

EN 61326-1:2006	Emissions for industrial environments, immunity for industrial environments
EN 55011	Group 1, class A and B (the product was tested in typical configuration)
EN 61000-4-2	CD 4 kV, AD 8 kV
EN 61000-4-3	10 V/m 80% AM 80 MHz - 1 GHz
	3 V/m 80% AM 1 MHz - 2 GHz
	1 V/m 80% AM 2 MHz - 2.7 GHz
EN 61000-4-4	2 kV power line
	1 kV USB line
EN 61000-4-5	1 kV line-line, 2 kV line-earth
EN 61000-4-6	3 V 80% AM, power line
EN 61010-1:2001	Safety requirements for electrical equipment for measurement, control and laboratory use

Figure 1. CE Logo

Chapter 1. Getting Started

Welcome to the world of Ultra-high Frequency (UHF). This first chapter supports you with the set-up of your UHF Instrument and prepares for your first measurements. This chapter comprises:

- Quick Start Guide for the impatient
- Inspecting the package content and accessories
- List of essential handling and safety instructions
- Installing LabOne, the UHF Instrument software, on your host computer
- Powering-on the device and connecting the device to a host computer
- Performing basic operation checks on the instrument
- Handy list of troubleshooting guidelines

This chapter is delivered as hard copy with all initial instrument delivery to customers. It is integral part of the UHF User Manual.

1.1. Quick Start Guide

This page addresses all the people who impatiently are awaiting their new gem to arrive and want to see it up and running quickly. Please proceed with the following steps:

1. Check the package content. Besides the Instrument there should be a country specific power cable, an USB cable, an Ethernet cable and a hard copy of the user manual Chapter 1 .
2. Check the Handling and Safety Instructions in Section 1.3 .
3. Download and install the latest LabOne software from the **Zurich Instruments Download Center** [www.zhinst.com/downloads]. Access credentials are usually provided by email along with the shipping information. Choose the download file that fits your PC (e.g. Windows with 64-bit addressing). For more detailed information see Section 1.4 .
4. Connect the Instrument to the power line, turn it on and then connect in with the measurement PC by using the USB cable. The necessary drivers will now be installed automatically. The front panel LED will blink orange at this stage. For more detailed information see Section 1.5.2 .
5. Start the LabOne User Interface UHF from the Windows Start Menu. The default Web Browser will open and show a start screen. The front panel LED turns from blinking orange to a steady blue.
6. Press the Default UI button on the lower right the UI. The default configuration loaded and the first measurements can be taken. In cases the device could not be found or the UI does not start at all, please be referred to Section 1.5.2 .

Once the Instrument is up and running we recommend to go through some of the tutorials given in Chapter 3 . Moreover, Chapter 4 provides a general Introduction to the various tools and settings tabs with tables in each section providing a detailed description of every UI element as well. For specific application know-how the **Blog section** [www.zhinst.com/blogs/] of the Zurich Instruments web page will serve as a valuable resource that is constantly updated and expanded.

Note

The responsiveness of web browser user interface can be rather slow and still consuming plenty of CPU power when graphical hardware acceleration is not enabled. On most computers the situation can easily be improved by either

- Go to the NVIDIA control panel. Select graphic processor. Apply.
- Control panel: Control Panel\Appearance and Personalization\Display\Screen Resolution. Advanced settings. Trouble shoot. Change settings. (Does not work with NVIDIA, with NVIDIA you need to use the NVIDIA control panel)

Some computers have two graphic chip sets installed, an Intel and a NVIDIA chip set. Activating the NVIDIA along with the accelaration is strongly recommended to achieve best possible performance. The only drawback changing these settings is a slightly increased power consumption.

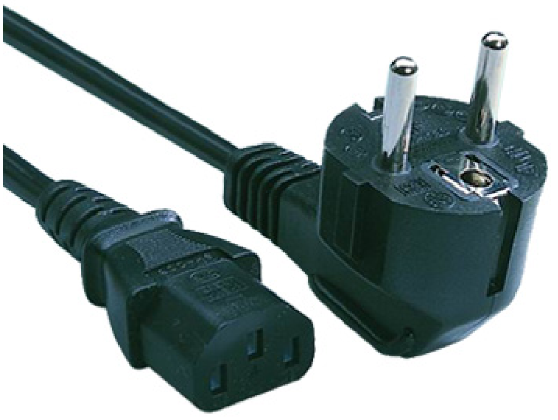
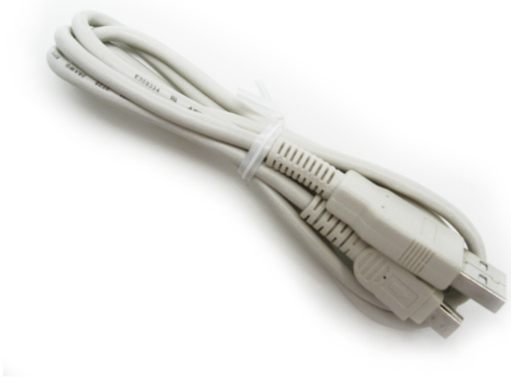
1.2. Inspect the Package Contents

If the shipping container appears to be damaged, keep the container until you have inspected the contents of the shipment and have performed basic functional tests.

Please verify:

- You have received 1 Zurich Instruments UHF Instrument
- You have received 1 power cord with a power plug suited to your country
- You have received 1 USB cable and/or 1 LAN cable (category 5/6 required)
- A printed version of the "Getting Started" section
- The "Next Calibration" sticker on the rear panel of the Instrument indicates approximately 2 years ahead in time. Zurich Instruments recommends calibration intervals of 2 years
- The MAC address of the instrument is displayed on a sticker on the back panel

Table 1.1. Package contents for the UHF Instrument

	
 the power cord (e.g. EU norm)	 the USB cable

 the power inlet, with power switch and fuse holder	 the LAN / Ethernet cable (category 5/6 required)
 the "Next Calibration" sticker on the back panel of your instrument	 the MAC address sticker on the back panel of your instrument

The UHF Instrument is equipped with a multi-mains switched power supply, and therefore can be connected to most power systems in the world. The fuse holder is integrated with the power inlet, and can be extracted by grabbing the holder with two finger nails (or small screwdrivers) at the top and at the bottom at the same time. A spare fuse is contained in the fuse holder. The fuse description is mentioned in the specification chapter.

Carefully inspect your Instrument. If there is mechanical damage or the amplifier does not pass the basic tests, then you should immediately notify the Zurich Instruments support team at `<support@zhinst.com>` .

1.3. Handling and Safety Instructions

The UHFLI is a sensitive electronic instrument which under no circumstances should be opened, as there are high-voltage parts inside which may be harmful to human beings. Moreover, there are no serviceable parts inside the instrument. Opening the instrument immediately cancels the warranty provided by Zurich Instruments.

The following general safety instructions must be observed during all phases of operation, service, and handling of the instrument. The disregard of these precautions and all specific warnings elsewhere in this manual may affect correct operation of the equipment and its lifetime.

Zurich Instruments assumes no liability for the user's failure to observe and comply with the instructions in this user manual.

Table 1.2. Safety Instructions

Ground the instrument	The chassis must be correctly connected to earth ground by means of the supplied power cable. Alternatively also the ground pin on the rear panel can be used. This avoids electrical shocks and potential damage to the instrument.
Maximum ratings	The specified electrical ratings for the connectors of the instrument should not be exceeded at any time during operation (please refer to section Section 5.1).
Do not service or adjust anything yourself	There are no serviceable parts inside the Instrument.
Software updates	Frequent software updates provide the user with many important improvements as well as new features. Only the last released software version is supported by Zurich Instruments.
Warnings	Instructions contained in any warning issued by the instrument, either by the software, the graphical user interface, or mentioned in this manual must be followed.
Notes	Instructions contained in the notes of this user manual are of essential importance for the correct interpretation of the acquired measurement data.
Location and ventilation	Keep and operate the Instrument in a dry location that suits the general specifications. Do not block the ventilator opening on the back or the air intake on the side of the chassis and allow a reasonable space for the air to flow.
RJ45 plugs	The two RJ45 plugs on the back panel labeled 'Peripheral ZCtrl' are not intended for Ethernet LAN connection. Connecting these plugs with an Ethernet device may damage the Instrument and/or the Ethernet device.
Operation and storage	Do not operate or store at a location outside the specified ambient conditions (please refer to section Section 5.3)

Handling	Do not throw the Instrument, handle with due care, do not store liquids on the device as there is a chance of spilling and damage.

When you notice any of the situations listed below, immediately stop the operation of the Instrument, disconnect the power cord, and contact the support team at Zurich Instruments, either through the website form or by email at `<support@zhinst.com>` .

Table 1.3. Unusual Conditions

Fan is not working properly or not at all	Switch off the Instrument immediately to prevent overheating of sensitive electronic components.
Power cord or power plug on instrument is damaged	Switch off the Instrument immediately to prevent overheating, electric shock, or fire. Please exchange the power cord with a quality product
Instrument emits abnormal noise, smell, or sparks	Switch off the Instrument immediately to prevent large damage.

1.4. Software Installation

The UHF Instrument is controlled entirely by a host computer that requires the software LabOne. For the software installation administrator rights are required; to run the instrument a regular user account is sufficient.

Note

It may also be necessary to perform a firmware upgrade on your UHF Instrument (necessary if performing a software update), see Section 1.6 .

1.4.1. Windows Installation

The installation packages for the Zurich Instruments software are available as Windows installer .msi packages. The software is available on the Zurich Instruments download portal at http://www.zhinst.com/downloads.

Proceed in the following order for installation:

1. Login on the website using the login and password provided by Zurich Instruments
2. Download the software package suitable to your operating system and processor architecture (32-bit or 64-bit).

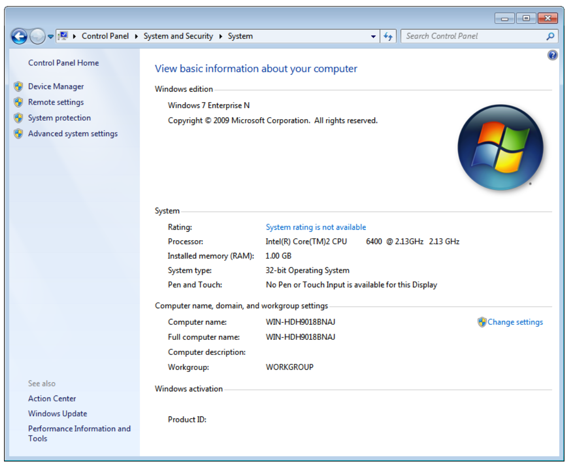
Important

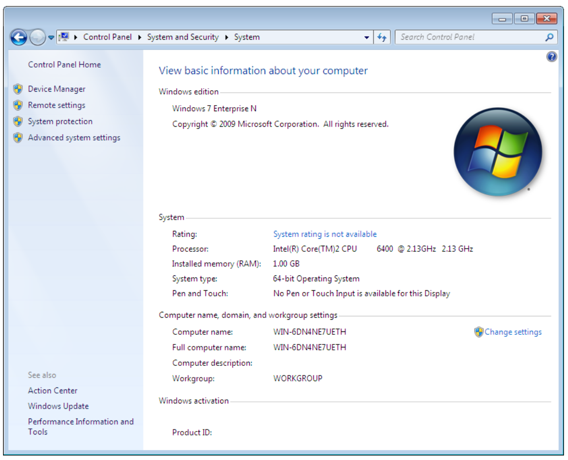
When downloading the software packages, please make sure that you download and install the software that is suited to the addressing mode (32-bit: x86, 64-bit: x64) of your operating system.

Zurich Instruments supports Microsoft Windows XP, Windows 7 and Windows 8 for both 32-bit and 64-bit processors. In case you are not sure which Windows architecture you are using, you can check that as follows:

- Windows 7: `Control panel -> System and Security -> System / System type`
- Windows 8: `Control panel -> System -> System / System type`

Table 1.4. Find out the OS addressing architecture (32-bit or 64-bit)





Windows 7 (32-bit: x86)	Windows 7 (64-bit: x64)

Windows .NET Framework Requirement

The Zurich Instruments software requires the Microsoft .NET Framework to be installed on the host computer. This is the case for 95% of the computers. The installation of LabOne will fail if this is not the case. It is possible to check the installation of the Microsoft .NET Framework under Windows Start → Control panel → Add and Remove Programs.

The minimum requirement is Microsoft .NET Framework 3.5 Service Pack 1.

In case the required version is not installed, it can be installed through Windows Update tool (Windows Start → Control panel → Windows Update).

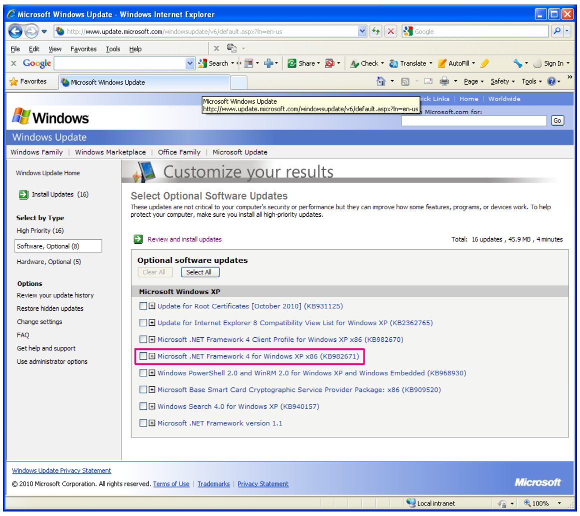


Figure 1.1. Installation of .NET Framework

Windows LabOne Installation

1. The UHF Instrument should not be connected to your computer during the LabOne software installation process
2. Start the `LabOne32/64-XX.XX.XXXXX.msi` LabOne installer program by a double click and follow the instructions. Please note that Windows Administrator rights are required for installation. The installation proceeds as follows:
   - On the welcome screen click the **Next** button

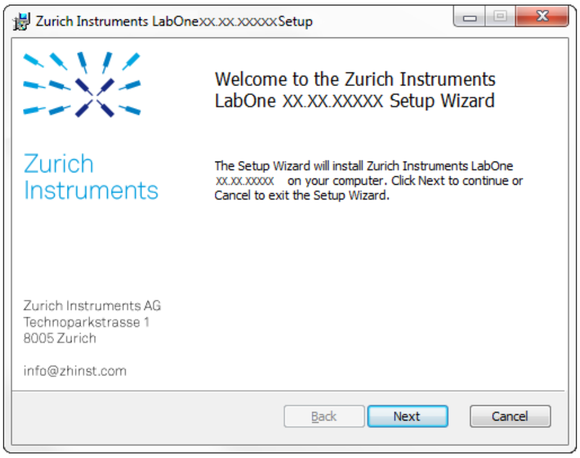


Figure 1.2. Installation welcome screen

- After reading through the Zurich Instruments license agreement, check the "I accept the terms in the License Agreement" check box and click the **Next** button
- Review the features you want to have installed. For UHF devices the `UHF Series Device` feature, the `Web Server` feature, and the `API` feature is required. If HF2 devices are used on the same PC it is important to keep the `HF2 Series Device` feature enabled as well. If you like to install shortcuts on your desktop area enable the feature `Desktop Shortcuts`. To proceed click the **Next** button

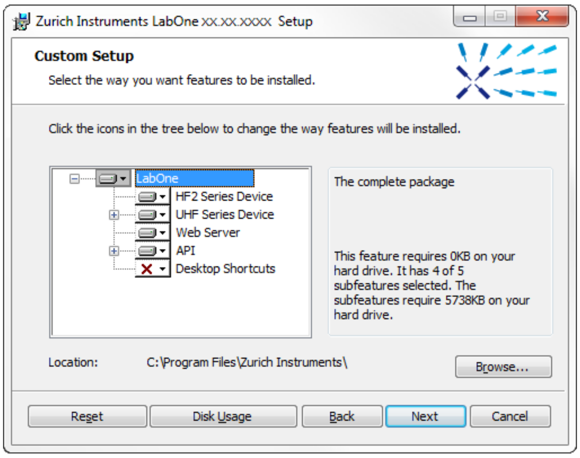


Figure 1.3. Custom setup screen

- Click the **Install** button to start the installation process
- Windows will ask up to two times to reboot the computer. Make sure you have no unsaved work on your computer. Actually a reboot is practically never required, so that one may safely press **OK**

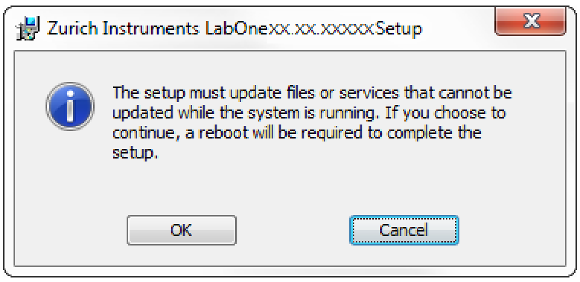


Figure 1.4. Installation reboot request

- On Windows Server 2008 and Windows 7 it is required to confirm the installation of up to 2 drivers from the trusted publisher Zurich Instruments. Click on **Install**

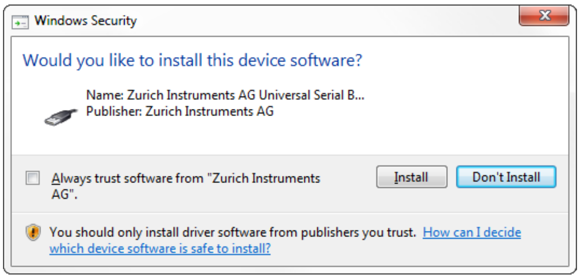


Figure 1.5. Installation driver acceptance

- Click **OK** on the following pretty obvious notification

Figure 1.6. Installation completion screen

3. Click **Finish** to close the Zurich Instruments LabOne installer

Warning

Do not install drivers from another source and therefore not trusted as originated from Zurich Instruments

1.4.2. Linux Installation

Requirements

Please ensure that the following requirements are fulfilled before trying to install the LabOne software package:

1. Officially, only Ubuntu 12.04 LTS (i386, amd64) is supported although in practice the LabOne package may work on other platforms. Please ensure that you are using a Linux distribution that is compatible with Ubuntu/Debian, but preferably Ubuntu 12.04 LTS.
2. You have administrator rights for the system.
3. The correct version of the LabOne installation package for your operating system and platform have been downloaded from the Zurich Instruments downloads page [http://www.zhinst.com/downloads] (login required):
   - LabOneLinux<arch>-<release>.<revision>.tar.gz, for example:

     ```
     LabOneLinux32/64-XX.XX.XXXXX.tar.gz
     ```

Please ensure you download the correct architecture (32-bit/64-bit) of the LabOne installer. The `uname` command can be used in order to determine which architecture you are using, by running:

```
uname -m
```

in a command line terminal. If the command outputs "`x686`" the 32-bit version of the LabOne package is required, if it displays "`x86_64`" the 64-bit version is required.

Linux LabOne Installation

Please proceed with the installation in a command line shell as follows:

1. Extract the LabOne tarball in a temporary directory:

   ```
   tar xzvf LabOneLinux<arch>-<release>-<revision>.tar.gz
   ```

2. Navigate into the extracted directory.

   ```
   cd LabOneLinux<arch>-<release>-<revision>
   ```

3. Run the install script with administrator rights and proceed through the guided installation, using the default installation path if possible:

   ```
   sudo bash install.sh
   ```

   The install script lets you choose between the following three modes:

   - Type "a" to install the Data Server program, documentation and APIs.
   - Type "u" to install `udev` support (only necessary if HF2 Instruments will be used with this LabOne installation, not for the UHF Lock-in Amplifier).
   - Type "ENTER" to install both options "a" and "u".

4. Test the installation by starting the Data Server (administrator rights required) and the Web Server:

   ```
   sudo ziDataServer
   ```

   ```
   startWebServerUHF
   ```

   and entering the address `127.0.0.1:8006` in a web browser to start the LabOne User Interface.

Uninstalling LabOne on Linux

The LabOne software package copies an uninstall script to the base installation path (the default installation directory is `/opt/zi/`). To uninstall the LabOne package please perform the following steps in a command line shell:

1. Navigate to the path where LabOne is installed, for example, if LabOne is installed in the default installation path:

   ```
   cd /opt/zi/
   ```

2. Run the uninstall script with administrator rights and proceed through the guided steps:

```
sudo bash uninstall_LabOne<arch>-<release>-<revison>.sh
```

1.5. Connecting to the UHF Instrument

After the LabOne software has been installed, the UHF instrument can be connected to a PC by using either the USB cable, the 1 Gbit/s (1GbE) Ethernet LAN cable or the 10 Gbit/s (10GbE) cable supplied with the instrument. Using the LAN connection is particularly straight forward when DHCP IP address allocation is activated in the network, e.g. by using a switch. Direct point-to-point connection can also be used. The 10GbE cable and module are only available when the associated option UHF-10G was purchased.

1.5.1. Controlling the instrument from the PC

Your Zurich Instruments lock-in amplifier can be accessed by several software clients simultaneously (LabOne User Interface clients and/or API clients), and also by several users accessing the same device from different computers. All clients access the instrument by means of the "LabOne Data Server UHF" program, a dedicated server that is in charge of all communication to and from the device.

1.5.2. LabOne Software Architecture

This section gives a brief overview on the software architecture of the LabOne software package. This will help to better understand the following chapters.

The software of Zurich Instruments lock-in amplifiers is server based. This allows for multiple clients to access devices with synchronized settings.

The Zurich Instruments LabOne software is organized in layers.

LabOne Software Layers

An overview of the software layers is shown in Figure 1.7 .

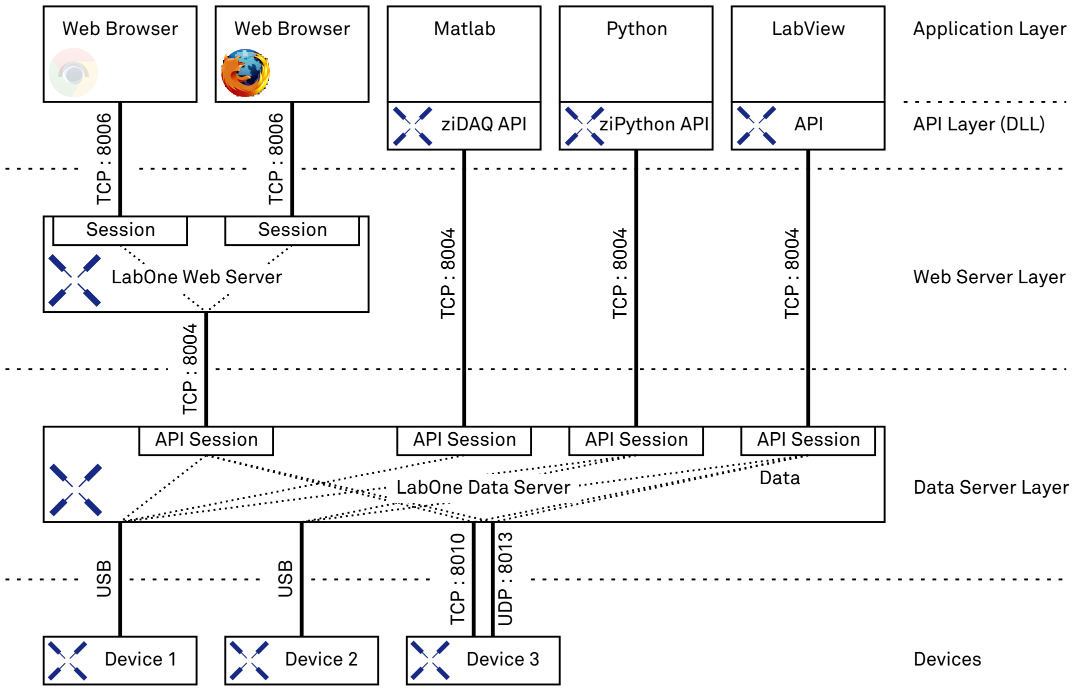


Figure 1.7. Software architecture

Each device is internally controlled by firmware (FW). If a software release offers new device functionality the device firmware may need an upgrade as well. Upgrading the firmware is described in detail in Section 1.6 .

The lowest layer running on the PC is the LabOne Data Server which is the interface to all the connected lock-in amplifiers. The middle layer consists of a LabOne Web Server which is the server for the web-browser-based LabOne User Interface. In addition to a user interface the device can be controlled by custom software or other applications over the API layer. The following sections explain the different layers and their functionality in more detail.

LabOne Data Server

The LabOne Data Server can control a single or also multiple lock-in amplifiers. The devices are connected over USB or Ethernet interfaces. An Ethernet connection to the instrument uses always both a TCP and UDP connection. The UDP connection will transmit the high bandwidth data as for instance demodulator samples or scope data. The LabOne Data Server will distribute the measurement data to all the clients that subscribe to it. It also ensures that settings changed by one client are transferred to other clients. The device settings are therefore synchronized on all clients. On a PC only one single instance of a LabOne Data Server should be started. If the server is configured to listen to other IP addresses than localhost it is possible to access measurement data from a different PC. The data access to the device must always be performed over the LabOne Data Server.

LabOne Web Server

The LabOne Web Server is an application dedicated to serving up the web pages that constitute the LabOne user interface. The LabOne Web Server supports multiple clients simultaneously. That is to say that more than one session can be used to view data and manipulate the instrument. A session could be running in a tab in a browser on the PC on which the LabOne software is installed. It could equally well be running in a tab of a browser on a remote machine. The user interface is touch enabled. Therefore, it is possible to use the LabOne User Interface on a mobile device like a tablet. The measurement data of the instrument can be viewed remotely from any device that has a browser and has access to the Web Server via the LAN. To connect the instrument, the user simply has to type the IP address or domain name of the computer running the LabOne web server together with the port number 8006. Examples are:

- `127.0.0.1:8006`
- `localhost:8006`
- `myPC.company.com:8006`

The most recent versions of the most popular browsers are supported: Chrome, Firefox, Internet Explorer, Safari and Opera.

LabOne API Layer

The lock-in amplifier can also be controlled via one or more of the Zurich Instruments provided APIs. APIs are currently provided in the form of DLLs for the following programming environments:

- MATLAB
- Python
- LabVIEW
- C

The instrument can therefore be controlled by an external program and the resulting data directly processed. The device can be concurrently accessed via one or more of the APIs and via the user interface. This enables easy integration into larger laboratory setups. See the LabOne programming manual for further information.

Using the APIs, the programmer has access to the same functionality that is available in the LabOne User Interface.

Controlling the Instrument via the LabOne User Interface

This section describes the LabOne User Interface startup. If the LabOne Software is not yet installed on the PC please follow the instructions in Section 1.4 Software Installation. If the device is not yet connected by USB or Ethernet please find more information in Section 1.5.3 Device Connectivity.

The most straight forward method to control and obtain data from the instrument is to use the LabOne User Interface, which can be found under the Windows Start Menu (see Figure 1.8): Click and select `Start Menu → Programs → Zurich Instruments → LabOne User Interface UHF`. This will open the User Interface in a new tab in your default web browser and start the

LabOne Data Server UHF and LabOne Web Server UHF programs in the background. A detailed description of the software structure is found in the Section 1.5.2 LabOne Software Architecture.

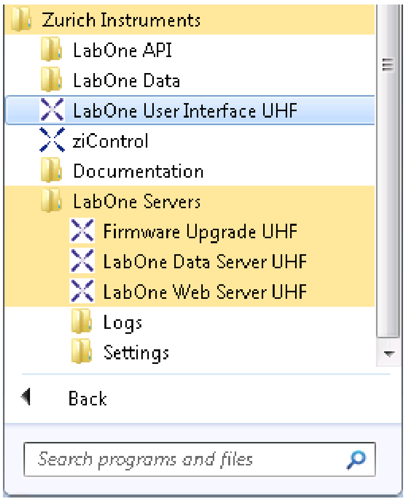


Figure 1.8. Windows Start Menu

The LabOne User Interface is an HTML5 browser-based program. This simply means that the user interface runs in a web browser and that a connection using a mobile device is also possible; simply specify the IP address (and port 8006) of the PC running the user interface.

Note

The user interface requires a so-called LabOne Web Server (that runs in combination with the LabOne Data Server). Instead of starting the user interface directly in your default browser as described above, it's possible to start the LabOne Data Server UHF and LabOne Web Server UHF programs independently and then connect via a browser of your choice:

1. Start the LabOne Data Server UHF and then the LabOne Web Server UHF program by selecting `Start Menu → Programs → Zurich Instruments → LabOne Servers → LabOne Data Server UHF` and `Start Menu → Programs → Zurich Instruments → LabOne Servers → LabOne Web Server UHF`.
2. In a web browser of your choice start the LabOne User Interface (graphical user interface) by entering the localhost address with port 8006 to connect to the LabOne Web Server: `127.0.0.1:8006`

Note

Zurich Instruments supports the most recent versions of the most popular browsers: Chrome, Internet Explorer, Opera, Firefox or Safari.

Note

By creating a shortcut to Google Chrome on your desktop with the Target `path\to\chrome.exe -app=http://127.0.0.1:8006` set in Properties you run the LabOne User Interface in Chrome in application mode which improves the user experience by removing the unnecessary browser controls.

Device And Settings Dialog

After starting the LabOne user interface software, a dialog is shown to select the device and settings for the session.

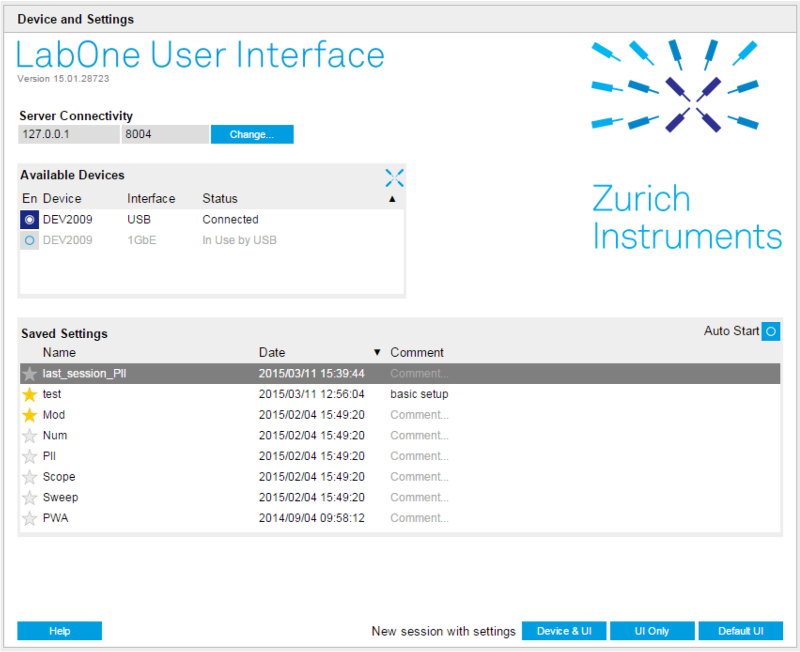


Figure 1.9. Dialog Device and Settings

The term session is used for an active connection between the user interface and the device. Such a session is defined by device-specific and user interface settings. Several sessions can be started in parallel. The sessions run on a shared LabOne Web Server. A detailed description of the software architecture can be found in Section 1.5.2 Software Architecture.

The following steps are required to start a new session

1. Select a LabOne Data Server. The default address `127.0.0.1:8004` uses the local server.
2. Select a device. If not connected the device will be connected at session start.
3. Select a setting file unless the default user interface is used.
4. Start the session by pressing **Device & UI**, **UI Only**, or **Default UI**

If there are no setting files listed starting the LabOne User Interface by pressing the button **Default UI** will start a session using factory defaults.

The following sections describe the steps in detail. If failures are detected further dialogs are shown.

Server Connectivity

The standard LabOne Data Server is expected under the localhost address `127.0.0.1` and port `8004`. Use the **Change...** button to connect to a different LabOne Data Server. If the LabOne Data Server is not accessible under the given address the dialog in Figure 1.10 will be shown to specify the address.

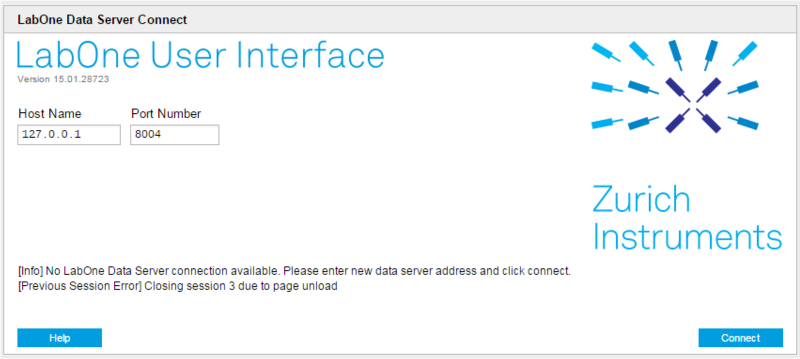


Figure 1.10. Dialog LabOne Data Server Connect

Available Devices

The Available Devices box is a list of visible devices. A device is ready for use if either marked free or connected.

The first column of the list is the **Connect** button. If the button is enabled the device is connected by the LabOne Data Server. In this case no other LabOne Data Server running on another PC can access the device. Only one interface and LabOne Data Server can access the device.

The second column indicates the device serial. A device may be listed multiple times if it supports several physical interfaces.

The third column indicates the interface. For UHF devices the interfaces USB, 1GbE, or 10GbE are available. The interface is listed if physically connected. The LabOne Data Server will scan for the available devices and interfaces every second. If a device has just been switched on or physically connected it may take up to 20s before it becomes visible to the LabOne Data Server. If an interface is physically connected but not visible please read Section 1.5.3 Device Connectivity.

The last column indicates the status of the device.

Device Status

Table 1.5 explains the meaning of the possible device status information.

Table 1.5. Device Status Information

Free	The device is not in use by any LabOne Data Server and can be connected by pressing the **Connect** button. If the device is selected a session can be started immediately without prior connecting. The session start will automatically connect the device.
In Use	The device is in use by a LabOne Data Server. As a consequence the device cannot be accessed by the specified interface. To access the device, a disconnect is needed.
Connected	The device is connected to the LabOne Data Server that the user is connected to. The user can start a session to work with that device.
Device needs FW upgrade	The firmware of the device is out of date. Please first upgrade the firmware. See Section 1.6 Upgrading the Lock-In Amplifier Firmware.

Device not yet ready	The device is visible and starting up. When the device is ready it will be flagged as free.

Messages

The LabOne Web Server will show additional messages in case of a missing component or a failure condition. These messages display information about the failure condition. The following paragraphs list these messages and give more information on the user actions needed to resolve the problem.

Lost Connection to the LabOne Web Server

In this case the browser is no longer able to connect to the LabOne Web Server. This can happen if the Web Server and Data Server run on different PCs and a network connection is interrupted. As long as the Web Server is running and the session did not yet time out, it is possible to just attach to the existing session and continue. Thus, within about 15 seconds it is possible with **Retry** to recover the old session connection. The **Reload** button opens the dialog Device and Settings shown in Figure 1.9 . An example of the connection lost dialog is shown below.

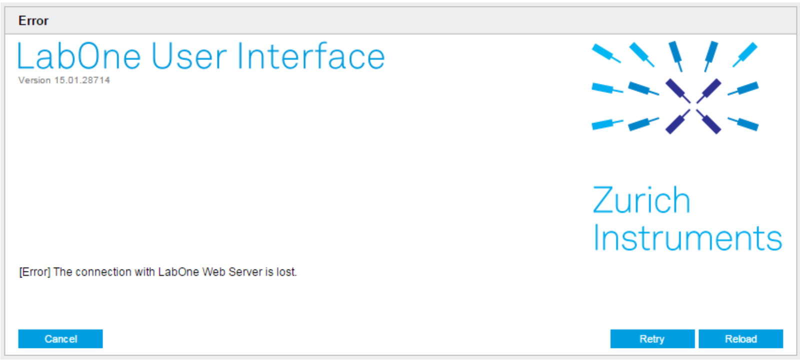


Figure 1.11. Dialog Connection Lost

Reloading...

If a session error cannot be handled the LabOne Web Server will restart and present a new Dialog Device and Settings as shown in the section called “Device And Settings Dialog” . During the restart a window is displayed indicating that the LabOne User Interface will reload. If reloading does not happen the same effect can be triggered by pressing F5 on the browser window. The figure below shows an example of this dialog.

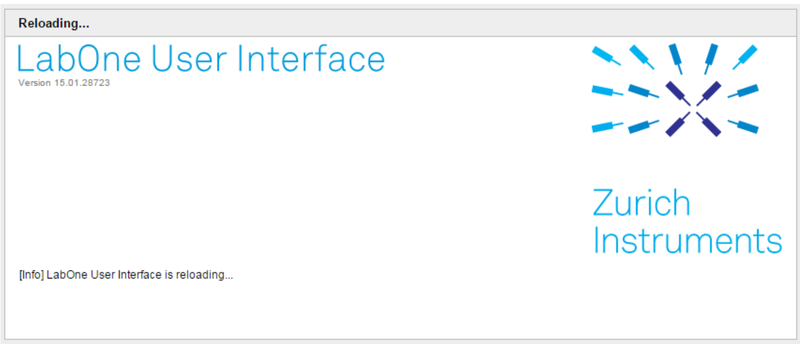


Figure 1.12. Dialog Reloading

No Device Discovered

An empty "Available Devices" list means that no devices were discovered in the network. In this situation the LabOne Data Server is running but failed to detect any devices. The device may be switched off or the interface connection fails. For more information on the USB and Ethernet interface between device and PC see Section 1.5.3 Device Connectivity.

Since a session requires an active connection, the start buttons are inactive.

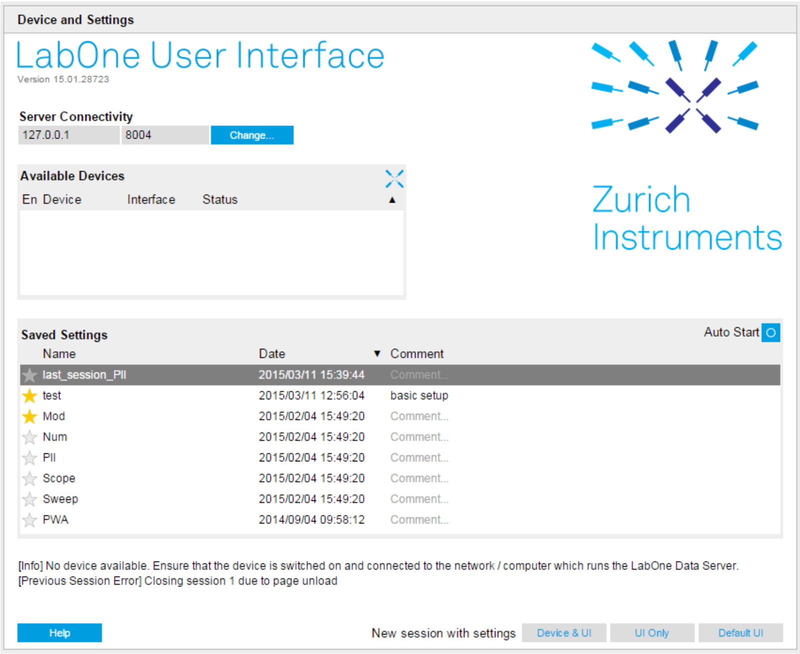


Figure 1.13. No Device Discovered

No device Available

If all the devices in the "Available Devices" list are shown grayed, this indicates that they are either in use by another Data Server, or need a firmware upgrade. For firmware upgrade see Section 1.6 . If all the devices are in use, access is not possible until a connection is relinquished by the another Data Server.

Since the session requires an active connection, the start buttons are inactive.

Device firmware upgrade needed

If a device needs a firmware upgrade, see Section 1.6 Upgrading the Lock-In Amplifier Firmware.

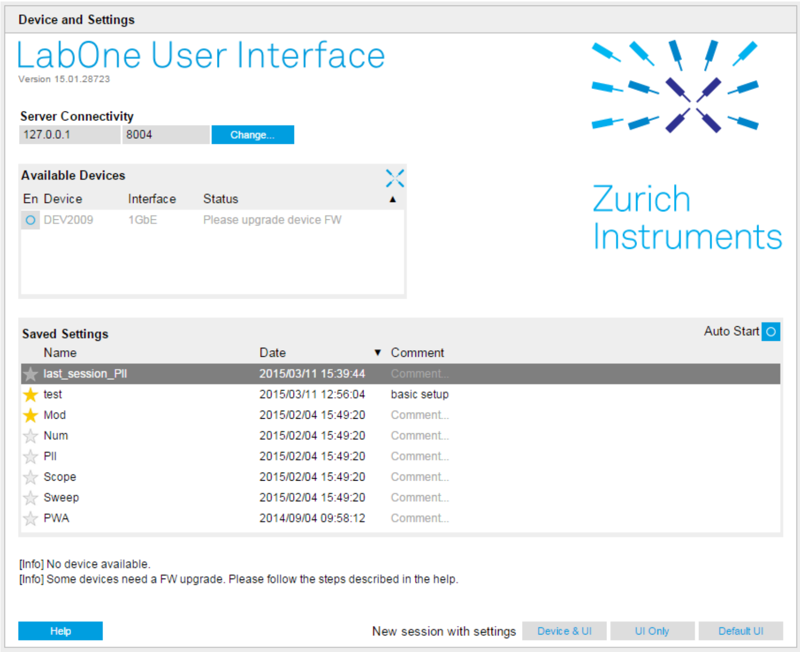


Figure 1.14. Message FW Upgrade Needed

Saved Settings

Settings files can contain both UI and device settings. UI settings control the structure of the LabOne User Interface e.g. the position and ordering of opened tabs. Device settings specify the set-up of a device. The device settings persist on the device until the next power off or until overwritten by loading another settings file.

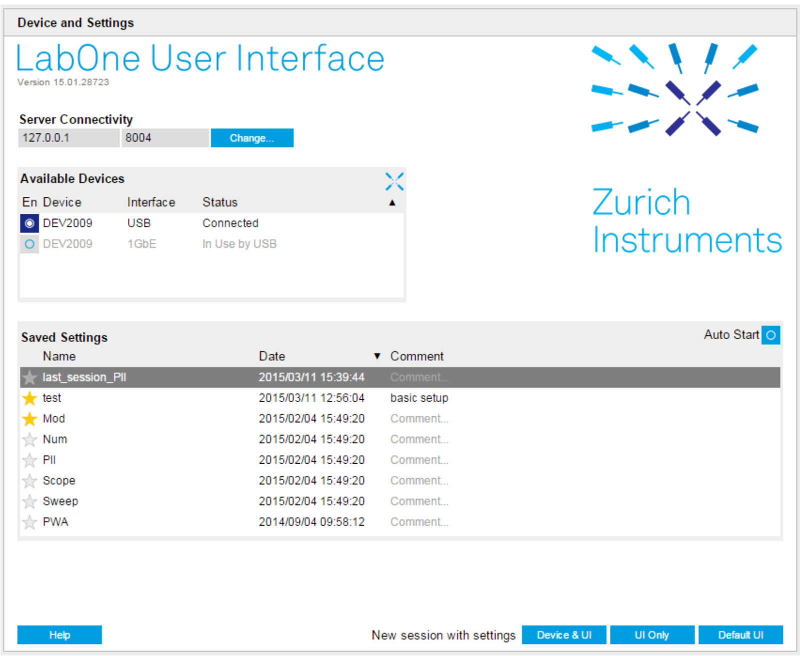


Figure 1.15. Dialog Device and Settings

The columns are described in Table 1.6 . The table rows can be sorted by clicking on the column header that should be sorted. The default sorting is by time. Therefore, the most recent settings are found on top. Sorting the favorite marker or setting file name may be useful as well.

Table 1.6. Column Descriptions

Star	Allows favorite settings files to be grouped together. By activating the stars adjacent to a settings files and clicking on the column heading, the chosen files will be grouped together at the top or bottom of the list accordingly. Subsequent clicks will toggle between the top and bottom of the list. The favorite marker is saved to the settings file. When the LabOne user interface is started next time, the row will be marked as favorite again.
Name	The name of the settings file. In the file system, the file name has the extension .xml.
Date	The date and time the settings file was last written.
Comment	Allows a comment to be stored in the settings file. By clicking on the comment field a text can be typed in which is subsequently stored in the settings file. This comment is very useful to describe the specific conditions of a measurement. The comment can be added at any time.

Special Settings Files

Certain file names can be observed with the prefix "last_session_". Such files are created automatically by the LabOne Web Server when a session is terminated either explicitly by the user, or under critical error conditions, and save the current UI and device settings. The prefix is prepended to the name of the most recently used settings file. This allows any unsaved changes to be recovered upon starting a new session.

If a user loads such a last session settings file the "last_session_" prefix will be cut away from the file name. Otherwise, there is a risk that an auto-save will overwrite a setting which was saved explicitly by the user.

The settings file with the name "default_ui" also has special meaning. As the name suggests this file contains the default UI settings. See button description in Table 1.7 .

Table 1.7. Button Descriptions

Device & UI:	The Device and UI settings contained in the selected settings file will be loaded.
UI Only:	Only the UI settings contained in the selected settings file will be loaded. The device settings remain unchanged.
Default UI:	Loads the default LabOne UI settings. The device settings remain unchanged.
Auto Start:	Skips the session dialog at startup if selected device is available. The default UI settings will be loaded with unchanged device settings.

Note

The factory default UI settings can be customized by saving a file with the name "default_ui" in the Config tab once the LabOne session has been started and the desired UI setup has been established. If a "default_ui" setting file exists, pressing the button **Default UI** loads it instead of the factory default. To use factory defaults again, the "default_ui" file must be removed from the user setting directory.

Note

The user setting files are saved to an application specific folder in the user directory structure. On Windows, the folder can be opened in a file explorer by following the link in the Windows Start Menu: Click and select `Start Menu → Programs → Zurich Instruments → LabOne Servers → Settings`.

Note

Double clicking on a device row in the Available Devices block is a quick way of starting the default LabOne UI. This action is equal to selecting the desired device and pressing the **Default UI** button.

Double clicking on a row in the Saved Settings block is a quick way of loading the LabOne UI with the those device and UI settings. This action is equal to selecting the desired settings file and pressing the **Device & UI** button.

1.5.3. Device Connectivity

There are several ways to connect to the Zurich Instruments lock-in amplifier from a host computer. The device can either be connected by Universal Serial Bus (USB) or by Ethernet. The USB connection is a point to point connection between the device and the PC on which the Data Server runs. The Ethernet connection can be a point to point connection or an integration of the device into the global network (LAN). Depending on the network configuration and the installed network card, one or the other connectivity is better suited. This section gives a brief introduction to different methods.

If a device is connected to a network multiple PCs can access the same device. However, there is no shared device access possible at the same time. To control the access to a device two different connectivity states are needed: visible and connected.

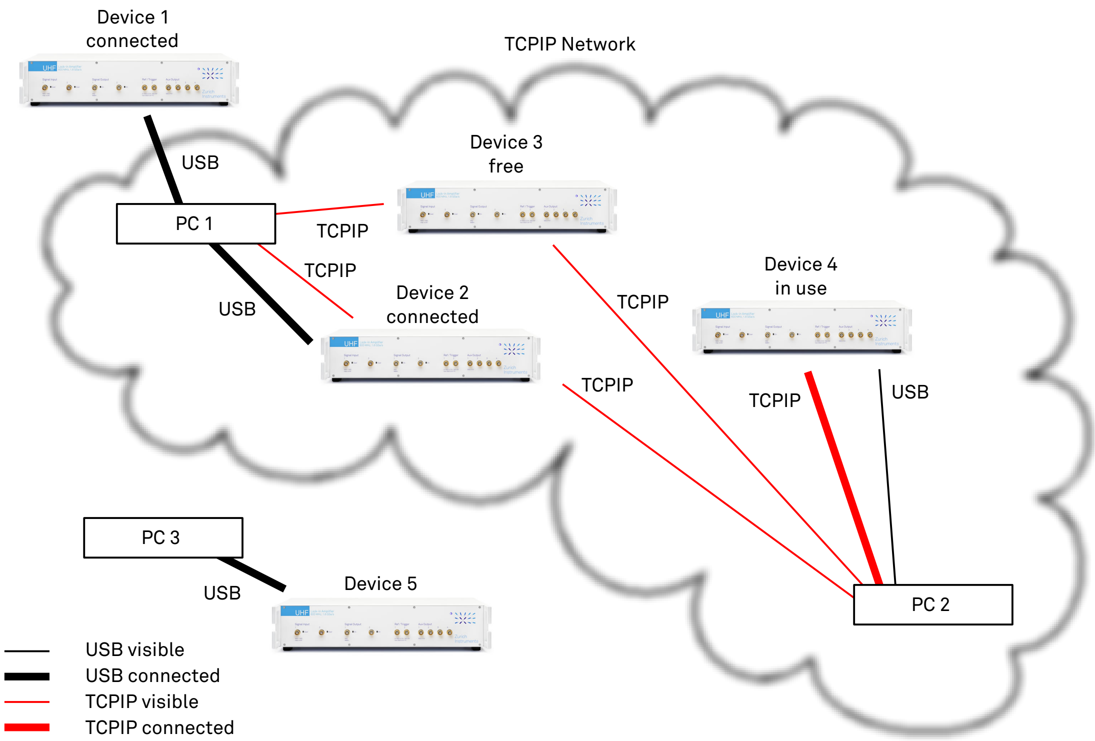


Figure 1.16. Connectivity

Figure 1.16 shows some examples of possible configurations of PC to device connectivity.

- Server on PC 1 is connected to device 1 (USB) and device 2 (USB).
- Server on PC 2 is connected to device 4 (TCPIP).
- Server on PC 3 is connected to device 5.
- The device 3 is free and visible to PC 1 and PC 2 over TCPIP.
- Both device 2 and device 4 are accessible by TCPIP and USB interface. Only one interface is logically connected to the server.

It is important to distinguish if a device is just physically connected over USB or Ethernet or actively controlled be the LabOne Data Server. In the first case the device is visible to the LabOne Data Server. In the second case the device is connected (logically).

Visible Devices

A device is visible if the Data Server can identify it. On a TCPIP network several PCs running a Data Server will detect the same device as visible. If a device is once discovered, the server might initiate a connection to access the device and stream measurement data. Only one single connection is allowed at the time.

Connected Device

Once connected to a device, the Data Server has exclusive access to data of that device. If another Data Server from another PC already has an active connection to the device, the device is still visible but cannot be connected by a second PC.

It should be note here that although a Data Server has exclusive access to a connected device, multiple browser and API client sessions still have simultaneous access and control over the device. Therefore changes made to the settings of a device by say a Python session via the programming API will be seen by a browser session connected to that device. The device data can be streamed to multiple client sessions simultaneously.

Universal Serial Bus (USB) Connection

To control the device over USB, connect the instrument with the supplied USB cable to the PC on which the LabOne Software is installed. The USB driver needed for controlling the device is included in the LabOne Installer package. Ensure that the device uses the latest firmware. The software will automatically use the USB interface for controlling the device if available. If the USB connection is not available, the Ethernet connection may be selected. It is possible to enforce or exclude a specific interface connection.

Note

To use the device exclusively over the USB interface modify the shortcut of the LabOne User Interface UHF and LabOne Data Server UHF in the Windows Start menu. Right-click and go to Properties, then add the following command line argument to the Target LabOne User Interface UHF: `--interface-usb true --interface-ip false`

Device Discovery USB

Devices connected over USB can be automatically connected by the Data Server as there is only a single host PC to which the device interface is physically connected.

auto-connect = on

This is the default behavior. If a device is attached via a USB cable, a connection will be established automatically.

auto-connect = off

To disable automatic connection via USB, add the following command line argument when starting the Data Server: `--auto-connect=off`

This is achieved by right clicking the LabOne Data Server shortcut in the Start menu, selecting "Properties" and adding the text to the Target field as shown in Figure 1.17 .

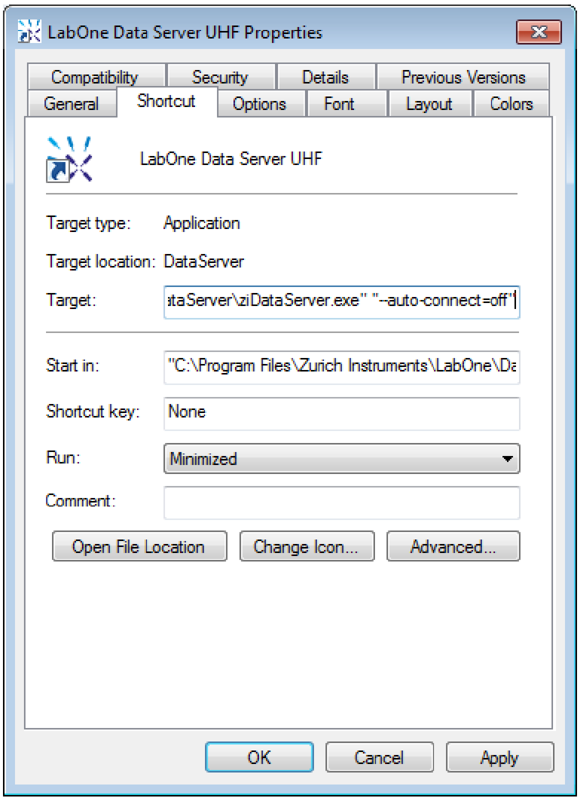


Figure 1.17. auto-connect

Device Discovery TCP/IP 1GbE

Various methods are possible for connecting to the device via TCP/IP.

- multicast DHCP (simplest method)
- Multicast point to point (P2P)
- Static IP

The sample transfer performance of different connections varies greatly. Generally it can be stated that a point-to-point connection will lead to larger transfer rates compared to a network-based connection, at the expense of more complexity in the connection.

For very high sample transfer rates, one must consider advanced network configurations that might be in contradiction with the local policies, e.g. the enabling of Jumbo frames.

Note

To use the device exclusively over the Ethernet interface, modify the shortcut of the LabOne User Interface UHF and LabOne Data Server UHF in the Windows Start menu. Right-click and go to Properties, then add the following command line argument to the Target field: `--interface-usb false --interface-ip true`

Multicast DHCP

The most straightforward Ethernet connection method is to rely on a LAN configuration to recognize the UHF Instrument. By connecting the instrument in a LAN, a dynamic IP address will be assigned like any other PC by the DHCP server. In case of restricted networks, the network administrator may be required to register the device on the network by means of the MAC address. The MAC address is indicated on the back panel of the instrument. The Zurich Instruments software (LabOne Data Server) will detect the device in the network by means of a multicast.

If the network configuration does not allow or does not support multicast, or the host computer has other network cards installed, it is necessary to use a static IP setup as described below. The UHF Instrument is configured to accept the IP address from the DHCP server, or to fall back into IP address `192.168.1.10` if it does not get the address from the DHCP server.

Requirements

- Network supports multicast (especially router)

Multicast Point to Point (P2P)

When you have two LAN cards installed in your host computer, one of which is used for network connectivity (e.g. internet), the other can be used for a direct connection to the UHF Instrument. Notebooks can generally profit from wireless LAN for network connectivity. It is important to note that if you set a static IP on your host computer you may lose the connection to the internet.

1. Use one of the network cards and set it to static IP in TCP/IPv4 using the following IP address and mask (go to `Control Panel` → `Internet Options` → `Network and Internet` → `Network and Sharing Center` → `Local Area Connection` → `Properties`). Note that the IP address of the PC should be `192.168.1.n`, where n=[2..9] and the mask should be `255.255.255.0`. The device itself will use the fall-back address `192.168.1.10` if it doesn't get the address.

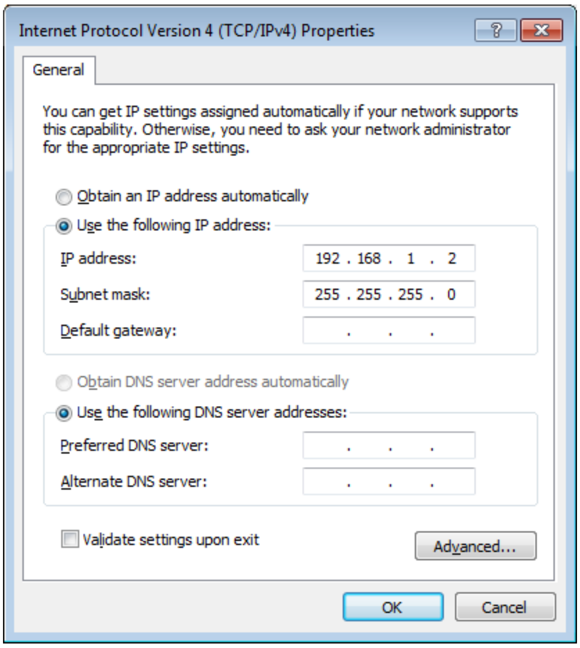


Figure 1.18. Static IP configuration

Requirements

- Two networks cards needed for additional connection to internet
- Network adapter (NIC) of PC supports multicast
- Network adapter connected to the device must be in static IP4 configuration

Note

A power cycle of the UHF Instrument is required if it was previously connected to a network that provided a IP address to the instrument and then the user decides to run in static IP configuration.

Note

Only IP v4 is currently supported. There is no support for IP v6.

Warning

Changing the IP settings of your network adapters manually can interfere with its later use, as it cannot be used anymore for network connectivity until it is set again for dynamic IP.

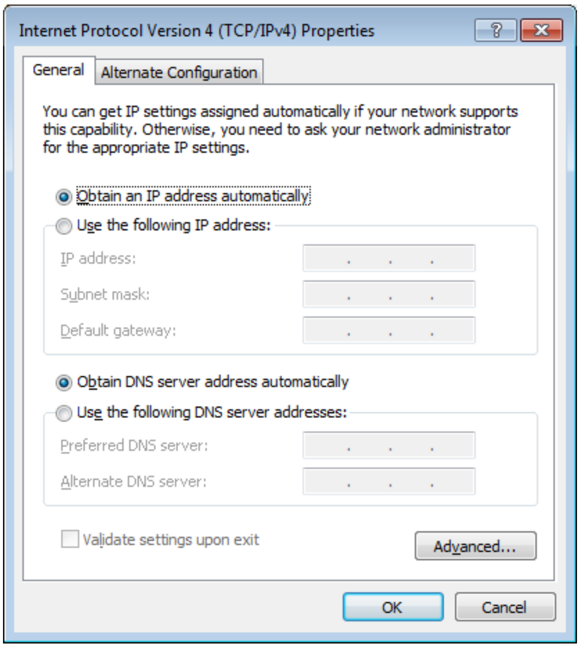


Figure 1.19. Dynamic IP configuration

Static IP

1. Connect the Ethernet port of the static IP configured network card to the 1GbE port on the back panel of the UHF Instrument
2. Modify the shortcut of the LabOne User Interface UHF and LabOne Data Server UHF in the Windows Start menu. Right-click and go to Properties, then add the following command line argument to the Target field: `--device-ip 192.168.1.10`.

The LabOne User Interface UHF shortcut Target field should look like this:

```
"C:\Program Files\Zurich Instruments\LabOne\WebServer\ziWebServer.exe"
--auto-start=1 --server-port=8004 --resource-path "C:\Program Files
\Zurich Instruments\LabOne\WebServer\html\\" --device-ip 192.168.1.10
```

The LabOne Data Server UHF shortcut Target field should look like this:

```
"C:\Program Files\Zurich Instruments\LabOne\DataServer
\ziDataServer.exe" --device-ip 192.168.1.10
```

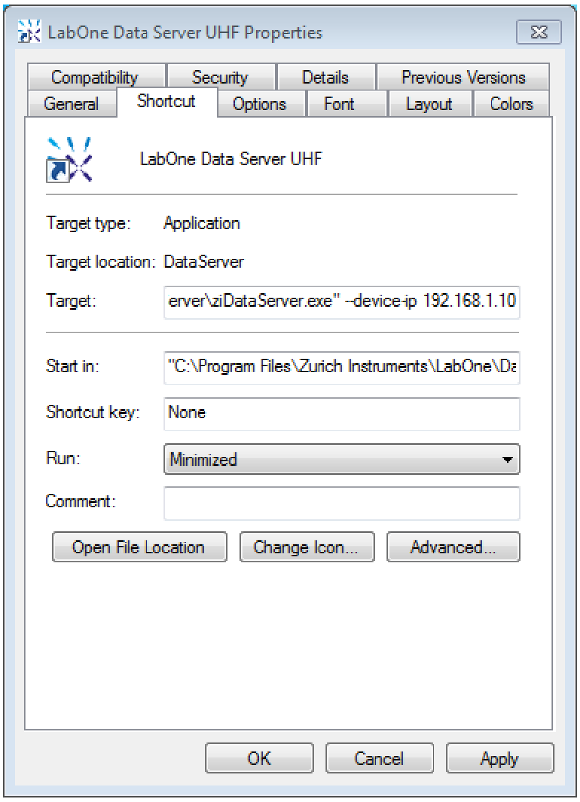


Figure 1.20. Static IP shortcut modification

3. (Optional) To verify the connection between the host computer and the UHF Instrument, open a DOS command window and ping the IP address entered above

Requirements

- Device IP must be known
- Needs network administrator support on networks with dynamic IP configuration

Device Discovery TCP/IP 10GbE (UHF-10G)

The 10GbE interface is a hardware option UHF-10G for the Zurich Instruments UHFLI. It is possible to upgrade any UHFLI with this option.

The UHF-10G option consists of following components.

- PCIe card 10 Gigabit XF SR Server Adapter

- Cisco X2-10GB-SR module
- 5m multi-mode fiber optic patch cord
- 10G option code `XXXXXXXX-XXXXXXXX-XXXXXXXX-XXXXXXXX-XXXXXXXX-XXXXXXXX-XXXXXXXX-XXXXXXXX-XXXXXXXX`

Hardware Installation

1. Install the PCIe card in the PC. The card must be inserted into a x8 or x16 PCIe slot.
2. If the option is bought after delivery of the instrument: Turn the UHF device off and disconnect it from the power source. Unscrew the 10GbE cover. Carefully insert the module with the heat sink facing up. Make sure that the module is snapped in. A click should be noticeable.
3. Remove the protectors from both ends of the fiber cable.
4. Carefully connect the cable.

The physical link can be checked after programming the UHF-10G feature code as described in the next section.

Software Setup

The optical 10GbE interface is a point to point network. Therefore the network card should be setup as explained in the section called “Multicast Point to Point (P2P)” . The default 10GbE address is `192.168.2.10`. Hence the following static IP of the PC should be selected `192.168.2.n` where n=[2..9]. The network mask should be `255.255.255.0`.

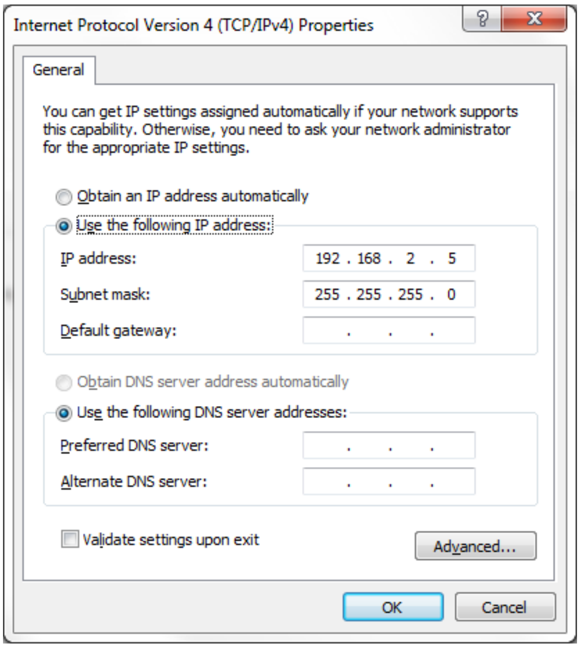


Figure 1.21. 10GbE IP configuration

The 10GbE network connection to the device creates high CPU load on the PC due to the high bandwidth of measurement data. It is thus essential that the network card is configured so that CPU load is optimized. The setting with highest impact is the enabling of Jumbo frames. Since the processor processes larger packages, the interrupt load will decrease. Therefore the 10GbE should always be used with Jumbo frames enabled. As the network is a P2P connection there is no side effect on other network devices.

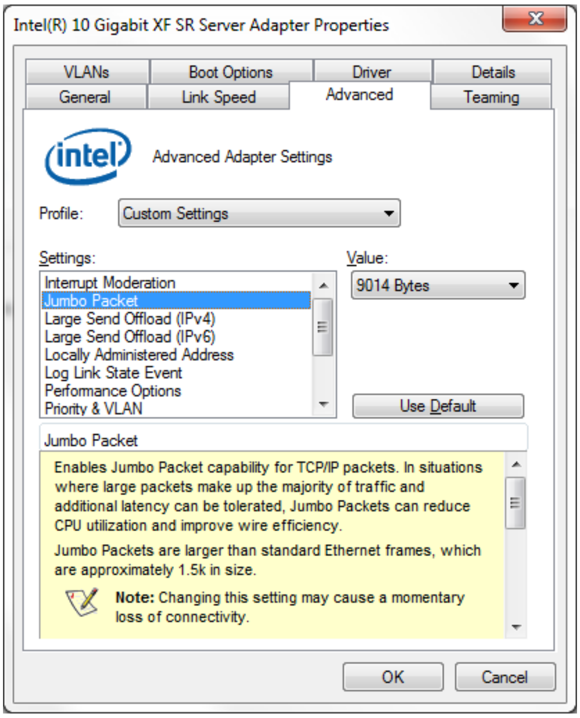


Figure 1.22. Advanced 10GbE network card configuration

The following settings should be configured on the advanced 10GbE network card.

- Interrupt Moderation: Enabled
- Jumbo Packet: 9014 Bytes
- Large Send Offload (IPv4): Enabled
- Receive Side Scaling: Enabled
- Receive Side Scaling Queues: 4 Queues
- TCP/IP Offloading Options: All Enabled

The UHF instrument must have the UHF-10G option installed. The option key will be supplied when the option is bought. If not already installed on delivery, a USB or 1GbE connection is needed to the device to program the UHF-10G option. The programming can be performed with the LabOne User Interface in the device tab. After option programming a device restart is needed. If the device is enabled, the UHF-10G option programmed, and the hardware installed, the link status can be checked in the Intel 10 Gigabit XF SR Server Adapter Properties window by opening the sub tab Link Speed. The link status should be green at 10Gbps/Full Duplex.

After UHF instrument restart, the 10GbE interface should be available, see the the section called “Device And Settings Dialog” .

Note

If a 10GbE network card is enabled, the multicast will be sent over that interface. As a consequence other devices connected to the 1GbE network will not be visible anymore. The access the device over 1GbE the 10GbE interface should be temporarily disabled.

Note

Once the device is running the connectivity can be checked with the link flag visible in the network card configuration.

1.6. Upgrading the Lock-In Amplifier Firmware

The LabOne software consists of both software that runs on your PC and software that runs on the UHF Lock-in Amplifier itself. In order to distinguish between the two, the later will be referred to as firmware for the rest of this document. When upgrading to a new software release, it's also necessary to upgrade the UHF firmware. If the device firmware is out of date and needs an upgrade, this is indicated in the Device and Settings Dialog of the LabOne user interface. See the section called “Device And Settings Dialog” .

1.6.1. Preparation

In order to upgrade the UHF firmware, you must first take the following steps:

1. Download and install the appropriate version (32bit/64bit) of the LabOne software on your PC. Administrator rights are necessary for the software installation. Please see Section 1.4 Software Installation.
2. Either start the UHF Lock-in Amplifier or, if the UHF was already running, switch off and restart the UHF Lock-in Amplifier.
3. Connect the UHF to the PC with the LabOne installation via USB cable.

1.6.2. Starting the UHF Firmware Upgrade Utility

The UHF Firmware Upgrade Utility is the program used to perform a UHF firmware upgrade, it is a GUI (Graphical User Interface) included in the standard LabOne installation.

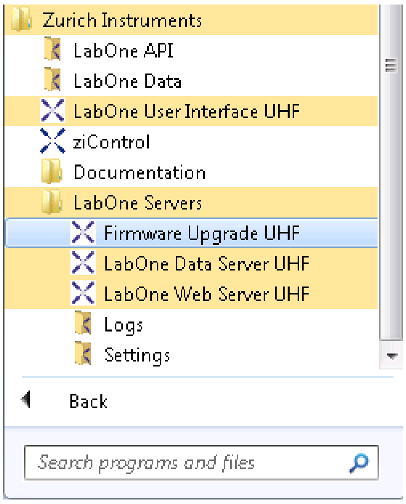


Figure 1.23. Starting the Firmware Upgrade Utility via the Windows Start Menu

To start the Firmware Upgrade Utility:

Click and select `Start Menu` → `All Programs` → `Zurich Instruments` → `LabOne Servers` → `Firmware Upgrade UHF`.

Note

It's not necessary to have administrator rights in order to start or use the UHF Firmware Upgrade Utility.

Important

Do not disconnect the USB cable to the UHF or power-cycle the UHF whilst performing any of the following steps.

Upon starting the Firmware Upgrade Utility it should detect the device that is connected to the PC via USB. The device ID is displayed next to "Device:".

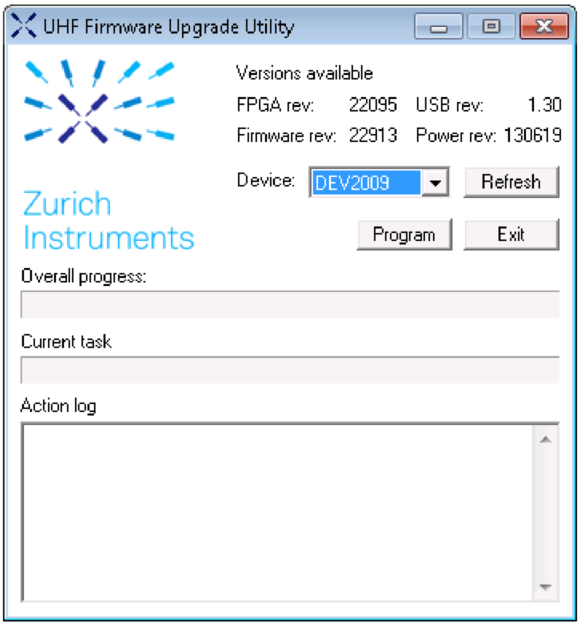


Figure 1.24. The UHF Firmware Upgrade Utility upon start-up

Select the device you would like to upgrade

Select which device you would like to upgrade via the pull-down menu. If no device is listed, please try the following steps:

1. Ensure that the USB cable is properly connected.
2. Try power-cycling the device.
3. Click the **Refresh** button.

Program the firmware of the connected device

Click the **Program** button to check the version of the current firmware and install the new firmware on the device.

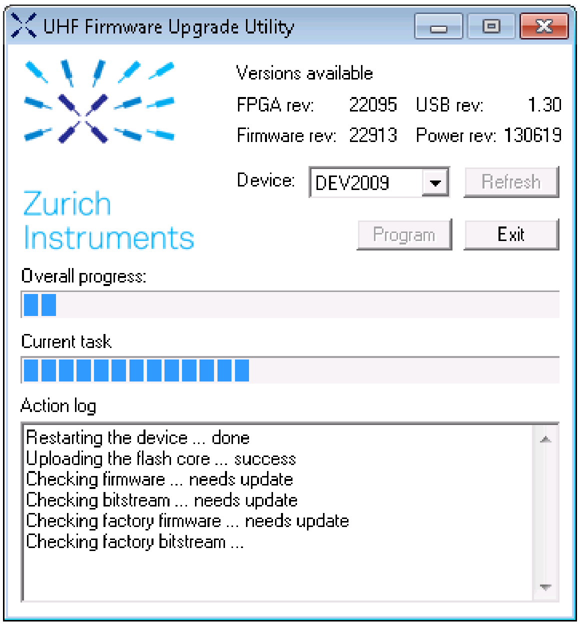


Figure 1.25. Verifying the UHF firmware version

Important

After clicking Program and the upgrade is finished it is always necessary to power-cycle the UHF to resume normal operation, even if the firmware was previously up-to-date.

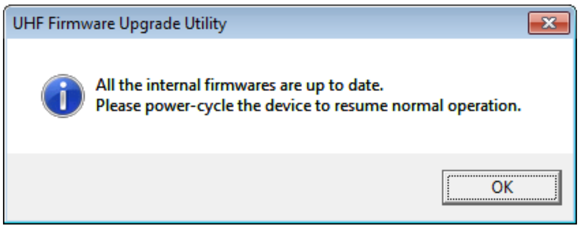


Figure 1.26. Pop-up Box indicating successful installation of the new firmware

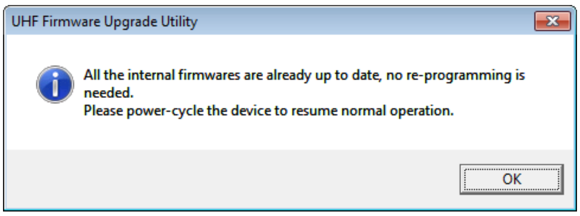


Figure 1.27. Pop-up Box indicating that the firmware was already up-to-date

Close the UHF Firmware Upgrade Utility

Click the **Exit** button to close the UHF Firmware Upgrade Utility.

If you encounter any issues whilst upgrading the UHF firmware, please contact Zurich Instruments at support@zhinst.com.

1.7. Troubleshooting

1.7.1. List of trouble issues

This section provides an easy to follow checklist and specific solution to the most common technical issues with the UHFLI. Also keep this list in mind to avoid wrongly acquired measurement data.

The software cannot be installed or uninstalled: please verify you have Windows administrator rights.

The Instrument does not turn on: please verify the power supply connection, the power-on switch on the back panel of the instrument.

The Instrument has a very high input noise floor (when connected to host computer by USB): the USB cable connects the Instrument ground to computer ground, which might cause crosstalk from computer noise to measurements results. For situations where this is a problem, it is recommended to use LAN (if available) connection instead of USB, or achieve electrical isolation with the USB Ranger 2211 from Icron Technologies. In-house test has shown that by using the USB Ranger 2211 for USB connection between the PC and the Instrument , no USB switching activities on the PC can be detected on the measured noise floor. The ground connection between the PC and the Instrument will be high impedance with this solution.

The Instrument performs poorly at low frequencies (below 160 kHz with 50Ω or below 100 Hz with 1 MΩ coupling): the signal inputs of the instrument might be set to AC operation. Please verify to turn-off the AC switch on the user interface.

The Instrument performs poorly during operation: the demodulator filters might be set too wide (too much noise) or too narrow (not enough signal) for your application. Please verify if the demodulator filter settings match your frequency versus noise plan.

The Instrument performs poorly during operation: clipping of the input signal may be occurring. This is detectable by monitoring the red LEDs on the front panels or on the status tab on the graphical user interface. This can be avoided by adding enough margin on the input range setting (for instance 50% to 70% of the maximum signal peak.

The Instrument performs strangely when working with the multi-frequency (MF) options: it is easy to turn-on more signal generators than initially planned. Check the generated Signal Output with the integrated oscilloscope and check the number of simultaneously activated oscillator voltages.

The Instrument performs close to specification, but higher performance is expected: after 2 years since the last calibration, a few analog parameters are subject to drift. This may provoke inaccurate measurements. Zurich Instruments recommends to re-calibrate the Instrument every 2 years.

The Instrument measurements are unpredictable: please monitor the status tabs if any of the warning is occurring or has occurred in the past.

The Instrument does not generate any output signal: verify that signal output switch has been activated the related control panel.

The Instrument locks poorly using the digital I/O as reference: make sure that the digital input signal has a high slew rate and clean level crossings.

The Instrument locks poorly using the auxiliary analog inputs as reference: the input signal amplitude might be too small. Use proper gain setting of the input channel.

The sample stream from the Instrument to the host computer is not continuous: check the sample loss and the packet loss flags. The sample loss flag indicates occasional sample loss due to sampling rate set to high (the instruments sends more samples than the interface and the host computer can absorb. Reduce the sample rate settings. The packet loss indicates an important failure of the communications to the host computer and compromises the behavior of the instrument. Reduce the sample rate settings.

The Instrument is connected but no communication to the computer is happening: check the clock fail flag. This abnormal situation needs to be detected, a clock must be fed to the Instrument is external clock is selected. If internal clock source is selected and the flag is still active, then the situation might indicate a serious hardware failure: in this case contact Zurich Instruments support team at `<support@zhinst.com>` .

The user interface does not start or starts but remains idle: verify that the ziServer (HF2 Instrument), LabOne Data Server UHF and LabOne Web Server UHF (UHF Instrument) have been started and are running on your host computer.

The user interface is slow and the web-browser process consumes a lot of CPU power, when the graphical hardware acceleration is disabled. Make sure that the hardware acceleration is enabled for the web browser that is used for the user interface. For the Windows operating system, the hardware acceleration can be enabled in Control Panel\Display\Screen Resolution. Go to Advanced Settings and then Trouble Shoot. In case you use a NVIDIA graphics card, you have to use the NVIDIA control panel. Go to Manage 3D Settings, then Program Settings and select the program that you want to customize.

1.7.2. Location of the log files

For Windows 8 and Windows 7 the log files are located in the following directories:

- LabOne Data Server: `C:\Users\[USER]\AppData\Local\Temp\Zurich Instruments\LabOne\ziDataServerLog`
- LabOne Web Server: `C:\Users\[USER]\AppData\Local\Temp\Zurich Instruments\LabOne\ziWebServerLog`
- ziServer (HF2 Instrument)
  - started by service: `C:\Windows\Temp\ziServerLog`
  - started manually: `C:\Users\[USER]\AppData\Local\Temp\ziServerLog`
- ziControl (HF2 Instrument): `C:\Users\[USER]\Documents\LabVIEW Data` and the file name is called `com.zhinst.ziControlStatusLog.txt`.

On Windows XP:

- LabOne Data Server UHF : `C:\Documents and Settings\[USER]\Local Settings\Temp\Zurich Instruments\LabOne\ziDataServerLog`
- LabOne Web Server UHF: `C:\Documents and Settings\[USER]\Local Settings\Temp\Zurich Instruments\LabOne\ziWebServerLog`
- ziServer (HF2 Instrument)
  - started by service: `C:\WINDOWS\Temp\ziServerLog`
  - started manually: `C:\Documents and Settings\[USER]\Local Settings\Temp\ziServerLog`

- ziControl (HF2 Instrument): `C:\Documents and Settings\[USER]\Documents\LabVIEW Data` and the file name is called `com.zhinst.ziControlStatusLog.txt`.

Chapter 2. Functional Overview

This chapter provides the overview of the features provided by the UHF Instrument. The first section contains the description of the graphical overview and the hardware and software feature list. The next section details the front panel and the back panel of the measurement instrument. The following section provides product selection and ordering support.

2.1. Features

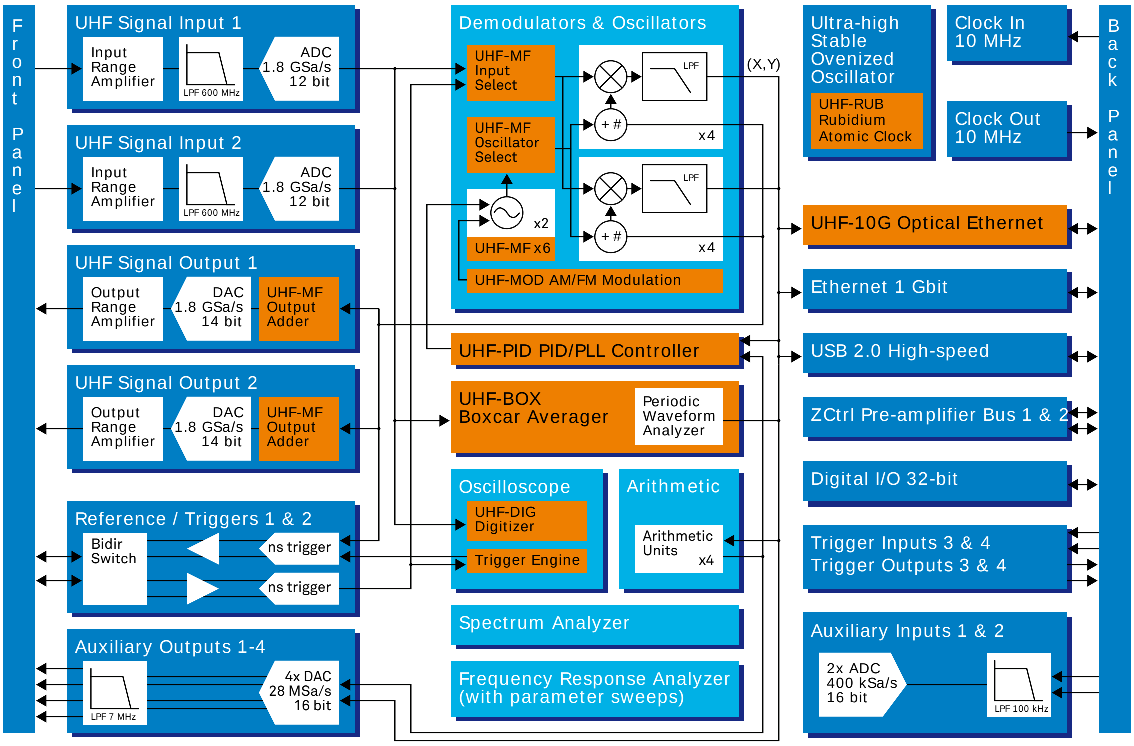


Figure 2.1. UHF Instrument overview

The UHF Instrument according to Figure 2.1 consists of several internal units (light blue color) surrounded by several interface units (dark blue color) and the front panel on the left-hand side and the back panel on the right-hand side. The orange blocks are optional units that can be either ordered at the beginning or upgraded later in the field (exceptions are mentioned in Section 2.5). The arrows between the panels and the interface units indicates the physical connections and the data direction flow. Only a very small subset of internal connections is depicted.

The signal of interest to be measured is often connected to one of the two UHF signal inputs where it is amplified to a defined range and digitized at very high speed. The resulting samples are fed into the digital signal processor consisting of up to 8 dual-phase demodulators. The output samples of the demodulators flow into one digital interface to be transferred to a host computer (LAN and USB interfaces) or are available on the auxiliary outputs on the front panel of the UHF Instrument.

The numerical oscillators generate sine and cosine signal pairs that are used for the demodulation of the input samples and also for the generation of the UHF output signals. For this purpose, the Output Adder can generate a linear combination of the oscillator outputs to generate a multi-frequency output signal: digital to analog conversion and signal scaling (range) are supported.

Hardware trigger and reference signals are used for various purposes inside the instrument, such as triggering demodulation, triggering oscilloscope data acquisition, or to generate external reference clocks or triggering signals to other equipment.

Lock-in Operating Modes

- Internal reference mode
- External reference mode

- Auto reference mode
- Dual-lock-in operation (two independent lock-in amplifiers in the same box)
- Triple-harmonic mode (simultaneous measurement at three harmonic frequencies)
- Arbitrary frequency mode (optional, simultaneous measurement at six arbitrary frequencies)

Ultra-high-frequency Signal Inputs

- 2 low-noise UHF inputs, single-ended, 600 MHz bandwidth
- Variable input range
- Switchable input impedance
- Selectable AC/DC coupling

Ultra-high-frequency Signal Outputs

- 2 low-distortion UHF outputs, single-ended, 600 MHz bandwidth
- Variable output range

Demodulators & Reference

- Up to 8 dual-phase demodulators
- Up to 8 programmable numerical oscillators
- Up to 2 external reference signals
- Up to 4 input and up to 4 output trigger signals
- Individually programmable demodulator filters
- 128-bit internal processing
- 64-bit resolution demodulator sample
- 48-bit internal reference resolution

Auxiliary Input and Outputs

- 4 auxiliary outputs, user defined signals
- 2 auxiliary inputs, general purpose

High-speed Connectivity

- USB 2.0 high-speed 480 Mbit/s host interface
- LAN 1 Gbit/s controller interface
- DIO: 32-bit digital input-output port
- ZCtrl: 2 ports peripheral control
- Clock input connector (10 MHz)
- Clock output connector (10 MHz)

Extensive Time and Frequency Domain Analysis Tools

- Numeric tool
- Oscilloscope
- Frequency response analyzer
- FFT spectrum analyzer
- ZoomFFT spectrum analyzer

- Spectroscope
- SW trigger

Software Features

- Web-based, high-speed user interface with multi-instrument control
- Data server with multi-client support
- API for C, LabVIEW, MATLAB, Python based instrument programming

2.2. Front Panel Tour

The front panel BNC connectors and control LEDs are arranged as shown in Figure 2.2 and listed in Table 2.1 .

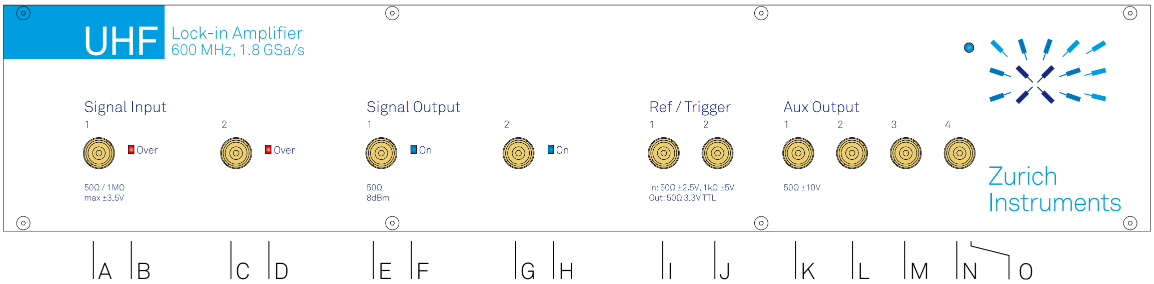


Figure 2.2. UHF Instrument front panel

Table 2.1. UHF Instrument front panel description

Position	Label / Name	Description
A	Signal Input 1	single-ended UHF input
B	Signal Input 1 Over	this red LED indicates that the input signal saturates the A/D converter and therefore the input range must be increased or the signal must be attenuated
C	Signal Input 2	single-ended UHF input
D	Signal Input 2 Over	this red LED indicates that the input signal saturates the A/D converter and therefore the input range must be increased or the signal must be attenuated
E	Signal Output 1	single-ended UHF output
F	Signal Output 1 ON	this blue LED indicates that the signal output is actively driven by the instrument
G	Signal Output 2	single-ended UHF output
H	Signal Output 2 ON	this blue LED indicates that the signal output is actively driven by the instrument
I	Ref / Trigger 1	analog reference input, TTL reference output, or bidirectional digital TTL trigger
J	Ref / Trigger 2	analog reference input, TTL reference output, or bidirectional digital TTL trigger
K	Aux Output 1	this connector provides an user defined signal, often used to output demodulated samples (X,Y) or (R,Θ)
L	Aux Output 2	this connector provides an user defined signal, often used to output demodulated samples (X,Y) or (R,Θ)
M	Aux Output 3	this connector provides an user defined signal, often used to output demodulated samples (X,Y) or (R,Θ)
N	Aux Output 4	this connector provides an user defined signal, often used to output demodulated samples (X,Y) or (R,Θ)
O	Power	this LED indicates that the instrument is powered
		color blue: the device has an active connection over USB or Ethernet

Position	Label / Name	Description
		color orange: indicates ready to connect. The device is ready for connection over USB or Ethernet. The internal auto calibration process is also indicated by an orange LED
		color orange blinking: device is in startup mode and waiting for an IP address. As long as the device does not have a dynamic IP address or does use its static default address a connection attempt over Ethernet will fail

2.3. Back Panel Tour

The back panel is the main interface for power, control, service and connectivity to other ZI instruments. Please refer to Figure 2.3 and Table 2.2 for the detailed description of the items.

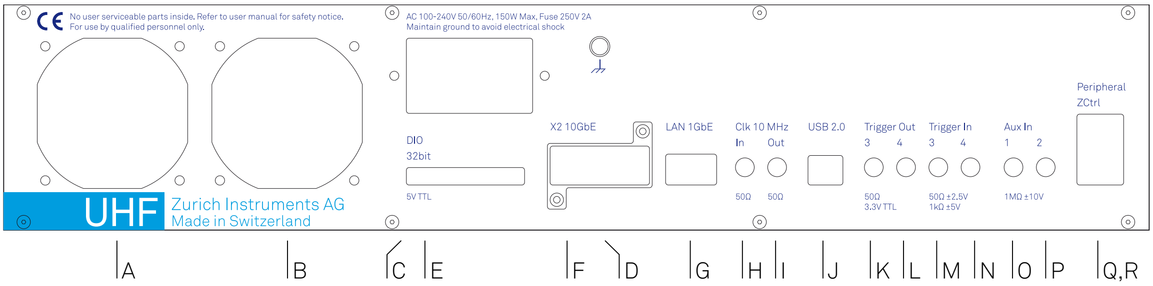


Figure 2.3. UHF Instrument back panel

Table 2.2. UHF Instrument back panel description

Position	Label / Name	Description
A	-	ventilator (important: keep clear from obstruction)
B	-	ventilator (important: keep clear from obstruction)
C	Power inlet	power inlet with ON/OFF switch
D	Earth ground	4 mm banana jack connector for earth ground, electrically connected to the chassis and the earth pin of the power inlet
E	DIO	32-bit digital input/output connector
F	X2 10GbE	10 Gbit LAN connector
G	LAN 1GbE	1 Gbit LAN connector
H	Clk 10 MHz In	clock input (10 MHz) to be used for synchronization from external instruments
I	Clk 10 MHz Out	clock output (10 MHz) to be used for synchronization of external instruments
J	USB	universal serial bus host computer connection
K	Trigger Out 3	digital TTL trigger output - note: some UHF Instruments indicate Trigger 1 on the back panel instead of Trigger 3
L	Trigger Out 4	digital TTL trigger output - note: some UHF Instruments indicate Trigger 2 on the back panel instead of Trigger 4
M	Trigger In 3	digital trigger input - note: some UHF Instruments indicate Trigger 1 on the back panel instead of Trigger 3
N	Trigger In 4	digital trigger input - note: some UHF Instruments indicate Trigger 2 on the back panel instead of Trigger 4
O	Aux In 1	auxiliary input
P	Aux In 2	auxiliary input
Q	ZCtrl 1	peripheral pre-amplifier power & control bus - attention: this is not an Ethernet plug, connection to an Ethernet network might damage the instrument
R	ZCtrl 2	peripheral pre-amplifier power & control bus - attention: this is not an Ethernet plug, connection to an Ethernet network might damage the instrument

2.4. Signalling pathways diagram

The following diagram illustrates the UHF's various signal inputs, signal outputs, functional blocks along with the multitude of signalling pathways inside the instrument and towards the host computer.

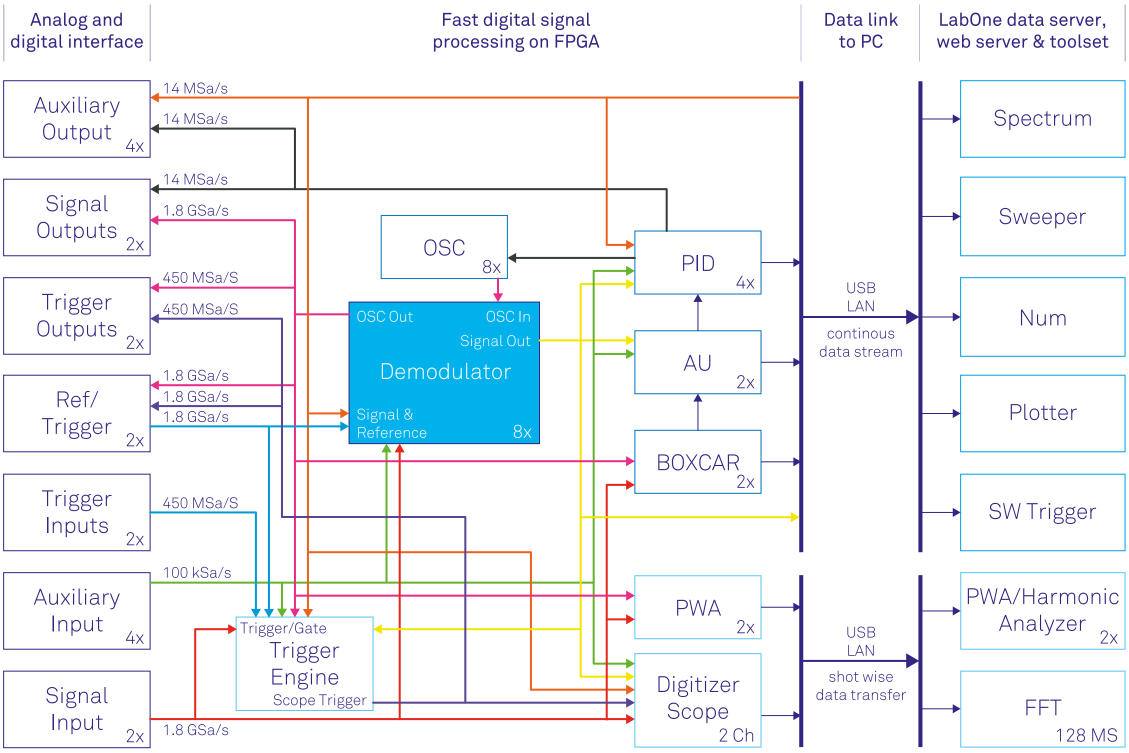


Figure 2.4. UHF Instrument main functional blocks and associated signal pathways

The main goal is to illustrate how much complexity can be absorbed by a single instrument and to inspire users finding our new uses cases by combining the different entities in new ways. The colors of the signal paths are arbitrary and meant to increase contrast but have no technical meaning. Also the plot neither aims for completeness or ultimate accuracy.

2.5. Ordering Guide

Table 2.3 provides an overview of the available UHF products. Upgradeable features are options that can be purchased anytime without need to send the Instrument to Zurich Instruments.

Table 2.3. UHF Instrument product codes for ordering

Product code	Product name	Description	Upgrade in the field possible
UHFLI	UHFLI Lock-in Amplifier	base product	-
UHF-PID	UHF-PID Quad PID/PLL Controller	option	yes
UHF-DIG	UHF-DIG Digitizer	option	yes
UHF-MF	UHF-MF Multi-frequency	option	yes
UHF-MOD	UHF-MOD AM/FM Modulation	option	yes
UHF-BOX	UHF-BOX Boxcar Averager	option	yes
UHF-RUB	UHF-RUB Rubidium Atomic Clock	option	no
UHF-10G	UHF-10G Optical Ethernet	option	yes

Table 2.4. Product selector

Feature	UHFLI	UHFLI + UHF-MF	UHFLI + UHF-PID	UHFLI + UHF-MF + UHF-PID
Internal reference mode	yes	yes	yes	yes
External reference mode	yes	yes	yes	yes
Auto reference mode	yes	yes	yes	yes
Dual-channel operation (2 independent measurement units)	yes	yes	yes	yes
Signal generators	2	2	2	2
Superposed output sinusoidals per generator	1	up to 8	1	up to 8
Quad-harmonic mode	yes	yes	yes	yes
Multi-frequency mode	-	yes	-	yes
Arbitrary frequency mode	-	yes	-	yes
Number of demodulators	8	8	8	8
Simultaneous frequencies	2	8	2	8
Simultaneous harmonics	4+4	-	4+4	-
External references	2	2	2	2
PID controllers	-	-	4	4
600 MHz, 1.8 GSa/s	yes	yes	yes	yes
Dynamic reserve	100 dB	100 dB	100 dB	100 dB
Lock-in range	600 MHz	600 MHz	600 MHz	600 MHz

Feature	UHFLI	UHFLI + UHF-MF	UHFLI + UHF-PID	UHFLI + UHF-MF + UHF-PID
USB 2.0 480 Mbit/s	yes	yes	yes	yes
LAN 1 Gbit/s	yes	yes	yes	yes

Chapter 3. Tutorials

The tutorials in this chapter have been created to allow users to become more familiar with the basic technique of lock-in amplification, the operation of host-based lock-in amplifiers, the LabOne web browser based user interface, as well as some more advanced lock-in measurement techniques. In order to successfully carry out the tutorials, users are required to have certain laboratory equipment and basic equipment handling knowledge. The equipment list is given below.

Note

For all tutorials, you must have LabOne installed as described in the Getting Started Chapter .

- 1 USB 2.0 cable, 1 LAN cable (supplied with your UHFLI Instrument)
- 3 BNC cables
- SMA cable and adaptors
- 1 male BNC shorting cap (optional)
- 1 oscilloscope (optional)
- 1 BNC T-piece (optional)
- 1 resonator (for the PLL tutorial)

3.1. Tutorial Simple Loop

Note

This tutorial is applicable to all UHF Instruments. No specific options are required. N.B. if the UHF-MF multi-frequency option is installed then some of the required settings will vary from those indicated below.

3.1.1. Goals and Requirements

This tutorial is for people with no or little prior experience with Zurich Instruments lock-in amplifiers. By using a very basic measurement setup, this tutorial shows the most fundamental working principles of an UHF instrument and the LabOne UI in a step-by-step hands on approach.

There are no special requirements for this tutorial.

3.1.2. Preparation

In this tutorial, you are asked to generate a signal with the UHFLI Instrument and measure that generated signal with the same instrument. This is done by connecting Signal Output 1 to Signal Input 1 with a short BNC cable (ideally < 30 cm). Alternatively, it is possible to connect the generated signal at Signal Output 1 to an oscilloscope by using a T-piece and an additional BNC cable. Figure 3.1 displays a sketch of the hardware setup.

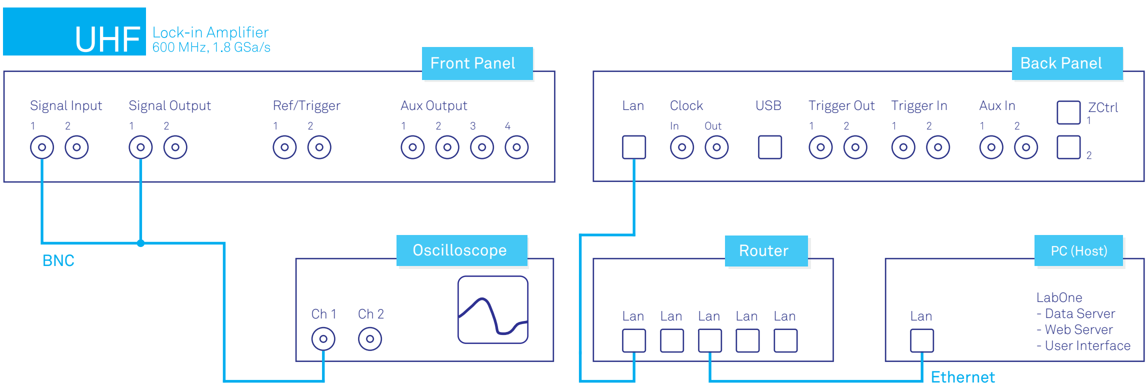


Figure 3.1. Tutorial simple loop setup (LAN connection shown)

Note

This tutorial is for all UHF units with lock-in capability irrespective of which particular option set is installed. (Note that if the UHF-MF multi-frequency option is installed there is slight difference in the test signal generation procedure, section 3.1.3).

Connect the cables as described above. Make sure that the UHF unit is powered on and then connect the UHF directly by USB to your host computer or by Ethernet to your local area network (LAN) where the host computer resides. Start the LabOne User Interface UHF from the Windows start menu. The LabOne Data Server UHF and the LabOne Web Server are automatically started and run in the background.

3.1.3. Generate the Test Signal

Perform the following steps in order to generate a 30 MHz signal of 0.5 V peak amplitude on Signal Output 1.

1. Change the frequency value of oscillator 1 (Lock-in tab, Oscillators section) to 30 MHz: click on the field, enter 30'000'000 or 30M in short and press either <TAB> or <ENTER> on your keyboard to activate the setting.
2. In the Signal Outputs section (right hand side on the Lock-in tab), set the Range pull-down to 1.5 V, the Offset to 0 V and the amplitude to 500 mV for Output 1.
3. By default all physical outputs of the UHF are inactive to prevent damage to connected circuits. Now it is time to turn on the main output switch by clicking on the button labeled "On". The switch turns to blue indicates now "On"
4. If you have an oscilloscope connected to the setup, you should now be able to see the generated signal.

Table 3.1 quickly summarizes the instrument settings to be made.

Table 3.1. Settings: generate the reference signal

Tab	Section	#	Label	Setting / Value / State
Lock-in	Oscillator	1	Frequency	30 MHz
Lock-in	Output	1	Amplitude	500 mV
Lock-in	Output	1	Offset	0 V
Lock-in	Output	1	On	On

3.1.4. Check the Test Input Signal

Next, you adjust the input parameters range, impedance and coupling to match the following values:

Table 3.2. Settings: generate the reference signal

Tab	Section	#	Label	Setting / Value / State
Lock-in	Signal Inputs	1	Range	1 V
Lock-in	Signal Inputs	1	Scaling	1 V / V
Lock-in	Signal Inputs	1	AC	On
Lock-in	Signal Inputs	1	50 Ω	On

The range setting ensures that the analog amplification on the Signal Input 1 is set such that the dynamic range of the input high-speed digitizer is optimal without clipping the signal. The graphical range indicator next to the numerical range setting shows about 50% usage of the possible dynamic range.

The incoming signal can now be observed over time by using the Scope Tab. A Scope view can be placed in the web browser by clicking on the icon in the left sidebar or by dragging the Scope Icon to one of the open Tab Rows. Choose the following settings on the Scope Tab to display the signal entering Signal Input 1:

Table 3.3. Settings: generate the reference signal

Tab	Section	#	Label	Setting / Value / State
Scope	Horizontal		Sampling Rate	1.8 GHz
Scope	Horizontal		Length	2560 pts
Scope	Vertical		Channel 1	Signal Input 1
Scope	Trigger		Enable	On
Scope	Trigger		Level	0 V

The Scope tool now displays single shots of Signal Input 1 with a temporal distance given by the Hold off Time. The scales on top and on the right of the graphs indicate the zoom level for orientation. The icons on the left and below the figure give access to the main scaling properties and allow to store the measurement data as a SVG image file or plain data text file. Moreover, panning can be achieved by clicking and holding the left mouse button inside the graph while moving the mouse.

Note

Zooming in and out along the horizontal dimension can by achieved with the mouse wheel, for the vertical zoom the shift key needs to be pressed and again the mouse wheel can by used for adjustments.

Having set the Input Range to 1 V ensures that no signal clipping occurs. If you set the Input Range to 0.2 V, clipping can be seen immediately on the scope window accompanied by a red error flag on the status bar in the lower right corner of the LabOne User Interface. At the same time, the LED next to the Signal Input 1 BNC connector on the instruments' front pan will turn red. The error flag can be cleared by pressing the clear button marked with the letter C on the right side of the status bar after setting the Input Range back to 1 V.

The Scope is a very handy tool for checking quickly the quality of the input signal. Users can either use Scope to adjust the optimal input range setting or to check if the software trigger level is set correctly. The Scope window can display up to 64k points/samples on the web browser. For the full description of the Scope tool please refer to the functional description.

3.1.5. Measure the Test Input Signal

Now, you are ready to use UHFLI to demodulate the input signal and measure its amplitude and phase. You will use two tools of the LabOne User Interface: Numerical and the Plotter.

First, adjust the following parameters on the Lock-in Tab for demodulator 1 (or choose another demodulator if desired):

Table 3.4. Settings: generate the reference signal

Tab	Section	#	Label	Setting / Value / State
Lock-in	Demodulators	1	Harm	1
Lock-in	Demodulators	1	Phase	0
Lock-in	Demodulators	1	Input	Sig In 1
Lock-in	Demodulators	1	Sinc	OFF

Tab	Section	#	Label	Setting / Value / State
Lock-in	Demodulators	1	Order	3 (18 dB/Oct)
Lock-in	Demodulators	1	TC / BW 3dB	9.3 ms / 8.7 Hz
Lock-in	Demodulators	1	Rate	100 Sample/s (automatically adjusted to 107 Sample/s)
Lock-in	Demodulators	1	Trigger	Continuous
Lock-in	Demodulators	1	Enable	ON

These above settings configure the demodulation filter to the third-order low-pass operation with a 9 ms integration time constant. Alternatively, the corresponding bandwidths BW NEP or BW 3 dB can be displayed and entered. The output of the demodulator filter is read out at a rate of 107 Hz, implying that 107 data samples are sent to the host PC per second with equidistant spacing. These samples can be viewed in the Numerical and the Plotter tool which we will examine now.

The Numerical tool provides the space for 16 or more measurement panels. Each of the panels has the option to display the samples in the Cartesian (X,Y) or in the polar format (R,Θ) plus other quantities such as the Demodulation Frequencies and Auxiliary Inputs. The unit of the (X,Y,R) values are by default given in V_{RMS}. The scaling and the displayed unit can be altered in the Signal Input section of the Lock-in Tab. The numerical values are supported by graphical bar scale indicators to achieve better readability, e.g. for alignment procedures. Display zoom is also available by holding the control key pressed while scrolling with the mouse wheel. Certain users may observe rapidly changing digits. This is due to the fact that you are measuring thermal noise that maybe in the μV or even nV range depending on the filter settings. This provides a first glimpse of the level of measurement precision capable with your UHFLI instrument.

If you wish to play around with the settings, you can now change the amplitude of the generated signal, and observe the effect on the demodulator output.

Next, we will have a look at the Plotter tool that allows users to observe the demodulator signals as a function of time. It is possible to adjust the scaling of the graph in both directions, or make detailed measurements with 2 cursors for each direction. Signals of the same signal property are automatically added to the same default y-axis group. This ensures that the axis scaling is identical. Signals can be moved between groups. More information on y-axis groups can be found in the section called “Plot area elements” .

Try zooming in along the time dimension using the mouse wheel or the icons below the graph to display about one second of the data stream. While zooming in, the mode in which the data are displayed will change from a min-max envelope plot to linear point interpolation depending on the density of points along the x axis as compared to the number of pixels available on the screen.

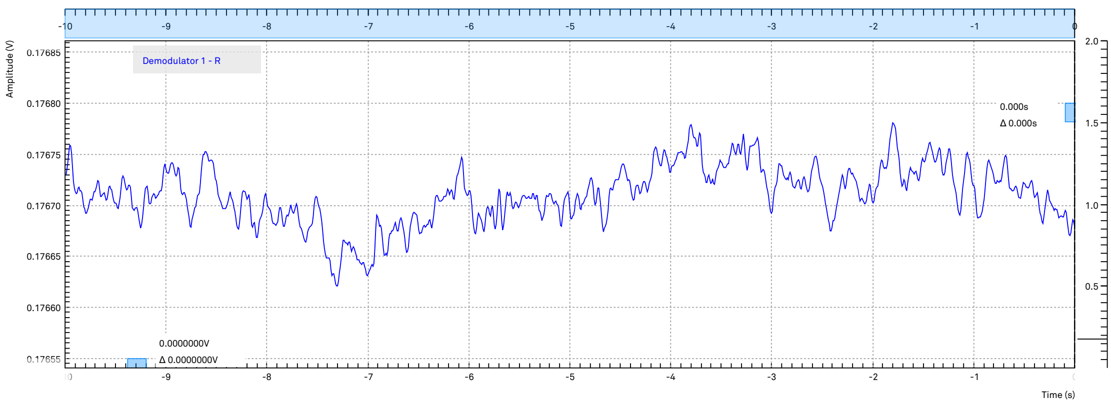


Figure 3.2. LabOne User Interface Plotter displaying demodulator results continuously over time (roll mode)

3.1.6. Different Filter Settings

As next step in this tutorial you will learn to change the filter settings and see their effect on the measurement results. For this exercise, use the second demodulator with the same settings as the first except in changing the time constant of the integration to 1 ms which corresponds to a 3 dB bandwidth of 83 Hz.

Table 3.5. Settings: generate the reference signal

Tab	Section	#	Label	Setting / Value / State
Lock-in	Demodulators	1	Order	3 (18 dB/Oct)
Lock-in	Demodulators	1	TC / BW 3dB	1 ms / 83 Hz

Lowering the time constant reduces the filter integration time of the demodulators. This will in turn 'smooth out' the demodulator outputs and hence increases available time resolution. Note that it is recommended to keep the sample rate 7 to 10 times the filter 3 dB bandwidth. The sample rate will be rounded off to the next available sampling frequency. For example, typing 1 k in the Rate field will result in 1.7 kSa/s which is sufficient to not only properly resolve the signal, but also to avoid aliasing effects. Figure 3.3 shows data samples displayed for the two demodulators with different filter settings described above.

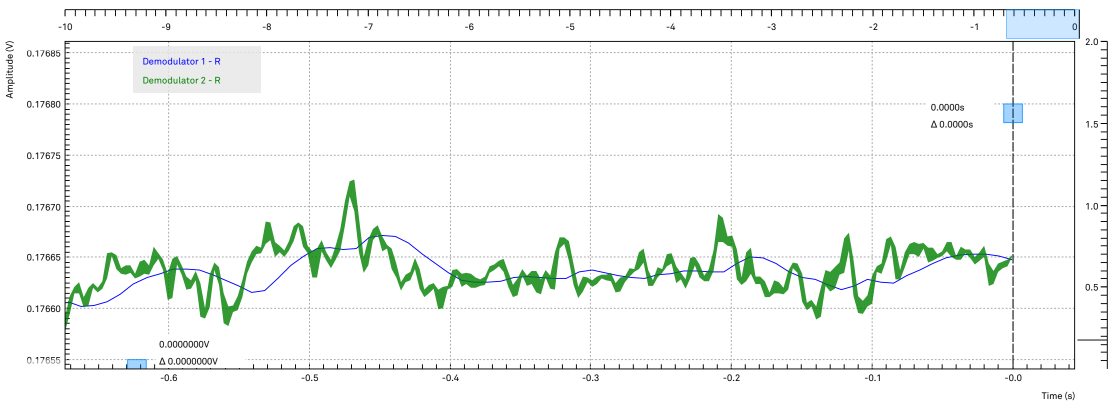


Figure 3.3. LabOne User Interface Plotter: Demodulator 1 (TC = 9.3 ms, blue), Demodulator 2 (TC = 1 ms, green)

Moreover, you may for instance "disturb" the demodulator with a change of test signal amplitude, for example from 0.5 V to 0.7 V and vice-versa. The green plot will go out of the display range which can be re-adjusted by pressing the "Auto Scale" button. With a large time constant, the demodulated data change slower in reaction to the change in the input signal compared to a low time constant. In addition, the number of stable significant digits in the Numerical tool will also be higher with a high time constant.

3.2. Tutorial External Reference

Note

This tutorial is applicable to all UHF Instruments. No specific options are required. N.B. if the UHF-MF multi-frequency option is installed then some of the required settings will vary from those indicated below.

3.2.1. Preparation

This tutorial explains how to perform demodulation using an external reference frequency. An external reference will be simulated by using one of the UHFLI internal oscillators. The signal from this internal oscillator will be fed to one of the signal outputs and then fed back in using various connections in order to reference another internal oscillator used for demodulation.

First of all, connect the Signal Output 2 connector to both Signal Input 1 and to the Ref/Trigger Input 1 connector using two BNC cables and a BNC T-junction. The measurement setup is shown in the following figure.

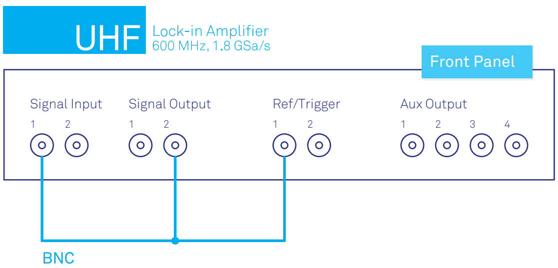


Figure 3.4. External reference on Signal Input 2

Connect the cables as described above. Make sure the UHFLI is powered on, and then connect the UHFLI through the USB to your PC, or to your local area network (LAN) where the host computer resides. After starting LabOne the default web browser opens with the LabOne graphical user interface.

The tutorial can be started with the default instrument configuration (e.g. after a power cycle) and the default user interface settings (i.e. as is after pressing F5 in the browser).

3.2.2. Generate the Test Signal

In this section you generate a 30.0 MHz signal oscillating between 0 V and +/-0.5 V on Output 2 for use as the external reference. The Lock-in settings for generating and analyzing the test signal are shown in the following table.

Table 3.6. Settings: generate the reference signal

Tab	Section	#	Label	Setting / Value / State
Lock-in	Output	2	Range	1.5 V

Tab	Section	#	Label	Setting / Value / State
Lock-in	Output	2	Amplitude	1.0 V
Lock-in	Output	2	Offset	0.0
Lock-in	Output	2	On	On
Lock-in	Oscillators	2	Frequency	30 MHz
Lock-in	Demodulators	5	Enable	On
Lock-in	Input	2	Range	1.5 V
Lock-in	Input	2	AC	ON
Lock-in	Input	2	50 Ω	ON

To quickly verify the signal, we can reconnect the Signal Output 2 with Signal Input 2 and check the signal shape on the Scope using the following settings.

Table 3.7. Settings: acquire the reference signal

Tab	Section	#	Label	Setting / Value / State
Scope	Vertical		Channel 1	Signal Input 2
Scope	Trigger		Trigger	ON
Scope	Trigger		Signal	Signal Input 2
Scope	Trigger		Level	50 mV
Scope			Run / Stop	ON

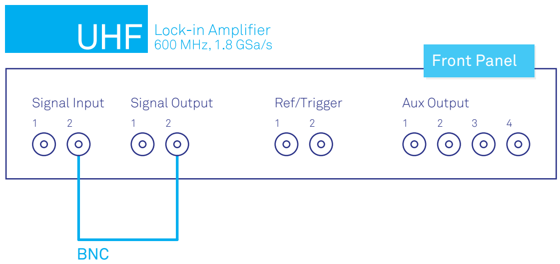


Figure 3.5. External reference on Signal Input 2

The resulting scope trace should look similar as indicated in the following screen capture.

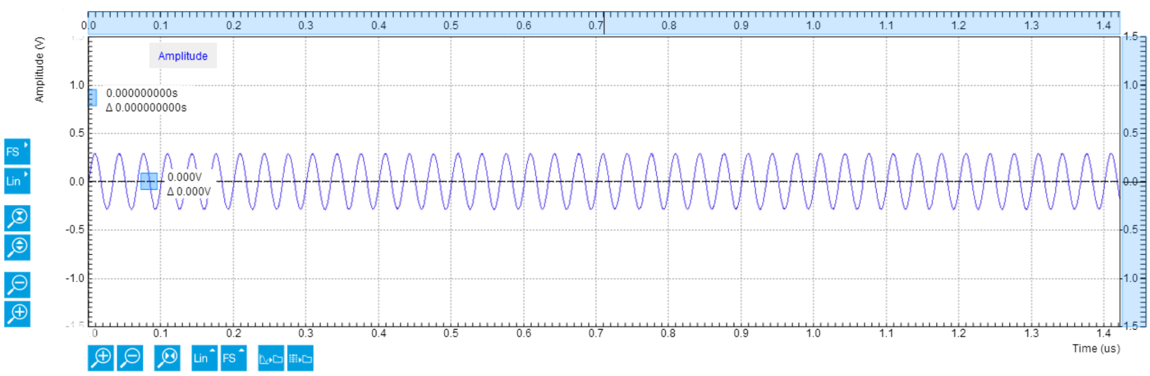


Figure 3.6. Reference signal viewed with the internal scope

Note

Alternatively, the Scope mode Frequency Domain FFT (instead of Time Domain) can be used to check the frequency content of the signal. Set the scale settings automatic for the X axis and logarithmic scale (dB) for the Y axis for convenient viewing. The averaging filter can be set Exp Moving Avg to reduce the noise floor on the display.

3.2.3. Activate the External Reference Mode

After putting back the cable as indicated in Figure 3.4 the external reference mode can be activated and output the regenerated signal of interest. The following additional settings have to be adjusted:

Table 3.8. Settings: acquire the reference signal

Tab	Section	#	Label	Setting / Value / State
Lock-in	Output	2	Range	1.5 V
Lock-in	Output	2	Offset	0 V
Lock-in	Output	2	Amplitude	1 V
Lock-in	Output	2	Enable	ON
Lock-in	Demodulator	1	Enable	ON
Lock-in	Signal Input	1	Range	1.2 V
Lock-in	Signal Input	1	AC	OFF
Lock-in	Signal Input	1	50 Ω	OFF

In general, Demodulator 4 and Demodulator 8 can be set to the external reference mode to track the external reference at Signal Input 1 and Signal Input 2, respectively. The external reference can come from the Sig In 1 and 2,Trig 1 and 2 (in the front), Trig 3 and 4 (in the back), or Aux In 3 and 4 (in the back). The 4 Auxiliary Outputs can also be chosen in the external reference mode although they are not exactly to be considered as an external reference. They are useful in the case of tandem demodulation where the result of a first lock-in operation is fed into a second lock-in, typically at a lower frequency. For this tutorial, Sig In 1 is selected as the external reference for Demodulator 4 (i.e. under the Signal column) and activated by selecting ExtRef in the (Reference) Mode column.

Table 3.9. Settings: choosing trigger source and switch to external reference mode

Tab	Section	#	Label	Setting / Value / State
Lock-in	Demodulators	4	Signal	Sig In 1
Lock-in	Demodulators	4	Mode	ExtRef

As a result the oscillator 1 frequency indicator in the Oscillator section almost immediately changes from 10 MHz to 30 MHz. Once the external reference mode has been enabled, the frequency of oscillator 1 changes continuously, adapting to the frequency of the external reference signal. This can be verified by changing the frequency of oscillator 2 and noting how the frequency of oscillator 1 follows. A green indicator appears besides the reference selection for channel 1 indicating that the instrument has locked to an external reference. Graphically, this can be nicely viewed in the Plotter by displaying the frequency of Demodulator 1 and then changing the frequency of the oscillator 2 in quantities of, say, 1 kHz:

Table 3.10. Settings: displaying demodulator reference frequency over time

Tab	Section	#	Label	Setting / Value / State
Plotter	Tree		Input Signal	/0/sample/Frequency
Plotter			Run / Stop	On

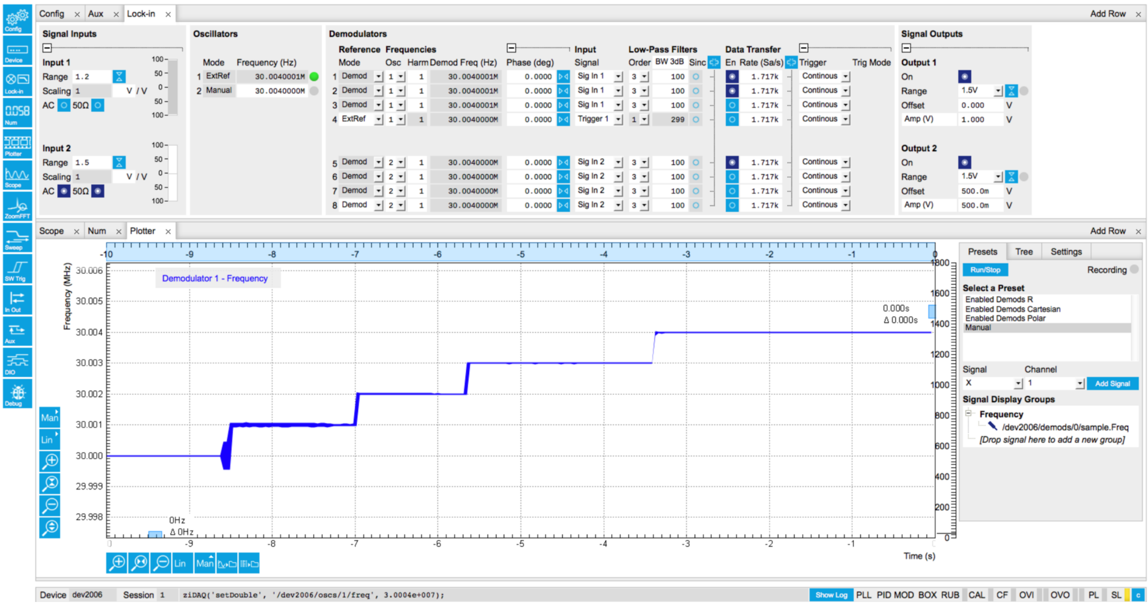


Figure 3.7. LabOne enabling external reference mode

At this point, it is worth noting that the external reference signal is never used directly for demodulation. Instead, the frequency and phase of the external reference signal is mapped to one of the internal oscillators first through an internal phase locked loop. This internal oscillator can then serve as a reference for any of the demodulators. This mapping procedure is implemented with an automatic bandwidth adjustment that assures optimum operation over the whole frequency range for a broad variety of signal qualities in terms of frequency stability as well as the signal-to-noise ratio. Over the course of automatic adjustment, the Low-Pass Filter bandwidth of the associated demodulators 4 or 8 usually ramps down until a final value is reached after a few seconds. The indicated bandwidth also marks an upper limit to the bandwidth of the phase locked loop that does the mapping of the external signal to the internal oscillator. The following figure shows a typical result in the plotter for the frequency tracking immediately after it is turned on.

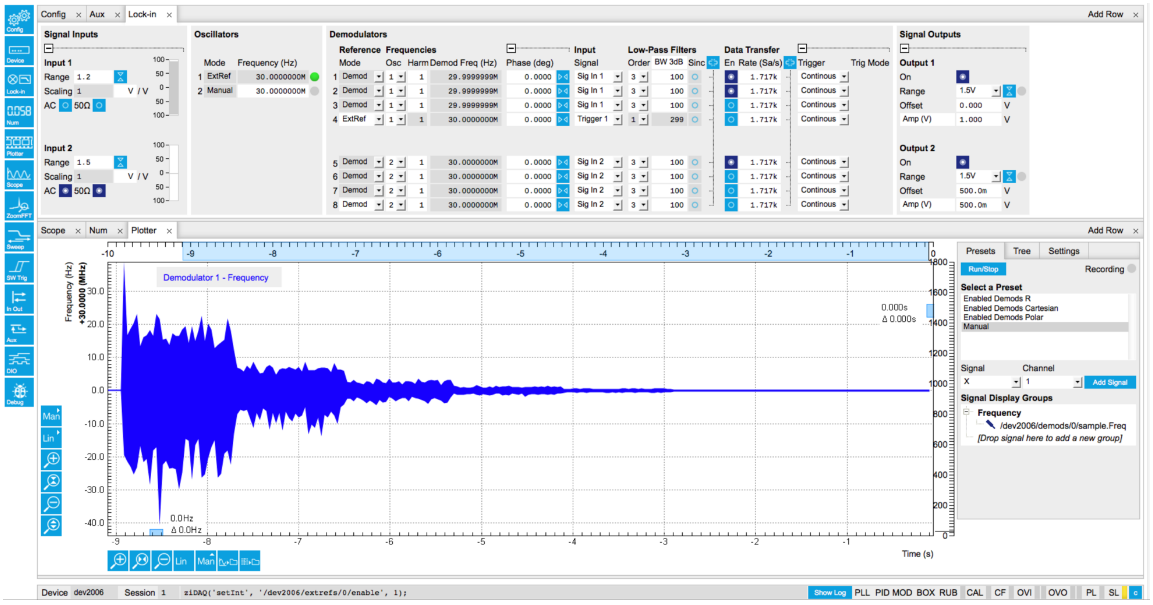


Figure 3.8. Frequency tracking of an external reference signal over time with automatic bandwidth adjustment

3.2.4. Providing the Reference Signal to Ref / Trigger Input

In this section you will slightly modify the setup to use Ref/Trigger Input 1 (instrument front side) as a entry port for the external reference instead of Signal Input 1. A sketch of the modified setup is shown in Figure 3.9 .

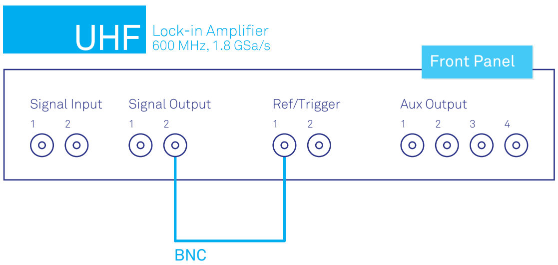


Figure 3.9. External reference using Ref/Trigger Input 1 setup

There are 2 Ref/Trigger inputs on the front side of the instrument and two more on the rear side. By using the dedicated trigger inputs, both Signal Inputs remain available for simultaneous two-input measurement . The drawback is that one cannot observe the external reference signal on the Scope tool when an REF/Trigger inputs are used.

Ref/Trigger Inputs are comparator based digital channels where the input impedance can be set to either 50Ω or 1 kΩ in the Ref / Trigger section in the DIO tab. Moreover, a suitable Trigger threshold can be defined by adjusting the Input Level definitions.

Note

It is important to know that the trigger to discriminate the two logical states operates on the positive edge with a hysteresis of about 100 mV. Consequently, a peak-to-peak signal amplitude of minimum 200 mV should be provided as a external reference signal to guarantee reliable switching.

Note

For signal frequencies larger than 10 MHz, the 50Ω input termination is strongly recommended to avoid signal reflections in the cable that can lead to false switching events.

The following DIO settings are used for this example:

Table 3.11. Settings: acquire the reference signal

Tab	Section	#	Label	Setting / Value / State
DIO	Ref / Trigger	1	Input Level	250 mV
DIO	Ref / Trigger	1	Coupling 50 Ω	ON
DIO	Ref / Trigger	1	Drive	OFF

When the signal is applied with a proper discrimination threshold chosen, both control LEDs will turn on to indicate that the channel alternates quickly between high-low logical states. Once this is happening, one can then select Trigger 1 as a Signal Input for demodulator 4 in order to reference oscillator 1.

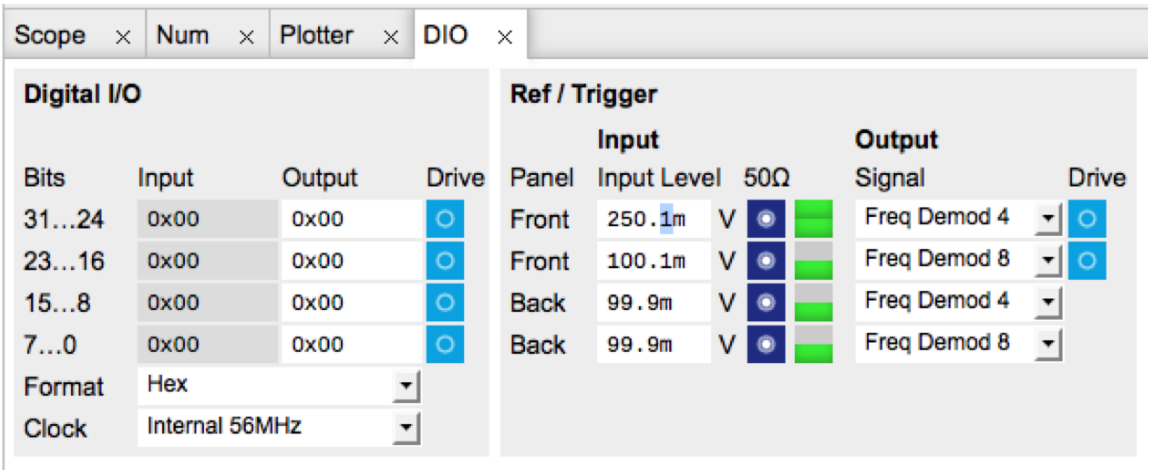


Figure 3.10. Configuring DIO 0 as reference input

The default settings are chosen such that a standard 3.3 V TTL signal can be directly attached without further adjustments. This can be easily tested by connecting a TTL reference signal to the outputs on the back panel. A sketch of the modified setup is shown on Figure 3.11 . You should now see as well that the oscillator 1 now tracks the frequency generated from oscillator 2.

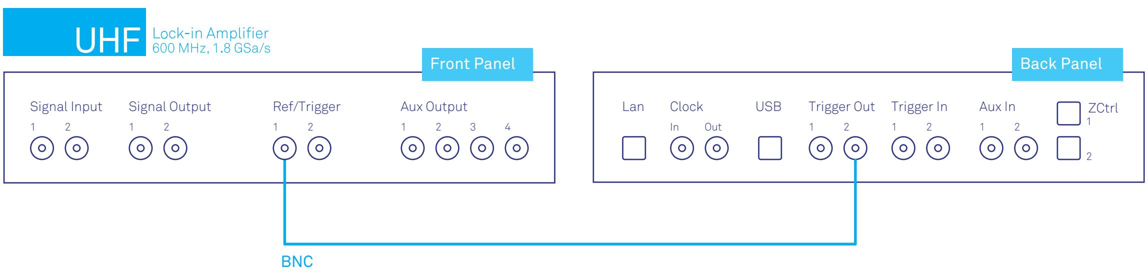


Figure 3.11. Referencing to a TTL signal using Ref/Trigger Input 1

3.2.5. Using the Ref/Trigger Input with TTL signals

In this section you will modify the setup to use Ref/Trigger Input 2 (instrument front side) as a entry port for TTL reference signal provided on Trigger Output 1 (instrument backside). A sketch of the modified setup is shown on Figure 3.12 .

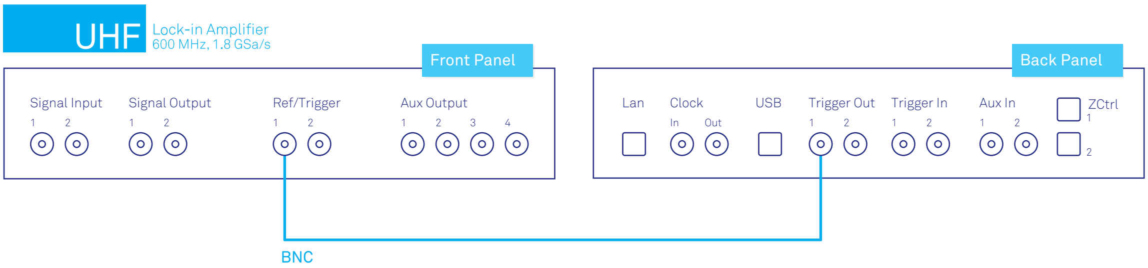


Figure 3.12. Referencing to a TTL signal using Ref/Trigger Input 1

When using the Ref/Trigger Inputs, one needs to be aware that they are comparator based digital channels where the input coupling can be selected to be either 50Ω or 1 kΩ in the Ref / Trigger section in the DIO tab. Moreover, a suitable Trigger threshold can be defined by adjusting the Input Level definitions.

Note

It is important to know that the trigger to discriminate the two logical states operates on positive slopes with a hysteresis of about 100 mV. As a consequence a peak to peak signal amplitude of minimum 200 mV should be provided as a external reference signal to guarantee reliable operation.

Note

For signal frequencies larger than 10 MHz using 50Ω input coupling is strongly recommended to avoid signal reflections in the cable that can lead to false events or measurement artefacts.

The default settings are chosen such that a standard 3.3 V TTL signal can be directly attached without further adjustments. The following DIO settings are used for this example.

Table 3.12. Settings: acquire the reference signal

Tab	Section	#	Label	Setting / Value / State
DIO	Ref / Trigger	1	Input Level	250 mV
DIO	Ref / Trigger	1	Coupling 50 Ω	ON
DIO	Ref / Trigger	1	Drive	ON

When the signal is applied and a proper discrimination threshold chosen both control LEDs are lid to indicate that the channel alternates quickly between both logical states. As soon as this is the case, one can select Trigger 2 as a Signal Input for demodulator 8 in order to reference oscillator 2 to oscillator 1.

3.3. Tutorial Amplitude Modulation

Note

This tutorial is applicable to UHF Instruments having the UHF-MF Multi-frequency and the UHF-MOD AM/FM Modulation options installed.

3.3.1. Goals and Requirements

This tutorial explains how to generate an amplitude modulated (AM) signal as well as how to demodulate an AM signal by reading out both the carrier and double-sidebands' amplitude and phase simultaneously. The tutorial can be done using a simple loop back connection.

3.3.2. Preparation

To perform this tutorial, one simply needs to connect a BNC cable from Signal Output 1 to Signal Input 1 as shown in Figure 3.13 . This will allow the user to perform the AM modulation and demodulation in this tutorial without needing an external source.

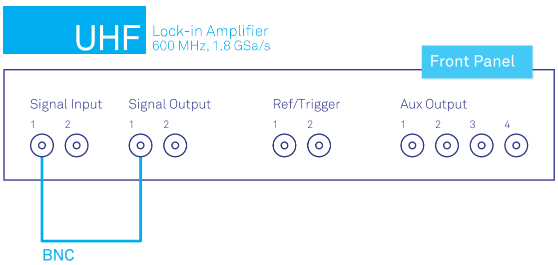


Figure 3.13. Internally generated AM signal measured on Signal Input 1

Note

This tutorial is for all UHF units with lock-in capability as well as having the UHF-MF Multi-frequency and UHF-MOD AF/FM Modulation options installed.

Connect the cables as described above. Make sure the UHFLI is powered on, and then connect the UHFLI through the USB to your PC, or to your local area network (LAN) where the host computer resides. After starting LabOne, the default web browser opens with the LabOne graphical user interface.

The tutorial can be started with the default instrument configuration (e.g. after a power cycle) and the default user interface settings (e.g. as is after pressing F5 in the browser).

3.3.3. Generate the Test Signal

In this section you will learn how to generate an AM signal with a 10.0 MHz, 1.0V sinusoidal carrier modulated by a second 100 kHz, 500 mV sinusoid. The Lock-in tab and the MOD tab settings are shown in the following table.

Table 3.13. Settings: generate the AM signal

Tab	Section	#	Label	Setting / Value / State
MOD	Oscillators	1	Enable	ON
MOD	Oscillators	1	Carrier	AM / 10.0M
MOD	Oscillators	1	Sideband 1	100.0k
MOD	Input	1	Channel	Sig In 1
MOD	Generation	1	Signal Outputs	1
MOD	Generation	1	Carrier (V)	1.0 / ON
MOD	Generation	1	Modulation (V)	200.0m / ON
Lock-in	Output	1	Range	1.5 V
Lock-in	Output	1	On	ON
Lock-in	Demodulators	1	Enable	ON
Lock-in	Demodulators	2	Enable	ON
Lock-in	Demodulators	3	Enable	ON
Lock-in	Demodulators	5	Enable	OFF
Lock-in	Input	1	Range	1.5 V
Lock-in	Input	1	50 Ω	ON

To quickly verify that the AM signal is generated correctly, we can check the spectrum of the AM signal on Signal Input 1 using the Scope tool with the following settings. The Scope basically displays the FFT spectrum of Signal Input 1. With a sampling rate of 28 MHz, it satisfies sufficiently the Nyquist rate to see the 10 MHz carrier. The 64'000 points samples correspond to about 2.3 ms of the sampled duration. This should be enough to capture the frequency spectrum at kHz resolution.

Note

The maximum sample window displayed in the Scope is 64000 points.

Table 3.14. Settings: acquire the reference signal

Tab	Section	#	Label	Setting / Value / State
Scope	Horizontal		Mode	Freq Domain FFT
Scope	Horizontal		Sampling Rate	28 MHz
Scope	Horizontal		Length (pts)	64000
Scope			Run/Stop	ON

You should now observe a spectrum like the one shown in the screen capture below. All amplitudes are measured in peak values. The center carrier frequency and the sideband frequencies should have half of the generated amplitudes i.e. about 0.5 V and 50 mV, respectively. This is due to the voltage divider effect from the combination of the 50 Ω output port impedance and the 50 Ω input termination impedance. The additional 0.5 factor for the two sidebands is due to the fact that the original AM modulation signal power is shared between two sidebands.

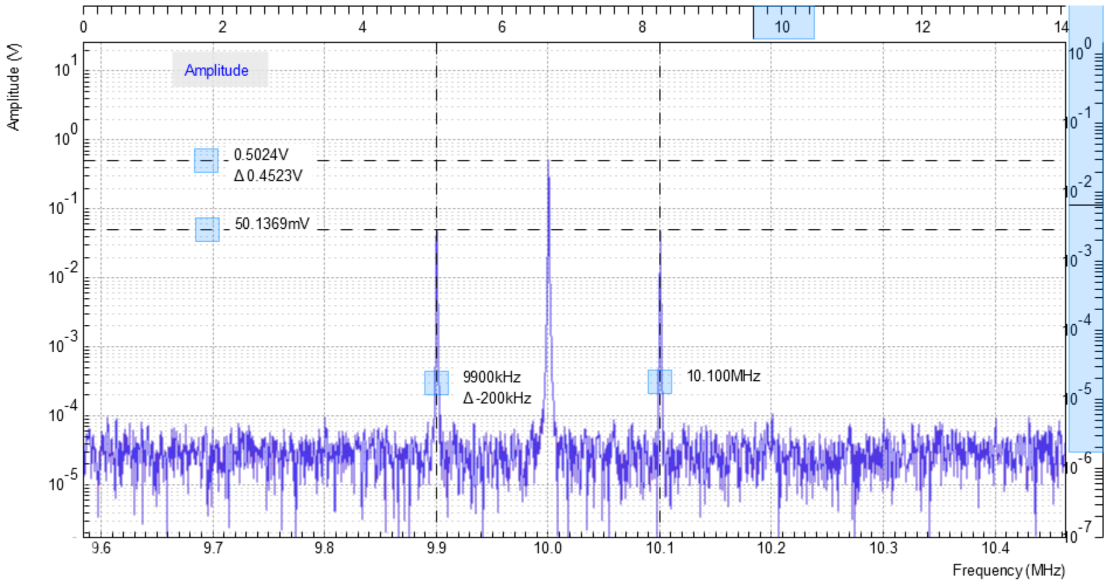


Figure 3.14. Generated AM signal with UHFLI

3.3.4. AM Demodulation Result

If you look at the Demod Freq column under the Lock-in tab, you will see that the demodulation frequencies of all three frequency components are stated clearly: 10 MHz on demodulator 1, 10.1 MHz on demodulator 2 and 9.9 MHz on demodulator 3. You can now read out simultaneously the magnitude and the phase (R,Θ) or (X, Y) of the carrier component on demodulator 1, and the upper and lower sideband components on demodulator 2 and 3, respectively. The measurement result is shown under the Numeric tab as shown in Figure 3.15

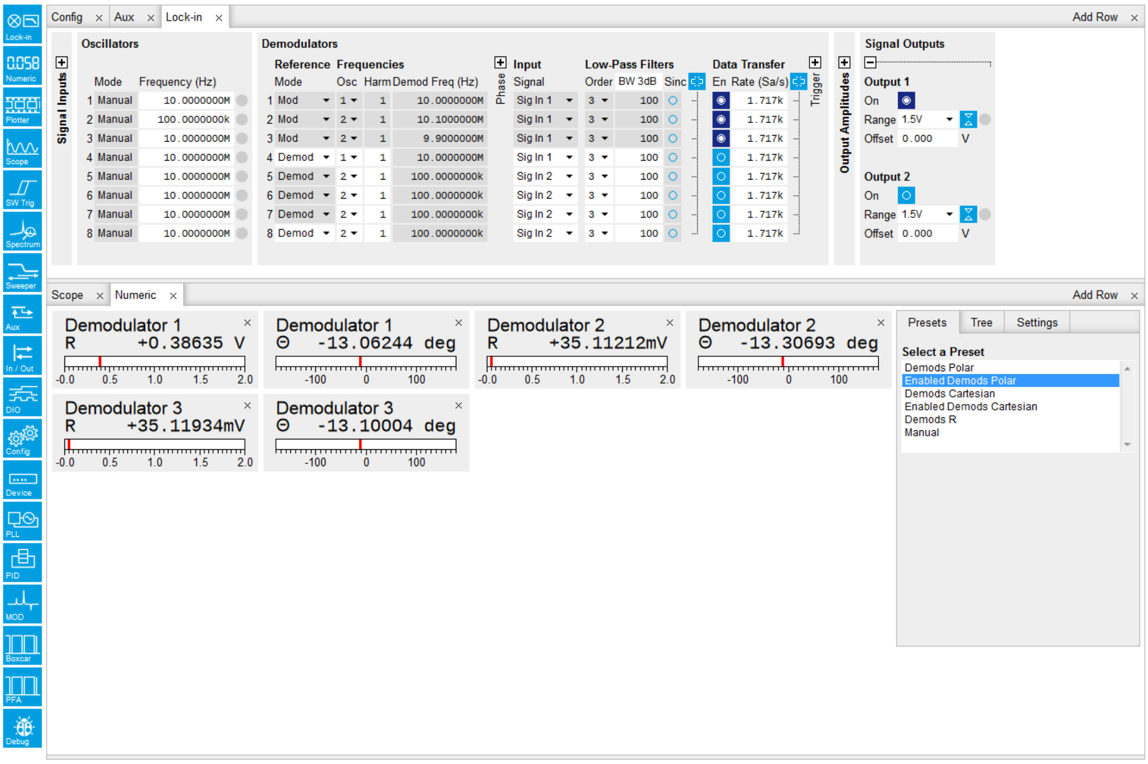


Figure 3.15. Numerical results of AM demodulation under the Numeric tab

Note

By selecting 'Enable Demod Polar' in the Numeric tab, only the enabled demodulator outputs will show.

If we take the sum of the double sidebands' amplitude (i.e. demodulator 2 and 3) and divide it by the amplitude of the carrier (demodulator 1), we will get an AM modulation index of $h=A_{sideband}/A_{carrier}=0.2$. This is exactly the index we had used to generate the AM signal in the MOD tab.

3.4. Tutorial Phase-locked Loop

Note

This tutorial is applicable to UHF Instruments having the UHF-PID Quad PID/PLL Controller option installed.

3.4.1. Goals and Requirements

This tutorial explains how to track the resonance frequency shift of a resonator using the PLL. To perform this tutorial, one simply needs to connect a resonator between Signal Output 2 to Signal Input 2.

3.4.2. Preparation

Connect the cables and the resonator as shown in the diagram below. Make sure the UHFLI is powered on, and then connect the UHFLI through the USB to your PC, or to your local area network (LAN) where the host computer resides. After starting LabOne the default web browser opens with the LabOne graphical user interface. .

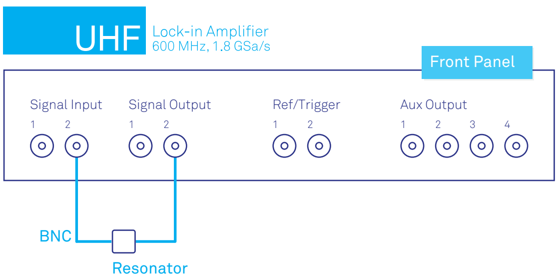


Figure 3.16. PLL connection with UHF

The tutorial can be started with the default instrument configuration (e.g. after a power cycle) and the default user interface settings (e.g. as is after pressing F5 in the browser).

3.4.3. Determine the Resonance of the Resonator

In this section you will learn first how to find the resonance of your resonator by using the frequency sweeper tool under the Sweeper tab. To get started, one could in theory define a frequency sweep range from DC to 600 MHz and slowly narrow down the range using multiple sweeps in order to find the resonance peak of interest. But in practice, it would make more sense to already have a small guess range in the span of a couple of MHz, not more. This will save the overall sweep time especially in cases where your resonator Q is low and therefore the peak would be close to the noise floor. The Sweeper tab and Lock-in tab setup is shown below. The frequency sweeper can be found under the Sweeper tab.

Table 3.15. Settings: acquire the reference signal

Tab	Section	#	Label	Setting / Value / State
Lock-in	Output Amplitudes	8	Amp 2 (V)	100.0m / ON
Lock-in	Signal Outputs		Output 2	ON
Lock-in	Demodulators	8	Osc	8
Lock-in	Demodulators	8	Input	Sig In 2
Lock-in	Data Transfer	8	Amp 2 (V)	ON
Sweeper	Settings		Sweep Param.	oscs/7/freq
Sweeper	Settings		Input Channel	Demod R / 8
Sweeper	Settings		Start (Hz)	1.0M
Sweeper	Settings		Stop (Hz)	3.0M
Sweeper	History		Length	2
Sweeper	Settings		Dual Plot	ON
Sweeper	Settings		Run/Stop	ON

In this exercise, we are using the DEMODULATOR 8 row to generate the sweep signal as well as demodulating the resonator output. The Lock-in settings ensure especially that the oscillator used both for the sweep signal and the demodulation is the same (i.e. the oscillator 2). In addition, the input must be set to Signal Input 2 as shown in the connection diagram.

Once the Sweeper Run/Stop button is pressed, the sweeper will continuously and repeatedly sweep the frequency response of the quartz oscillator. The user can then use the zoom tools to get a higher resolution on the interested resonance peak since one may have several resonance peaks in the frequency spectrum. The history length of 2 allows the user to keep on the screen one previous sweep while adjusting the zoom. To redefine the start and stop frequencies for a finer sweeper range, one needs to deactivate first the Dual Plot mode and then pres the Copy Range button. This will automatically entering the zoomed sweep window range into the Start and Stop of the swept frequency range. Remember to turn off Run/Stop button under the Sweeper tab when done.

Note

The sweep frequency resolution will get finer when zooming in horizontally using the Copy Range button even without changing the number of points.

When a resonance peak has been found, you should get a spectrum similar to two screen shots below. In this example, we have selected the resonance peak at about 2.151 MHz. The phase response of the resonator started at about 90 degrees but decreases abruptly until reaching the value of about 4.7 degrees at the resonance peak.

Note

For most resonators, a phase shift of approximately 90 degrees at resonance can be expected, if the cables are not excessively long.

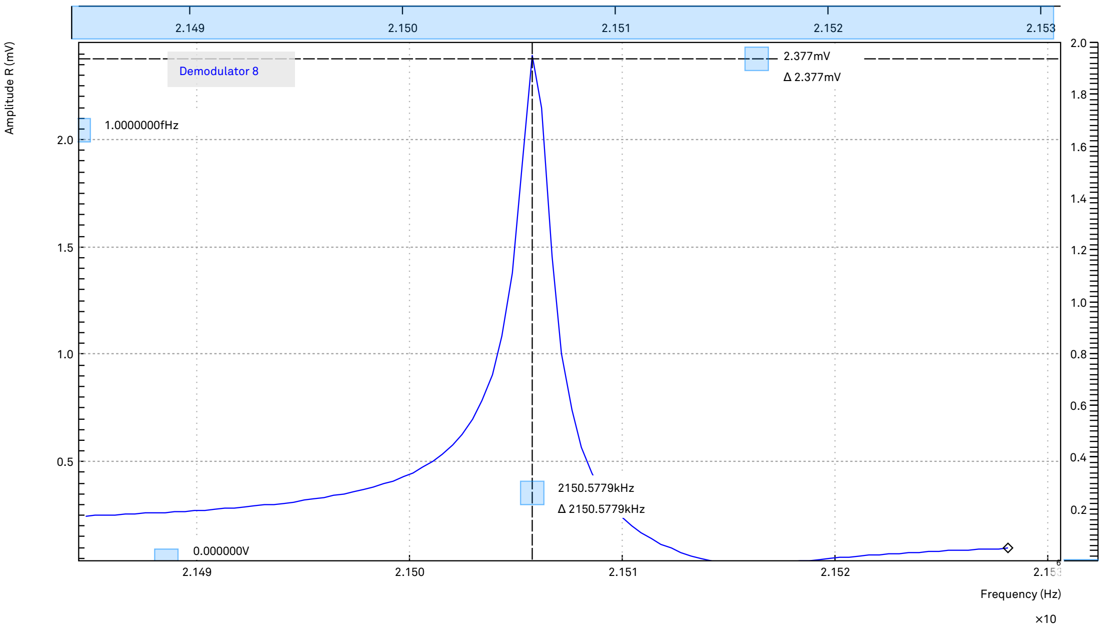


Figure 3.17. frequency sweep amplitude response

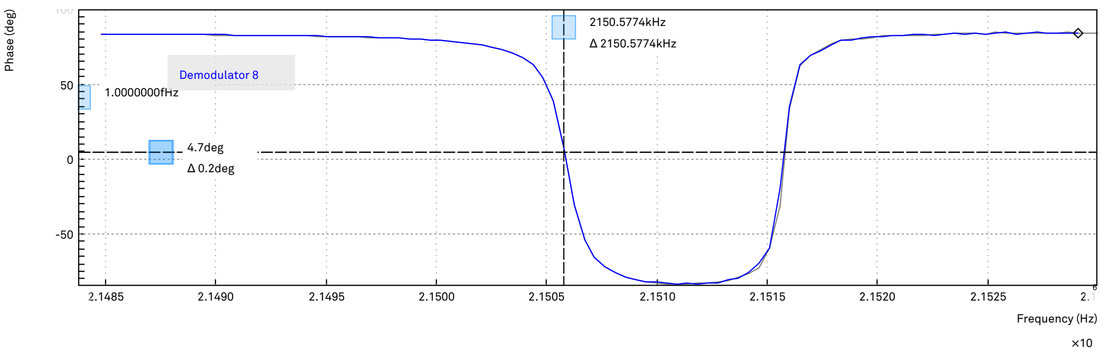


Figure 3.18. frequency sweep phase response

3.4.4. Resonance Tracking with the PLL

Now that we have located the resonance frequency and its phase, we can now track the drift in resonance frequency by locking on to the phase that we just measured using the Sweeper, hence the name phase locked loop. The phase locked loop is available under the PLL tab. There are two PLLs in each UHF unit. For this tutorial, we will use PLL 2. We first set up the basic PLL 2 fields as shown in the table below, using the values from the Sweeper.

Table 3.16. Settings: acquire the reference signal

Tab	Section	#	Label	Setting / Value / State
PLL	PLL 2		Center Freq (Hz)	2.1506M
PLL	PLL Settings		Oscillator	8
PLL	PLL Settings		Demodulator	8
PLL	PID Settings	1	Setpoint (deg)	+4.7

In this case, we must also select the 8th oscillator and demodulator 8 for the phase locked loop operation. Now, we need to set up the closed loop response of the PLL. One can use the PLL Advisor for such purpose. For this tutorial, we will not use Advanced Mode but rather will just set the Target BW (Hz) to be 1.0k. One then needs to press on the Advise button to see the simulated open loop response. This will also generate a set of PID parameters as shown in the screen shot below. One can observe that the -3dB point is roughly at 1kHz as specified. Once you are happy with the response, then simply press on the ToPLL button to copy the PID parameters back to the PLL 2 setting. To start the PLL operation, simply click on the Enable button. This will launch the phase locked loop operation.

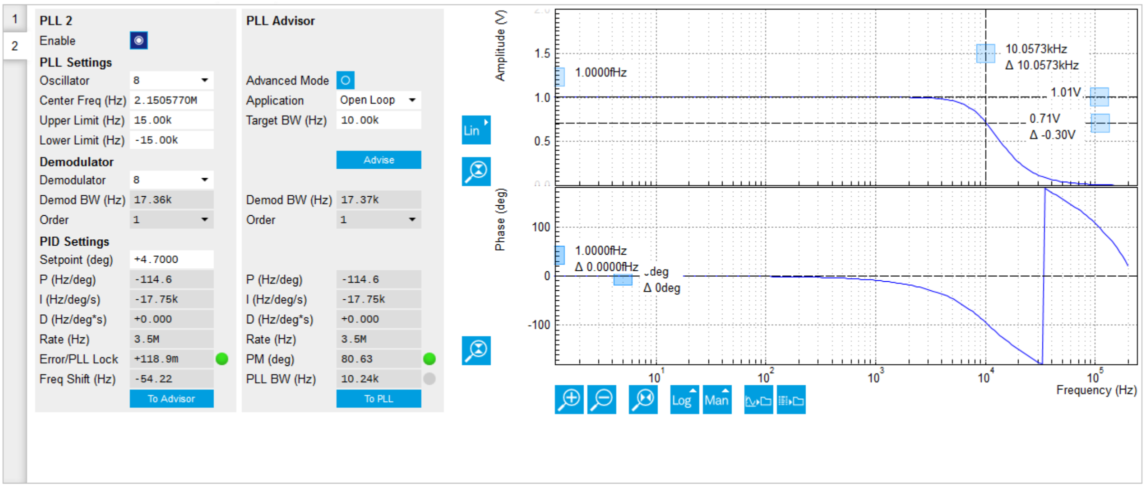


Figure 3.19. PLL settings and simulation in the PLL tab

When the PLL is locked, the green indicator beside the label Error/PLL Lock will be switched on. The actual frequency shift is shown in the field Freq Shift (Hz).

Note

At this point, it is recommended to adjust the signal input range by pressing on the Auto Range button in the Lock-in tab. This will sometimes help the PLL to lock to an input signal with a better signal-to-noise ratio.

The easiest way to visualize the frequency drift is to use the Plotter tool. One simply needs to select Frequency and Channel 8 and then press the button Add Signal. This will add an additional signal in the Plotter window. The frequency short-term drift noise can be further reduced sometimes by decreasing the PLL bandwidth.

3.5. Tutorial Automatic Gain Control

Note

This tutorial is applicable to UHF Instruments having the UHF-PID Quad PID/PLL Controller option installed.

3.5.1. Goals and Requirements

This tutorial explains how to set up a PID controller for automatic gain control. The tutorial can also be performed as a continuation to the previous PLL tutorial i.e. the PLL can be kept running. Just like the PLL tutorial, an external quartz resonator is used as the device-under-test. To perform this tutorial, one simply needs to connect a resonator between Signal Output 2 to Signal Input 2.

3.5.2. Preparation

Connect the cables as illustrated below. Make sure the UHFLI is powered on, and then connect the UHFLI through the USB to your PC, or to your local area network (LAN) where the host computer resides. After starting LabOne the default web browser opens with the LabOne graphical user interface.

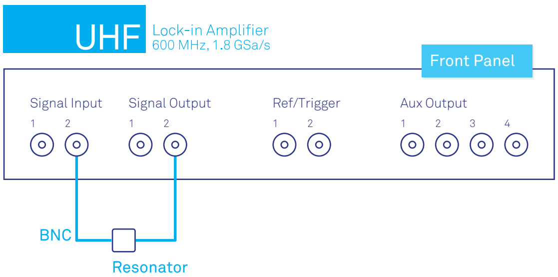


Figure 3.20. PID connection with UHF

The tutorial can be started with the default instrument configuration (e.g. after a power cycle) and the default user interface settings (e.g. as is after pressing F5 in the browser).

3.5.3. Automatic Gain Control

In this section you will learn how to control the output amplitude of your device-under-test. In theory, you can control the amplitude of any devices connected in the feedback configuration through a PID. In this case, we will use a resonator driven at its resonance frequency by one of two UHFLI signal generators and then measured with one of two lock-in channels.

If you are continuing the PLL tutorial, then we can just leave the PLL enabled. Otherwise, you should know how to generate an excitation signal at the modulation that you require and then measure the signal amplitude that you want to control. The device-under-test does not need to be a resonator. As shown in the screen shot below, we are measuring an amplitude of about 2.4

mV at the peak of the resonance. The goal is to control this amplitude to be a programmable value given by the user on-the-fly.

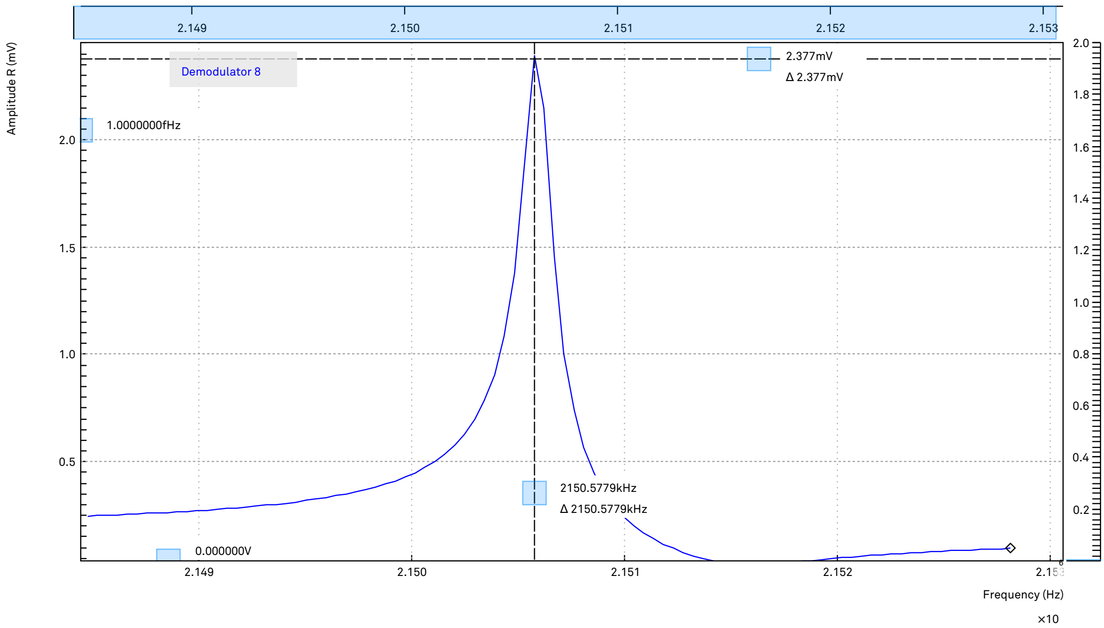


Figure 3.21. resonance amplitude to be controlled

For using the PID for AGC, we need to pull up a PID tab. For this tutorial, let us use PID 3. And then we need to set up the input and output of the PID 3 controller. The settings are shown in the table below.

Note

Please note that PLL 1 and PLL 2 are in fact the same as PID 1 and PID 2, respectively.

Table 3.17. Settings: acquire the reference signal

Tab	Section	#	Label	Setting / Value / State
PID	Input	3		Demodulator: R / 8
PID	Output	3		Output 1 Amplitude / 8
PID	Output	3	Center (V)	0
PID	Output	3	Upper Limit (V)	1.0
PID	Output	3	Lower Limit (V)	0

The most difficult part of PID controller setting is to select the proper P, I and D gain values. In this tutorial, we will use the Good Gain method developed by Finn Haugen of Telemark University College in Norway in 2010 for PID controller tuning. This is, in essence, a procedure to select PID parameters through real time observation of the closed loop step response.

Note

The Good Gain method can be considered to be a closed loop tuning method. Other types of closed loop PID tuning methods include the Ziegler-Nichols method, the Tyreus-Luyben method, and the damped oscillation method. The open loop tuning methods are, for example, the open loop

Ziegler-Nichols method, the C-H-R method, the Cohen and Coon method, the Fertik method, the Ciancone-Marline method, the IMC method, and the minimum error criteria methods.

The Good Gain method has the merit of being easily observable. There are only a few steps to follow using this PID tuning method:

1. Enable the PID. We are, initially, trying to manually adjust the system in open loop such that the controlled signal is close to its final value.
2. Set all P, I and D values to zero. Increase P gradually until you get a slight overshoot in the step response. This is done by manually adjust the set point and observe the controlled signal response. You should now observe the error between the measurement and the set point value getting smaller and smaller as P increases. Note that with the P controller, one can get close but never exactly to the final setpoint value. Make sure that the PID input or output is not unintentionally soft limited in minimum or maximum values (e.g. limited in amplitude, frequency etc).

Note

The Plotter tool is a very good way to observe the step response while adjusting the PID gain parameters as shown below.

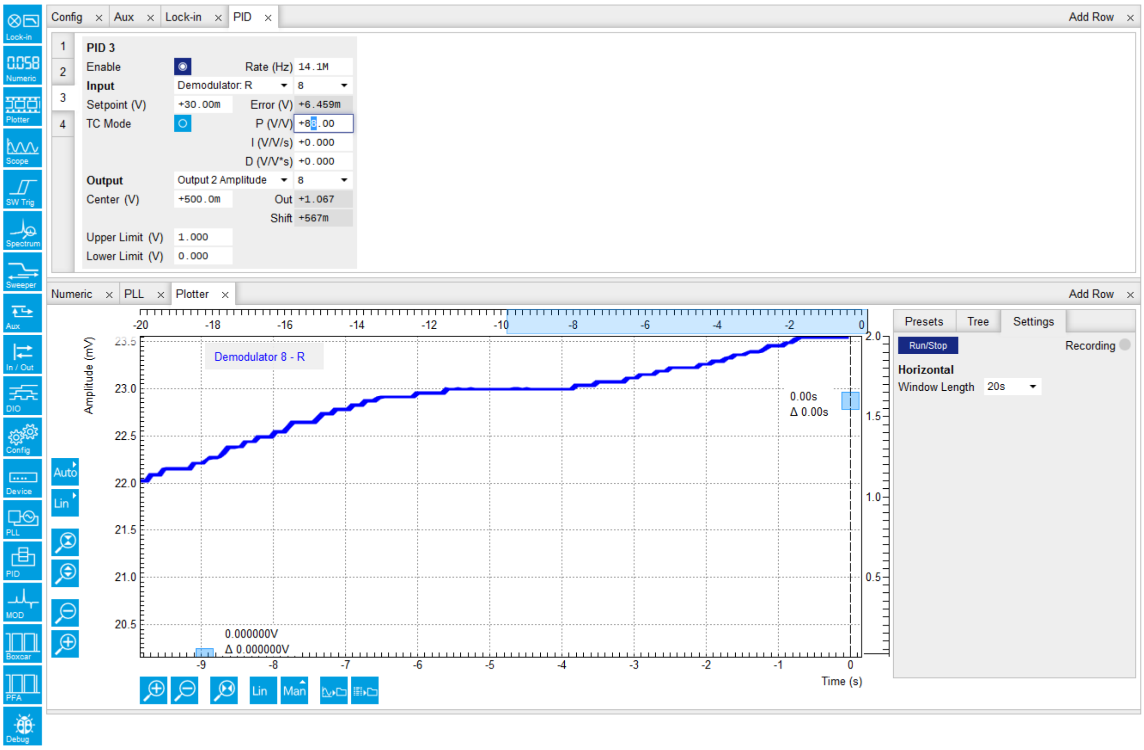


Figure 3.22. PID step response observation using the Plotter

3. Once the above condition is met, then set I to the value of $1.5T_{ou}$. T_{ou} is the delta time between the overshoot and the undershoot of the step response. Increase I gradually until the error value gets very close to 0. One can slightly decrease the P value by 50% to 80% if PID becomes slightly unstable.
4. One can potentially set D to 1/4 of I although it is not necessary and sometimes it might not even bring any improvement.

5. Check loop response again by applying a step response like in Step 2. Adjust mainly the P, I value accordingly for fine tuning.

Note

The set point can be manually toggled to create the step response condition.

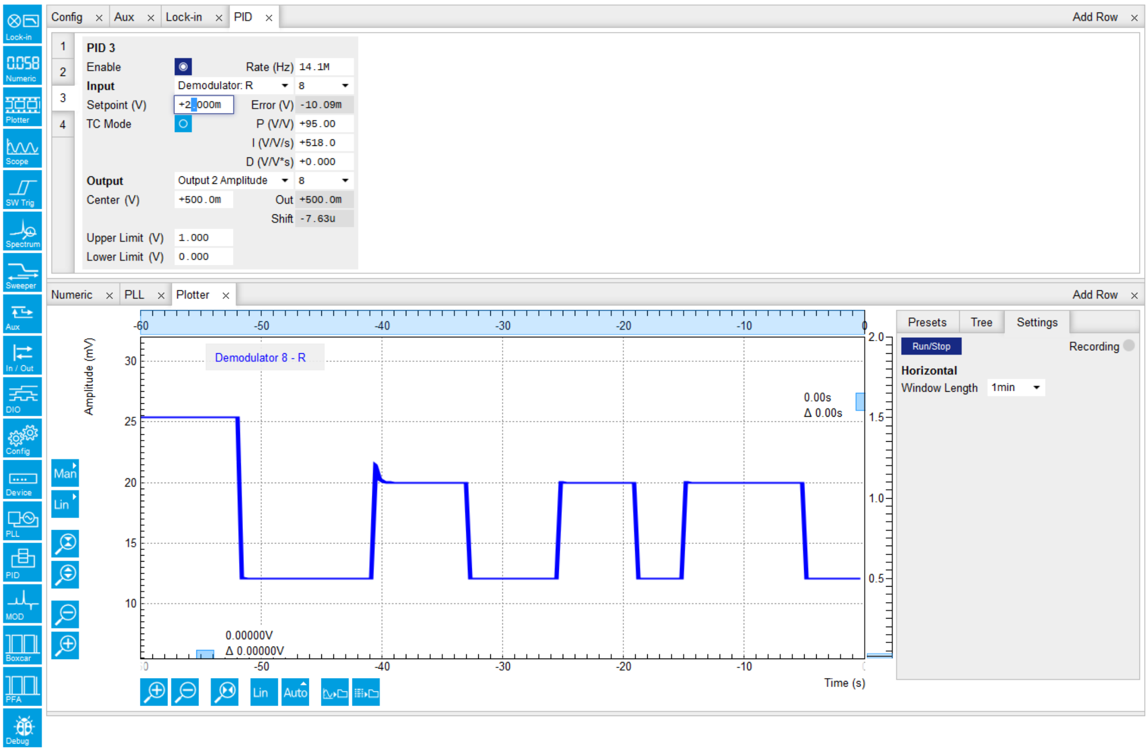


Figure 3.23. PID step response fine tuning by trying out different responses to set points

3.6. Tutorial PWA and Boxcar Averager

Note

This tutorial is applicable to UHF Instruments having the UHF-BOX Boxcar Averager option installed.

3.6.1. Goals and Requirements

This tutorial explains how to set up a periodic waveform analyzer (PWA) as well as utilize a boxcar averager for periodic signal measurement. The advantages of using the PWA and the boxcar averager over a digital scope or a lock-in amplification technique will be explained and demonstrated as follows.

The duty cycle and the signal energy that is available in the fundamental frequency scale almost linearly. For example, a rectangular signal pulse with 50% duty cycle has only 1/3 of the signal amplitude in the fundamental frequency. And if the duty cycle is further halved, then the signal in the fundamental is then also halved. Hence, lock-in amplification, which normally references to the fundamental frequency, may not always be the best way to recover a signal if the pulse waveform has a duty cycle smaller than 50%. In this case, boxcar averaging may be the more efficient measurement method. For instance, if one sees the signal spread out over many harmonic components without any prominent peak, a boxcar detection scheme might be the wiser choice to achieve the best possible signal-to-noise ratio.

To perform this tutorial, one will require at least one 3rd-party programmable arbitrary wave generator for narrow pulse generation.

3.6.2. Preparation

Connect the cables as illustrated below. Make sure the UHF is powered on, and then connect the UHF through the USB to your PC, or to your local area network (LAN) where the host computer resides. After starting LabOne the default web browser opens with the LabOne graphical user interface.

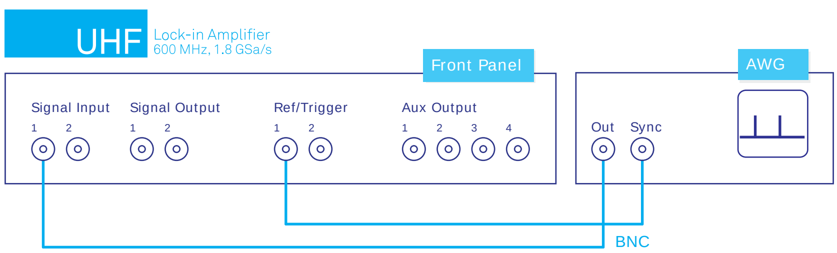


Figure 3.24. UHF connections to an external arbitrary wave generator

The tutorial can be started with the default instrument configuration (e.g. after a power cycle) and the default user interface settings (e.g. as is after pressing F5 in the browser).

3.6.3. Low Duty Cycle Signal Measurement

There are a couple of ways to measure a low duty cycle signal with the UHF. The obvious method is to use the digital scope function inside the LabOne interface to observe the sampled signal in the time domain. The other method is to utilise the PWA and the boxcar averager. Both methods will be shown. The first task is to generate a test signal.

Narrow Pulse Signal Generation

Using the external arbitrary waveform generator, generate a pulse with the following specifications.

Table 3.18. Narrow pulse signal specifications

Pulse Specification	Section
Pulse Type	Square
Amplitude	100 mVpp
Frequency	9.7 MHz
Duty Cycle	< 16%

Note

For this exercise, an Agilent 33500B Truefrom waveform generator is used. The minimum duty cycle for a 9.7 MHz signal is limited to about 16%.

The LabOne Scope can be used to observe the generated pulse waveform. Connect the output of the AWG directly to Signal Input 1 of the UHF. The Scope settings in LabOne are given in the table below. Also, the AWG should also be able to provide a TTL synchronization signal to be connected to the UHF REF Trigger input. This trigger signal will be used later on in for the PWA.

Table 3.19. Settings: observe the pulse waveform

Tab	Section	#	Label	Setting / Value / State
Lock-in	Signal Inputs	1	AC	On
Lock-in	Signal Inputs	1	50Ω	On
Lock-in	Signal Inputs	1	Range	200.0m
Scope	Display/Vertical		Channel 1	Signal Input 1/On
Scope	Trigger		Signal	Signal Input 1/On
Scope	Trigger		Enable	On
Scope	Trigger		Hysteresis	10.0m
Scope	Trigger		Run/Stop	On

One should now be able to observe Signal Input 1 similar to the following waveform in the Scope window. The Scope is set to self trigger on the pulse edges. Use the horizontal zoom to zoom into one single period. This can be done by rolling the mouse wheel forward to zoom in the horizontal axis. To zoom in on the vertical axis, press down the Shift key and roll the mouse wheel. One can also recenter the waveform by pressing on the left mouse button and dragging the Scope plot area.

One can observe that the shape of the supposedly square pulse does not have square edges as one would expect. This is due to the effect of the 600 MHz low pass filter at the input of the UHF.

In fact, the signal input bandwidth of 600 MHz corresponds to about 1.5 ns rise time (20% - 80%). Here, the sampled pulse width shown in the Scope is measured to be about 29ns or 30% duty cycle. The smeared out waveform has a duty cycle bigger than the 16% that was originally set.

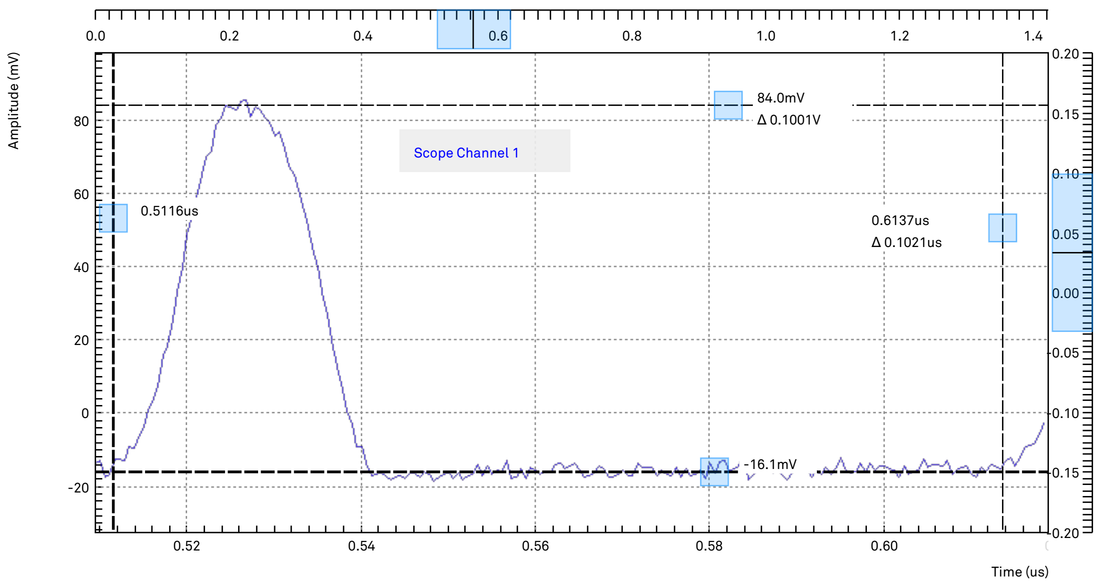


Figure 3.25. Digitized pulse waveform in Scope

Low Duty Cycle Analysis with Period Waveform Analyzer

To analyze the pulse waveform using the PWA, the UHF first has to lock to the trigger signal of the pulses. This is done using the Ext Ref mode of the UHF. The trigger signal is fed to the Ref/trigger connector on the front panel which can be an analog signal or a TTL signal. The trigger level can be adjusted in the DIO tab as shown in Section 3.2.5 . To lock to the trigger signal, the Lock-in tab should have the following settings; the goal is to lock the internal oscillator 1 to the external trigger from the AWG. The frequency of oscillator 1 in the Lock-in tab should now display 9.7 MHz, with the green light on to indicate a lock condition.

Table 3.20. Settings: lock oscillator 1 to external trigger 1

Tab	Section	#	Label	Setting / Value / State
Lock-in	Demodulators		Reference/4	ExtRef
Lock-in	Demodulators		Input Signal	Trigger 1

Then, to activate the PWA function, place one instance of the Boxcar tool in the LabOne web interface. To display the 9.7 MHz pulse over a single period, the following parameters need to be set.

Table 3.21. Settings: activate PWA

Tab	Section	#	Label	Setting / Value / State
Boxcar	PWA/Signal Input	1	Input Signal	Sig In 1/On
Boxcar	PWA	1	Run/Stop	On

Immediately, one can see in the PWA a very stable and smooth peak in one pulse period. The horizontal axis is shown in phase over 360 degrees to represent one period of the pulse waveform. The position of the peak also indicates the precise phase delay with respect to the trigger signal. In this phase representation, the PWA sub-divide the full 360 degrees into 1024 bins. The phase resolution is therefore about 0.35 deg; for a signal of 9.7 MHz this corresponds to a time resolution of about 100 ps.

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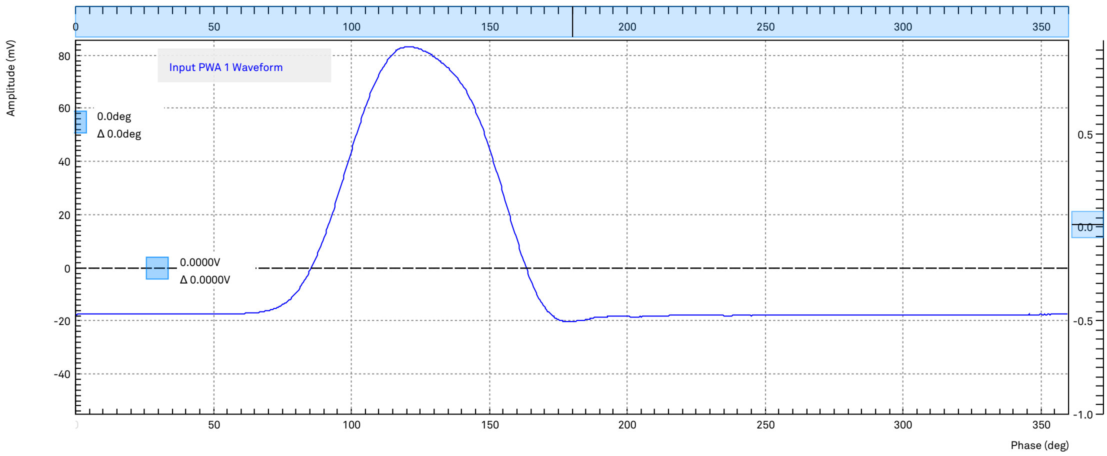


Figure 3.26. Pulse waveform in PWA

If this resolution is not sufficient, one can use the Zoom mode. Then by changing the Width (deg), one can then get more details of the characteristics of the pulse. The redefined phase range will then again be subdivided into 1024 bins. To acquire the same number of samples for a smaller range will increase acquisition time.

Note

The Zoom mode references internally the input signal to a higher harmonic of the reference frequency which allows zooming into the region of interest, and hence increasing the temporal resolution down to millidegrees. This gives a precise analysis for pulsed signals with low duty cycles or any other periodically repeating transient. Of course the real resolution is still limited by the signal input bandwidth, as in the case of the Scope.

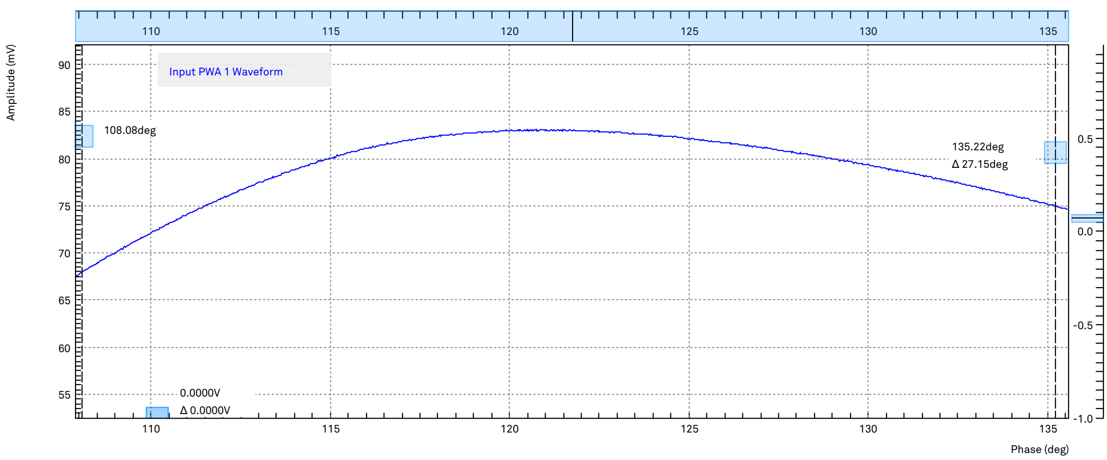


Figure 3.27. Pulse waveform in PWA with a zoom width of 27 degrees

Beside the phase domain display, one can also choose the horizontal display axis in the unit of time or frequency. The harmonics of the pulse waveform can also be analyzed by choosing Mode to be Harmonic. These options are all part of the multi-channel, multi-domain PWA for peak analysis.

Lastly, the frequency of 9.7 MHz is not chosen accidentally. In general, one should avoid choosing a modulation frequency that shares the same divisor as the maximum UHF-BOX repetition rate of 450 MHz i.e. the two numbers should not be commensurable. For example, 10 MHz and 450 MHz are commensurable since they can be both divided by 10. This commensurability issue arises from the internal UHF sampling effect which may cause certain bins to get filled constantly but not others. Such an example is shown in the figure below. A red warning indicator will be switched on when a potential commensurability problem is detected.

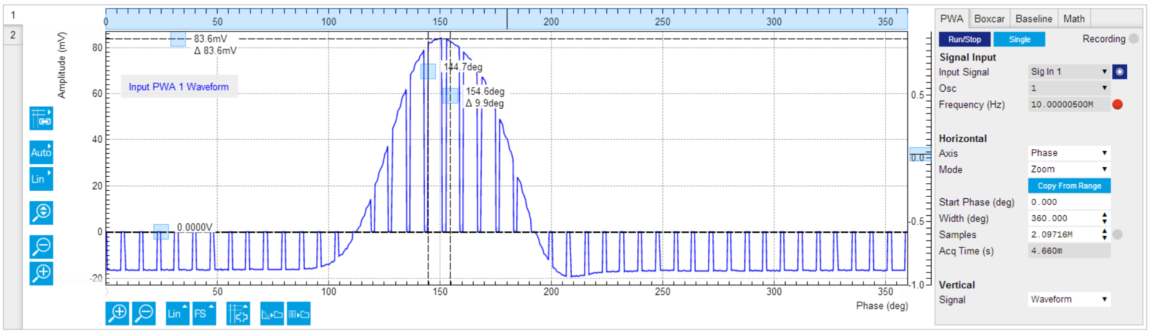


Figure 3.28. Problem of commensurability with the choice of the modulation frequency

Low Duty Cycle Analysis with Scope

The digitized waveform in the Scope can be jittery and noisy. One must remember that the pulse is sampled at 1.8 GSa/s which corresponds to a minimum resolution of 555 ps. This resolution implies that in the zero-crossing triggering, the triggered point on the waveform will not be the same for every pulse. This is indeed one major source of jitter observed.

The Scope comes with averaging and the persistence function which can in theory help to minimize jitter and noise. To use the averaging mode, one simply has to set Avg Filter field under Scope Display tab to Exp Moving Avg. Then one can choose the number of Averages desired. Below is the averaged pulse waveform at 10 points. Compared to the previous non-averaged waveform, it can be seen that now the spikes are smoothed out.

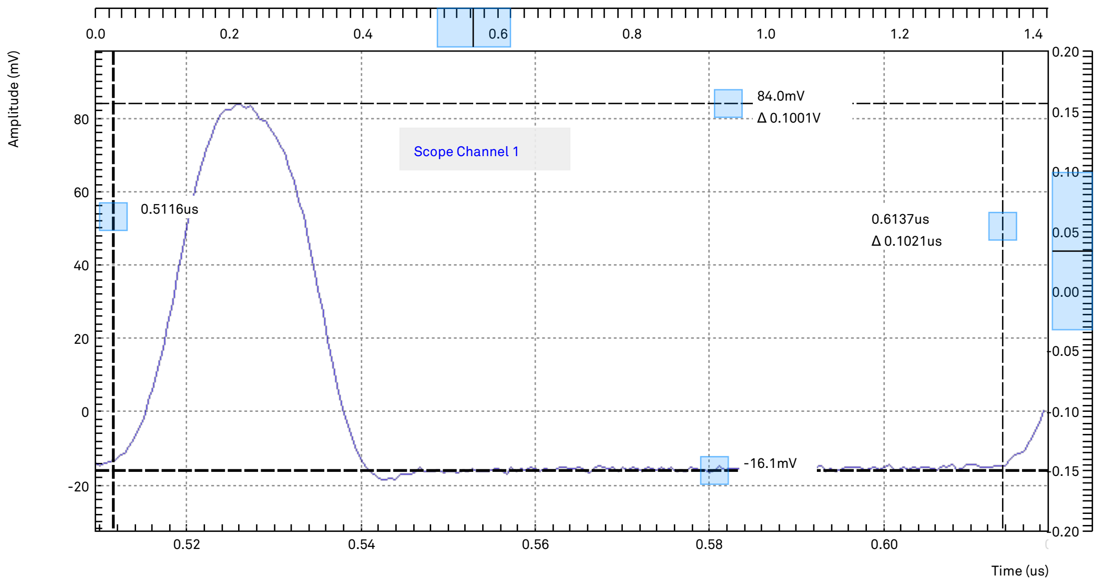


Figure 3.29. Scope waveform with 10 exponential moving averages

In order to observe the extent of jitter and noise, one can use the Persistence mode. Persistence can be enabled in the Display tab which overlaps the plot window in each triggered waveform. The result of the persistence is shown in the graph below where the overlapped traces are in red. One can measure an amplitude variation of about 7 mV and a time jitter of about 1.6 ns from the thickness of the red trace. Under this condition, the Scope method can be said to be not an ideal tool to analyze a narrow peak, especially when the peak width would be below a nanosecond.

Note

The vertical axis of the Scope needs to be in manual mode in Persistence mode. Persistence cannot be used simultaneously with averaging.

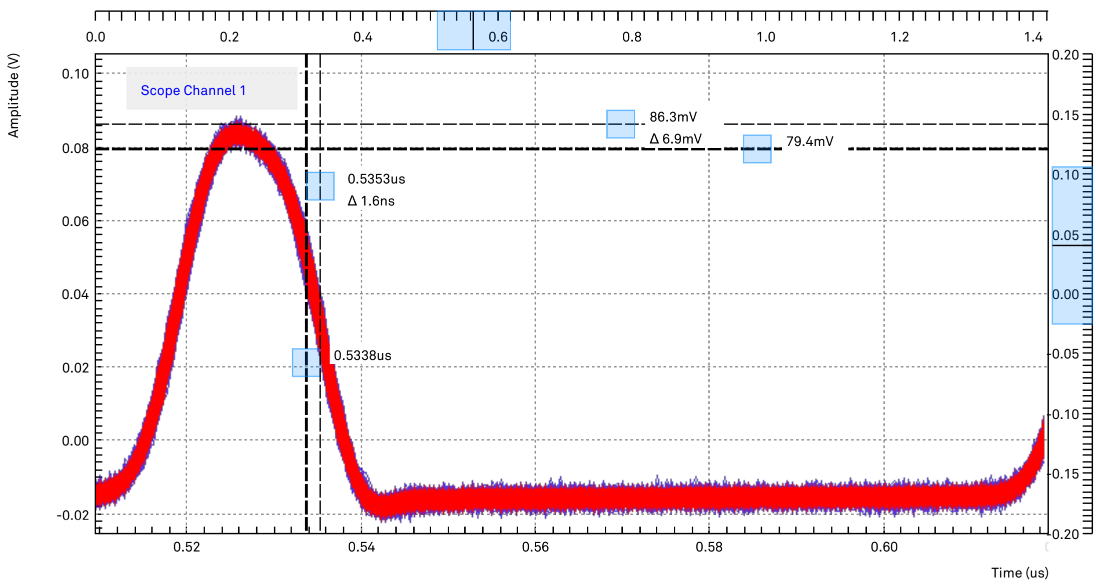


Figure 3.30. Scope waveform with persistence

By comparison, the PWA tool is certainly a more precise and elegant way to analyze this type of narrow pulse waveform.

Boxcar Integration

To use the boxcar averager, one can simply click on the Boxcar sub-tab. The boxcar averager integrates a section of the signal and has the output has a unit of volt-second (Vs). The integrated gate can be set either manually in the Start Phase (deg) and Width (deg) fields, or by positioning to vertical cursors and then by pressing Copy From Cursor. The integrated value is updated in the Value (Vs) field. An example boxcar setting is shown below. The integration width is chosen to be 10 degrees around the maximum peak.

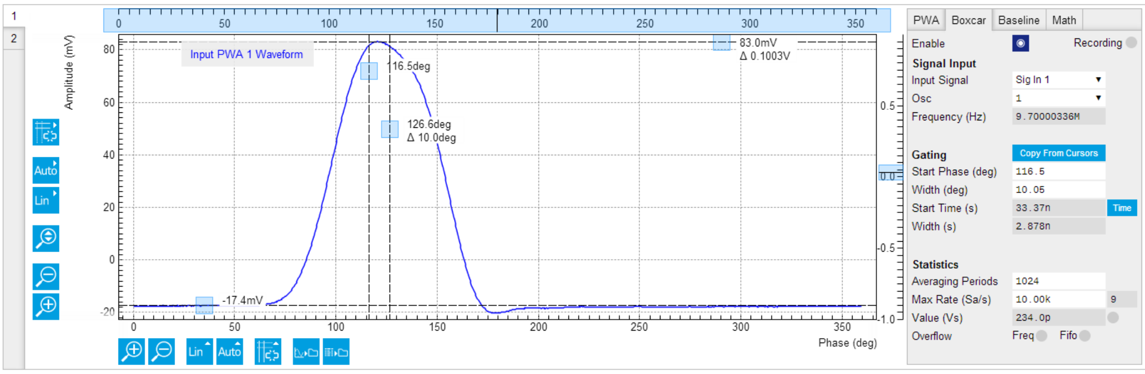


Figure 3.31. Boxcar integration of the pulse waveform

The result of the integration can also be shown graphically using the Plotter tool, as shown below.

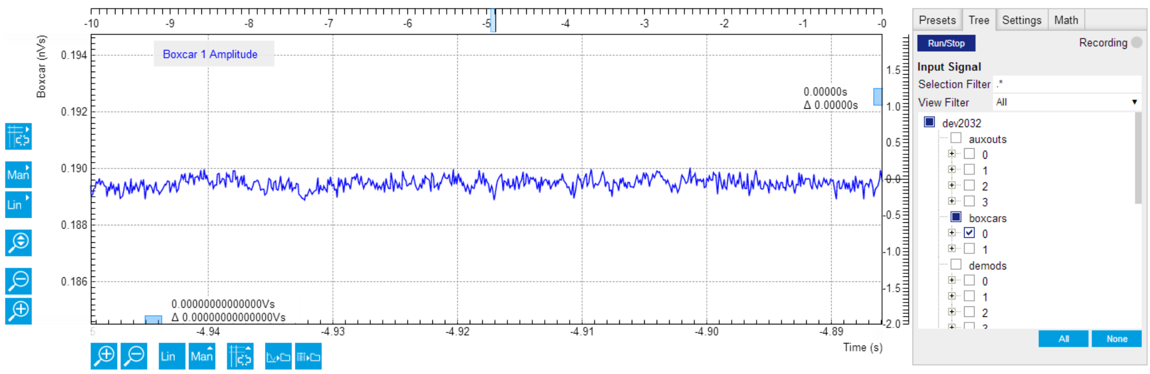


Figure 3.32. Boxcar integration result on Plotter output

Baseline Subtraction

It may happen that sometimes a noise signal is superimposed on the measured boxcar output. This noise can come from the power supply, emf noise coupled through the external wirings or even from the experiment itself. In this case, the baseline subtraction function can be applied to remove the undesired noise found in the Boxcar integration. To show the benefits of the baseline subtraction, the following connections can be made to simulate an undesired period noise injection. In this example, the UHF Signal Output 1 is used to generated a 10 kHz sine wave superimposed on top of the AWG waveform through a T-connector.

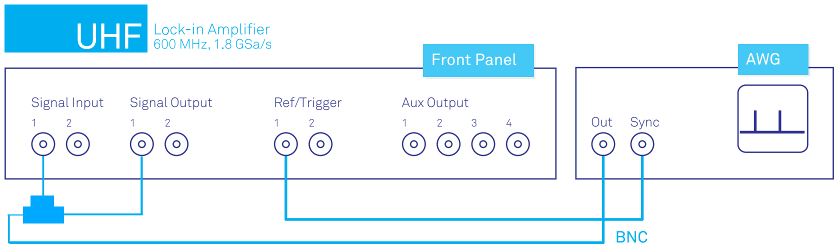


Figure 3.33. UHF connection for baseline subtraction test

Table 3.22. Settings: superpose a sine wave on top of the pulse waveform

Tab	Section	#	Label	Setting / Value / State
Lock-in	Oscillators	2		10.0k
Lock-in	Output Amplitudes	2		1.5
Lock-in	Signal Outputs		Output 1	On

When this is done, the Plotter tool will display an integrated value with the 10 kHz sine component instead of the flat line shown previously.

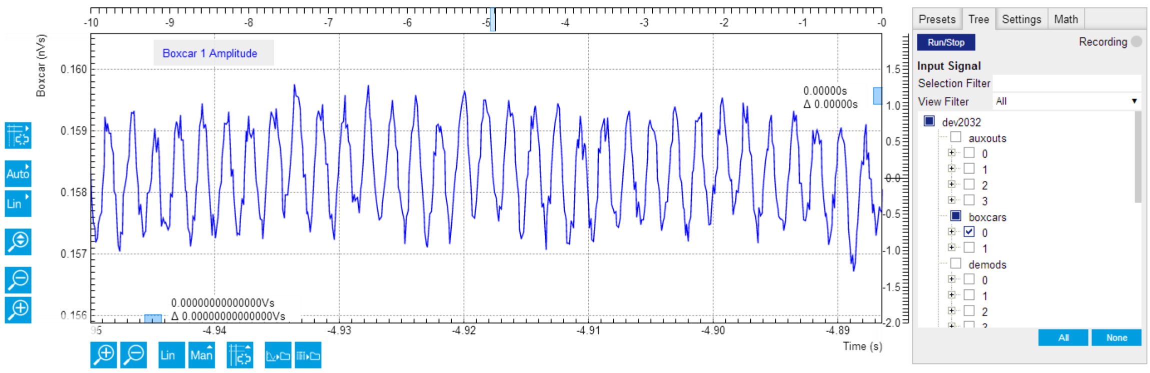


Figure 3.34. Boxcar output without baseline subtraction

In order to eliminate this undesired sine variation, one can simply go to the Baseline sub tab in the Boxcar tool. The important point is to select a baseline window with the cursor with the same width as the Boxcar integration window (e.g. 10 degrees in this tutorial). The baseline window is chosen to center around the zero crossing value of the PWA waveform, when possible. This is done so the baseline integration only integrates the superimposed sine and not the pulse waveform itself. The subtraction will then be only on the sine component.

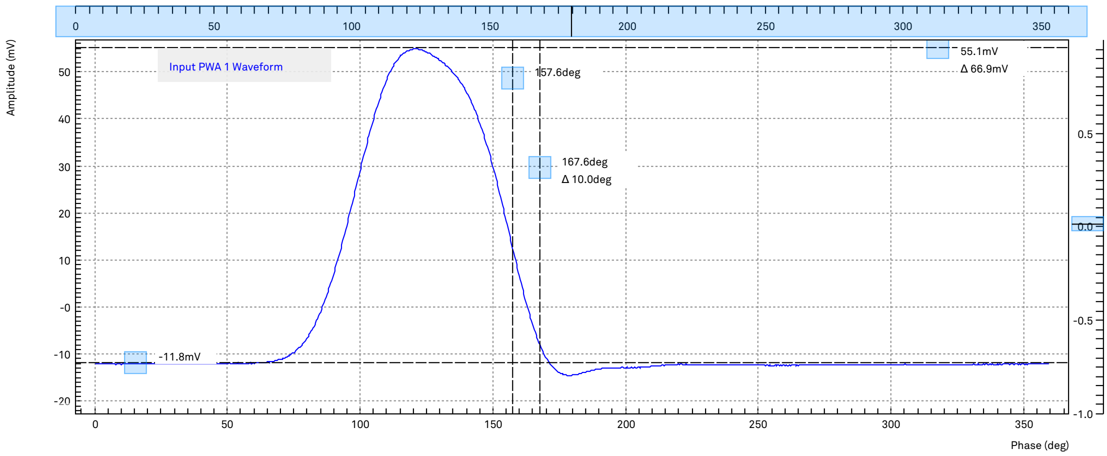


Figure 3.35. Baseline subtraction setup

Once the cursors are defined, one simply clicks on Run/Stop in the Baseline sub tab. One will see right away in the Plotter window that the sine component disappears. The trace that is left is again the original Boxcar averager value.

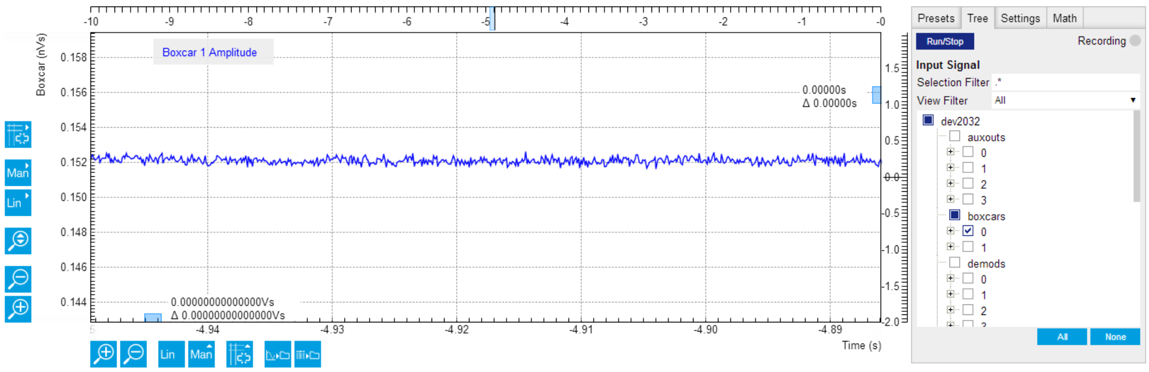


Figure 3.36. Boxcar output with baseline subtraction

3.7. Tutorial Multi-channel Boxcar Averager

Note

This tutorial is applicable to UHF Instruments having the UHF-BOX Boxcar Averager option installed.

3.7.1. Goals and Requirements

This tutorial explains how to extract the envelope of an amplitude modulated carrier in the Out PWA tool from the boxcar averager. More generally, the multi-channel boxcar feature serves to measure signals that are modulated with two time bases: the fast time base produces the pulses as measured by the boxcar averager, and the slow time base corresponds to a change of the envelope. A typical application would be an amplitude modulated narrow laser pulse waveform.

To perform this tutorial, an external arbitrary waveform generator with an external AM modulation capability is required. In this section you will learn how to measure a narrow pulse waveform that is amplitude modulated. Both the boxcar averager and the output PWA tools will be utilised in this example. First, one needs to generate a test signal.

3.7.2. Preparation

Connect the cables as illustrated below. Make sure the UHFLI is powered on, and then connect the UHFLI through the USB to your PC, or to your local area network (LAN) where the host computer resides. After starting LabOne the default web browser opens with the LabOne graphical user interface.

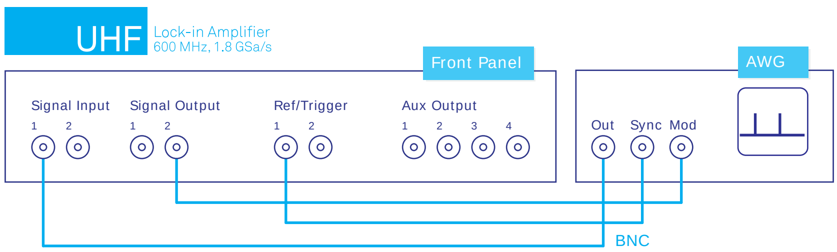


Figure 3.37. UHF connections to an external arbitrary wave generator

The tutorial can be started with the default instrument configuration (e.g. after a power cycle) and the default user interface settings (e.g. as is after pressing F5 in the browser).

3.7.3. Amplitude Modulated Narrow Pulse Measurement

AM Modulated Narrow Pulse Test Signal Generation

Using the external arbitrary waveform generator, a pulse waveform with the following specification should be generated.

Table 3.23. Narrow pulse signal specifications

Pulse Specification	Section
Pulse Type	Square
Amplitude	100 mVpp
Frequency	9.7 MHz
Duty Cycle	< 16%

Note

An Agilent 33500B Truefrom waveform generator is used in this example. The minimum duty cycle for a 10 MHz signal is limited to about 16%. An external AM modulation scheme is activated with 100% AM depth.

Furthermore, a sine wave should be generated from the UHF to amplitude modulate the AWG output. The output settings of the UHF are given below.

Table 3.24. Settings: observe the pulse waveform

Tab	Section	#	Label	Setting / Value / State
Lock-in	Oscillators		Frequency (Hz)	10.0 kHz
Lock-in	Signal Outputs	2	Amp (Vpk)	1.5 V
Lock-in	Signal Outputs	2	On	On
Scope	Display		Sampling Rate	28.1 MHz
Scope	Trigger		Signal	Signal Input 1/On
Scope	Trigger		Enable	On
Scope	Trigger		Run/Stop	On

Now, one should be able to see a waveform in Scope that is similar to the one shown below.

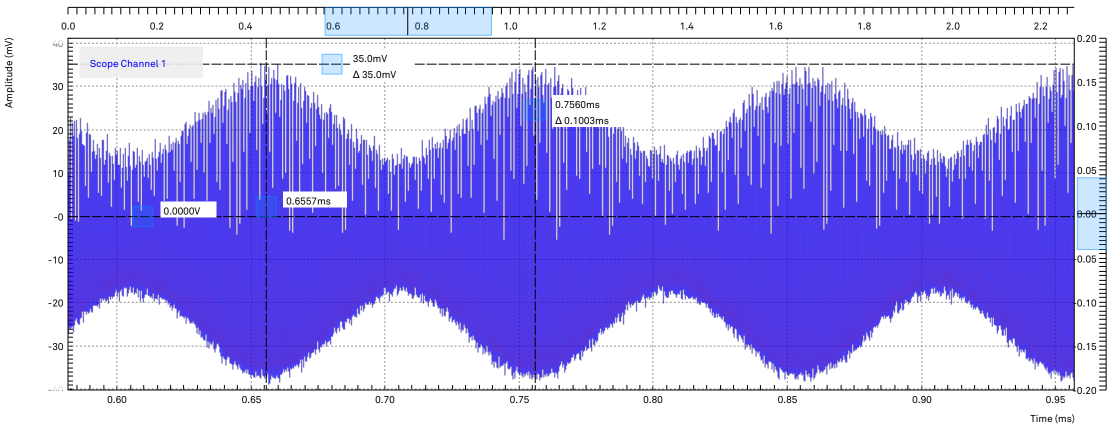


Figure 3.38. AM modulated pulse waveform

Envelope Recovery with the Output PWA

Just like the previous tutorial in the section called "Low Duty Cycle Analysis with Period Waveform Analyzer" , the PWA can be used to observe the pulse train. Although the measured result is similar to the previous tutorial, one can see in the PWA screen shot below that the amplitude is no longer 80 mV peak but rather around 40 mV. One has to remember that we have now an amplitude modulated pulse, and the PWA is showing the average amplitude of these pulses over time. If one decreases the number of averages in PWA then an amplitude-fluctuating behaviour can be observed more clearly.

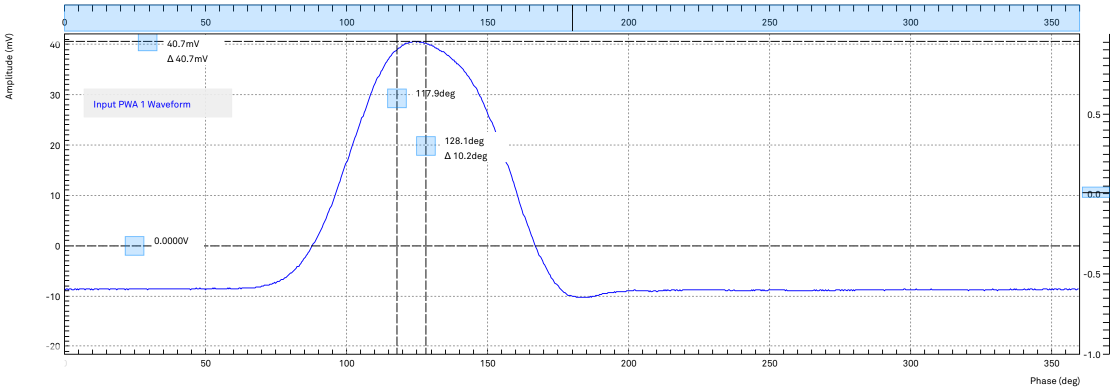


Figure 3.39. Carrier pulse in PWA

As shown previously, the Boxcar tool can be used to obtain the integrated pulse energy over a pre-defined gate width. This integrated value will of course be amplitude modulated as well. Now, the Output PWA can be used to recover this envelope of the integrated value. To do this, one now has to place an instance of the Out PWA tool on the LabOne web interface. The settings of the Output PWA are given below.

Table 3.25. Settings: observe the pulse waveform

Tab	Section	#	Label	Setting / Value / State
Out PWA	Settings/Signal Input	1	Input Signal	Boxcar 1
Out PWA	Settings/Signal Input	1	Osc Select	2
Out PWA	Settings/Signal Input	1		Run/Stop

One should be able to observe a sine wave similar to the one shown below. The Vs magnitude is proportional to the AM modulation depth. One can verify this by changing the AM depth to 50% (see second screen shot). The envelope magnitude indeed decreased by a factor of 2. Out PWA acts like a multi-channel boxcar that can be used to do multiple sideband analysis. The UHF-MF option may be required to observe more than one modulation frequency.

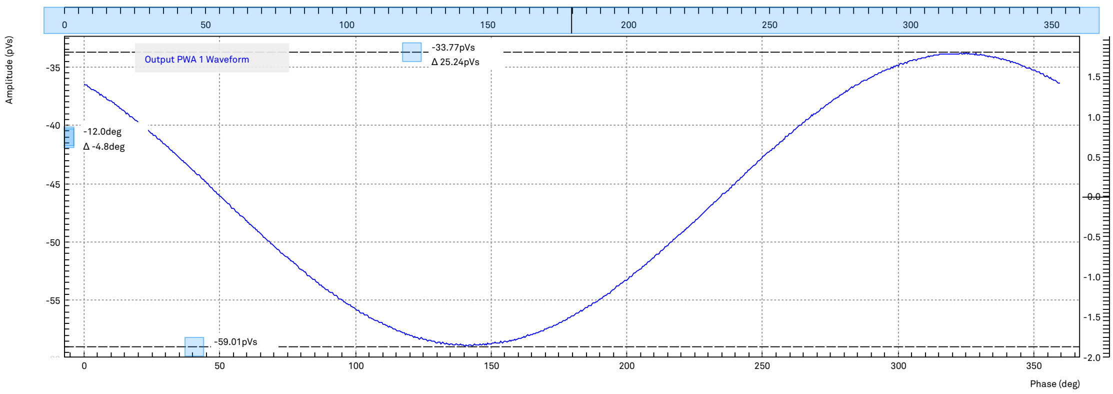


Figure 3.40. AM envelope in Out PWA with 100% and 50% AM depth

Chapter 4. Functional Description LabOne User Interface

This chapter gives a detailed description of all panels of the LabOne User Interface (UI) for the Zurich Instruments UHFLI. LabOne provides a data server and a web server that allow to access and control the Instrument with any of the most common web browsers (e.g. Firefox, Chrome, etc.). This architecture allows a platform independent interaction with the instrument by using various devices (PC, tablet, smart phone, etc.) even at the same time if needed.

On top of standard functionality like acquiring and saving data points this UI provides a wide variety of measurement tools for time and frequency domain analysis of measurement data as well as for convenient servo loop implementation and diagnosis.

4.1. User Interface Overview

4.1.1. UI Nomenclature

This section provides an overview of the LabOne User Interface, its main elements and naming conventions. The LabOne User Interface is a browser based UI provided as the primary interface to the UHFLI. Multiple browser sessions can access the instrument simultaneously and the user can have displays on multiple computer screens. Parallel to the UI the Instrument can be fully controlled and read out (possibly concurrently) by custom programs written in any of the supported languages (e.g. LabVIEW, MATLAB, C, etc.) connecting through the LabOne APIs.

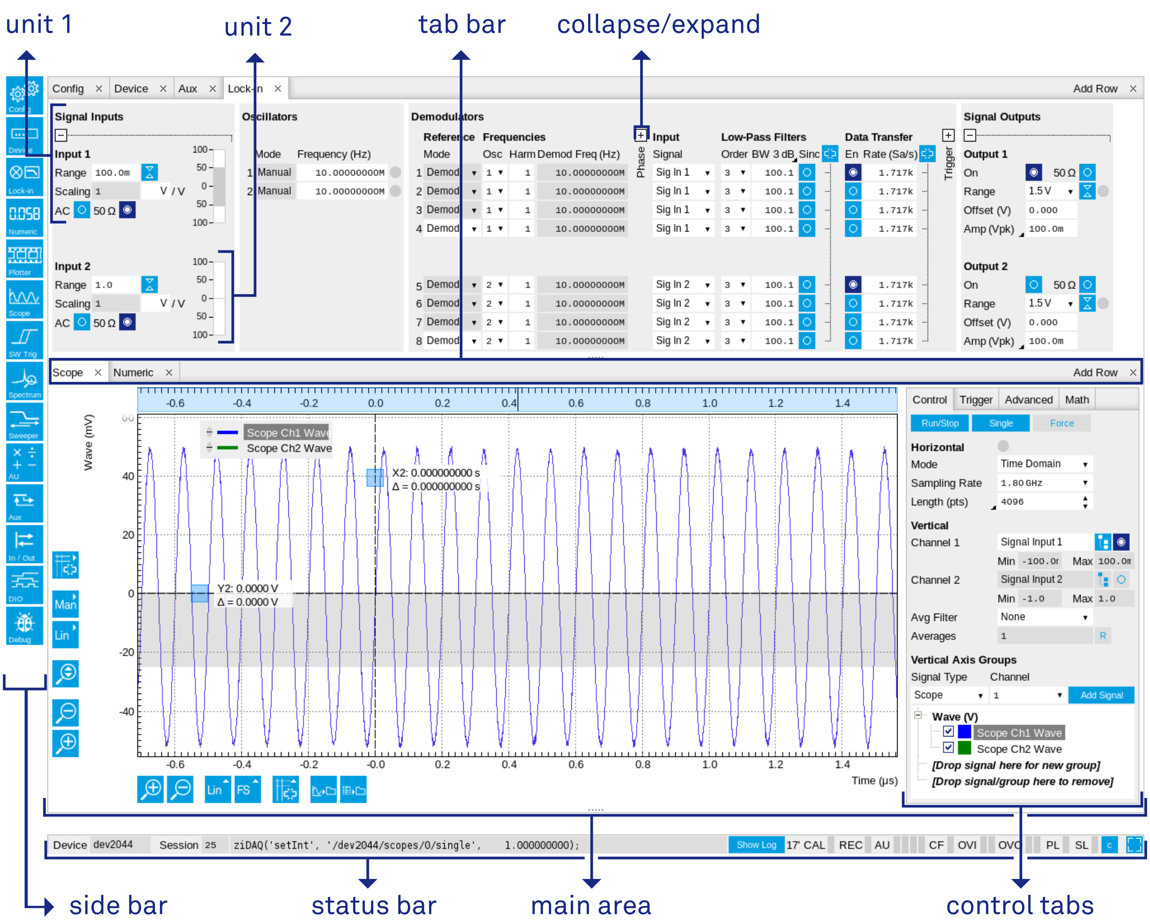


Figure 4.1. LabOne User Interface (default view)

Figure 4.1 shows the default screen after a new measurements session has been started. The appearance of the UI is by default divided in two tab rows, each containing a tab structure that allows to access the different settings and tools. Depending on display size and application, tab rows can be freely added and deleted with the control elements on the right hand side of each tab bar. Similarly the individual tabs can be deleted or added by selecting app icons from the left side bar. A simple click on an icon adds the requested tab to the active tab row, alternatively the icon can be dragged to the tab bar where it supposed to be placed. Moreover, tab positions can simply be changed by dragging them with the mouse within a row or across rows to the new location. Further items are highlighted in Figure 4.2 .

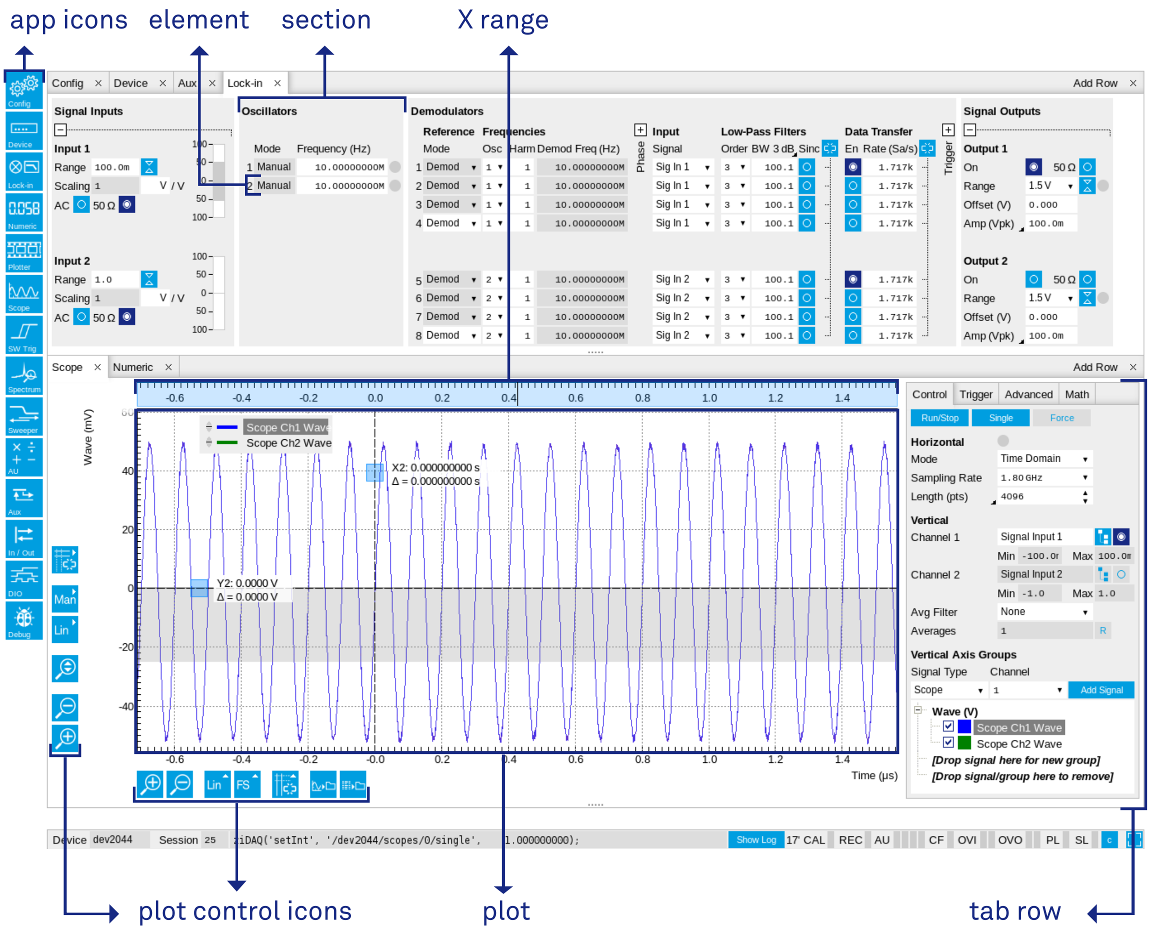


Figure 4.2. LabOne User Interface (more items)

Table 4.1 gives s brief descriptions and naming conventions for the most important UI items.

Table 4.1. LabOne User Interface features

Item name	Position	Description	Contains
side bar	left-hand side of the UI	contains app icons that activate the tool tabs and settings tabs - a click to a tab icon adds or activates the corresponding tab in the active row tab	app icons
status bar	bottom side of the UI	contains important status indicators, warning lamps, device and session information and access to the command log	status indicators
main area	center of the UI	accommodates all active tabs (tool tabs and setting tabs) - new rows can be added	rows and columns of tab rows, each consisting of tab bar and the active tab area

Item name	Position	Description	Contains
		and removed by using the control elements on the right hand side of the tab bar, located on the top of each tab row	
tab area	inside of each tab	provides the active part of each tab consisting of settings, controls and measurement tools	sections, plots, control tabs, unit selections

4.1.2. Unique Set of Analysis Tools

All Instruments feature a comprehensive tool set for time and frequency domain analysis for both incoming signals and demodulated signals. The selection of app icons however is limited by the software options installed on a particular device.

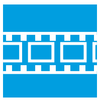
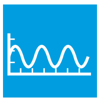
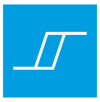
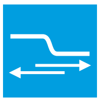
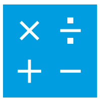
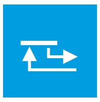
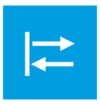
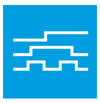
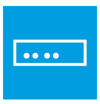
The icons provided by the icon bar on the left side of the UI can be roughly divided into two categories: settings and tools. Settings related tabs are in direct connection of the instrument hardware allowing the user to control all the settings and instrument states. Tools on the other side focus on the display and analysis of the gathered measurement data. There is no strict distinction between settings and tools, e.g. will the sweeper change certain demodulator settings while performing a frequency sweep. Within the tools one can further discriminate between time domain and frequency domain analysis, moreover, a distinction between the analysis of fast input signals - typical sampling rate of 1.8 GSa/s - and the measurement of orders of magnitude slower data - typical sampling rate of <28 MSa/s - derived for instance from demodulator outputs and auxiliary Inputs. Table 4.2 provides a brief classification of the tools.

Table 4.2. Tools for time domain and frequency domain analysis

	Time Domain	Frequency Domain
Fast signals (1.8 GSa/s)	Oscilloscope (Scope Tab)	FFT Analyzer (Scope Tab)
	Periodic Waveform Analyzer (Boxcar Tab)	Multi-Harmonic Analyzer (Boxcar Tab)
Slow signals (<28 MSa/s)	Numeric	Spectrum Analyzer (Spectrum Tab)
	Plotter	Sweeper
	Software Trigger	Multi-harmonic Analyzer (Out PWA Tab)
	Periodic Waveform Analyzer (Out PWA Tab)	-

The following table gives the overview of all app icons.

Table 4.3. Overview of app icons and short description

Control/Tool	Option/Range	Description
Lock-in		Quick overview and access to all the settings and properties for signal generation and demodulation.
Lock-in MF		Quick overview and access to all the settings and properties for signal generation and demodulation.
Numeric		Access to all continuously streamed measurement data as numerical values.
Plotter		Displays various continuously streamed measurement data as traces over time (roll-mode).
Scope		Displays shots of data samples in time and frequency domain (FFT) representation.
SW Trig		Provides complex trigger functionality on all continuously streamed data samples and time domain display.
Spectrum		Provides FFT functionality to all continuously streamed measurement data.
Sweeper		Allows to scan one variable (of a wide choice, e.g. frequency) over a defined range and display various response functions including statistical operations.
AU		Real-time arithmetic operations on demodulator outputs.
Aux		Controls all settings regarding the auxiliary inputs and auxiliary outputs.
In/Out		Access to all controls relevant for the main Signal Inputs and Signal Outputs on the instrument's front.
DIO		Gives access to all controls relevant for the digital inputs and outputs including the Ref/Trigger connectors.
Config		Provides access to software configuration.
Device		Provides instrument specific settings.

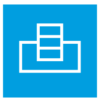
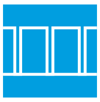
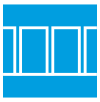
Control/Tool	Option/Range	Description
PID		Features all control and analysis capabilities of the PID controllers.
PLL		Features all control and analysis capabilities of the phase-locked loops.
MOD		Control panel to enable (de)modulation at linear combinations of oscillator frequencies.
Boxcar		Boxcar settings and periodic waveform analyzer for fast input signals.
Out PWA		Multi-channel boxcar settings and measurement analysis for boxcar outputs.

Table 4.4 gives a quick overview over the different status bar elements along with a short description.

Table 4.4. Status bar description

Control/Tool	Option/Range	Description
Command log	last command	Shows the last command. A different formatting (Matlab, Python, ..) can be set in the config tab. The log is also saved in [User]\Documents\Zurich Instruments\LabOne\WebServer\Log
Show Log	Show Log	Show the command log history in a separate browser window.
Session	integer value	Indicates the current session identifier.
Device	devXXX	Indicates the device serial number.
Next Calibration	Time or 'M'	Remaining minutes until the first calibration is executed or a recalibration is requested. A time interval longer than 99 minutes is not displayed. Manual calibration mode is indicated by a 'M'.
CAL	grey/yellow/red	State of device self calibration. Yellow: device is warming up and will automatically execute a self calibration after 16 minutes. Grey: device is warmed-up and self calibrated. Red: it is recommended to manually execute a self calibration to assure operation according to specifications.
REC	grey/green	A green indicator shows ongoing data recording (related to global recording settings in the Config tab).
AU	grey/green	Arithmetic Unit - Green: indicates which of the arithmetic units is enabled.
CF	grey/yellow/red	Clock Failure - Red: present malfunction of the external 10 MHz reference oscillator. Yellow: indicates a malfunction occurred in the past.

Control/Tool	Option/Range	Description
OVI	grey/yellow/red	Signal Input Overflow - Red: present overflow condition on the signal input also shown by the red front panel LED. Yellow: indicates an overflow occurred in the past.
OVO	grey/yellow/red	Overflow Signal Output - Red: present overflow condition on the signal output. Yellow: indicates an overflow occurred in the past.
PL	grey/yellow/red	Packet Loss - Red: present loss of data between the device and the host PC. Yellow: indicates a loss occurred in the past.
SL	grey/yellow/red	Sample Loss - Red: present loss of sample data between the device and the host PC. Yellow: indicates a loss occurred in the past.
C	C	Reset status flags: Clear the current state of the status flags
RUB	grey/yellow/green	Rubidium Clock - Grey: no rubidium clock is installed. Yellow: Rubidium clock is warming up (takes approximately 300 s). Green: Rubidium clock is warmed up and locked.
BOX	grey/green	Boxcar - Green: indicates which of the boxcar units is enabled.
MOD	grey/green	MOD - Green: indicates which of the modulation kits is enabled.
PID	grey/green	PID - Green: indicates which of the PID units is enabled.
PLL	grey/green	PLL - Green: indicates which of the PLLs is enabled.
Full Screen		Toggles the browser between full screen and normal mode.

4.1.3. Plot Functionality

Several tools - Plotter, Scope, SW Trig, Spectrum. Sweeper, Boxcar and outPWA - provide a graphical display of measurement data in the form of plots. These are multi-functional tools with zooming, panning and cursor capability. This section introduces some of the highlights.

Plot area elements

Plots consist of the plot area, the X range and the range controls. The X range (above the plot area) indicates which section of the wave is displayed by means of the blue zoom region indicators. The two ranges show the full scale of the plot which does not change when the plot area displays a zoomed view. The two axes of the plot area instead do change when zoom is applied.

The mouse functionality inside of plot is summarized in Table 4.5

Table 4.5. Mouse functionality inside plots

Name	Action	Description	Performed inside
Panning	left click on any location and move around	moves the waveforms	plot area
Zoom X axis	mouse wheel	zooms in and out the X axis	plot area
Zoom Y axis	shift + mouse wheel	zooms in and out the Y axis	plot area
Window zoom	shift and left mouse area select	selects the area of the waveform to be zoomed in	plot area
Absolute jump of zoom area	left mouse click	moves the blue zoom range indicators	X and Y range, but outside of the blue zoom range indicators
Absolute move of zoom area	left mouse drag and drop	moves the blue zoom range indicators	X and Y range, inside of the blue range indicators
Zoom	mouse wheel	zooms in and out the related axis	X and Y range
Full Scale	double click	set X and Y axis to full scale	plot area

Each plot area contains a legend that lists all the shown signals in the respective color. The legend can be moved to any desired position by means of drag and drop.

The X range and Y range controls are described in Table 4.6 .

Table 4.6. Plot control description

Control/Tool	Option/Range	Description
Axis scaling mode	Auto FS Man Auto	Selects between automatic, full scale and manual axis scaling.
Axis mapping mode	Lin Lin Log dB	Select between linear, logarithmic and decibel axis mapping.
Axis zoom in		Zooms the respective axis in by a factor of 2.
Axis zoom out		Zooms the respective axis out by a factor of 2.
Rescale axis to data		Rescale the foreground Y axis in the selected zoom area.
Save figure		Generates an SVG of the plot area or areas for dual plots to the local download folder.
Save data		Generates a TXT consisting of the displayed set of samples. Select full scale to save the complete wave. The save data function only saves one shot at a time (the last displayed wave).

Cursors and Math

The plot area provides two X and two Y cursors which appear as dashed lines inside of the plot area. The four cursors are selected and moved by means of the blue handles individually by means of drag and drop. For each axis there is a primary cursor indicating its absolute position and a secondary cursor indicating both absolute and relative position to the primary cursor.

Cursors have an absolute position which does not change by pan or zoom events. In case the cursors move out of the zoom area, the corresponding handle is displays on the related side of the plot area. Unless the handle is moved, the cursor keeps the current position. This functionality is very effective to measure large deltas with high precision (as the absolute position of the other cursors does not move).

The cursor data can also be used to define the input data for the mathematical operations performed on plotted data. This functionality is available in the Math sub-tab of each tool. The following Table 4.7 gives an overview of all the elements and their functionality. It is important to know that the Signals and Operations defined will always be performed only on the currently chosen active trace.

Table 4.7. Plot math description

Control/Tool	Option/Range	Description
Source Select	Cursor Loc	Cursor coordinates as input data.
	Cursor Area	Consider all plot data inside the rectangle defined by the cursor coordinates as input for statistical functions (Min, Max, Avg, Std, Int).
	Tracking	Output plot value at current cursor position. Options are X1 and X2.
	Wave	Consider all plot data currently displayed in the Plot as input for statistical functions (Min, Max, Avg, Std, Int).
	Peak	Find and determine the various peaks in the plotted data and their associated values.
	Histogram	Select Histogram related data as Math input.
Operation Select	X1, X2, X2-X1, Y1, Y2, Y2-Y1	Cursors values and their differences.
	Min, Max, Avg, Std, Int	Statistical Functions applied to a set of samples.
	Pos, Level	Finds the Position (x-values) and the Levels (y-values) of Peaks on a set of samples.
Add	Add	Add the selected math function to the result table below.
Add All	Add All	Add all operations for the selected signal to the result table below.
Select All	Select All	Select all lines from the result table above.
Clear Selected	Clear Selected	Clear selected lines from the result table above.
Unit Prefix	Unit Prefix	Adds a suitable prefix to the SI units to allow for better readability and increase of significant digits displayed.

Control/Tool	Option/Range	Description
CSV	CSV	Values of the current result table are saved as a text file into the download folder.
Link	Link	Provides a LabOne Net Link to use the data in tools like Excel, Matlab, etc.
Help	Help	Opens the LabOne User Interface help.

Note

For calculation of the standard deviation the corrected sample standard deviation is used as defined by $\sqrt{\frac{1}{N-1}\sum_{i=1}^{N}(x_i-\overline{x})^2}$ with a total of N samples x_i and an arithmetic average $\overline{x}$.

Tree Sub-Tab

The Numeric tab and Plotter tab are able to display so many different types of signal that a number of different options are provided to access them. One of them is the Tree sub-tab that allows essentially to access all streamed measurement data in a hierarchical structure by checking the boxes of the signal that should be displayed.

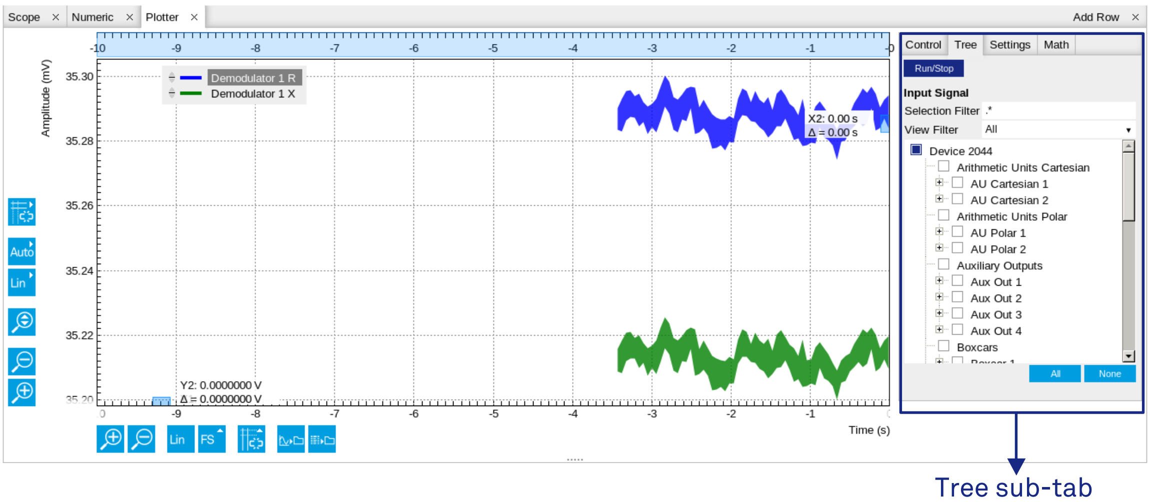


Figure 4.3. Tree sub-tab in Plotter tab

Table 4.8. Tree description

Control/Tool	Option/Range	Description
Selection Filter	Regular expression	Create a filter to define which streaming nodes are selected. The View Filter presents a number of presets that can serve as examples.
View Filter	All	Show all available nodes.

Control/Tool	Option/Range	Description
	R,X,Y	Show demodulator streaming nodes.
	Streams	Show all streaming nodes.
	Boxcar	Show boxcar streaming nodes.
	AU	Show arithmetic unit streaming nodes.
All	All	Select all nodes that can be selected in the relevant context.
None	None	Unselect all nodes.

Vertical Axis Groups

Vertical Axis groups are available in the Plotter tab, SW Trigger tab and Sweeper tab. These tools are able to show signals with different axis properties within the same plot. As a frequency and amplitude axis have fundamentally different limits they have each their individual axis which allows for correct auto scaling. However, signals of the same type e.g. Cartesian demodulator results should preferably share one scaling. This allows for fast signal strength comparison. To achieve this the signals are assigned to specific axis group. Each axis group has its own axis system. This default behavior can be changed by moving one or more signals into a new group.

The tick labels of only one axis group can be shown at once. This is the foreground axis group. To define the foreground group click on one of the group names in the Vertical Axis Groups box. The current foreground group gets a high contrast color.

Select foreground group: Click on a signal name or group name inside the Vertical Axis Groups. If a group is empty the selection is not performed.

Split the default vertical axis group: Use drag&drop to move one signal on the field **[Drop signal here to add a new group]**. This signal will now have its own axis system.

Change vertical axis group of a signal: Use drag&drop to move a signal from one group into another group that has the same unit.

Group separation: In case a group hosts multiple signals and the unit of some of these signals changes, the group will be split in several groups according to the different new units.

Remove a signal from the group: In order to remove a signal from a group drag&drop the signal to a free area inside the Vertical Axis Groups box.

Remove a vertical axis group: A group is removed as soon as the last signal of a custom group is removed. Default groups will remain active until they are explicitly removed by drag&drop. If a new signal is added that match the group properties it will be added again to this default group. This ensures that settings of default groups are not lost, unless explicitly removed.

Rename a vertical axis group: New groups get a default name 'Group of ...'. This name can be changed by double-clicking on the group name.

Hide/show a signal: Uncheck/check the check box of the signal. This is faster than fetching a signal from a tree again.

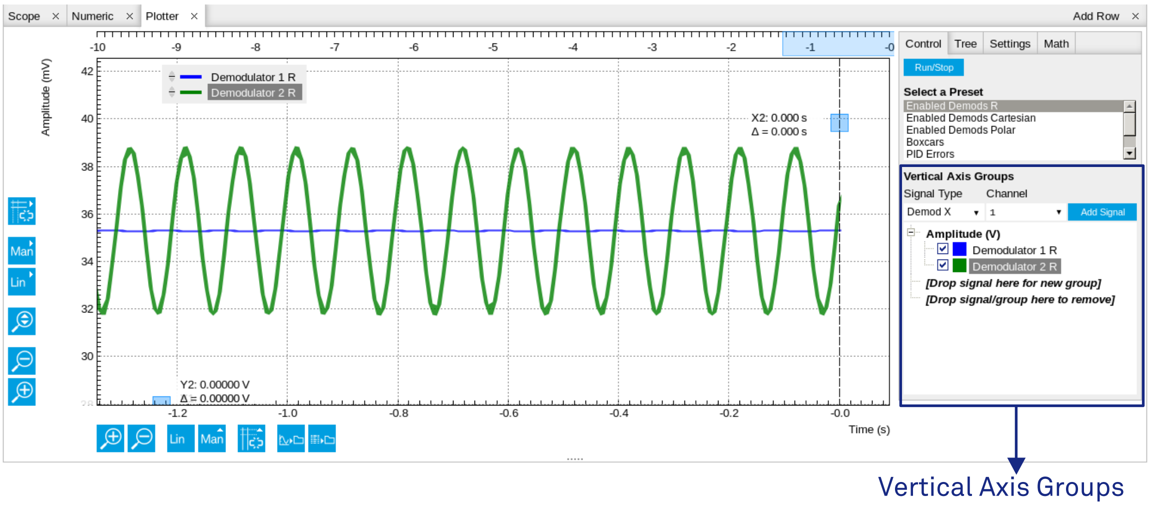


Figure 4.4. Vertical Axis Group in Plotter tool

Table 4.9. Vertical Axis Groups description

Control/Tool	Option/Range	Description
Vertical Axis Group		Manages signal groups sharing a common vertical axis. Show or hide signals by changing the check box state. Split a group by dropping signals to the field [Drop signal here to add new group]. Remove signals by dragging them on a free area. Rename group names by editing the group label. Axis tick labels of the selected group are shown in the plot. Cursor elements of the active wave (selected) are added in the cursor math tab.
Signal Type	Demod X, Y, R, Theta	Select signal types for the Vertical Axis Group.
	Frequency	
	Aux Input 1, 2	
	HW Trigger	
	PID Error	
	PID Shift	
	PID Value	
	Boxcar	
	AU Cartesian	
	AU Polar	
Channel	integer value	Selects a channel to be added.
Add Signal	Add Signal	Adds a signal to the plot. The signal will be added to its default group. It may be moved by drag and drop to its own group. All signals within a group share a common y-axis. Select a group to bring its axis to the foreground and display its labels.

4.2. Lock-in Tab

This tab is the main lock-in amplifier control panel. Instruments with UHF-MF multi-frequency option installed are referred to Section 4.3 .

4.2.1. Features

- Control for 2 separate lock-in units with 4 demodulators each
- Auto ranging, scaling, arbitrary input units for both input channels
- Control for 2 oscillators
- Range setting for signal inputs and signal outputs
- Flexible choice of reference source, trigger options and data transfer rates

4.2.2. Description

The lock-in tab is the main control center of the instrument and open after start up by default. Whenever closed or a new instance is needed the following symbol pressed will generate a new instance of the tab.

Table 4.10. App icon and short description

Control/Tool	Option/Range	Description
Lock-in		Quick overview and access to all the settings and properties for signal generation and demodulation.

The Lock-in tab (see Figure 4.5) is horizontally divided into two identical sections. The upper section is related to Signal Input 1 and Signal Output 1, and the lower section to Signal Input 2 and Signal Output 2, i.e. the main BNC connectors on the front side of the instrument. The two input channels and output channels are identical in all aspects.

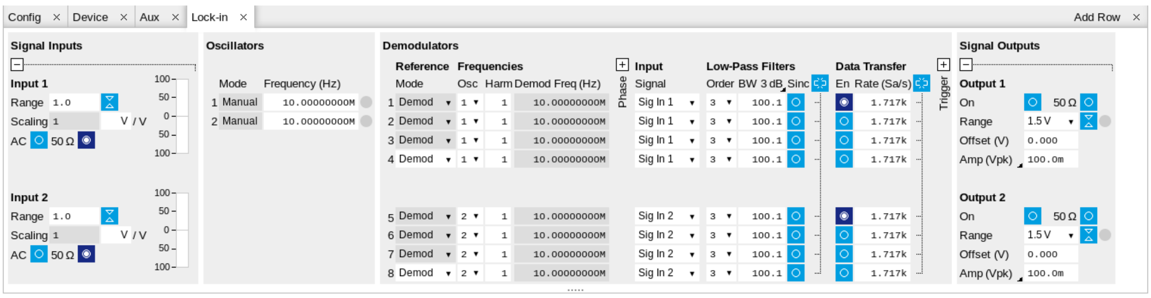


Figure 4.5. LabOne User Interface Lock-in

From left to right the tab is organized in the following sections: the Signal Inputs section allows the user to define all relevant settings specific to the signal entered as for example input coupling, range, etc. The Oscillators section indicates the frequencies of both internal oscillators. These frequencies can be either manually defined by typing a frequency value in the field or they can be referenced to an external source. The Demodulators section holds the main settings for the 8 dual-phase demodulator units. Some of the available options like phase adjustment and the trigger functionality are collapsed by default. It takes one mouse click "+" icon in order to expand those controls. On the right hand side of the Lock-in tab the Signal Outputs section allows to define signal amplitudes, offsets and range values.

The Scaling field below the Range field can be used to multiply the Signal Input data to account for the gain of an external amplifier. In case there is a gain of 10 applied to the input signal externally, then the Scaling field can be set to 0.1 to compensate for it.

There are two buttons below the Scaling field that can be toggled: the AC/DC button and the 50 Ω/1 MΩ. The AC/DC button sets the coupling type: AC coupling has a high-pass cutoff frequency that can be used to block large DC signal components to prevent input signal saturation during amplification. The 50 Ω/1 MΩ button toggles the input impedance between low (50 Ω) and high (approx. 1 MΩ) input impedance. 50 Ω input impedance should be selected for signal frequencies above 10 MHz to avoid artifacts generated by multiple signal reflections within the cable. With 50 Ω input impedance, one will expect a reduction of a factor of 2 in the measured signal if the signal source also has an output impedance of 50 Ω.

To the right of the Signal Inputs section, one finds the Oscillators section which has two entries. The Mode column indicates whether the oscillators frequency is fixed to a value entered by the user (Manual) or if another instrument resource determines the frequency (e.g. ExtRef, PLL). In such cases the associated frequency field will be greyed-out. In internal reference mode, a demodulator operates at the ideal internally generated frequency and provides the best possible demodulation. For external reference mode, it is required to internally recover the demodulation frequency with a high-quality PLL. A green light right next to the frequency will then indicate smooth operation.

The next section contains the Demodulators settings. In total there are 8 lines each representing one demodulator. The Mode column is read only for all demodulators except 4 and 8, which can be to set to either internal reference (Demod) or external reference mode (ExtRef). When internal reference mode is selected, it is possible to demodulate the input signal with 4 demodulators simultaneously, using different filter settings or at different harmonic frequencies of the reference frequency. For external reference mode, one demodulator is used for the reference recovery and a few settings are greyed-out, and therefore 3 demodulators remain for simultaneous measurements.

The Signal column always defines the signal that is taken as input for the demodulator. A wide choice of signals can be selected, among the Signal Inputs, the Trigger Inputs, the Auxiliary Inputs and Auxiliary Outputs. Like this it is possible to flexibly generate advanced measurement topologies adapting to many needs of the users.

For each demodulator an additional phase shift can be introduced to the associated oscillator by entering the phase offset in the Phase column. This phase is added both, to the reference channel and the output of the demodulator. Hence, when the frequency is generated and detected using the same demodulator, signal phase and reference phase change by the same amount and no change will be visible in the demodulation result. Demodulation of frequencies that are integer multiples of any of the oscillator frequencies is achieved by entering the desired factor in the Harm column. The demodulator readout can be obtained using the Numeric tab which is described in Section 4.4 .

In the middle of the Lock-in tab is the Low-Pass Filters section where the filter order can be selected in the drop down list for each demodulator and the filter bandwidth (BW 3dB) can chosen by typing a numerical value. Alternatively the time constant of the filter (TC) or the noise equivalent power filter bandwidth (BW NEP) can be chosen by clicking on the column's header. For example, setting the filter order to 4 corresponds to a roll off of 24 dB/oct or 80 dB/dec i.e. an attenuation of 10^4 for a tenfold frequency increase. If the Low-Pass Filter bandwidth is comparable to or larger than the demodulation frequency, the demodulator output may contain frequency components at the frequency of demodulation and its higher harmonics. In this case, the additional Sinc Filter can be enabled. It attenuates those unwanted harmonic components in the demodulator output. The Sinc Filter is also useful when measuring at low frequencies, since it allows to apply a Low-

Pass Filter bandwidth closer to the demodulation frequency, thus speeding up the measurement time.

Each demodulator is activated by the En button in the Data Transfer section where also the sampling rate (Rate) for each demodulator can be defined.

The Trigger section next to the Data Transfer allows for setting trigger conditions in order to control and initiate data transfer from the Instrument to the host PC by the application of logic signals (e.g. TTL) to either Trigger Input 3 or 4 on the back panel.

In the Signal Outputs section the On buttons allow to activate each of the Signal Outputs. For Instruments with no UHF-MF option installed this is also the place where the output amplitudes for each of the Signal Outputs can be set in adjustable units. The Range drop down list is used to select the proper output range setting. On each Signal Output a digital offset voltage (Offset) can be defined. The maximum output signal permitted is ±1.5 V.

The block diagram displayed in Figure 4.6 indicates the main demodulator components and their interconnection. The understanding of the wiring is essential for successfully operating the instrument.

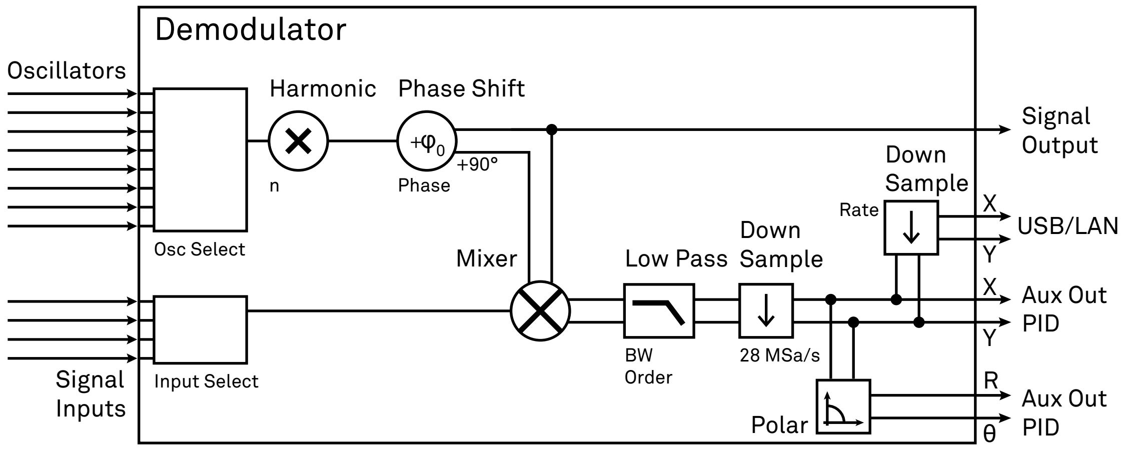


Figure 4.6. Demodulator block diagram

4.2.3. Functional Elements

Table 4.11. Lock-in tab

Control/Tool	Option/Range	Description
Range	10 mV to 1.5 V	Defines the gain of the analog input amplifier. The range should exceed the incoming signal by roughly a factor two including a potential DC offset. Note 1: the value inserted by the user may be approximated to the nearest value supported by the Instrument. Note 2: a proper choice of range setting is crucial in order to achieve good accuracy and best possible signal to noise ratio

Control/Tool	Option/Range	Description
		as it targets to use the full dynamic range of the input ADC.
Auto		Automatic adjustment of the Range to about two times the maximum signal input amplitude measured over about 100 ms.
Scaling	inactive	Scaling of the input signal with an arbitrary factor throughout the graphical user interface. This field can be used for unit conversions, e.g. from mV to V.
Measurement Unit	unit acronym	Defines the measurement unit of the input. The value in this field modifies the readout of all measurement tools in the user interface. Typical uses of this field is to make measurements in the unit before the sensor/transducer, e.g. to take an transimpedance amplifier into account and to directly read results in Ampere instead of Volts.
AC	ON: AC coupling	Defines the input coupling for the Signal Inputs. AC coupling inserts a high-pass filter.
	OFF: DC coupling	
50 Ω	ON: 50 Ω	Sets the matching impedance for the signal inputs.
	OFF: 1 MΩ	
Mode	Manual	The user setting defines the oscillator frequency.
	PLL	The UHF-PID option controls the oscillator frequency.
	PID	The UHF-PID option controls the oscillator frequency.
	ExtRef	An external reference is mapped onto the oscillator frequency.
Frequency (Hz)	0 to 600 MHz	Frequency control for each oscillator.
Locked	ON / OFF	Oscillator locked to external reference when turned on.
Mode	Demod	Default operating mode with demodulator used for lock-in demodulation.
	ExtRef	The demodulator is used for external reference mode and tracks the frequency of the selected reference input.
	PLL	The demodulator is used in PLL mode for frequency tracking of the signal. Note this function requires the UHF-PID option to be installed and active on your instrument.
	Mod	The demodulator is used by the UHF-MOD option, e.g. for the direct demodulation of carrier and sideband signals.
Osc	oscillator index	Connects the selected oscillator with the demodulator corresponding to this line. Number of available oscillators depends on the installed options.

Control/Tool	Option/Range	Description
Harm	1 to 1023	Multiplies the demodulator's reference frequency with the integer factor defined by this field.
Demod Freq (Hz)	0 to 600 MHz	Indicates the frequency used for demodulation and for output generation. The frequency is calculated with oscillator frequency times the harmonic factor. When the MOD option is used linear combinations of oscillator frequencies including the harmonic factors define the demodulation frequencies.
Phase (deg)	-180° to 180°	Phase shift applied to the reference input of the demodulator and also to signal on the Signal Outputs.
Zero		Adjust the demodulator phase automatically in order to read zero degrees. Shifts the phase of the reference at the input of the demodulator in order to achieve zero phase at the demodulator output. This action maximizes the X output, zeros the Y output, zeros the Θ output, and leaves the R output unchanged.
Signal	Sig In 1	Signal Input 1 is connected to the corresponding demodulator.
	Sig In 2	Signal Input 2 is connected to the corresponding demodulator.
	Trigger 1	Trigger 1 is connected to the corresponding demodulator.
	Trigger 2	Trigger 2 is connected to the corresponding demodulator.
	Aux Out 1	Auxiliary Output 1 is connected to the corresponding demodulator.
	Aux Out 2	Auxiliary Output 2 is connected to the corresponding demodulator.
	Aux Out 3	Auxiliary Output 3 is connected to the corresponding demodulator.
	Aux Out 4	Auxiliary Output 4 is connected to the corresponding demodulator.
	Aux In 1	Auxiliary Input 1 is connected to the corresponding demodulator.
	Aux In 2	Auxiliary Input 2 is connected to the corresponding demodulator.
Order	1	1st order filter 6 dB/oct
	2	2nd order filter 12 dB/oct
	3	3rd order filter 18 dB/oct
	4	4th order filter 24 dB/oct
	5	5th order filter 30 dB/oct
	6	6th order filter 36 dB/oct
	7	7th order filter 42 dB/oct

Control/Tool	Option/Range	Description
	8	8th order filter 48 dB/oct
TC/BW Select	TC	Defines the low pass filter characteristic using time constant of the filter.
	BW NEP	Defines the low pass filter characteristic using the noise equivalent power bandwidth of the filter.
	BW 3 dB	Defines the low pass filter characteristic using the cut-off frequency of the filter.
TC/BW Value	numeric value	Defines the low pass filter characteristic in the unit defined above.
Sinc	ON / OFF	Enables the sinc filter. When the filter bandwidth is comparable to or larger than the demodulation frequency, the demodulator output may contain frequency components at the frequency of demodulation and its higher harmonics. The sinc is an additional filter that attenuates these unwanted components in the demodulator output.
Lock		Makes all demodulators filter settings equal (order, time constant, bandwidth). Pressing the lock copies the settings from demodulator one into the settings of all demodulators. When the lock is pressed, any modification to a field is immediately changing all other settings. Releasing the lock does not change any setting, and permits to individually adjust the filter settings for each demodulator.
Enable Streaming	ON: demodulator active	Enables the streaming of demodulated samples in real time to the host computer. The streaming rate is defined is the field on the right hand side. As a consequence demodulated samples can be visualized on the plotter and a corresponding numeric entry in the numerical tool is activated. Note: increasing number of active demodulators increases load on physical connection to the host computer.
	OFF: demodulator inactive	Disables the streaming of demodulated samples to the host computer.
Rate (Sa/s)	0.42 Sa/s to 2.3 MSa/s	Defines the demodulator sampling rate, the number of samples that are sent to the host computer per second. A rate of about 7-10 higher as compared to the filter bandwidth usually provides sufficient aliasing suppression. This is also the rate of data received by LabOne Data Server and saved to the computer hard disk. This setting has no impact on the sample rate on the auxiliary outputs connectors. Note: the value inserted by the user may be approximated to the nearest value supported by the instrument.

Control/Tool	Option/Range	Description
Demodulator Output Rate Lock		Makes all demodulator output rates equal. Pressing the lock copies the settings from demodulator one into the settings of all demodulators. When the lock is pressed, any modification to a field is immediately changing all other settings. Releasing the lock does not change any setting, and permits to individually adjust the demodulator output rate for each demodulator.
Trigger	Continuous	Selects continuous data acquisition mode. The demodulated samples are streamed to the host computer at the Rate indicated on the left hand side. In continuous mode the numerical and plotter tools are continuously receiving and display new values.
	Trigger 3	Selects external triggering by means of the Trigger 3 connector. Demodulated samples are sent to the host computer for each event defined in the Trig Mode field. When edge trigger is selected the rate field is greyed out and has no meaning. Note: some UHF Instruments feature Trigger 1/2 on the back panel instead of Trigger 3/4.
	Trigger 4	Selects external triggering by means of the Trigger 4 connector. Demodulated samples are sent to the host computer for each event defined in the Trig Mode field. When edge trigger is selected the rate field is greyed out and has no meaning. Note: some UHF Instruments feature Trigger 1/2 on the back panel instead of Trigger 3/4.
Trig Mode	Rising	Selects triggered sample acquisition mode on rising edge of the selected Trigger input.
	Falling	Selects triggered sample acquisition mode on falling edge of the selected Trigger input.
	Both	Selects triggered sample acquisition mode on both edges of the selected Trigger input.
	High	Selects continuous sample acquisition mode on high level of the selected Trigger input. In this selection, the sample rate field determines the frequency in which demodulated samples are sent to the host computer.
	Low	Selects continuous sample acquisition mode on low level of the selected Trigger input. In this selection, the sample rate field determines the frequency in which demodulated samples are sent to the host computer.
Amplitude Unit	Vpk, Vrms, dBm	Select the unit of the displayed amplitude value. The dBm value is only valid for a system with 50 Ω termination.

Control/Tool	Option/Range	Description
On	ON / OFF	Main switch for the Signal Output corresponding to the blue LED indicator on the instrument front panel.
50Ω	ON / OFF	Select the load impedance between 50Ω and HiZ. The impedance of the output is always 50Ω. For a load impedance of 50Ω the displayed voltage is half the output voltage to reflect the voltage seen at the load.
Range	150 mV	Selects output range ±150 mV.
	1.5 V	Selects output range ±1.5 V.
Auto Range		Selects the most suited output range automatically.
Output Clipping	grey/red	Indicates that the specified output amplitude(s) exceeds the range setting. Signal clipping occurs and the output signal quality is degraded. Adjustment of the range or the output amplitudes is required.
Offset	-range to range	Defines the DC voltage that is added to the dynamic part of the output signal.
Output	-range to range	Defines the output amplitude for each demodulator frequency as rms or peak-to-peak value. A negative amplitude value is equivalent to a phase change of 180 degree. Demodulator 2 is the signal source for Signal Output 1, demodulator 4 is the source for Signal Output 2.

4.3. Lock-in MF Tab

This tab is the main lock-in amplifier control panel for all instruments with the multi-frequency option (UHF-MF) installed. Users with instruments without this option installed are kindly referred to Section 4.2 .

4.3.1. Features

- Control for 2 separate lock-in units with 8 demodulators in total
- Auto ranging, scaling, arbitrary input units for both input channels
- Control for 8 oscillators
- Range setting for signal inputs and signal outputs
- Flexible choice of reference source, trigger options and data transfer rates

4.3.2. Description

The lock-in tab is the main control center of the instrument and open after start up by default. Whenever closed or a new instance is needed the following symbol pressed will generate a new instance of the tab.

Table 4.12. App icon and short description

Control/Tool	Option/Range	Description
Lock-in MF		Quick overview and access to all the settings and properties for signal generation and demodulation.

The Signal Inputs section on the left and the Signal Outputs section on the right of Lock-in tab (see Figure 4.7) are horizontally divided into two identical sections. The upper section is related to Signal Input 1 and Signal Output 1, and the lower section to Signal Input 2 and Signal Output 2, i.e. the main BNC connectors on the front side of the instrument. The two input channels and output channels are identical in all aspects.

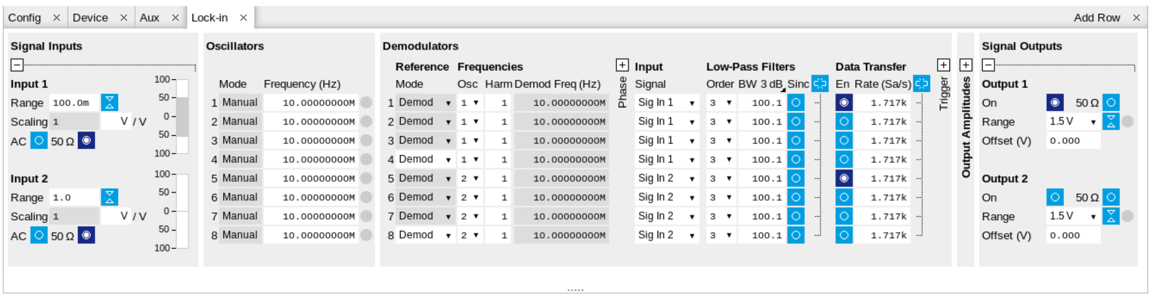


Figure 4.7. LabOne User Interface Lock-in MF tab

From left to right the tab is organized in the following sections: the Signal Inputs section allows the user to define all relevant settings specific to the signal entered as for example input coupling, range, etc. The Oscillators section indicates the frequencies of both internal oscillators. These frequencies can be either manually defined by typing a frequency value in the field or they can be referenced to an external source. The Demodulators section holds the main settings for the

8 dual-phase demodulator units. Some of the available options like phase adjustment and the trigger functionality are collapsed by default. It takes one mouse click "+" icon in order to expand those controls. On the right hand side of the Lock-in tab the Signal Outputs section allows to define signal amplitudes, offsets and range values.

The Scaling field below the Range field can be used to multiply the Signal Input data to account for the gain of an external amplifier. In case there is a gain of 10 applied to the input signal externally, then the Scaling field can be set to 0.1 to compensate for it.

There are two buttons below the Scaling field that can be toggled: the AC/DC button and the 50 Ω/1 MΩ. The AC/DC button sets the coupling type: AC coupling has a high-pass cutoff frequency that can be used to block large DC signal components to prevent input signal saturation during amplification. The 50 Ω/1 MΩ button toggles the input impedance between low (50 Ω) and high (approx. 1 MΩ) input impedance. 50 Ω input impedance should be selected for signal frequencies above 10 MHz to avoid artifacts generated by multiple signal reflections within the cable. With 50 Ω input impedance, one will expect a reduction of a factor of 2 in the measured signal if the signal source also has an output impedance of 50 Ω.

To the right of the Signal Inputs section, one finds the Oscillators section which has two entries. The Mode column indicates whether the oscillators frequency is fixed to a value entered by the user (Manual) or if another instrument resource determines the frequency (e.g. ExtRef, PLL). In such cases the associated frequency field will be greyed-out. In internal reference mode, a demodulator operates at the ideal internally generated frequency and provides the best possible demodulation. For external reference mode, it is required to internally recover the demodulation frequency with a high-quality PLL. A green light right next to the frequency will then indicate smooth operation.

The next section contains the Demodulators settings. In total there are 8 lines each representing one demodulator. The Mode column is read only for all demodulators except 4 and 8, which can be to set to either internal reference (Demod) or external reference mode (ExtRef). When internal reference mode is selected, it is possible to use demodulate the input signal with 4 demodulators simultaneously, using different filter settings or at different harmonic frequencies of the reference frequency. For external reference mode, one demodulator is used for the reference recovery and a few settings are greyed-out, and therefore 3 demodulators remain for simultaneous measurements.

The Signal column always defines the signal that is taken as input for the demodulator. A wide choice of signals can be selected, among the Signal Inputs, the Trigger Inputs, the Auxiliary Inputs and Auxiliary Outputs. Like this it is possible to flexibly generate advanced measurement topologies adapting to many needs of the users.

For each demodulator an additional phase shift can be introduced to the associated oscillator by entering the phase offset in the Phase column. This phase is added both, to the reference channel and the output of the demodulator. Hence, when the frequency is generated and detected using the same demodulator, signal phase and reference phase change by the same amount and no change will be visible in the demodulation result. Demodulation of frequencies that are integer multiples of any of the oscillator frequencies is achieved by entering the desired factor in the Harm column. The demodulator readout can be obtained using the Numeric tab which is described in Section 4.4 .

In the middle of the Lock-in tab is the Low-Pass Filters section where the filter order can be selected in the drop down list for each demodulator and the filter bandwidth (BW 3dB) can chosen by typing a numerical value. Alternatively the time constant of the filter (TC) or the noise equivalent power filter bandwidth (BW NEP) can be chosen by clicking on the column's header. For example, setting the filter order to 4 corresponds to a roll off of 24 dB/oct or 80 dB/dec i.e. an attenuation of 10^4 for a tenfold frequency increase. If the Low-Pass Filter bandwidth is comparable to or larger than the demodulation frequency, the demodulator output may contain frequency components at the frequency of demodulation and its higher harmonics. In this case, the additional Sinc Filter can be enabled. It attenuates those unwanted harmonic components in the demodulator output.

The Sinc Filter is also useful when measuring at low frequencies, since it allows to apply a Low-Pass Filter bandwidth closer to the demodulation frequency, thus speeding up the measurement time.

Each demodulator is activated by the En button in the Data Transfer section where also the sampling rate (Rate) for each demodulator can be defined.

The Trigger section next to the Data Transfer allows for setting trigger conditions in order to control and initiate data transfer from the Instrument to the host PC by the application of logic signals (e.g. TTL) to either Trigger Input 3 or 4 on the back panel.

The Output Amplitudes sections is only available for Instruments with the UHF-MF option installed and allows for the flexible adjustment of output amplitudes of different demodulators and their summation on either Signal Output 1 or Signal Output 2. In order to avoid signal clipping the sum of amplitudes of each signal output needs to be smaller than the range defined in the Signal Outputs section on the right. By clicking the headline of each column one can switch between amplitude definitions in terms of root mean square values, peak-to-peak values or even units of dBm, when the 50 Ω option in the Signal Output section is activated.

In the Signal Outputs section the On buttons allow to activate each of the Signal Outputs of the front panel. The Range drop down list is used to select the proper output range setting. On each Signal Output a digital offset voltage (Offset) can be defined. The maximum output signal permitted is ±1.5 V.

The block diagram given in Figure 4.6 indicates the main demodulator components and their interconnection. The understanding of the wiring is essential for successful operating the instrument.

4.3.3. Functional Elements

Table 4.13. Lock-in MF tab

Control/Tool	Option/Range	Description
Range	10 mV to 1.5 V	Defines the gain of the analog input amplifier. The range should exceed the incoming signal by roughly a factor two including a potential DC offset. Note 1: the value inserted by the user may be approximated to the nearest value supported by the Instrument. Note 2: a proper choice of range setting is crucial in order to achieve good accuracy and best possible signal to noise ratio as it targets to use the full dynamic range of the input ADC.
Auto		Automatic adjustment of the Range to about two times the maximum signal input amplitude measured over about 100 ms.
Scaling	inactive	Scaling of the input signal with an arbitrary factor throughout the graphical user interface. This field can be used for unit conversions, e.g. from mV to V.
Measurement Unit	unit acronym	Defines the measurement unit of the input.

Control/Tool	Option/Range	Description
		The value in this field modifies the readout of all measurement tools in the user interface. Typical uses of this field is to make measurements in the unit before the sensor/transducer, e.g. to take an transimpedance amplifier into account and to directly read results in Ampere instead of Volts.
AC	ON: AC coupling	Defines the input coupling for the Signal Inputs. AC coupling inserts a high-pass filter.
	OFF: DC coupling	
50 Ω	ON: 50 Ω	Sets the matching impedance for the signal inputs.
	OFF: 1 MΩ	
Mode	Manual	The user setting defines the oscillator frequency.
	PLL	The UHF-PID option controls the oscillator frequency.
	PID	The UHF-PID option controls the oscillator frequency.
	ExtRef	An external reference is mapped onto the oscillator frequency.
Frequency (Hz)	0 to 600 MHz	Frequency control for each oscillator.
Locked	ON / OFF	Oscillator locked to external reference when turned on.
Mode	Demod	Default operating mode with demodulator used for lock-in demodulation.
	ExtRef	The demodulator is used for external reference mode and tracks the frequency of the selected reference input.
	PLL	The demodulator is used in PLL mode for frequency tracking of the signal. Note this function requires the UHF-PID option to be installed and active on your instrument.
	Mod	The demodulator is used by the UHF-MOD option, e.g. for the direct demodulation of carrier and sideband signals.
Osc	oscillator index	Connects the selected oscillator with the demodulator corresponding to this line. Number of available oscillators depends on the installed options.
Harm	1 to 1023	Multiplies the demodulator's reference frequency with the integer factor defined by this field.
Demod Freq (Hz)	0 to 600 MHz	Indicates the frequency used for demodulation and for output generation. The frequency is calculated with oscillator frequency times the harmonic factor. When the MOD option is used linear combinations of oscillator frequencies including the harmonic factors define the demodulation frequencies.

Control/Tool	Option/Range	Description
Phase (deg)	-180° to 180°	Phase shift applied to the reference input of the demodulator and also to signal on the Signal Outputs.
Zero		Adjust the demodulator phase automatically in order to read zero degrees. Shifts the phase of the reference at the input of the demodulator in order to achieve zero phase at the demodulator output. This action maximizes the X output, zeros the Y output, zeros the Θ output, and leaves the R output unchanged.
Signal	Sig In 1	Signal Input 1 is connected to the corresponding demodulator.
	Sig In 2	Signal Input 2 is connected to the corresponding demodulator.
	Trigger 1	Trigger 1 is connected to the corresponding demodulator.
	Trigger 2	Trigger 2 is connected to the corresponding demodulator.
	Aux Out 1	Auxiliary Output 1 is connected to the corresponding demodulator.
	Aux Out 2	Auxiliary Output 2 is connected to the corresponding demodulator.
	Aux Out 3	Auxiliary Output 3 is connected to the corresponding demodulator.
	Aux Out 4	Auxiliary Output 4 is connected to the corresponding demodulator.
	Aux In 1	Auxiliary Input 1 is connected to the corresponding demodulator.
	Aux In 2	Auxiliary Input 2 is connected to the corresponding demodulator.
Order	1	1st order filter 6 dB/oct
	2	2nd order filter 12 dB/oct
	3	3rd order filter 18 dB/oct
	4	4th order filter 24 dB/oct
	5	5th order filter 30 dB/oct
	6	6th order filter 36 dB/oct
	7	7th order filter 42 dB/oct
	8	8th order filter 48 dB/oct
TC/BW Select	TC	Defines the low pass filter characteristic using time constant of the filter.
	BW NEP	Defines the low pass filter characteristic using the noise equivalent power bandwidth of the filter.
	BW 3 dB	Defines the low pass filter characteristic using the cut-off frequency of the filter.

Control/Tool	Option/Range	Description
TC/BW Value	numeric value	Defines the low pass filter characteristic in the unit defined above.
Sinc	ON / OFF	Enables the sinc filter. When the filter bandwidth is comparable to or larger than the demodulation frequency, the demodulator output may contain frequency components at the frequency of demodulation and its higher harmonics. The sinc is an additional filter that attenuates these unwanted components in the demodulator output.
Lock		Makes all demodulators filter settings equal (order, time constant, bandwidth). Pressing the lock copies the settings from demodulator one into the settings of all demodulators. When the lock is pressed, any modification to a field is immediately changing all other settings. Releasing the lock does not change any setting, and permits to individually adjust the filter settings for each demodulator.
Enable Streaming	ON: demodulator active	Enables the streaming of demodulated samples in real time to the host computer. The streaming rate is defined is the field on the right hand side. As a consequence demodulated samples can be visualized on the plotter and a corresponding numeric entry in the numerical tool is activated. Note: increasing number of active demodulators increases load on physical connection to the host computer.
	OFF: demodulator inactive	Disables the streaming of demodulated samples to the host computer.
Rate (Sa/s)	0.42 Sa/s to 2.3 MSa/s	Defines the demodulator sampling rate, the number of samples that are sent to the host computer per second. A rate of about 7-10 higher as compared to the filter bandwidth usually provides sufficient aliasing suppression. This is also the rate of data received by LabOne Data Server and saved to the computer hard disk. This setting has no impact on the sample rate on the auxiliary outputs connectors. Note: the value inserted by the user may be approximated to the nearest value supported by the instrument.
Demodulator Output Rate Lock		Makes all demodulator output rates equal. Pressing the lock copies the settings from demodulator one into the settings of all demodulators. When the lock is pressed, any modification to a field is immediately changing all other settings. Releasing the lock does not change any setting, and permits to individually

Control/Tool	Option/Range	Description
		adjust the demodulator output rate for each demodulator.
Trigger	Continuous	Selects continuous data acquisition mode. The demodulated samples are streamed to the host computer at the Rate indicated on the left hand side. In continuous mode the numerical and plotter tools are continuously receiving and display new values.
	Trigger 3	Selects external triggering by means of the Trigger 3 connector. Demodulated samples are sent to the host computer for each event defined in the Trig Mode field. When edge trigger is selected the rate field is greyed out and has no meaning. Note: some UHF Instruments feature Trigger 1/2 on the back panel instead of Trigger 3/4.
	Trigger 4	Selects external triggering by means of the Trigger 4 connector. Demodulated samples are sent to the host computer for each event defined in the Trig Mode field. When edge trigger is selected the rate field is greyed out and has no meaning. Note: some UHF Instruments feature Trigger 1/2 on the back panel instead of Trigger 3/4.
Trig Mode	Rising	Selects triggered sample acquisition mode on rising edge of the selected Trigger input.
	Falling	Selects triggered sample acquisition mode on falling edge of the selected Trigger input.
	Both	Selects triggered sample acquisition mode on both edges of the selected Trigger input.
	High	Selects continuous sample acquisition mode on high level of the selected Trigger input. In this selection, the sample rate field determines the frequency in which demodulated samples are sent to the host computer.
	Low	Selects continuous sample acquisition mode on low level of the selected Trigger input. In this selection, the sample rate field determines the frequency in which demodulated samples are sent to the host computer.
Amplitude Unit	Vpk, Vrms, dBm	Select the unit of the displayed amplitude value. The dBm value is only valid for a system with 50 Ω termination.
Amp Enable	ON / OFF	Enables each individual output signal amplitude. It is possible to generate signals being the linear combination of the available demodulator frequencies.
Amp (V)	-range to range	Defines the output amplitude for each demodulator frequency as rms or peak-to-peak value.

Control/Tool	Option/Range	Description
		A negative amplitude value is equivalent to a phase change of 180 degree. Linear combination of multiple amplitude settings on the same output are clipped to the range setting. Note: the value inserted by the user may be approximated to the nearest value supported by the Instrument.
On	ON / OFF	Main switch for the Signal Output corresponding to the blue LED indicator on the instrument front panel.
50Ω	ON / OFF	Select the load impedance between 50Ω and HiZ. The impedance of the output is always 50Ω. For a load impedance of 50Ω the displayed voltage is half the output voltage to reflect the voltage seen at the load.
Range	150 mV	Selects output range ±150 mV.
	1.5 V	Selects output range ±1.5 V.
Auto Range		Selects the most suited output range automatically.
Output Clipping	grey/red	Indicates that the specified output amplitude(s) exceeds the range setting. Signal clipping occurs and the output signal quality is degraded. Adjustment of the range or the output amplitudes is required.
Offset	-range to range	Defines the DC voltage that is added to the dynamic part of the output signal.

4.4. Numeric Tab

The Numeric Tab provides a powerful time domain based measurement display as introduced in Section 4.1.2 . It is available in all UHF Instruments.

4.4.1. Features

- Display of demodulator output data and other streamed data, e.g. auxiliary inputs, auxiliary outputs, PID errors, Boxcar data, demodulator frequencies, AU data, etc.
- Graphical and numerical range indicators
- Polar and Cartesian formats
- Support for Input Scaling and Input Units

4.4.2. Description

The numeric tab serves as the main numeric overview display of multiple measurement data. The display can be configured by both choosing the values displayed and also arrange the display tiles at will. Whenever closed or a new instance is needed the following symbol pressed will generate a new instance of the tab.

Table 4.14. App icon and short description

Control/Tool	Option/Range	Description
Numeric		Access to all continuously streamed measurement data as numerical values.

The numeric tab (see Figure 4.8) is divided into a display section on the left and a settings section which is again subdivided into a number of sub-tabs.

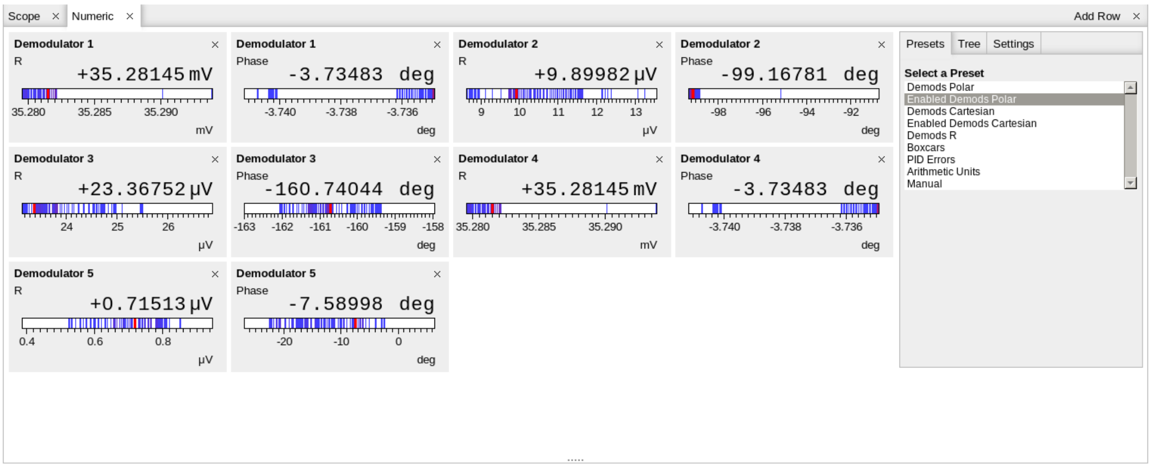


Figure 4.8. LabOne UI: Numeric tab

The numeric tab can be deployed to display the demodulated signal, phase, frequency as well as the signal levels at the auxiliary inputs and auxiliary outputs. By default, the user can display the demodulated data either in polar coordinates (R, Θ) or in Cartesian coordinates (X, Y) which can be toggled using the presets. To display other measurement quantities as available from any of the presets simply click on the tree tab besides the preset tab. The desired display fields can be selected under each demodulator's directory tree structure.

4.4.3. Functional Elements

Table 4.15. Numeric tab: Presets sub-tab

Control/Tool	Option/Range	Description
Select a Preset	Demods Polar	Shows R and Phase of all demodulators.
	Enabled Demods Polar	Shows R and Phase of enabled demodulators.
	Demods Cartesian	Shows X and Y of all demodulators.
	Enabled Demods Cartesian	Shows X and Y of enabled demodulators.
	Demods R	Shows R of all demodulators.
	Boxcars	Shows amplitude of all boxcars.
	PID Errors	Shows error of all PID.
	Arithmetic Units	Shows output of all Cartesian and polar arithmetic units.
	Manual	If additional signals are added or removed the active preset gets manual.

For the Tree sub-tab please see Table 4.8 in the section called "Tree Sub-Tab" .

Table 4.16. Numeric tab: Settings sub-tab

Control/Tool	Option/Range	Description
Name	text label	Name of the selected plot(s). The default name can be changed to reflect the measured signal.
Mapping	Lin	Enable linear scaling.
	Log	Enable logarithmic scaling.
	dB	Enable logarithmic scaling in dB.
Scaling	Manual/Full Scale	Scaling of the selected plot(s)
Zoom To Limits		Adjust the zoom to the current limits of the displayed histogram data.
Start Value	numeric value	Start value of the selected plot(s). Only visible for manual scaling.
Stop Value	numeric value	Stop value of the selected plot(s). Only visible for manual scaling.

4.5. Plotter Tab

The Plotter is one of the powerful time domain measurement tools as introduced in Section 4.1.2 and is available in all UHF Instruments.

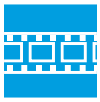
4.5.1. Features

- Plotting of all streamed data, e.g. demodulator data, auxiliary inputs, auxiliary outputs, Boxcar data, etc.
- Plotting of Scope data, e.g. Signal Inputs (requires UHF-DIG option)
- Vertical axis grouping for flexible axis scaling
- Polar and Cartesian data format for demodulator data
- Histogram and Math functionality for data analysis
- 4 cursors for data analysis
- Support for Input Scaling and Input Units

4.5.2. Description

The Plotter serves as graphical display for time domain data in a roll mode, i.e. continuous without triggering. Whenever closed or a new instance is needed the following symbol pressed will generate a new instance of the tab.

Table 4.17. App icon and short description

Control/Tool	Option/Range	Description
Plotter		Displays various continuously streamed measurement data as traces over time (roll-mode).

The plotter tab (see Figure 4.9) is divided into a display section and a control tab section.

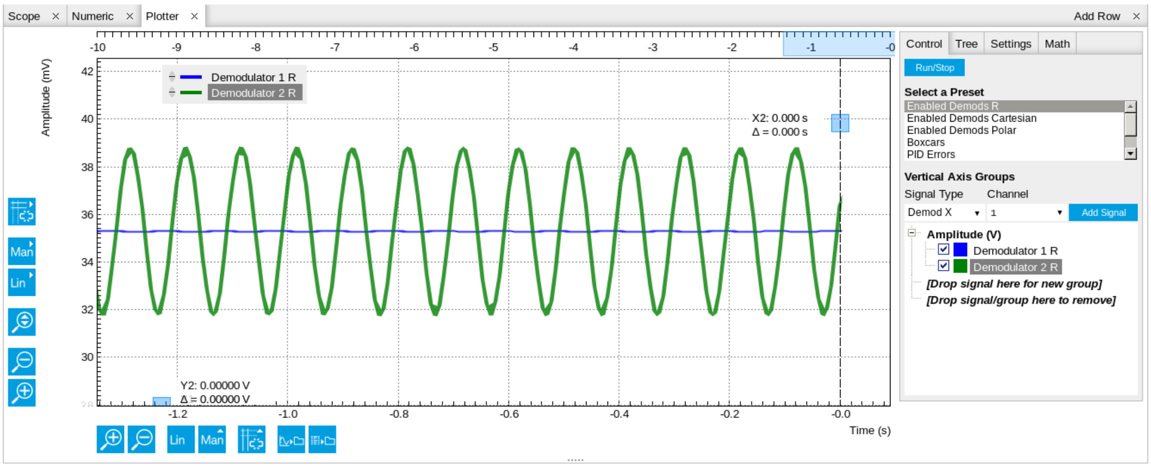


Figure 4.9. LabOne UI: Plotter tab

The plotter can be used to observe the changes of demodulated data and other streamed data continuously over time. Just as in the numeric tab any continuously streamed quantity can be displayed as for instance R, Θ, X, Y, frequency, PID errors, etc. New signals can be added by either using the quick add tool on the Presets sub-tab or by going through the tree and selecting every signal of interest in the tree structure. The vertical and horizontal axis can be displayed in Lin, Log or dB scale. The Plotter display can be zoomed in and out with the magnifier symbols, or through Man (Manual), Auto (Automatic) and FS (Full Scale) button settings (see also Section 4.1.3 .

The maximum duration data is kept in the memory can be defined as window length parameter in the Settings sub-tab.

Note

Setting the window length to large values when operating at high sampling rates can lead to memory problems on the PC used.

The sampling rate of the demodulator data is determined by the Rate value in Sa/s set in the Lock-in tab; similarly the rates for PID and Boxcar related data are set in the associated tabs. The plotter data can be continuously saved to disk by pressing the record button in the config tab which will be indicated by a green Recording (REC) LED in the status bar.

4.5.3. Functional Elements

Table 4.18. Plotter tab: Control sub-tab

Control/Tool	Option/Range	Description
Run/Stop	Run/Stop	Start and stop continuous data plotting (roll mode)
Select a Preset	Enabled Demods R	Selects the amplitude of all enabled demodulators.
	Enabled Demods Cartesian	Selects X and Y of all enabled demodulators.
	Enabled Demods Polar	Selects amplitude and phase of all enabled demodulators.
	Boxcars	Selects the amplitude of boxcar 1 and 2.
	PID Errors	Selects the error of all PID.
	Arithmetic Units	Selects the output of all Cartesian and polar arithmetic units.
	Manual	Selects the signals as defined in the tree sub-tab.

For the Vertical Axis Groups, please see Table 4.9 in the section called “Vertical Axis Groups” .

For the Tree sub-tab please see Table 4.8 in the section called “Tree Sub-Tab” .

Table 4.19. Plotter tab: Settings sub-tab

Control/Tool	Option/Range	Description
Window Length	10 s to 12 h	Plotter memory depth. Values larger than 10 s may cause excessive memory consumption for

Control/Tool	Option/Range	Description
		signals with high sampling rates. Auto scale or pan causes a refresh of the display for which only data within the defined window length are considered.
Histogram	ON / OFF	Shows the histogram in the display.
Rate	27.5 kHz to 28.1 MHz	Streaming Rate of the scope channels. The streaming rate can be adjusted independent from the scope sampling rate. The maximum rate depends on the interface used for transfer.
Enable	ON / OFF	Enable scope streaming for the specified channel. This allows for continuous recording of scope data on the plotter and streaming to disk.

For the Math sub-tab please see Table 4.7 in the section called “Cursors and Math” .

4.6. Scope Tab

The Scope is a powerful time domain and frequency domain measurement tool as introduced in Section 4.1.2 and is available in all UHF Instruments. The Scope records data from a single channel at up to 1.8 GSa/s. The channel can be selected among the two Signal Inputs, Auxiliary Inputs, Trigger Inputs and Demodulator Oscillator Phase. The Scope records data sets of up to 64'000 samples in the standard configuration, which corresponds to an acquisition time of 36 μs at the highest sampling rate. An FFT allows the analysis of the data set in the frequency domain. The performance of the Scope is comparable to that of entry level GHz sampling rate oscilloscopes. The Scope may be upgraded with the UHF-DIG Digitizer option, which enables two channels to be recorded in parallel, increases the available memory to 128 MSa/channel, and allows recording of data in a segmented fashion. The UHF-DIG Digitizer option also enables a continuous recording mode with a sampling rate of up to 28 MSa/s.

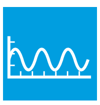
4.6.1. Features

- One input channel with 64 kSa memory; upgradable to two channels with 128 MSa memory per channel (requires UHF-DIG option)
- 12 bit nominal resolution
- Fast Fourier Transform (FFT): up to 900 MHz span, spectral density and power conversion, choice of window functions
- Sampling rates from 27 kSa/s to 1.8 GSa/s; up to 36 μs acquisition time at 1.8 GSa/s or 2.3 s at 27 kSa/s
- 8 signal sources including Signal Inputs and Trigger Inputs; up to 8 trigger sources and 2 trigger methods
- Independent hold-off, hysteresis, pre-trigger and trigger level settings
- Support for Input Scaling and Input Units
- Simultaneous display of both input channels with up to 1.8 GSa/s (requires UHF-DIG option)
- Segmented recording (requires UHF-DIG option)
- Continuous recording of both input channels at up to 7 MSa/s over USB, 14 MSa/s over 1GbE and 28 MSa/s over 10GbE (requires UHF-DIG option)

4.6.2. Description

The Scope tab serves as the graphical display unit for time domain data. Whenever it is closed or a new instance is needed, pressing the following symbol will generate a new instance of the tab.

Table 4.20. App icon and short description

Control/Tool	Option/Range	Description
Scope		Displays shots of data samples in time and frequency domain (FFT) representation.

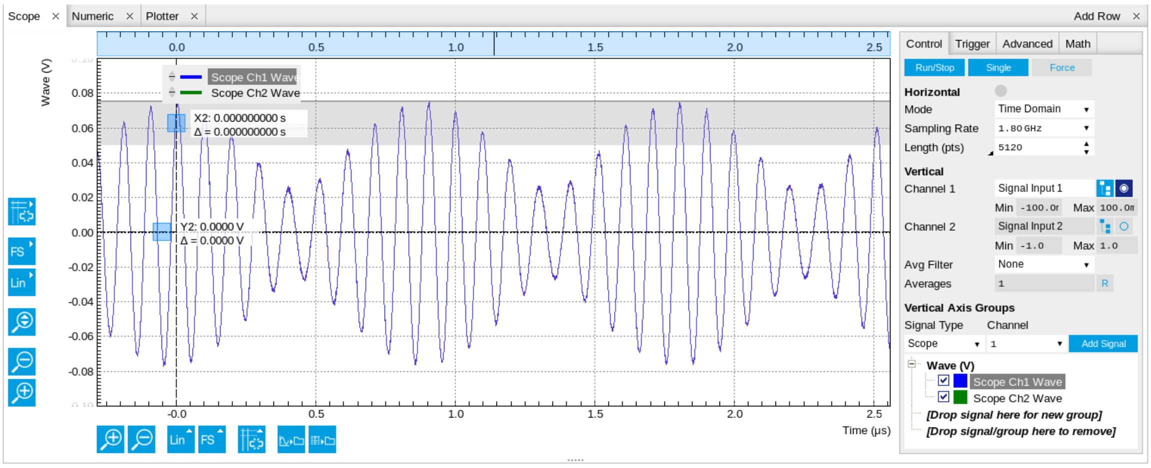


Figure 4.10. LabOne UI: Scope tab - Time domain

The Scope tab consists of a plot on the left and the control tabs on the right side. In essence, it is a single channel oscilloscope that can be used to observe a choice of signals in both time and frequency domain representation. Hence the X axis of the plot area is time (for time domain display, Figure 4.10) and frequency (for frequency domain display, Figure 4.12). It is possible to simply switch between the two representations also when the scope is not acquiring data. The Y axis displays the selected signal that can be modified and scaled using the arbitrary input unit feature of the Lock-in tab.

The Scope can display a signal sampled at up to 1.8 GSa/s selected from one out of 8 possible sources. The Scope is particular attractive if one wants to analyze raw samples at the signal inputs, auxiliary inputs or trigger connectors. For many applications this means that an additional standalone oscilloscope is not needed. Therefore, the UHF Instrument helps save valuable laboratory space and simplifies the user's setup.

The product of the inverse sampling rate and the number of acquired points (Length) directly determines the total recording time for each shot. Hence, longer time intervals can be captured by reducing the sample rate. The Scope can perform sample rate reduction either using decimation or BW Limitation as illustrated in Figure 4.11 . BW Limitation is activated by default, but it can be deactivated on a per-channel basis on the Advanced sub-tab. The figure shows an example of an input signal at the top, followed by the Scope output when the highest sample rate of 1.8 GSa/s (equal to 1.8 GHz) is used. The next signal shows the Scope output when a rate reduction by a factor of 4 (i.e. 450 MSa/s) is configured and the rate reduction method of decimation is used. For decimation, a rate reduction by a factor of N is performed by only keeping every Nth sample and discarding the rest. The advantage to this method is its simplicity, but the disadvantage is that the signal is undersampled because the input filter bandwidth of the UHF instrument is fixed at 600 MHz. As a consequence, the Nyquist sampling criterion is no longer satisfied and aliasing effects may be observed.The default rate reduction mechanism of BW Limitation is illustrated by the bottommost signal in the figure. BW Limitation means that for a rate reduction by a factor of N, each sample produced by the Scope is computed as the average of N samples acquired at the maximum sampling rate. The effective signal bandwidth is thereby reduced and aliasing effects are largely suppressed. As can be seen from the figure, with a rate reduction by a factor of 4, every output sample is simply computed as the average of 4 consequtive samples acquired at 1.8 GHz.

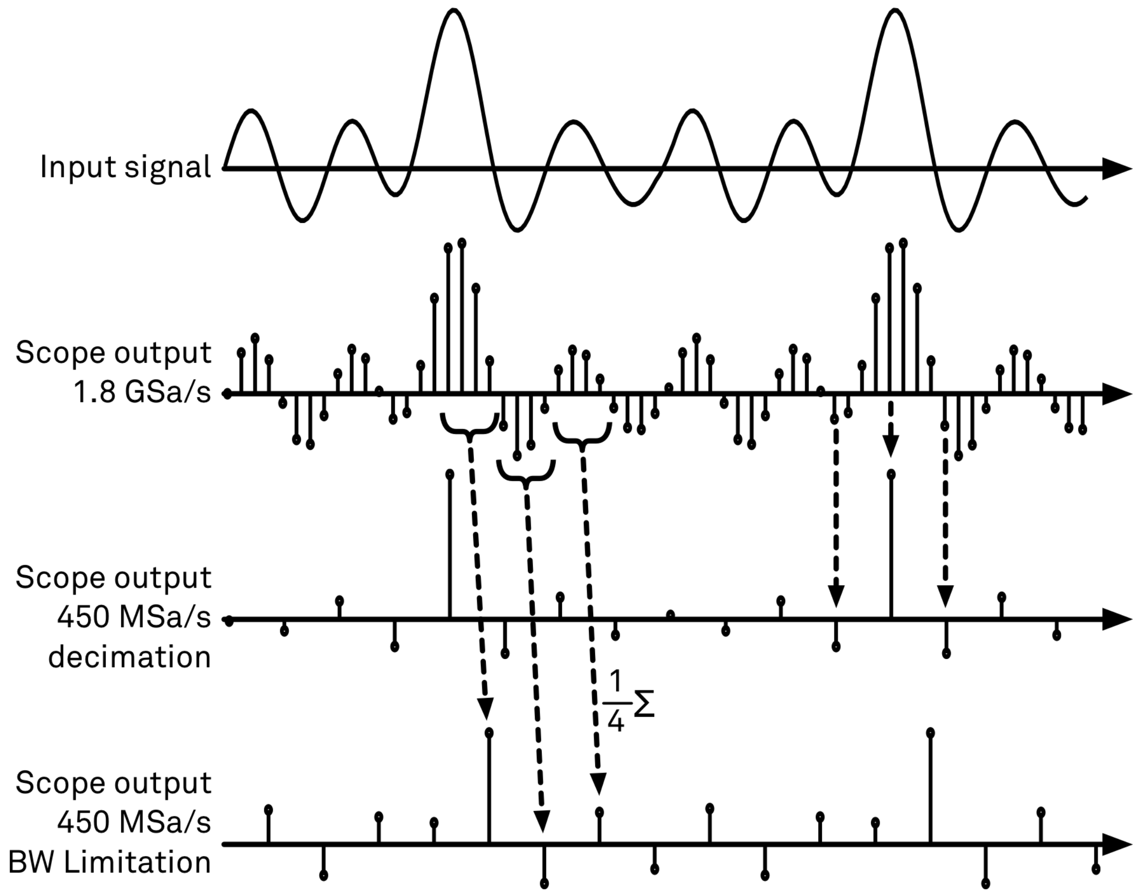


Figure 4.11. Illustration of how the Scope output is generated in BW Limitation and decimation mode when the sample rate is reduced from the default of 1.8 GSa/s to 450 MSa/s.

The Scope also offers an averaging filter that works on a shot to shot basis. The functionality is implemented by means of an exponential moving average filter with configurable filter depth. The averaging filter can help suppress noise components that are uncorrelated with the main signal. It is particularly useful when the spectrum of the signal is considered as it can help to reveal harmonic signals and disturbances that might otherwise be hidden below the noise floor.

The frequency domain representation is activated in the Control sub-tab by selecting Freq Domain FFT as the Horizontal Mode. It allows the user to observe the spectrum of the acquired shots of samples. All controls and settings are shared between the time domain and frequency domain representations making it a comprehensive tool for data analysis.

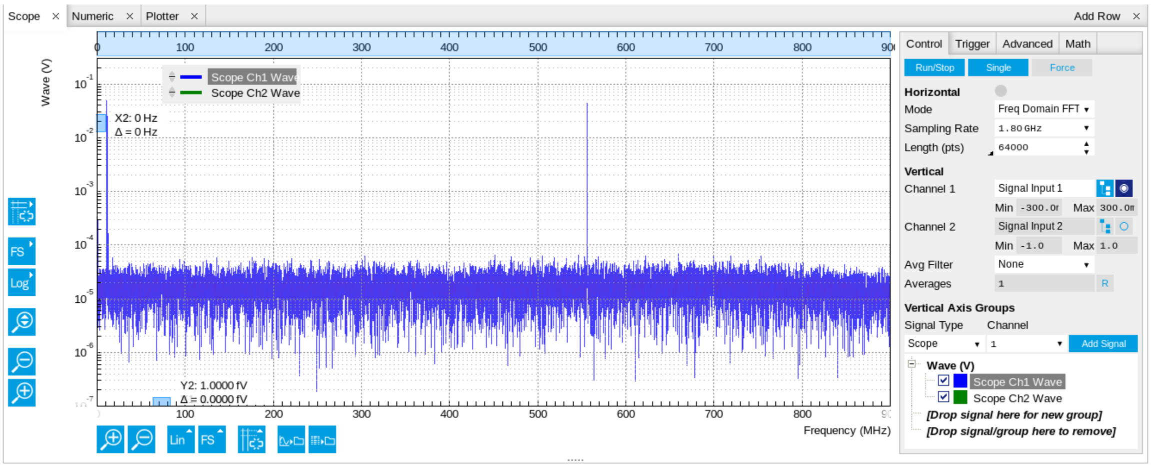


Figure 4.12. LabOne UI: Scope tab - Frequency domain

The Trigger sub-tab offers all the controls necessary for triggering on different signal sources. When the trigger is enabled, then oscilloscope shots are only acquired when the trigger conditions are met. Trigger and Hysteresis levels can be indicated graphically in the plot. A disabled trigger is equivalent to continuous oscilloscope shot acquisition.

Digitizer upgrade option

The UHF-DIG Digitizer option greatly enhances the performance of the Scope with the addition of the following features

- Simultaneous recording of two Scope channels
- Memory depth of 128 MSa for both Scope channels
- Additional input signal sources (Boxcar, Demodulator, Arithmetic Unit and PID data)
- Trigger gating
- Additional trigger input sources that allow for cross-domain triggering
- Additional trigger output sources based on the state of the Scope
- Segmented data recording
- Continuous scope data streaming (Plotter tool)

This additional functionality can be enabled on any UHF device by uploading an option key. Please contact Zurich Instruments to get more information. The following sections explain the Digitizer features in more detail.

Two channels and extended memory depth

With the UHF-DIG option enabled it is possible to record two channels simultaneously. The two channels are sampled at the same time. This allows for very exact time difference measurements. Each channel can be assigned a different signal source. Enabled triggering will control when the recording of both channels start. The sampling rate and recording length settings are shared between both channels. A single shot length of up to 128 MSa can be recorded. Compared to the standard memory depth of 64 kSa this allows for longer recording times and FFTs with finer frequency resolution.

Additional input sources

Besides the Signal Input, Trigger Input, Auxiliary Input, and Oscillator Phase the UHF-DIG option also allows for recording of Demodulator, PID, Boxcar and Arithmetic Unit signals. This functionality is very powerful in that it allows short bursts to be recorded with very high sampling rates. In order to achieve the best possible utilization of the 12 bit scope sample resolution the upper and lower limit of these input signals should be specified. Before sampling, a scaling and an offset are applied to the input signal in order to get 12 bit resolution between the lower and upper limit. The applied scaling and offset values are transferred together with the scope data, which allows for full recovery of the original physical signal strength in absolute terms. For directly sampled input signals like the Signal Inputs or Trigger Inputs the limits are read-only values and reflect the selected input range.

Trigger gating

With the UHF-DIG option installed the user can make full use of the Trigger Engine which is sketched in Figure 2.4 . If enabled, trigger gating will only trigger the scope recording if the gating input is active.

Additional trigger input sources

By using a Demodulator, PID, Boxcar, or Arithmetic Unit signal as trigger source, the Scope can be used in a cross-domain triggering mode. This allows, for example, for time domain signals to be recorded in a synchronous fashion triggered by the result from analyzing a signal in the frequency domain by means of a demodulator.

Note

Adjust a negative delay (pre-trigger) to compensate for the delay of the Demodulator, PID, Boxcar or Arithmetic Unit.

Segmented data recording

The scope sends the result of each shot to the PC over either the TCPIP or the USB interface, which both have limited data transfer bandwidth. As a consequence, a holdoff time is required between individual scope shots to allow the recorded data to be transferred to the PC. The segmented data recording mode can be enabled if the user requires a minimum holdoff time between shots. The mode allows a burst of up to 32'768 scope shots, called segments, to be recorded into the device memory. The holdoff time in this mode can be less than 100 μs between each shot, because the Scope does not have to wait for the data transfer to complete before the next shot can be started. The segmented data recording is most powerful when used over the API. The data of each shot will contain information on the segment number.

Continuous Scope data streaming

Normal scope operation records scope shots into the device memory. This allows for recording of up to 1.8 GSa/s until the memory is full. After each scope shot there will be a dead time, also known as holdoff time, to re-arm the trigger, address the next memory block and transfer the data to the

PC. Due to this dead time scope shots cannot be recorded back to back. In order to record very long scope shots (digitizer mode) the Scope data can be streamed directly to the client bypassing the device memory. This allows for continuous recording of very long Scope traces that exceed the available memory depth of the instrument. The streamed Scope data will be shown in the Plotter tab together with all other streaming data. Due to the limited transfer bandwidth over the TCPIP or USB interface the maximal sampling rate is restricted. The sampling rate for the Scope streaming channels and the enabling of each channel is controlled in the Settings sub-tab of the Plotter. As the sampling rate of the Scope streaming can be adjusted independently from the Scope shot sampling rate it is possible to record continuous data together with triggered high sampling rate Scope shots. The Scope streaming in the Plotter can be very useful for monitoring of the inputs.

Scope state output on Trigger Output

The UHF-DIG option extends the list of available Trigger Outputs by the six elements: Scope Trigger, Scope Armed, Scope Active and their logically inverse signals. The Trigger Output signals are controlled on the DIO tab (Section 4.13). Figure 4.13 shows an illustration of the signal that will be generated on the Trigger Output when one of the six new Scope related sources is selected. An example input signal is shown at the top of the figure. It is assumed that the Scope is configured to trigger on this input signal on a rising edge crossing the level indicated by the stippled line.

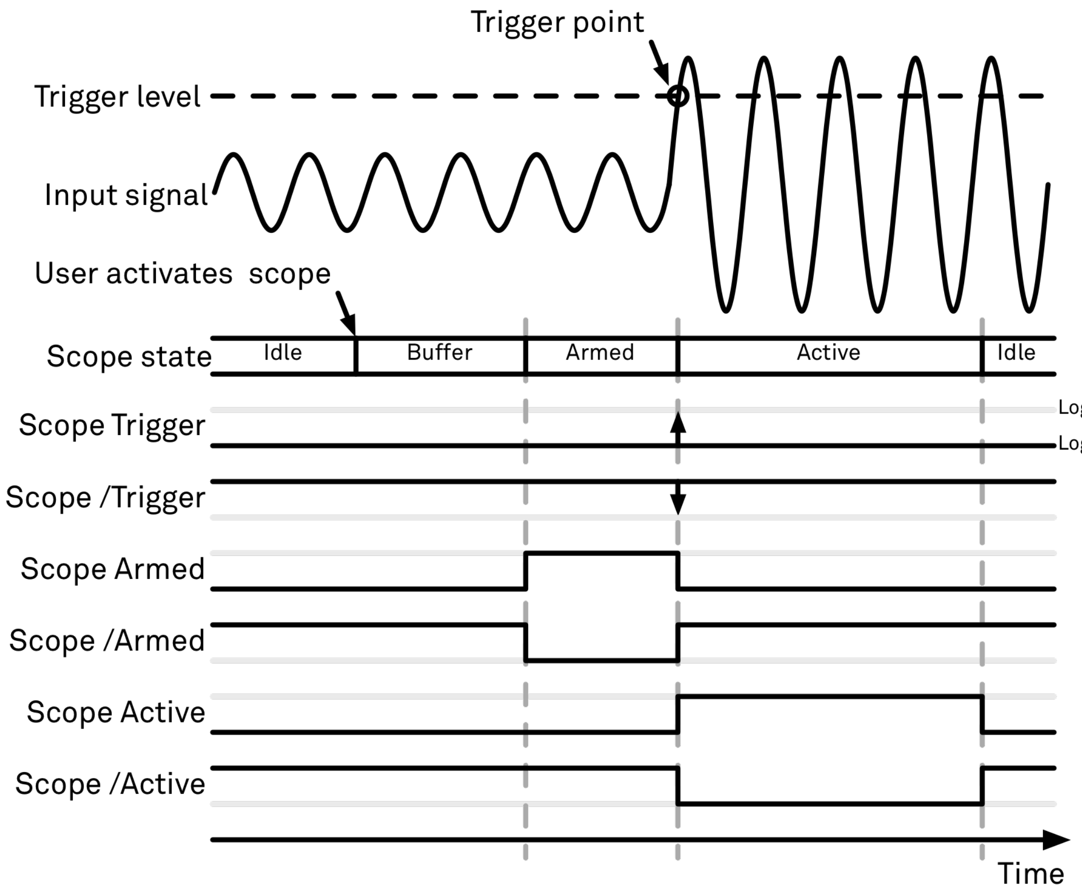


Figure 4.13. Illustration of the signal that will appear on the Trigger Output when one of the six Scope related sources is selected.

The Scope can be thought of as having a state, which changes over time. The state is shown below the input signal in the figure. When the Scope is completely inactive, it is said to be in the Idle state. When the user then activates the Scope, it will transition into a Buffer state. In this state the Scope will start to record the input signal. It will remain in this state until sufficient data has been recorded to fulfill the user requirement for recording data prior to the trigger point as controlled by the trigger Reference and Delay fields in the user interface. Once sufficient data has been recorded, the Scope will transition to the Armed state. In this state the Scope is ready to accept the trigger signal. Note that the Scope will continue to record data for as long as it is in the Armed state, and that if no trigger is defined, the Scope will simply pass straight through the Armed state. Once the input signal passes the Trigger level the Scope will trigger, and at the same time its state will change from Armed to Active. The Scope will remain in the Active state, where it also records data, until sufficient data has been recorded to fulfill the Length requirement configured in the user interface. Once enough data has been acquired, the Scope will transition back into the Idle state where it will wait for the time configured with the Holdoff time before it either starts the next measurement automatically (in case Run is active) or waits for the user to reactivate it.

The trigger source selector allows information about the Scope state to be reproduced on the Trigger Output in a number of ways. The signal that will appear on the output is shown with the six bottommost traces in the figure. Note that these traces are shown as digital signals with symbolic values of logic 0 and 1. These values will of course be actual voltages when measured on the device itself.

First, if Scope Trigger is selected then the trigger output will have a signal that is asserted, which means that it goes high, when the scope triggers, i.e. changes from the Armed to the Active state. The signal will normally have a very short duration and, therefore, it is shown with an arrow in the figure. The duration can be increased by means of the Width input field, which can be found next to the Output Signal selector on the DIO tab. If Scope /Trigger is selected, then the same signal will appear on the output, but it will simply be inverted logically.

Next, if the Scope Armed source is selected, the trigger output will be asserted as long as the Scope is in the Armed state. Again, this means that the Scope has recorded enough data to proceed with the acquisition and is waiting for the trigger condition to become satisfied. In this example, since a rising edge trigger is defined, the trigger condition becomes satisfied when the input signal goes from below the trigger level to above the trigger level.

Similarly, if Scope /Armed is selected, the trigger output will be asserted (i.e. at logic 1) whenever the Scope is in a state different from the Armed state. The same explanation holds for the remaining two configuration options, except here the trigger output is asserted when the Scope is in the Active state or when it is not in the Active state.

4.6.3. Functional Elements

Table 4.21. Scope tab: Control sub-tab

Control/Tool	Option/Range	Description
Run/Stop	Run/Stop	Runs the scope/FFT continuously.
Single	Single	Acquires a single shot of samples.
Force	Force	Force a trigger event.
Mode	Time Domain Freq Domain (FFT)	Switches between time and frequency domain display.
Sampling Rate	27.5 kSa/ s to 1.8 GSa/s	Defines the sampling rate of the scope.

Control/Tool	Option/Range	Description
Length Mode	Length (pts)	The scope shot length is defined in number of samples. The duration is given by the number of samples divided by the sampling rate. The UHF-DIG option greatly increases the available length.
	Duration (s)	The scope shot length is defined as a duration. The number of samples is given by the duration times the sampling rate.
Length (pts) or Duration (s)	numeric value	Defines the length of the recorded scope shot. Use the Length Mode to switch between length and duration display.
Window	Rectangular	Four different FFT windows to choose from. Each window function results in a different trade-off between amplitude accuracy and spectral leakage. Please check the literature to find the window function that best suits your needs.
	Hann	
	Hamming	
	Blackman Harris	
Resolution (Hz)	mHz to Hz	Spectral resolution defined by the reciprocal acquisition time (sample rate, number of samples recorded).
Channel 1/2	Signal Inputs, Trigger Inputs, Auxiliary Inputs, Demodulator Oscillator Phase, Demodulator X/Y/R/Theta, PID, Boxcar, AU	Selects the source for scope channel. Navigate through the tree view that appears and click on the required signal. Note: Channel 2 requires the UHF-DIG option.
Min	numeric value	Lower limit of the scope full scale range. For demodulator, PID, Boxcar, and AU signals the limit should be adjusted so that the signal covers the specified range to achieve optimal resolution.
Max	numeric value	Upper limit of the scope full scale range. For demodulator, PID, Boxcar, and AU signals the limit should be adjusted so that the signal covers the specified range to achieve optimal resolution.
Enable	ON / OFF	Activates the display of the corresponding scope channel. Note: Channel 2 requires the UHF-DIG option.
BW Limit Ch 1	ON	Selects sample averaging for sample rates lower than the maximal available sampling rate.
	OFF	Selects sample decimation for sample rates lower than the maximal available sampling rate.
BW Limit Ch 2	ON	Selects sample averaging for sample rates lower than the maximal available sampling rate.
	OFF	Selects sample decimation for sample rates lower than the maximal available sampling rate.
Power	ON / OFF	Calculate and show the power value. To extract power spectral density (PSD) this button should be enabled together with Spectral Density.
Spectral Density	ON / OFF	Calculate and show the spectral density. If power is enabled the power spectral density value

Control/Tool	Option/Range	Description
		is calculated. The spectral density is used to analyze noise.
Avg Filter	None	Averaging is turned off.
	Exponential Moving Avg	Consecutive scope shots are averaged with an exponential weight.
Averages	integer value	Adjusts the averaging weight function. A value of n sets the weight of the n'th shot to 1/e = 37%
Reset	R	Resets the averaging filter.
Persistence	ON / OFF	Keeps previous scope shots in the display. The color scheme visualizes the number of occurrences at certain positions in time and amplitude by a multi color scheme.
Histogram	ON / OFF	Shows the histogram in the display.

For the Vertical Axis Groups, please see Table 4.9 in the section called “Vertical Axis Groups” .

Table 4.22. Scope tab: Trigger sub-tab

Control/Tool	Option/Range	Description
Trigger	grey/green/yellow	When flashing, indicates that new scope shots are being captured and displayed in the plot area. The Trigger must not necessarily be enabled for this indicator to flash. A disabled trigger is equivalent to continuous acquisition. Scope shots with data loss are indicated by yellow. Such an invalid scope shot is not processed.
Enable	ON	Trigger based scope shot acquisition
	OFF	Continuous scope shot acquisition
Signal	Signal Inputs, Trigger Inputs, Auxiliary Inputs, Demodulator Oscillator Phase, Demodulator X/Y/R/Theta, PID, Boxcar, AU	Selects the trigger source signal. Navigate through the tree view that appears and click on the required signal.
Edge Rise	ON / OFF	Performs a trigger event when the source signal crosses the trigger level from low to high. For dual edge triggering, select also the falling edge.
Edge Fall	ON / OFF	Performs a trigger event when the source signal crosses the trigger level from high to low. For dual edge triggering, select also the rising edge.
Level (V)	trigger signal range (negative values permitted)	Defines the trigger level.
Hysteresis Mode	Hysteresis (V)	Selects absolute hysteresis.

Control/Tool	Option/Range	Description
	Hysteresis (%)	Selects a hysteresis relative to the adjusted full scale signal input range.
Hysteresis (V)	trigger signal range (positive values only)	Defines the voltage the source signal must deviate from the trigger level before the trigger is rearmed again. Set to 0 to turn it off. The sign is defined by the Edge setting.
Hysteresis (%)	numeric percentage value (positive values only)	Hysteresis relative to the adjusted full scale signal input range. A hysteresis value larger than 100% is allowed.
Show Level	ON / OFF	If enabled shows the trigger level as grey line in the plot. The hysteresis is indicated by a grey box. The trigger level can be adjusted by drag and drop of the grey line.
Trigger Gating	Trigger In 3 High	Only trigger if the Trigger Input 3 is at high level.
	Trigger In 3 Low	Only trigger if the Trigger Input 3 is at low level.
	Trigger In 4 High	Only trigger if the Trigger Input 4 is at high level.
	Trigger In 4 Low	Only trigger if the Trigger Input 4 is at low level.
Trigger Gating Enable	ON / OFF	If enabled the trigger will be gated by the trigger gating input signal. This feature requires the UHF-DIG option.
Holdoff Mode	Holdoff (s)	Holdoff is defined as time.
	Holdoff (events)	Holdoff is defined as number of events.
Holdoff (s)	numeric value	Defines the time before the trigger is rearmed after a recording event.
Holdoff (events)	1 to 1048575	Defines the trigger event number that will trigger the next recording after a recording event. A value one will start a recording for each trigger event.
Reference (%)	percent value	Trigger reference position relative to the plot window. Default is 50% which results in a reference point in the middle of the acquired data.
Delay (s)	numeric value	Trigger position relative to reference. A positive delay results in less data being acquired before the trigger point, a negative delay results in more data being acquired before the trigger point.
Enable	ON / OFF	Enable segmented scope recording. This allows for full bandwidth recording of scope shots with a minimum dead time between individual shots. This functionality requires the UHF-DIG option.
Segments	1 to 32768	Specifies the number of segments to be recorded in device memory. The maximum scope shot size is given by the available memory divided by the number of segments. This functionality requires the UHF-DIG option.
Shown Segment	integer value	Displays the number of recorded segments.
Shown Segment	integer value	Displays the number of triggered events since last start.

For the Math sub-tab please see Table 4.7 in the section called “Cursors and Math” .

4.7. Software Trigger Tab

The software trigger is one of the powerful time domain measurement tools as introduced in Section 4.1.2 and is available in all UHF Instruments.

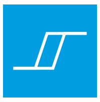
4.7.1. Features

- Scope and Plotter like time domain data display for all continuously streamed data
- 6 different trigger types
- Automatic trigger level determination
- Simulators display of multiple traces
- Adjustable record history
- Mathematical toolkit for signal analysis

4.7.2. Description

The software trigger tab serves mainly to display data sets shot wise after defined trigger events occurred. Whenever closed or a new instance is needed the following symbol pressed will generate a new instance of the tab.

Table 4.23. App icon and short description

Control/Tool	Option/Range	Description
SW Trig		Provides complex trigger functionality on all continuously streamed data samples and time domain display.

The software trigger tab (see Figure 4.14) is divided into a display section and a settings section subdivided into a number of tabs.

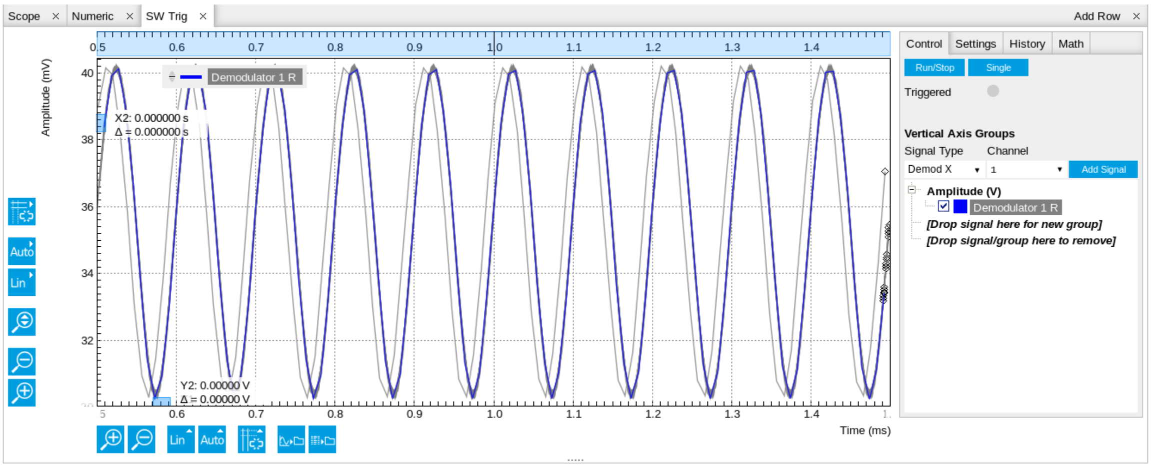


Figure 4.14. LabOne UI: Software trigger tab

The software trigger brings the trigger functionality of a scope to the continuously streamed data that can be viewed with the Plotter tool in a roll mode. The user can choose between a variety of different trigger options for the different signal inputs. Also, the recording Duration and the Delay (pre-trigger time) can be freely adjusted. Low pass filtering of the trigger signal with an flexible

Bandwidth can help to improve trigger quality in cases of low signal-to-noise ratio. Each trigger event is indicated by a green LED. Most conveniently trigger levels can be automatically found by pressing the Find button.

4.7.3. Functional Elements

Table 4.24. SW Trigger tab: Control sub-tab

Control/Tool	Option/Range	Description
Run/Stop	Run/Stop	Start and stop the software trigger
Single	Single	Run the SW trigger once (record Count trigger events)
Triggered	grey/green	When green, indicates that new trigger shots are being captured and displayed in the plot area.

For the Vertical Axis Groups, please see Table 4.9 in the section called “Vertical Axis Groups” .

Table 4.25. SW Trigger tab: Settings sub-tab

Control/Tool	Option/Range	Description
Trigger Type	Edge	Analog edge triggering based on high and low level. Hysteresis on the levels and low pass filtering can be used to reduce the risk of wrong trigger for noisy trigger signals.
	Digital	Digital triggering on the 32 bit DIO lines. The bit value defines the trigger conditions. The bit mask controls the bits that are used for trigger evaluation. For triggering just on DIO0 use a bit value 0x0001 and a bit mask 0x0001.
	Pulse	Triggers if a pulse on an analog signal is within the min and max pulse width. Pulses can be defined as either low to high then high to low (positive), the reverse (negative) or both.
	Tracking Edge	Edge triggering with automatic adjustment of trigger levels to compensate for drifts. The tracking speed is controlled by the bandwidth of the low pass filter. For this filter noise rejection can only be achieved by level hysteresis.
	HW Trigger	Trigger on one of the four trigger inputs. Ensure that the trigger level and the trigger coupling is correctly adjusted. The trigger input state can be monitored on the plotter.
	Tracking Pulse	Pulse triggering with automatic adjustment of trigger levels to compensate for drifts. The tracking speed is controlled by the bandwidth of the low pass filter. For this filter noise rejection can only be achieved by level hysteresis.
Force	Force	Forces a single trigger event.

Control/Tool	Option/Range	Description
Trigger Signal	X, Y, R, Phase, Frequency, Aux In 1/2	Source signal for trigger condition.
Demod Number	demodulator index	Selection of the demodulator index.
Pulse Type	Positive/ Negative/Both	Select between negative, positive or both pulse forms in the signal to trigger on.
Trigger Edge	Positive/ Negative/Both	Triggers when the trigger input signal is crossing the trigger level from either high to low, low to high or both. This field is only displayed for trigger type Edge and Tracking Edge.
Trigger Input	Trigger	Trigger on level crossings on hardware trigger inputs of the device.
	Trigger Out	Trigger changes send to the hardware trigger. This allows for triggering on scope armed, scope triggered, and scope active signals.
	Demod 4 Phase	Trigger on 0 degree oscillator phase crossing on demodulator 4.
	Demod 8 Phase	Trigger on 0 degree oscillator phase crossing on demodulator 8.
Bits	0 to 2^32-1	Specify the value of the DIO to trigger on. All specified bits have to be set in order to trigger. This field is only displayed for trigger type Digital.
Bit Mask	0 to 2^32-1	Specify a bit mask for the DIO trigger value. The trigger value is bits AND bit mask (bitwise). This field is only displayed for trigger type Digital.
Level	full signal range	Specify the trigger level value.
Find	Find	Automatically find the trigger level based on the current signal.
Hysteresis	full signal range	The hysteresis is important to trigger on the correct edge in the presence of noise. The hysteresis is applied below the trigger level for positive trigger edge selection. It is applied above for negative trigger edge selection, and on both sides for triggering on both edges.
Count	integer number	Number of trigger events to record (in Single mode)
Trigger progress	0% to 100%	The percentage of triggers already acquired (in Single mode)
Bandwidth (Hz)	0 to 0.5 * Sampling Rate	Bandwidth of the low pass filter applied to the trigger signal. For edge and pulse trigger use a bandwidth larger than the signal sampling rate divided by 20 to keep the phase delay. For tracking filter use a bandwidth smaller than signal sampling frequency divided by 100 to just track slow signal components like drifts.
Enable	ON / OFF	Enable low pass filtering of the trigger signal.

Control/Tool	Option/Range	Description
Hold Off Time	positive numeric value	Hold off time before the trigger is rearmed. A hold off time smaller than the duration will lead to overlapping trigger frames.
Hold Off Count	integer value	Number of skipped triggers until the next trigger is recorded again.
Delay	-2 s to 2 s	Time delay of trigger frame position (left side) relative to the trigger edge. For delays smaller than 0, trigger edge inside trigger frame (pre trigger). For delays greater than 0, trigger edge before trigger frame (post trigger)
Duration	up to 2 s	Recording length for each triggered dataset.
Pulse Min	0 to 1s	Minimum pulse width to trigger on.
Pulse Max	0 to 1s	Maximum pulse width to trigger on.

Table 4.26. SW Trigger tab: History sub-tab

Control/Tool	Option/Range	Description
History	History	Each entry in the list corresponds to a single trigger trace in the history. The number of triggers displayed in the plot is limited to 20. Use the toggle buttons to hide/display individual traces. Use the color picker to change the color of a trace in the plot. Double click on an entry to edit its name.
Clear All	Clear All	Remove all records from the history list.
All	All	Select all records from the history list.
None	None	Deselect all records from the history list.
Length	integer value	Maximum number of entries stored in the measurement history. The number of entries displayed in the list is limited to the most recent 100.
Save	Save	Save all trigger event based traces in the history to file. Specify which device data to save in the Config Tab

For the Math sub-tab please see Table 4.7 in the section called “Cursors and Math”.

4.8. Spectrum Analyzer Tab

The Spectrum Analyzer is one of the powerful frequency domain measurement tools as introduced in Section 4.1.2 and is available in all UHF Instruments.

4.8.1. Features

- Fast, high-resolution FFT spectrum analyzer of demodulated data (X+iY, R, Θ and f = dΘ/dt)
- Variable center frequency, frequency resolution and frequency span
- Auto bandwidth, auto span (sampling rate)
- Choice of 4 different FFT window functions
- Continuous and block wise acquisition with different types of averaging
- Detailed noise power analysis
- Support for Input Scaling and Input Units
- Mathematical toolbox for signal analysis

4.8.2. Description

The FFT spectrum analyzer is the main tool for doing frequency domain analysis on the demodulator output data that are streamed to the host PC with a user defined rate. Whenever closed or a new instance is needed the following symbol pressed will generate a new instance of the tab.

Table 4.27. App icon and short description

Control/Tool	Option/Range	Description
Spectrum		Provides FFT functionality to all continuously streamed measurement data.

The spectrum tab (see Figure 4.15) is divided into a display section and a settings section subdivided into a number of tabs.

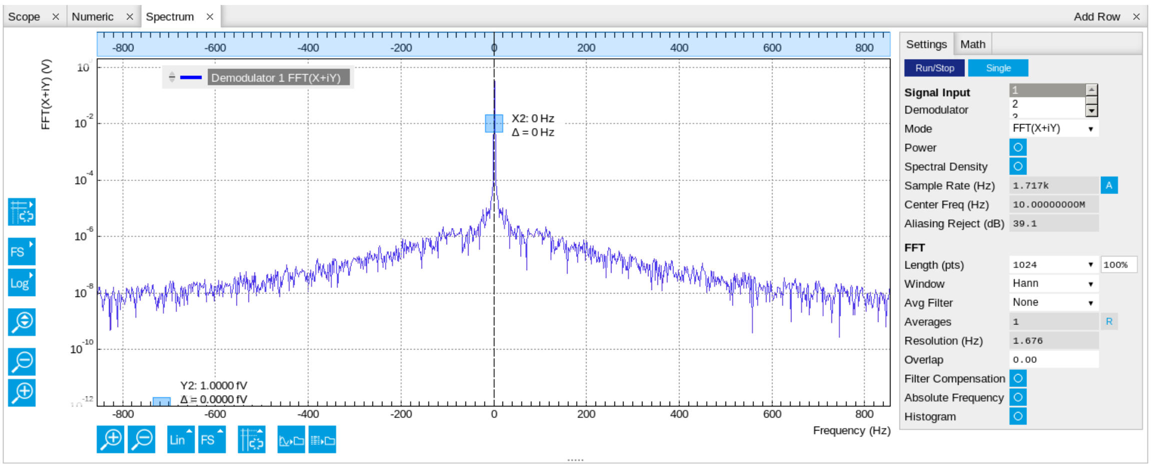


Figure 4.15. LabOne UI: Spectrum analyzer tab

The FFT spectrum analyzer allows for spectral analysis of all the demodulator data by performing the Fourier transform on the complex demodulator data samples X+iY (with i as the imaginary unit). As the demodulation process shifts the spectrum of the input signal by the demodulation frequency and the Fourier transform of the demodulated X+iY corresponds to the frequency spectrum of the input signal around the demodulation frequency we have effectively an FFT analyzer that focuses on a narrow frequency range around the demodulation frequency. FFT spectrum analyzer and Scope FFT coincide when the demodulation frequency is zero and the sampling rates match. However, since the spectrum analyzer tool operates on continuously transfered data samples it can acquire data for a extended period of time and therefore achieve very high frequency resolution which can also be calculated by taking the demodulator sampling rate divided by the number of recorded samples. Since a complex FFT operation is applied the spectrum generally has positive and negative frequency components and is centered around zero. Sometimes however it is convenient to shift the frequency axis by the demodulation frequency which allows to directly associate the measured frequency components to the signal present at the signal inputs on the front panel of the instrument. This can be done by activating Absolute Frequency on the Settings sub-tab. Another important property of the spectrum is the fact that the data samples have passed a well defined low pass filter of a certain order and bandwidth. This is most clearly resembled by the shape of the noise floor. One has to take care that the selected frequency span, which equals the demodulator sampling rate, is in a healthy ratio with respect to the filter bandwidth and order. When in doubt the user can always press the button labeled A next to the sampling rate in order to obtain a default setting that suits to the filter settings.

Other than displaying the frequency spectrum of the complex demodulator samples X+iY, the user can also choose to apply an FFT to the polar demodulator values R and Theta. This allows to carefully discriminate between phase noise components and amplitude noise components present in the signal. As these samples are real numbers the spectrum is single-sided with minimum frequency of 0 Hz.

The last option in the drop down list dΘ/dt allows to apply the FFT onto samples of demodulator frequencies. That is particularly useful when either the PLL or the ExtRef functionalities are used. The FFT of the frequency samples then provide a quantitative view of what frequency noise components are present in the reference signal and also allows to infer which bandwidth might be suited best to track the signal.

4.8.3. Functional Elements

Table 4.28. Spectrum tab: Settings sub-tab

Control/Tool	Option/Range	Description
Run/Stop	Run/Stop	Run the FFT spectrum analysis continuously
Single	Single	Run the FFT spectrum analysis once
Demodulator	demodulator index	Select the input demodulator for FFT spectrum analysis
Mode	FFT(X+iY)	Complex FFT of the demodulator result (zoom FFT). The center frequency is defined by the oscillator frequency of the demodulator. The span is twice the demodulator sampling rate.
	FFT(R)	FFT of the demodulator amplitude result sqrt(x^2 + y^2). The FFT is single sided as performed on real data.

Control/Tool	Option/Range	Description
	FFT(Θ)	FFT of the demodulator phase result atan2(y, x). The FFT is single sided as performed on real data.
	FFT(f)	FFT of the oscillator frequency of the selected demodulator. This mode is only interesting if the oscillator is controlled by a PID/PLL controller. The FFT is single sided as performed on real data.
	FFT(dΘ/dt)/(2π)	FFT of the demodulator phase derivative. This value is equivalent to the frequency noise observed on the demodulated signal. The FFT is single sided as performed on real data.
Power	ON / OFF	Calculate and show the power value. To extract power spectral density (PSD) this button should be enabled together with spectral density.
Spectral Density	ON / OFF	Calculate and show the spectral density. If power is enabled the power spectral density value is calculated. The spectral density is used to analyze noise.
Sample Rate (Hz)	numeric value	Equivalent to sampling rate of demodulator. The resulting frequency span is equal to the sample rate. Increase the sample rate to reduce aliasing.
Auto	A	Automatic adjustment of the sampling rate. The rate will be selected to achieve good enough anti-aliasing for the selected demodulator bandwidth.
Center Freq (Hz)	numeric value	Demodulation frequency of the selected demodulator used as input for the spectrum. For complex FFT(X+iY) the demodulation frequency defines the center frequency of the displayed FFT.
Aliasing Reject (dB)	numeric value	Resulting aliasing rejection based on demodulator sampling rate and low pass filter settings. If the value is too low either increase the sampling rate or lower the filter bandwidth.
Length (pts)	2^8 to 2^23	Number of lines of the FFT spectrum. A higher value increases the frequency resolution of the spectrum.
Sampling Progress	0% to 100%	The percentage of the FFT buffer already acquired.
Window	Rectangular	Four different FFT windows to choose from. Depending on the application it makes a huge difference which of the provided window function is used. Please check the literature to find out the best trade off for your needs.
	Hann	
	Hamming	
	Blackman Harris	
Avg Filter	None	Selects the type of averaging.
	Exp Moving Avg	
Averages	integer value	Defines the number of spectra which are averaged and displayed.
Reset	R	Press once to reset the averaging filter.

Control/Tool	Option/Range	Description
Resolution (Hz)	mHz to Hz	Spectral resolution defined by the reciprocal acquisition time (sample rate, number of samples recorded).
Overlap	0 to 1	Overlap of demodulator data used for the FFT transform. Use 0 for no overlap and 0.99 for maximal overlap.
Filter Compensation	ON / OFF	Spectrum is corrected by demodulator filter transfer function. Allows for quantitative comparison of amplitudes of different parts of the spectrum.
Absolute Frequency	ON / OFF	Shifts x-axis labeling to show the demodulation frequency in the center as opposed to 0 Hz, when turned off.
Histogram	ON / OFF	Shows the histogram in the display.

For the Math sub-tab please see Table 4.7 in the section called “Cursors and Math” .

4.9. Sweeper Tab

The Sweeper is a highly versatile measurement tool available in all UHF Instruments. The Sweeper allows to scan one variable over a defined range and at the same time detect certain parameters of the continuously streamed data. Sweeping oscillator frequencies for example allows to turn the instrument frequency response analyzer (FRA), a well known class of instruments.

4.9.1. Features

- Full-featured parametric sweep tool for frequency, phase shift, output amplitude, DC output voltages, etc.
- Full multi wave support for simultaneous display of data from different sources (Demodulators, PIDs, Boxcar, Arithmetic Unit)
- Different application Modes, e.g. Frequency response analyzer (Bode plots)
- different sweep options: single, continuous (run / stop), bidirectional, binary
- Persistent display of previous sweep results (overlap)
- Normalization of sweep
- Auto bandwidth, averaging, and display normalization
- Support for Input Scaling and Input Units
- Phase unwrap
- Full support of sinc filter

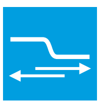
4.9.2. Description

The sweeper offers supports for a variety of different type of experiments where a sweep parameter is changed stepwise and numerous measurement results can be graphically displayed. Start the tool by pressing the corresponding app icon in the UI side bar. The Sweeper tab (see Figure 4.16) is divided into a plot area on the left with the control tabs on the right.

Important

Multiple sweeper tools can be activated in the user interface and run concurrently, and will correctly interfere with each other.

Table 4.29. App icon and short description

Control/Tool	Option/Range	Description
Sweeper		Allows to scan one variable (of a wide choice, e.g. frequency) over a defined range and display various response functions including statistical operations.

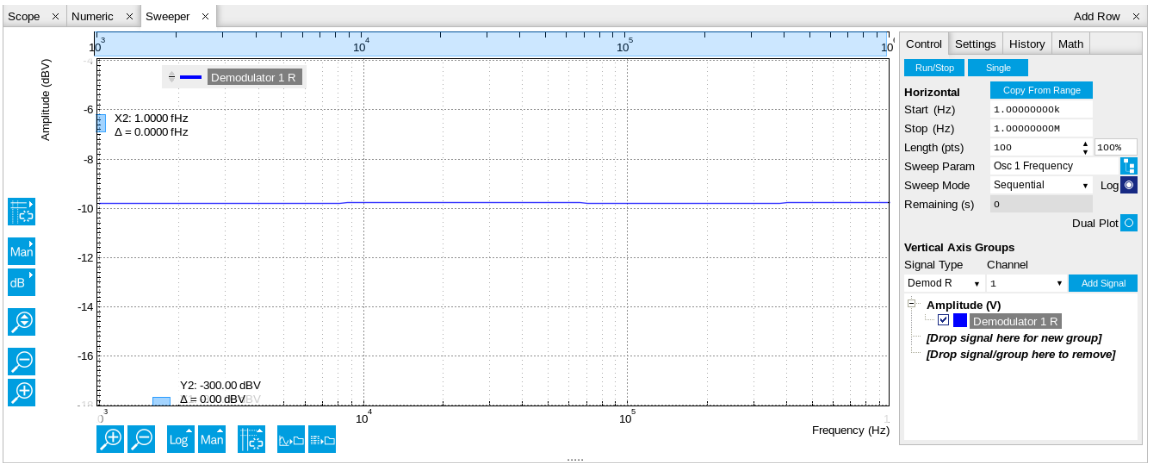


Figure 4.16. LabOne UI: Sweeper tab

A typical use of the Sweeper is to perform frequency sweeps over a well defined frequency range and generate a response of the device under test in the form of a Bode plot. As an example, AFM and MEMS users require to efficiently identify the resonance frequency of their devices as well as the phase delay. The sweeper can also be used to sweep parameters other than frequency, for instance amplitudes and offsets, e.g. a sweep of the auxiliary output offset can help to characterize I-V curves.

Note

It is important to realize that the Sweeper actively modifies the main settings of the demodulators and oscillators. So in particular for situations where multiple experiments are served maybe even from different control computers great care needs to be taken so that the parameters altered by the sweeper module do not have unwanted effects elsewhere.

For frequency sweeps the default sweep operation is logarithmic, i.e. with the Log button activated. In this mode, the sweep parameter points are distributed logarithmically - as opposed to equidistant for linear sweeps - between the start and stop values. This feature is particularly useful for sweeps over several decades, which is common for frequency sweeps. In order to cover the whole spectrum it is advantageous for these sweeps to rely on the auto bandwidth feature where the sweeper automatically changes the demodulator bandwidth during the sweep to accommodate for the local step size.

Regarding the details of signal acquisition and interpretation the sweeper offers generally two modes of operation: the Application Mode and the Advanced Mode. The Application Mode provides the choice between six measurement approaches that should help to obtain correct measurement results for certain applications quickly. Users who like to be in full control of all the settings can access them by switching to the Advanced Mode. That allows for instance to define the number of sample points taken for each sweep step as the maximum of the values number of samples (Counts) and time constants (TC). Also the filter settling time of each sweep point can by defined as the as the maximum of the values set in units of absolute time and a time derived from the targeted demodulator filter settling inaccuracy (e.g. 1m for 0.1%). Let's consider an example. For a 4th order filter and a 3 dB bandwidth set to 100 Hz we obtain a step response the arrives at 90 percent after about 4.5 ms. This can be easily measured by using the SW Trigger as indicated in Figure 4.17 . In case the full range is set to 1 V this means a measurement has a maximum error caused by imperfect settling of about 0.1 V. However, for most measurements the neighboring values are close compared to the full range and hence the real error caused is usually much smaller. It is also important to understand that the filter time constant (respectively the bandwidth and settling time) can change over the course of a sweep, e.g. for logarithmic sweeps with auto bandwidth adjust, and hence the settling time as well as the number of samples per sweep point.

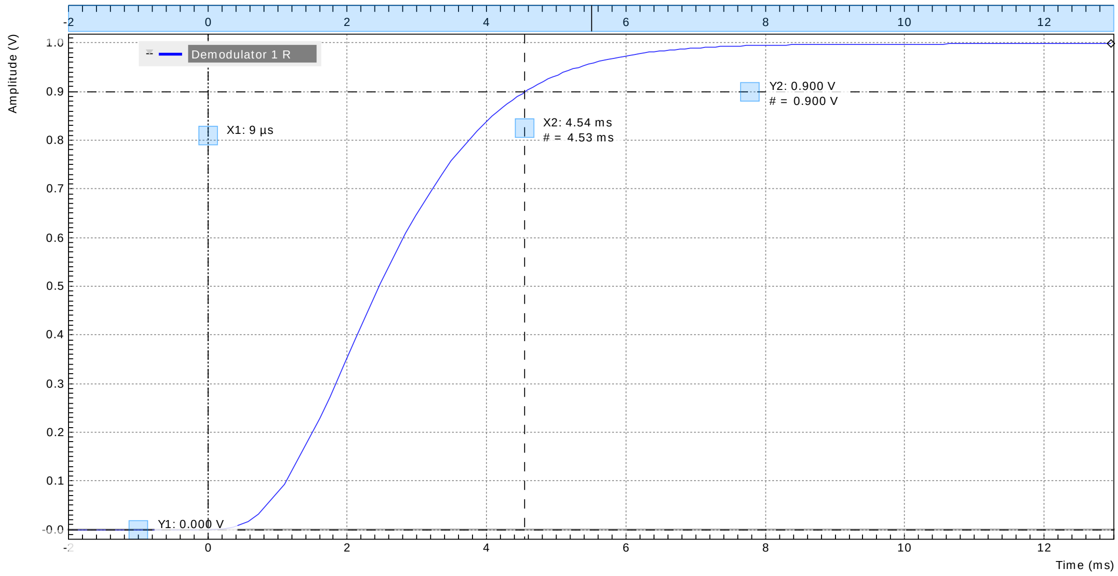


Figure 4.17. Demodulator settling time and inaccuracy

The plot area keeps the memory and display of the last 100 sweeps by default. This can be changed to any value in the History sub-tab, where it is also possible to select a subset of the sweeps that are displayed or kept in memory. Colors can be changed for each displayed curve so that the display becomes very versatile to generate high-quality plots.

Note

The Sweeper can get stuck whenever it does not receive the expected data samples. A common mistake is to select to display demodulator data without enabling the data transfer of the associated demodulator in the Lock-in tab.

Note

Once a sweep is performed the sweeper stores all data from the enabled demodulators and auxiliary inputs (always) even when they are not displayed immediately in the plot area. These data can be accessed at a later point in time simply by choosing the corresponding signal display settings (Input Channel).

4.9.3. Functional Elements

Table 4.30. Sweeper tab: Control sub-tab

Control/Tool	Option/Range	Description
Run/Stop	Run/Stop	Runs the sweeper continuously.

Control/Tool	Option/Range	Description
Single	Single	Runs the sweeper once.
Copy From Range	Copy From Range	Takes over start and stop value from the plot area.
Start (unit)	numeric value	Start value of the sweep parameter. The unit adapts according to the selected sweep parameter.
Stop (unit)	numeric value	Stop value of the sweep parameter. The unit adapts according to the selected sweep parameter.
Length	integer value	Sets the number of measurement points.
Progress	0 to 100%	Reports the sweep progress as ratio of points recorded.
Sweep Param.	Oscillator Frequency	Selects the parameter to be swept. Navigate through the tree view that appears and click on the required parameter. Note: the available selection depends on the configuration of the device.
	Demodulator Phase	
	Signal Output Amplitude	
	Auxiliary Output Offset	
	PID Setpoint	
	Modulation Index	
	Carrier Amplitude	
	Sideband 1 Amplitude	
	Sideband 2 Amplitude	
	Boxcar Integration Delay	
	Boxcar Integration Time	
	Signal Output Offset	
Sweep Mode	Sequential	Sequential sweep from Start to Stop value
	Binary	Non-sequential sweep continues increase of resolution over entire range
	Bidirectional	Sequential sweep from Start to Stop value and back to Start again
	Reverse	Reverse sweep from Stop to Start value
Log	ON / OFF	Selects between linear and logarithmic distribution of the sweep parameter.
Remaining	numeric value	Reporting of the remaining time of the current sweep.
Dual Plot	ON / OFF	Toggle between single plot view and dual plot view

For the Vertical Axis Groups, please see Table 4.9 in the section called “Vertical Axis Groups” .

Table 4.31. Sweeper tab: Settings sub-tab

Control/Tool	Option/Range	Description
Filter	Application Mode	The sweeper sets the filters and other parameters automatically.
	Advanced Mode	The sweeper uses manually configured parameters.
Application	Parameter Sweep	Only one data sample is acquired per sweeper point.
	Parameter Sweep Averaged	Multiple data samples are acquired per sweeper point of which the average value is displayed.
	Noise Amplitude Sweep	Multiple data samples are acquired per sweeper point of which the standard deviation is displayed (e.g. to determine input noise).
	Freq Response Analyzer	Narrow band frequency response analysis. Averaging is enabled.
	3-Omega Sweep	Optimized parameters for 3-omega application. Averaging is enabled.
	FRA (Sinc Filter)	The sinc filter helps to speed up measurements for frequencies below 50 HZ in FRA mode. For higher frequencies it is automatically disabled. Averaging is off.
Precision	Low -> fast sweep	Medium accuracy/precision is optimized for sweep speed.
	High -> slow sweep	High accuracy/precision takes more measurement time.
Bandwidth Mode	Auto	All bandwidth settings of the chosen demodulators are automatically adjusted. For logarithmic sweeps the measurement bandwidth is adjusted throughout the measurement.
	Fixed	Define a certain bandwidth which is taken for all chosen demodulators for the course of the measurement.
	Manual	The sweeper module leaves the demodulator bandwidth settings entirely untouched.
Time Constant/ Bandwidth Select	TC	Defines the low pass filter characteristic using time constant of the filter.
	Bandwidth NEP	Defines the low pass filter characteristic using the noise equivalent power bandwidth of the filter.
	Bandwidth 3 dB	Defines the low pass filter characteristic using the cut-off frequency of the filter.
Time Constant/ Bandwidth	numeric value	Defines the measurement bandwidth for Fixed bandwidth sweep mode, and corresponds to either noise equivalent power bandwidth (NEP), time constant (TC) or 3 dB bandwidth (3 dB) depending on selection.
Order	numeric value	Selects the filter roll off to use for the sweep in fixed bandwidth mode. Range between 6 dB/oct and 48 dB/oct.

Control/Tool	Option/Range	Description
Max Bandwidth (Hz)	numeric value	Maximal bandwidth used in auto bandwidth mode. The effective bandwidth will be calculated based on this max value, the frequency step size, and the omega suppression. The NEP is correctly taken into account for demodulation bandwidths of up to 1.25 MHz.
Omega Suppression (dB)	numeric value	Suppression of the omega and 2-omega components. Large suppression will have a significant impact on sweep time especially for low filter orders.
Min Settling Time (s)	numeric value	Minimum wait time in seconds between a sweep parameter change and the recording of the next sweep point. This parameter can be used to define the required settling time of the experimental setup. The effective wait time is the maximum of this value and the demodulator filter settling time determined from the Inaccuracy value specified.
Inaccuracy	numeric value	Demodulator filter settling inaccuracy defining the wait time between a sweep parameter change and recording of the next sweep point. Typical inaccuracy values: 10m for highest sweep speed for large signals, 100u for precise amplitude measurements, 100n for precise noise measurements. Depending on the order the settling accuracy will define the number of filter time constants the sweeper has to wait. The maximum between this value and the settling time is taken as wait time until the next sweep point is recorded.
Settling Time (TC)	numeric value	Calculated wait time expressed in time constants defined by the specified filter settling inaccuracy.
Algorithm	Averaging	Calculates the average on each data set.
	Standard Deviation	Calculates the standard deviation on each data set.
	Average Power	Calculates the electric power based on a 50 Ω input impedance.
Count (Sa)	integer number	Sets the number of data samples per sweeper parameter point that is considered in the measurement. The maximum between this value and the next setting is taken as effective calculation time.
Count (TC)	0/5/15/50 TC	Sets the effective measurement time per sweeper parameter point that is considered in the measurement. The maximum between this value and the previous setting is taken as effective calculation time.
Phase Unwrap	ON / OFF	Allows for unwrapping of slowly changing phase evolutions around the +/-180 degree boundary.

Control/Tool	Option/Range	Description
Spectral Density	ON / OFF	Selects whether the result of the measurement is normalized versus the demodulation bandwidth.
Sinc Filter	ON / OFF	Enables sinc filter if sweep frequency is below 50 Hz. Will improve the sweep speed at low frequencies as omega components do not need to be suppressed by the normal low pass filter.

Table 4.32. Sweeper tab: History sub-tab

Control/Tool	Option/Range	Description
History	History	Each entry in the list corresponds to a single sweep in the history. The number of displayed sweeps is limited to 20. Use the toggle buttons to hide/display individual sweeps. Use the color picker to change the color of a sweep. Double click on an entry to edit its name.
Clear All	Clear All	Remove all records from the history list.
All	All	Select all records from the history list.
None	None	Deselect all records from the history list.
Reference	Reference	Use the selected trace as reference for all active traces.
Length	integer value	Maximum number of entries stored in the measurement history. The number of entries displayed in the list is limited to the most recent 100.
Reference On	ON / OFF	Enable/disable the reference mode.
Reference name	name	Name of the reference trace used.
Save	Save	Save all sweeps in the history to file. Specify which device data to save in the Config tab.

For the Math sub-tab please see Table 4.7 in the section called “Cursors and Math” .

4.10. Arithmetic Unit Tab

The Arithmetic Unit (AU) tab allows the user to define arithmetic operations that are performed on lock-in demodulator outputs in real time. The results of the AUs can be provided to physical connectors or to other internal units. This functionality and tab is available in all UHF instruments.

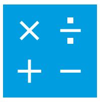
4.10.1. Features

- Four arithmetic units, more than 50 input parameters
- Add and subtract demodulator samples (X, Y, R, Θ) and Boxcar output samples
- Multiply and divide demodulator samples (X, Y, R, Θ) and Boxcar output samples
- Calculate polar coordinates from arbitrary Cartesian demodulator outputs
- Fixed coefficients and auxiliary inputs as scaling factors
- Results available on auxiliary outputs and with that they can also be used as demodulator inputs
- Results available as PID input (requires UHF-PID option)
- Streaming to host computer

4.10.2. Description

The AU tab is the tool used to define and monitor mathematical operations on measurement data in real time. Whenever unavailable pressing the following symbol will generate a new instance of the tab.

Table 4.33. App icon and short description

Control/Tool	Option/Range	Description
AU		Real-time arithmetic operations on demodulator outputs.

There are four expandable sections (see Figure 4.18), each corresponding to one arithmetic unit. Each unit operates independently and can be considered always ON, hence the defined operation is calculated all the time and the result is available to be used elsewhere in the system. Moreover, when streaming is enabled, the results can be transfered to the host computer, observed in the user interface, and stored to disk. A wide selection of input parameters including demodulator outputs and auxiliary inputs can be taken as operands.

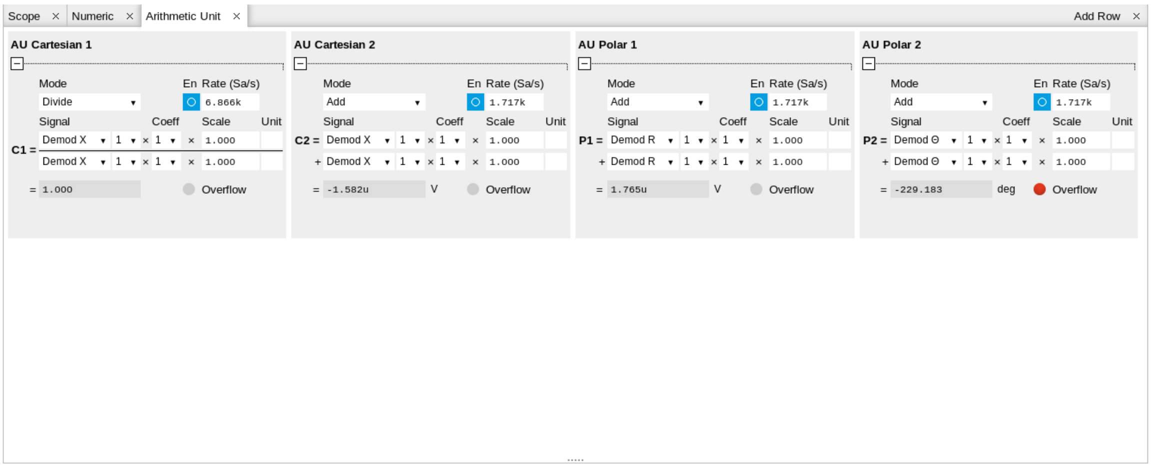


Figure 4.18. LabOne UI: Arithmetic unit tab

In total there are four units, two for Cartesian operations and two for polar operations. Each unit produces a scalar output along with a unit, both indicated in the last line. The Cartesian units can either add, multiply or divide two distinct X and Y values of all demodulators or alternatively the output samples of either Boxcar unit. In addition scaling factors can be applied based on adjustable variables, derived from the auxiliary inputs or even the other Cartesian unit. The polar units can perform similar computations on demodulator magnitude (Demod R) and angle (Demod Θ). In addition, the polar units can also operate on the magnitude and angle of a complex value computed from the two Cartesian units as C1 + iC2 (R(C1+iC2) or Θ(C1+iC2), respectively). Each polar unit must operate entirely on either magnitude or angle values. Similarly to the Cartesian units, the magnitude and angle values can be multiplied with an adjustable variable, a value from one of the auxiliary inputs or even the result of the other Polar unit.

4.10.3. Functional Elements

Table 4.34. Arithmetic unit tab

Control/Tool	Option/Range	Description
Mode	Add	The arithmetic unit is in add mode: two independent demodulator outputs can be added together.
	Divide	The arithmetic unit is in divide mode: two independent demodulator outputs can be divided by each other.
	Multiply	The arithmetic unit is in multiply mode: two independent demodulator outputs can be multiplied with each other.
En	ON	The arithmetic unit is operative and results are streamed to the host computer.
	OFF	The arithmetic unit is operative but results are not streamed to the host computer.
Rate	0.2 to 1.75 MSa/s	Defines the number of arithmetic unit result samples that are sent to the host computer per second.

Control/Tool	Option/Range	Description
Signal	Demod X	Use demodulator X (for Cartesian AU only).
	Demod Y	Use demodulator Y (for Cartesian AU only).
	Demod R	Use demodulator R (for polar AU only).
	Demod Θ	Use demodulator Θ (for polar AU only).
	R(C1 + iC2)	Use the magnitude of C1 + iC2 (for polar AU only).
	Θ(C1 + iC2)	Use the angle of C1 + iC2 (for polar AU only).
Channel	index	Select demodulator and/or Boxcar channel number.
Coeff	1	A coefficient of 1 is used (default).
	Aux In 1	The signal on Aux In 1 is used as coefficient.
	Aux In 2	The signal on Aux In 2 is used as coefficient.
	C1	Output of Cartesian AU 1 (C1) is used as coefficient (for Cartesian AU only).
	C2	Output of Cartesian AU 2 (C2) is used as coefficient (for Cartesian AU only).
	P1	Output of Polar AU 1 (P1) is used as coefficient (for Polar AU only).
	P2	Output of Polar AU 2 (P2) is used as coefficient (for Polar AU only).
Scale	Real number	Custom scaling factor.
Unit	Text	Unit of "Scale", for example "m/V".
Result value	Real number	Shows the result of the arithmetic unit.
Result unit	Text	Shows the unit of the result of the arithmetic unit. If the unit formula is not valid, it will be indicated as #Invalid! and invalid formula can be corrected by adjusting scaling units.
Overflow	Text	When red, indicates that an overflow has occurred in the arithmetic unit.

4.11. Auxiliary Tab

The Auxiliary tab is mainly a settings tabs dedicated to the four auxiliary outputs on the Instrument front panel and the two auxiliary inputs on the Instrument back panel. This tab is available in all UHF Instruments.

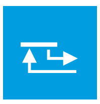
4.11.1. Features

- Monitor signal levels of auxiliary input connectors
- Monitor signal levels of auxiliary output connectors
- Auxiliary output signal sources: Demodulators, PIDs, Boxcars, AUs and manual setting
- Define Offsets and Scaling for auxiliary output values
- Control auxiliary output range limitations

4.11.2. Description

The auxiliary tab serves mainly as a monitor and control of the auxiliary inputs and outputs. Whenever closed or a new instance is needed the following symbol pressed will generate a new instance of the tab.

Table 4.35. App icon and short description

Control/Tool	Option/Range	Description
Aux		Controls all settings regarding the auxiliary inputs and auxiliary outputs.

The auxiliary tab (see Figure 4.19) is divided into three sections. The Aux Input section gives two graphical and two numerical monitors for the signal strength applied to the auxiliary inputs on the back panel. In the middle of the tab the Aux Output section allows to associate any of the measured signal to one of the 4 auxiliary outputs on the Instrument front panel. With the action buttons next to the Preoffset and Offset values the effective voltage on the auxiliary outputs can be automatically set to zero. The analog outputs can be limited to a certain range in order to avoid damaging the parts connected to them.

Note

Please note the change of units of the scaling factor depending on what measurement signal is chosen.

Two Aux Output Levels on the right again provides 4 graphical and 4 numerical indicators to monitor the voltages currently set on the auxiliary outputs.

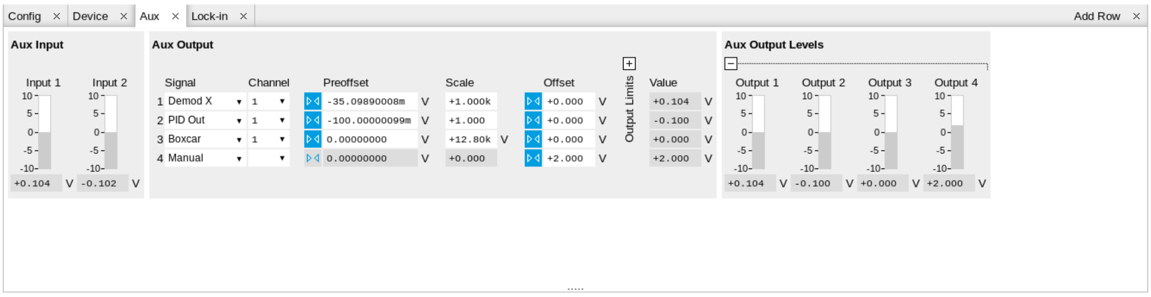


Figure 4.19. LabOne UI: Auxiliary tab

4.11.3. Functional Elements

Table 4.36. Auxiliary tab

Control/Tool	Option/Range	Description
Auxiliary Input Voltage	-10 V to 10 V	Voltage measured at the Auxiliary Input (rear panel).
Signal	X, Y, R, Θ	Select any of the 4 demodulator output quantities of any of the demodulators for auxiliary output.
	PID Out	Use one of the PID controllers output. UHF-PID option needs to be installed.
	PID Shift	Use one of the PID controllers shift results. UHF-PID option needs to be installed.
	Boxcar	Select one of the two Boxcar units for auxiliary output. UHF-Box option needs to be installed.
	AU Cartesian	Select one of the two Arithmetic Cartesian units for auxiliary output.
	AU Polar	Select one of the two Arithmetic Polar units for auxiliary output.
	Manual	Manually define an auxiliary output voltage using the offset field.
Channel	index	Select the channel according to the selected signal source.
Preoffset	numerical value in signal units	Add an pre-offset to the signal before scaling is applied. Auxiliary Output Value = (Signal +Preoffset)*Scale + Offset
Auto-zero		Automatically adjusts the Pre-offset to set the Auxiliary Output Value to zero.
Scaling	numerical value	Multiplication factor to scale the signal. Auxiliary Output Value = (Signal+Preoffset)*Scale + Offset
Offset	numerical value in Volts	Add the specified offset voltage to the signal after scaling. Auxiliary Output Value = (Signal +Preoffset)*Scale + Offset
Auto-zero		Automatically adjusts the Offset to set the Auxiliary Output Value to zero.

Control/Tool	Option/Range	Description
Lower Limit	-10 V to 10 V	Lower limit for the signal at the Auxiliary Output. A smaller value will be clipped.
Upper Limit	-10 V to 10 V	Upper limit for the signal at the Auxiliary Output. A larger value will be clipped.
Value	-10 V to 10 V	Voltage present on the Auxiliary Output. Auxiliary Output Value = (Signal+Preoffset)*Scale + Offset

4.12. Inputs/Outputs Tab

The In / Out tab is mainly a settings tabs and is available in all UHF Instruments.

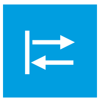
4.12.1. Features

- Signal input configuration
- Signal output configuration

4.12.2. Description

The In / Out tab provides access to the same sections as the left and the right most on the Lock-in tab. It is mainly intended to be used on small screens that can not show all the sections of the lock-in tab simultaneously. Whenever closed or a new instance is needed the following symbol pressed will generate a new instance of the tab.

Table 4.37. App icon and short description

Control/Tool	Option/Range	Description
In/Out		Access to all controls relevant for the main Signal Inputs and Signal Outputs on the instrument's front.

The In / Out tab (see Figure 4.20) is divided into two sections, one for the signal inputs and one for signal outputs, all four located on the Instrument front panel.

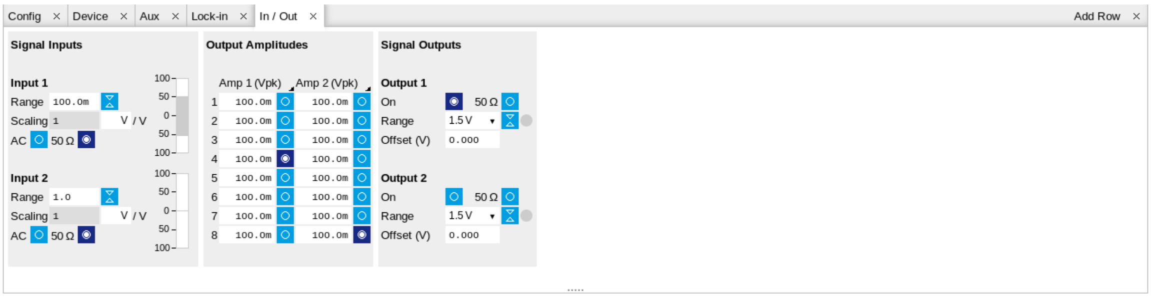


Figure 4.20. LabOne UI: Inputs/Outputs tab

4.12.3. Functional Elements

All functional elements are equivalent to the ones on the lock-in tab. See Section 4.2.2 (or Section 4.2.2 for UHF-MF) for a detailed description of the functional elements.

4.13. DIO Tab

The DIO tab is mainly a settings tabs and is available in all UHF Instruments.

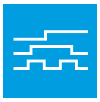
4.13.1. Features

- Monitor and control of digital I/O connectors
- Control settings for external reference and triggering

4.13.2. Description

The DIO tab is the main panel to control the digital inputs and outputs as well as the trigger levels and external reference channels. Whenever closed or a new instance is needed the following symbol pressed will generate a new instance of the tab.

Table 4.38. App icon and short description

Control/Tool	Option/Range	Description
DIO		Gives access to all controls relevant for the digital inputs and outputs including the Ref/Trigger connectors.

The DIO tab as displayed in Figure 4.21 is divided into two section, a Digital I/O section and the Ref/Trigger section.

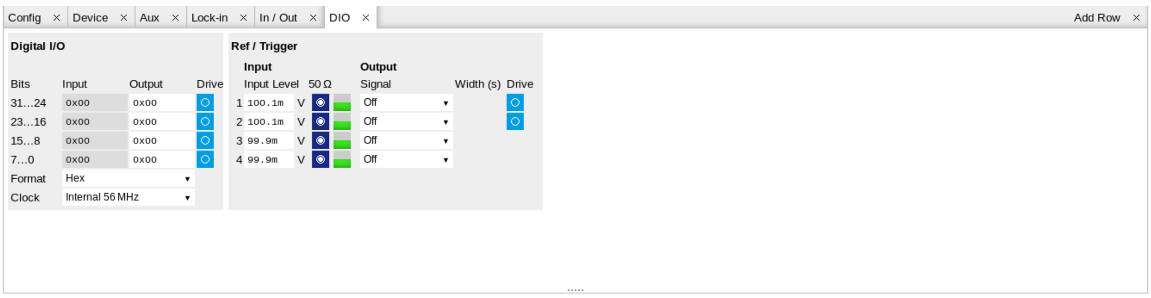


Figure 4.21. LabOne UI: DIO tab

The Digital I/O section provides numerical monitors to observe the states of the digital inputs and outputs. Moreover, with the values set in the Output column and the Drive button activated the states can also be actively set in different numerical formats.

The Ref/Trigger section for the 6 reference and trigger inputs and outputs. The two BNC connectors on the front panel are numbered 1 and 2 and can act as inputs as well as outputs. The first two lines in this section are associated to these front panel connectors. On the back panel of the Instrument are 2 more trigger inputs (line 3 and 4, left columns) and 2 more trigger outputs (line 3 and 4, right columns). All four are SMA connectors.

Note

The Input Level determines the trigger threshold for trigger state discrimination. Also a 100 mV hysteresis is applied that cannot be adjusted such that a minimum amplitude of more than 100 mV is needed for the Ref/Trigger inputs to work reliably.

4.13.3. Functional Elements

Table 4.39. Digital input and output channels, reference and trigger

Control/Tool	Option/Range	Description
DIO bits	label	Partitioning of the 32 bits of the DIO into 4 buses of 8 bits each. Each bus can be used as an input or output.
DIO input	numeric value in either Hex or Binary format	Current digital values at the DIO input port.
DIO output	numeric value in either hexadecimal or binary format	Digital output values. Enable drive to apply the signals to the output.
DIO drive	ON / OFF	When on, the corresponding 8-bit bus is in output mode. When off, it is in input mode.
Format	hex	DIO view format is hexadecimal.
	binary	DIO view format is binary.
Clock	Internal 56 MHz	The DIO is internally clocked with a fixed frequency of 56.25 MHz.
	Clk Pin 68	The DIO is externally clocked with a clock signal connected to DIO Pin 68. Available frequency range 1 Hz to 60 MHz.
Trigger level	-5 V to 5 V	Trigger voltage level at which the trigger input toggles between low and high. Use 50% amplitude for digital input and consider 100 mV hysteresis.
50 Ω	50 Ω/1kΩ	Trigger input impedance: When on, the trigger input impedance is 50 Ω, when off 1 kΩ.
Trigger Input status	high	A high state has been triggered.
	low	A low state has been triggered.
	toggling	The trigger signal is toggling.
Trigger output signal	Off	The output trigger is disabled.
	Osc Phase Demod 4	Trigger event is output for each zero crossing of the oscillator phase used on demodulator 4.
	Osc Phase Demod 8	Trigger event is output for each zero crossing of the oscillator phase used on demodulator 8.

Control/Tool	Option/Range	Description
	Scope Trigger	Trigger output is asserted when the scope trigger condition is satisfied.
	Scope /Trigger	Trigger output is deasserted when the scope trigger condition is satisfied.
	Scope Armed	Trigger output is asserted when the scope is waiting for the trigger condition to become satisfied.
	Scope /Armed	Trigger output is deasserted when the scope is waiting for the trigger condition to become satisfied.
	Scope Active	Trigger output is asserted when the scope has triggered and is recording data.
	Scope /Active	Trigger output is deasserted when the scope has triggered and is recording data.
Width	0 s to 0.149 s	Defines the minimal pulse width for trigger events signaled on the trigger outputs of the device.
Trigger drive	ON / OFF	When on, the bidirectional trigger on the front panel is in output mode. When off, the trigger is in input mode.

4.14. Config Tab

The Config tab is mainly a settings tabs and is available in all UHF Instruments.

4.14.1. Features

- define connection parameters to the instrument
- browser session control
- define UI appearance (grids, theme, etc.)
- store and load instrument settings and UI settings
- define data and data formats for recording data

4.14.2. Description

The Config tab serves mainly as a control panel for all general LabOne related settings and is opened after start up by default. Whenever closed or a new instance is needed the following symbol pressed will generate a new instance of the tab.

Table 4.40. App icon and short description

Control/Tool	Option/Range	Description
Config		Provides access to software configuration.

The config tab (see Figure 4.22) is divided into 4 sections to control connections, sessions, user interface appearance and data recording.

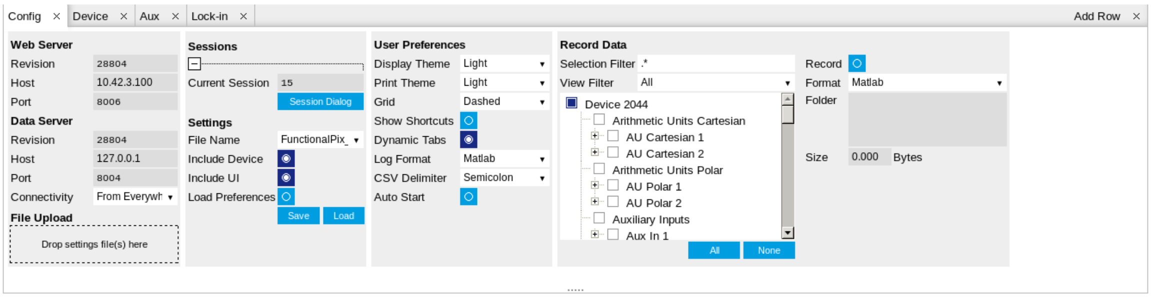


Figure 4.22. LabOne UI: Config tab

The Connection section provides information regarding TCP connection and server versions. Access from remote locations can be restricted with the connectivity setting.

The Session section provides the session number which is also displayed in status bar. Clicking on Session Dialog opens the session dialog window (same as start up screen) that allows to load different settings files as well as to connect to other instruments.

The Settings section allows to directly load and save instrument and UI settings, that are later available in the session dialogue.

The User Interface section contains the user preferences that are continuously stored and automatically reloaded the next time an UHFLI is used from the same computer account. For low ambient light lab conditions the use of the dark display theme is recommended (see Figure 4.23).

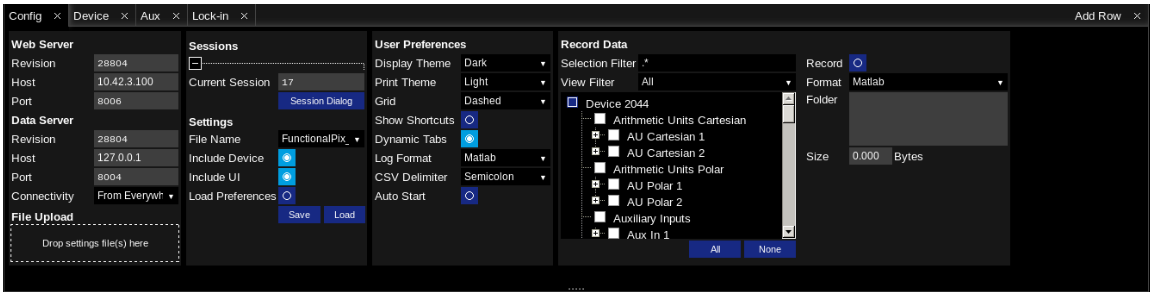


Figure 4.23. LabOne UI: Config tab - dark theme

The Record Data section is the central place where data streaming can be configured and initiated. The tree structure allows to deliberately select only the signals of interest to be recorded.

4.14.3. Functional Elements

Table 4.41. Config tab

Control/Tool	Option/Range	Description
Web Server Rev	number	Web Server revision number
Host	default is localhost: 127.0.0.1	IP-Address of the LabOne Web Server
Port	4 digit integer	LabOne Web Server TCP/IP port
Data Server Rev	number	Data Server revision number
Host	default is localhost: 127.0.0.1	IP-Address of the LabOne Data Server
Host	default is localhost: 127.0.0.1	Type IP-Address here to connect to LabOne Data Server running on a different PC.
Port	default is 8004	TCP/IP port used to connect to the LabOne Data Server.
Connectivity	Localhost Only	Forbid/Allow to connect to this Data Server from other computers.
	From Everywhere	
File Upload	drop area	Drag and drop files in this box to upload files. Clicking on the box opens a file dialog for file upload. Supported files: Settings (*.xml), software update (LabOneLinuxARM32*.tar.gz). Uploading software updates will automatically trigger the update process if the file is valid and has a different revision than the currently installed software.
Current Session	integer number	Session identifier. A session is a connection between a client and LabOne Data Server. Also indicated in status bar.

Control/Tool	Option/Range	Description
Session Dialog	Session Dialog	Open the session dialog window. This allows for device or session change. The current session can be continued by pressing cancel.
File Name	selection of available file names	Save/load the device and user interface settings to/from the selected file. File location: [user]\AppData\Roaming\Zurich Instruments \LabOne\WebServer\setting
Include Device	ON / OFF	Enable save/load of device settings.
Include UI	ON / OFF	Enable save/load of user interface settings.
Load Preferences	ON / OFF	Enable loading of user preferences from settings file.
Save	Save	Save the user interface and device setting to a file.
Load	Load	Load the user interface and device setting from a file.
Display Theme	Light	Choose theme of the user interface.
	Dark	
Print Theme	Light	Choose theme for printing SVG plots
	Dark	
Grid	Dashed	Select active grid setting for all graphs.
	Solid	
	None	
Show Shortcuts	ON / OFF	Displays a list of keyboard and mouse wheel shortcuts for manipulating plots.
Dynamic Tabs	ON / OFF	If enabled, sections inside the application tabs are collapsed automatically depending on the window width.
Log Format	Telnet	Choose the command log format. See status bar and [User]\Documents\Zurich Instruments \LabOne\WebServer\Log
	Matlab	
	Python	
CSV Delimiter	Comma	Select which delimiter to insert for CSV files.
	Semicolon	
	Tab	
Auto Start	ON / OFF	Skip session dialog at startup if selected device is available. In case of an error or disconnected device the session dialog will be reactivated.
Record	ON / OFF	Start and stop saving data to disk as defined in the selection filter
Format	Matlab	Data format of recorded data.
	CSV	
Folder	path indicating file location	Folder containing the saved data
Size	integer number	Cumulated size of saved data

For the tree functionality in the Record Data section, please see Table 4.8 in the section called "Tree Sub-Tab" .

4.15. Device Tab

The Device tab is the main settings tab for the connected instrument and is available in all UHF Instruments.

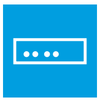
4.15.1. Features

- Option and upgrade management
- External clock referencing (10 MHz)
- Auto calibration settings
- Instrument connectivity parameters
- Device monitor

4.15.2. Description

The Device tab serves mainly as a control panel for all settings specific to the Instrument that is controlled by LabOne in this particular session. Whenever closed or a new instance is needed the following symbol pressed will generate a new instance of the tab.

Table 4.42. App icon and short description

Control/Tool	Option/Range	Description
Device		Provides instrument specific settings.

The Device tab (see Figure 4.24) is divided into four section: general instrument information, configuration, network related communication parameters and a device monitor.

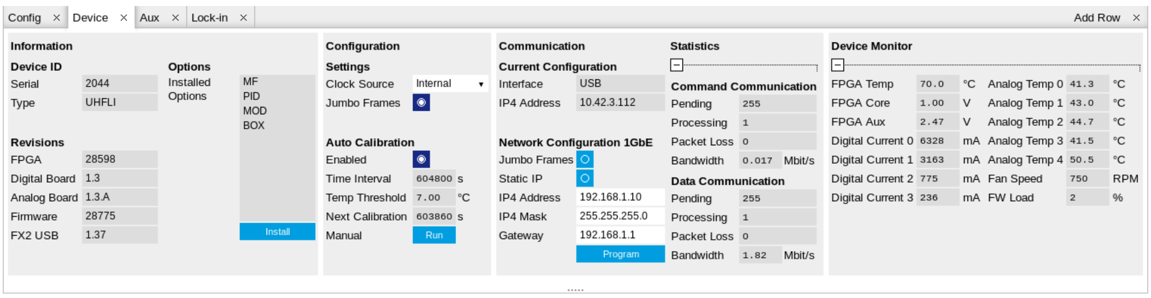


Figure 4.24. LabOne UI: Device tab

The Information section provides details about the Instrument hardware an also gives an overview regarding the upgrade options installed. This is also the place where new options can be added by entering the provided instrument key.

The Configuration section allows to change the reference oscillator from internal to external.

Note

Activating Jumbo-Frames is essential to achieve maximum data rates and also reduces load on the host PC.

The Communication section offers access to the instruments TCP/IP settings as well as choosing the connection type.

The Statistic section gives an overview on communication statistics. In particular the current data rate (Bandwidth) that is consumed.

Note

Packet loss on data streaming over UDP or USB: data packets maybe lost if total bandwidth exceeds the physical interface bandwidth available. Data may also be lost if the host computer is not able to handle high bandwidth data. Network card setting optimization and Jumbo frame enabling may increase the maximal effective bandwidth.

Note

Packet loss on command streaming over TCP or USB: command packets should never be lost as it creates an invalid state.

The Device monitor is collapsed by default and generally only needed for servicing. It indicates vitality signals of some of the Instruments hardware components.

Note

The calibration routine takes about 200 ms for that time the transfer of measurement data is stopped. That will lead to the following visible effects on the UI:

- missing data on the plotter
- the UI will shortly freeze
- the data loss flag will not report data loss (as the server intentionally trashed data)
- Sweeper, SW Trigger and Scope will behave as usual and wait until they get data again
- The Spectrum tool will restart as it can only analyze continuously sampled data

Please see also additional remarks regarding calibration in Section 5.6 .

4.15.3. Functional Elements

Table 4.43. Device tab

Control/Tool	Option/Range	Description
Serial	4 digit number	Device serial number

Control/Tool	Option/Range	Description
Type	string	Device type
FPGA	integer number	HDL firmware revision
Digital Board	version number	Hardware revision of the FPGA base board
Analog Board	version indicator	Hardware revision of the analog board
Firmware	integer number	Revision of the device internal controller software
FX2 USB	version number	USB firmware revision
Installed Options	short names for each option	Options that are installed on this device
Install	Install	Click to install options on this device. Requires a unique feature code and a power cycle after entry.
Clock Source	Internal	Internal 10 MHz clock is used as the frequency and time base reference.
	Clk 10 MHz	An external 10-MHz clock is used as the frequency and time base reference. Provide a clean and stable 10 MHz reference to the appropriate back panel connector.
Jumbo Frames	ON / OFF	Enables jumbo frames (4k) on the TCP/IP interface. This will reduce the load on the PC and is required to achieve maximal throughput. Make sure that jumbo frames (4k) are enabled on the network card as well. If one of the devices on the network is not able to work with jumbo frames, the connection will fail.
Enabled	ON / OFF	Enables an automatic instrument self calibration about 16 min after start up. In order to guarantee the full specification, it is recommended to perform a self calibration after warm-up of the device.
Time interval	time in seconds	Time interval for which the self calibration is valid. After this time it is recommended to rerun the auto calibration. A LED indicator in the status bar indicates when another self calibration is recommended.
Calibration temperature threshold	temperature in °C	When the temperature changes by the specified amount, it is recommended to rerun the self calibration. A LED indicator in the status bar indicates when another self calibration is recommended.
Next calibration	time in seconds	Remaining seconds until the first calibration is executed or a recalibration is requested.
Manual self calibration	Run	Initiate self calibration to improve input digitizer linearity.
Interface	USB, 1GbE, 10GbE	Active interface between device and PC used by the server. In case multiple options are available, the following order of priority is used: 1. USB, 2. 1GbE, 3. 10GbE.

Control/Tool	Option/Range	Description
IP4 Address	default 192.168.001.010	Current IP address of the device. This IP address is assigned dynamically by a DHCP server, defined statically, or is a fall-back IP address if the DHCP server could not be found (for point to point connections).
Jumbo Frames	ON / OFF	Enable jumbo frames for this device and interface as default.
Static IP	ON / OFF	Enable this flag if the device is used in a network with fixed IP assignment without a DHCP server.
IP4 Address	default 192.168.001.010	Static IP address to be written to the device.
IP4 Mask	default 255.255.255.000	Static IP mask to be written to the device.
Gateway	default 192.168.001.001	Static IP gateway
Program	Program	Click to program the specified IP4 address, IP4 Mask and Gateway to the device.
Pending	integer value	Number of buffers ready for receiving command packets from the device.
Processing	integer value	Number of buffers being processed for command packets. Small values indicate proper performance. For a TCP/IP interface, command packets are sent using the TCP protocol.
Packet Loss	integer value	Number of command packets lost since device start. Command packets contain device settings that are sent to and received from the device.
Bandwidth	numeric value	Command streaming bandwidth usage on the physical network connection between device and data server.
Pending	integer value	Number of buffers ready for receiving data packets from the device.
Processing	integer value	Number of buffers being processed for data packets. Small values indicate proper performance. For a TCP/IP interface, data packets are sent using the UDP protocol.
Packet Loss	integer value	Number of data packets lost since device start. Data packets contain measurement data.
Bandwidth	numeric value	Data streaming bandwidth usage on the physical network connection between device and data server.
FW Load	numeric value	Indicates the CPU load on the processor where the firmware is running.

4.16. PID Tab

The PID tab relates to the UHF-PID Quad PID/PLL Controller option and is only available if this option is installed on the UHF Instrument (see Information section in the Device tab).

Note

The PID option and its settings creates interdependencies with settings that are controlled from other panels. If the PID output controls a certain variable, e.g. Signal Output Offset, this variable will be shown as read only in its natural position (i.e. the Signal Output section on the Lock-in tab for this case).

Note

As well as the PID controls other Instrument resources, each of the PIDs can also be used from other Instrument entities. In particular when the user selects ExtRef for either Demodulator 4 or 8 (see Lock-in tab, Demodulator section, Mode column) one PID will be blocked. Similarly using the PLLs will cause one PID controller to be blocked for each enabled PLL and can then only be controller from the PLL tab, however, all the values are still updated in the PID tab as read only values.

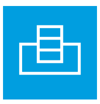
4.16.1. Features

- Four independent proportional, integral, derivative (PID) controllers
- PID Advisor with multiple DUT models, transfer function and step function modeling to achieve a adjustable target bandwidth
- Auto tune PID that automatically minimizes the average PID error signal by adjusting various set of parameters and bandwidth
- High speed operation with up to 300 kHz loop filter bandwidth
- Input parameters: demodulator data, auxiliary inputs, auxiliary outputs and arithmetic unit
- Output parameters: Output Amplitudes, Oscillator frequencies, Demodulator Phase, Auxiliary Outputs and Signal Output Offsets
- Phase unwrap for demodulator Θ data (± 64 π), e.g. for optical phase locked loops
- Low pass filter for derivative branch

4.16.2. Description

The PID tab is the main control center of general servo loop related settings. Whenever closed or a new instance is needed the following symbol pressed will generate a new instance of the tab.

Table 4.44. App icon and short description

Control/Tool	Option/Range	Description
PID		Features all control and analysis capabilities of the PID controllers.

The PID tab (see Figure 4.25) is divided into four identical sub-tabs, each of them providing access to the settings functionality for one of the four PID controllers and the related PID Advisor.

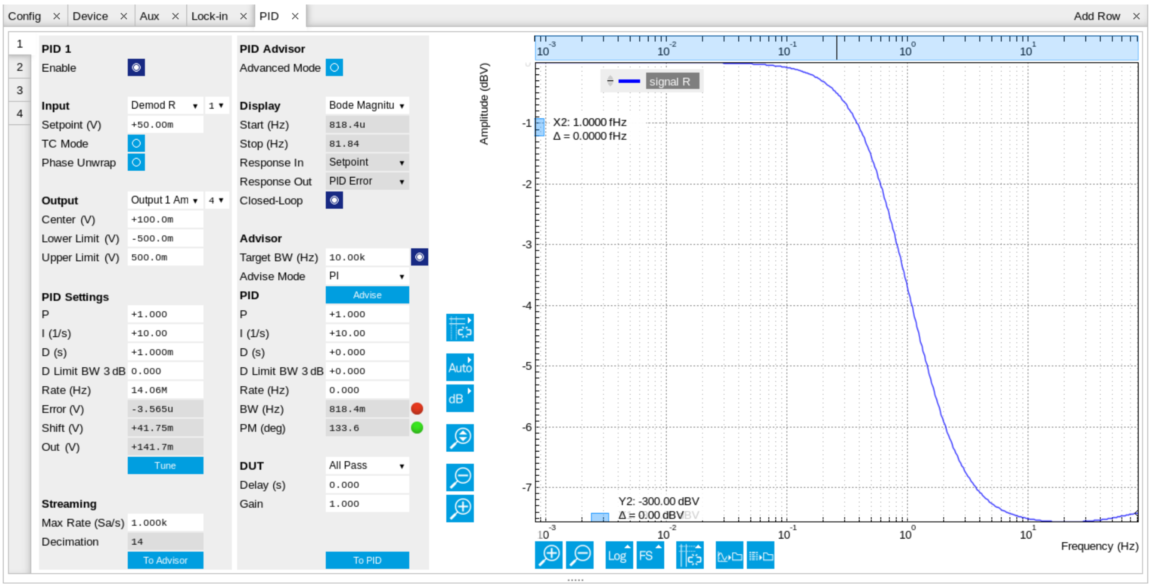


Figure 4.25. LabOne UI: PID tab

With its wide range of different input and output connections the on-board PID controllers are extremely versatile and can be used over a wide range of different applications. With low internal delays the speed is even high enough to cater to demanding laser locking applications. Figure 4.26 shows a block diagram of all PID controller components, their interconnections and the variables to be specified by the user.

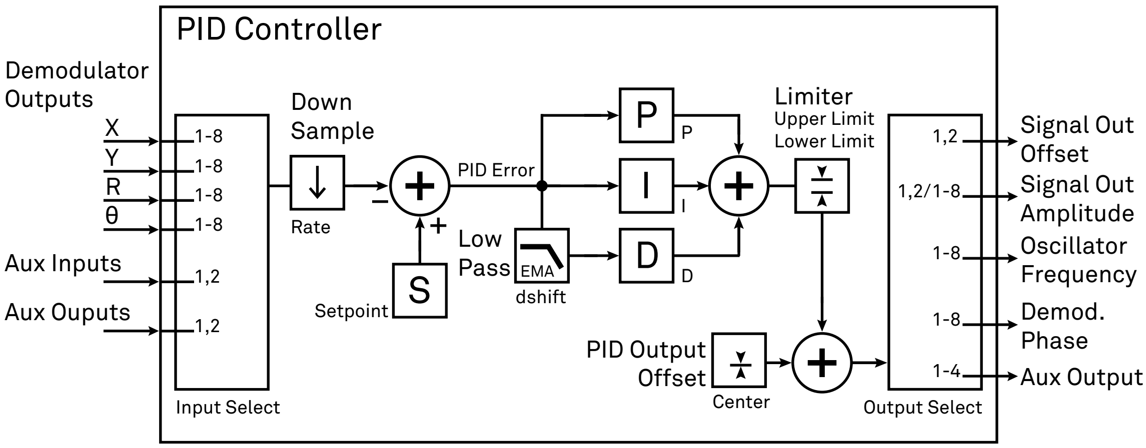


Figure 4.26. PID controller block diagram

Setting up a control loop

Application dependent there is a number of sensible ways to setup a control loop. Let's consider a few different approaches and see how the Advisor can help to reduce the effort and improve on the result and understanding of the setup.

Manual approach

In cases where the transfer function of the DUT is entirely unknown but little (and stationary) noise couples into the system from the environment, a manual approach is often the quickest way to get going. For manual configuration of a new control loop it is generally recommended to start with a small value for P and set the other parameters (I, D, D Limit) to zero at first. By enabling the controller one will then immediately see if the sign was estimated correctly and the feedback is provided to the correct output parameter for instance by checking the numbers (Error, Shift, Out) given directly in the PID tab. A slow increase of I will then help to zero the PID error signal completely once the bandwidth is high enough. Great care is usually required when enabling the D part as this often introduces an instable servo behavior which sometime can be mitigated by activating the associated low pass filter. At this stage a Plotter tab opened in parallel and displaying the PID error over time can be a great help. The math tools offered by the Plotter allows to display the standard deviation and the mean of the error. These values should be minimized by tweaking the PID parameters and the associated histogram should have a symmetric (ideally Gaussian) envelope. After a few iterations one can then check the performance by introducing a step response by changing the PID setpoint slightly. The SW Trigger is the ideal tool to record the step function trace of the PID input value by setting the trigger condition half way of the step and the Delay and Duration according to the expected bandwidth. One should also make sure that the data rate set for the transfer of the PID input data is high enough to fully resolved the behavior in the time domain.

Auto tune

The auto tune feature can now help to fully optimize on the residual noise performance of the error signal. The implemented simplex algorithm will vary the parameters, as selected in the Advise Mode field in the PID advisor section, in order to minimize the root mean square of the PID error signal. That is often accompanied by a lowering of the effective servo loop bandwidth and works great as long as there are no occasional large disruptions entering the loop. A typical example where the use of the auto tune feature makes no sense are situations where the loop serves to follow a step change of a certain parameter, e.g. the setpoint, that needs to be accommodated within a required time interval. The transfer function of the PID settings chosen can always be checked by copying the values to the Advisor pressing the "To Advisor" button and selecting the Advanced Mode. With the Response In set to Setpoint, the Response Out set to PID Output and with Closed-Loop not activated one can visualize the Bode Magnitude of the PID controllers transfer function. This graph is what is usually given in textbooks and entirely independent of the model function chosen in the DUT section. However, in order to simulate step responses or to calculate a bandwidth a suitable model for the entire loop is required. If one is only interested in the PID bandwidth one can chose the All Pass DUT model function with Gain 1 and a Delay set to 0. The PID bandwidth will then be indicated below the PID parameters in the advisor section.

Using DUT model functions with the PID Advisor

For many experimental situations the external device or DUT that needs to be controlled can be well approximated by a simple model. At the moment LabOne offers a number of different choices all of the providing a setting for the delay that occurs outside the instrument. Depending on the servo bandwidth one is aiming for the external delay can often be the limiting factor and should be sensibly chosen.

Note

The delay specified for each model resembles the earliest possible response for a step change of the instrument output to be seen on the instrument input. It describes the causality of the system and does not affect the shape of the DUT transfer function. Standard BNC cables cause a signal delay of about 5 ns/m.

Now, the most simple approach to modeling is to assume a DUT with a unity transfer function by using All Pass. The low pass filters allow for limiting the bandwidth, to set an overall gain and a damping for the second order filter. Resonator Frequency is a model that applies well in situations with a passive external component, e.g. a AFM cantilever, a quartz-resonator, whose frequency should be tracked by a PLL and excited at resonance frequency also when it is changing over time. In cases where the amplitude of the resonator signal needs to be stabilized with a second control loop, the Resonator Amplitude model is the right choice. Setting the resonance frequency and the Q factor, both can be obtained before by a frequency scan over the resonance using the sweeper module, allows the Advisor to estimate the gain and low pass behavior of the resonator. Internal PLL is used whenever an external oscillating signal is provided that shall be followed by one of the internal oscillators. The VCO setting describes a situation where the input variable of the DUT is a voltage and the output is a frequency. The gain is then the conversion factor of how much voltage change on the input causes how much frequency shift on the VCO output. In case the frequency of the VCO can be tracked by using the external reference mode, one can easily obtain this gain with the sweeper by scanning the Auxiliary Output voltage and displaying the resulting oscillator frequency. The gain is given by the slope of the resulting line at the frequency of interest.

With a suitable model chosen and the proper parameter set to best describe the actual measurement situation, one can now continue by defining a target bandwidth for the entire control loop and the Advise Mode, i.e. the parameters that shall be used for the control operation. Whenever the input signal is derived from one of the demodulators it is convenient to activate the box next to target bandwidth. With that in place the Advise algorithm will automatically adjust the demodulator bandwidth to a value about 5 time higher than the target bandwidth in order to avoid to be limited by demodulation speed. With all the model information and the Target Bandwidth the Advise algorithm will now calculate a target step response function that it will try to achieve by adjusting the parameters in the next step. Before doing so in case of a newly set up DUT model the algorithm will first try to estimate the PID parameters by using the Ziegler-Nichols method. When there has been a previous run the user can also change the parameters in the model manually which will the be used as new start parameters of the next Advise run. The last step of the advise algorithm is a simplex search similar to the one used for the auto tune feature describe above. The main difference is that the advise algorithm tries to achieve a least square fit to the target step response function where as the auto tune minimizes the average PID Error, i.e. an experimental parameter. The simulated result is numerically characterized by a bandwidth and a phase margin. Moreover, the large diagram on the right allows to characterize the result of the model by displaying transfer functions, magnitude and phase, and step responses between different signal notes inside the loop. Once the modelling is finished one can simply copy the resulting parameters to the actual PID by pressing the button "To PID".

Table 4.45. DUT transfer functions

Name	Function	Parameters
All pass	$H(s) = g$	1. Gain g
Low pass 1st	$H(s) = g\frac{1}{t_c s + 1} = g\frac{\omega_n}{s + \omega_n}$	1. Gain g 2. Filter bandwidth (BW) $f_{-3\mathrm{dB}} = \omega_\mathrm{n}/2\pi$
Low pass 2nd	$H(s) = g\frac{\omega_n^2}{s^2 + 2\omega_n \zeta s + \omega_n^2}$	1. Gain g 2. Resonance frequency $f_\mathrm{res} = \omega_\mathrm{n}/2\pi$

Name	Function	Parameters
		3. Damping ratio ζ with $f_{-3dB} = 2\zeta f_{res}$
Resonator frequency	$H(s) = \frac{1}{t_c s + 1}$ with $t_c = \frac{1}{2\pi f_{-3dB}} = \frac{2Q}{2\pi f_{res}}$	1. Resonance frequency f_{res} 2. Quality factor Q
Resonator amplitude	$H(s) = g\frac{\omega_{res}/Q \cdot s}{s^2 + \omega_{res}/Q \cdot s + \omega_{res}^2}$ with $\omega_{res} = 2\pi f_{res}$	1. Gain g 2. Resonance frequency f_{res} 3. Quality factor Q
Internal PLL	$H(s) = -\frac{360}{s}$	1. none
VCO	$H(s) = g\frac{360}{s(t_c s + 1)}$ with $t_c = \frac{1}{2\pi f_{-3dB}}$	1. Gain g (Hz/V) 2. Bandwidth (BW) f_{-3dB}

Note

It is generally recommended to use the Advise feature in a stepwise approach where one increases the free parameter from PI to PID and then to PIDF. This helps to avoid optimizing into local minima and sometimes requires less time. Also it can be quite illustrative which part of the loop filter leads to which effect.

Note

The low pass filter in the differential part is implemented as an exponential moving average filter described by $y_t = (1-\alpha) y_{t-1} + \alpha x_t$ with $\alpha = 2^{-\mathrm{dshift}}$. The default value for dshift is 0, i.e. no averaging or unity filter transfer function. On the UI the filter properties can conveniently be changed in units of bandwidth or a time constant.

In particular when the feedback is provided to sensitive external equipment it is highly recommended to make use of the center value and the upper and lower limit values as this will guarantee the output to be in the defined range even when the lock fails and the integrator goes into saturation.

4.16.3. Functional Elements

Table 4.46. PID tab

Control/Tool	Option/Range	Description
Enable	ON / OFF	Enable the PID controller
Input	Demodulator: X	Input source of PID controller
	Demodulator: Y	

Control/Tool	Option/Range	Description
	Demodulator: R	
	Demodulator: Theta	
	Aux Input	
	Aux Output	
Input Channel	index	Select input channel of PID controller.
Setpoint	numeric value	PID controller setpoint
TC Mode	ON / OFF	Enables time constant representation of PID parameters.
Phase Unwrap	ON / OFF	Enables the phase error unwrapping up to +/-32pi.
Output	Sig Out 1/2 Amplitude	Feed back to the main signal output amplitudes
	Osc Frequency	Feed back to any of the internal oscillator frequencies
	Demodulator Phase	Feed back to any of the 8 demodulator phase set points
	Aux Output Offset	Feed back to any of the 4 Auxiliary Outputs' Offset
	Signal Output Offset	Feed back to the main Signal Output offset adjustment
Output Channel	index	Select output channel of PID controller.
Center, Upper, Lower Limit	numeric value	After adding the Center value to the PID output, the signal is clamped to Center + Lower Limit and Center + Upper Limit.
P, I, D	numeric value	PID Output indicator defined as out = P*Error + I*Int(Error, dt) + D*dError/dt
D Limit TC/BW 3 dB	102 ns to 2.33 ms/68.3 Hz to 1.56 MHz	The cutoff of the low pass filter for the D limitation, shown as either the filter time constant or the 3 dB cutoff frequency, depending on the selected TC mode. When set to 0, the low pass filter is disabled.
Rate	109.9 kHz to 14 MHz	PID sampling rate and update rate of PID outputs. Needs to be set substantially higher than the targeted loop filter bandwidth. Note: The numerical precision of the controller is influenced by the loop filter sampling rate. If the target bandwidth is below 1 kHz is starts to make sense to adjust this rate to a value of about 100 to 500 times the target bandwidth. If the rate is set to high for low bandwidth applications, integration inaccuracies can lead to non linear behavior.
Error	numeric value	Error = Set point - PID Input
Shift	numeric value	Difference between the current output value Out and the Center
Out	numeric value	Current output value

Control/Tool	Option/Range	Description
Tune	Tune	Optimize the PID parameters so that the noise of the closed-loop system gets minimized. The tuning method needs a proper starting point for optimization (away from the limits). The tuning process can be interrupted and restarted. The tuning will try to match the PID bandwidth with the loop bandwidth of the DUT, signal input (demodulator), and signal output.
Max Rate (Sa/s)	1 to 14 MSa/s	Target Rate for PID output data sent to PC. This value defines the applied decimation for sending data to the PC. It does not affect the Aux Output.
Decimation	Integer value, ideally 0	Decimation factor applied to ensure a sampling rate smaller than the Max Rate set.
To Advisor	To Advisor	Copy the current PID settings to the PID Advisor.
Advanced	ON / OFF	Enables manual selection of display and advice properties. If disabled the display and advise settings are automatically with optimized default values.
Display	Bode Magnitude	Display the Bode magnitude plot.
	Bode Phase	Display the Bode phase plot.
	Step Resp	Display the step response plot.
Start (Hz)	numeric value	Start frequency for Bode plot display. For disabled advanced mode the start value is automatically derived from the system properties and the input field is read-only.
Stop (Hz)	numeric value	Stop frequency for Bode plot display. For disabled advanced mode the stop value is automatically derived from the system properties and the input field is read-only.
Start (s)	numeric value	Start time for step response display. For disabled advanced mode the start value is zero and the field is read-only.
Stop (s)	numeric value	Stop time for step response display. For disabled advanced mode the stop value is automatically derived from the system properties and the input field is read-only.
Response In	Demod Input	Start point is at the demodulator input.
	Setpoint	Start point is at the setpoint in front of the PID.
	PID Output	Start point is at PID output.
	Instrument Output	Start point is at the instrument output.
	DUT Output	Start point is at the DUT output and instrument input.
Response Out	PID Output	End point is at PID output.
	Instrument Output	End point is at the instrument output.
	DUT Output	End point is at the DUT output and instrument input.

Control/Tool	Option/Range	Description
	Demod Input	End point is at the demodulator input.
	PID Error	End point is at the PID error calculation of the PID.
Closed-Loop	ON / OFF	Switch the display of the system response between closed or open loop.
Target BW (Hz)	numeric value	Target bandwidth for the closed loop feedback system which is used for the advising of the PID parameters. This bandwidth defines the trade-off between PID speed and noise.
Auto Bandwidth	ON / OFF	Adjusts the demodulator bandwidth to fit best to the specified target bandwidth of the full system. If disabled, a demodulator bandwidth too close to the target bandwidth may cause overshoot and instability. In special cases the demodulator bandwidth can also be selected smaller than the target bandwidth.
Advise Mode	P	Only optimize the proportional gain.
	I	Only optimize the integral gain.
	PI	Only optimize the proportional and the integral gain.
	PID	Optimize the proportional, integral, and differential gains.
	PIDF	Optimize the proportional, integral, and differential gains. Also the differential gain bandwidth will be optimized.
Advise	Advise	Calculate the PID coefficients based on the used DUT model and the given target bandwidth. If optimized values can be found the coefficients are updated and the response curve is updated on the plot. Only PID coefficients specified with the advise mode are optimized. The Advise mode can be used incremental, means current coefficients are used as starting point for the optimization unless other model parameters are changed in-between.
P, I, D	numeric value	PID coefficients used for calculation of the response of the PID model. These parameters can be optimized with the PID advise or can be changed manually. The parameters only get active on the PID after pressing the button to PID.
D Limit TC/BW 3 dB	numeric value	The cutoff of the low pass filter for the D limitation, shown as either the filter time constant or the 3 dB cutoff frequency, depending on the selected TC mode. When set to 0, the low pass filter is disabled.
Rate	109.9 kHz to 14 MHz	PID sampling rate used for simulation. The advisor will update the rate to match with the specified target bandwidth. A sampling rate close

Control/Tool	Option/Range	Description
		to the target bandwidth and excessive higher bandwidth will results in a simulation mismatch.
BW (Hz)	numeric value	Simulated bandwidth of the full close loop model with the current PID settings. This value should be larger than the target bandwidth.
Target BW LED	green/red	Green indicates that the target bandwidth can be fulfilled. For very high PID bandwidth the target bandwidth might be only fulfilled using marginal stable PID settings. In this case try to lower the bandwidth or optimize the loop delays of the PID system.
PM (deg)	numeric value	Simulated phase margin of the PID with the current settings. The phase margin should be greater than 60 deg for stable conditions. An Infinite value is shown if no unity gain crossing is available to determine a phase margin.
Stable LED	green/red	Green indicates that the phase margin is fulfilled and the PID system should be stable.
DUT	numeric value	Parameter that specifies the DUT property. This parameter will influence the DUT model used for the advise.
To PID	To PID	Copy the PID Advisor settings to the PID.

4.17. PLL Tab

The PLL tab allows convenient setup of a phase locked loop using one of the demodulators as phase detector and one of the PID controllers to provide feedback to an internal oscillator. This tab is only available when the UHF-PID/PLL controller option is installed on the UHF Instrument (see Information section in the Device tab).

Note

Demodulator and PID parameters that are used within an active PLL are set to read-only values on the Lock-in tab and PID tab.

4.17.1. Features

- Two fully programmable 600 MHz phased-locked loops
- Programmable PLL center frequency and phase set point
- Programmable PLL phase detector filter settings and PID controller parameters
- PLL Advisor for model based parameter suggestion and transfer function analysis
- Phase unwrap for extended lock range and increased stability
- Auto-zero functions for center frequency and set point
- Generation of sub-multiple frequencies by use of harmonic multiplication factor

4.17.2. Description

The PLL tab offers the user a convenient way to use the PID controllers and demodulators in combination to set up a phase locked loop where the frequency from an external signal is mapped to one of the Instruments' numeric oscillators. An advisor functionality that is based on mathematical models helps the user finding and optimizing the different parameters and quickly optimizing the servo bandwidth for the application. Whenever closed or a new instance is needed the following symbol pressed will generate a new instance of the tab.

Table 4.47. App icon and short description

Control/Tool	Option/Range	Description
PLL		Features all control and analysis capabilities of the phase-locked loops.

The PLL tab (see Figure 4.27) is divided into two side-tabs one for each PLL and contains a settings sections on the left and a modelling section with graph support on the right.

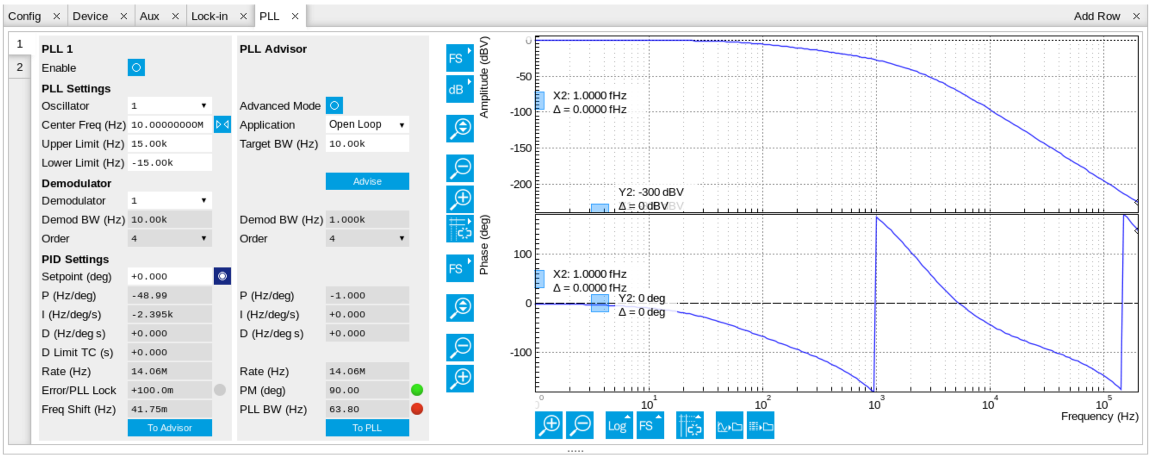


Figure 4.27. LabOne UI: PLL tab

Figure 4.28 shows a block diagram of the PLL with its components, their interconnections and the variables to be specified by the user. The demodulator and the PID controller are slightly simplified for this sketch. Their full detailed block diagrams are given in Figure 4.6 and Figure 4.26 respectively.

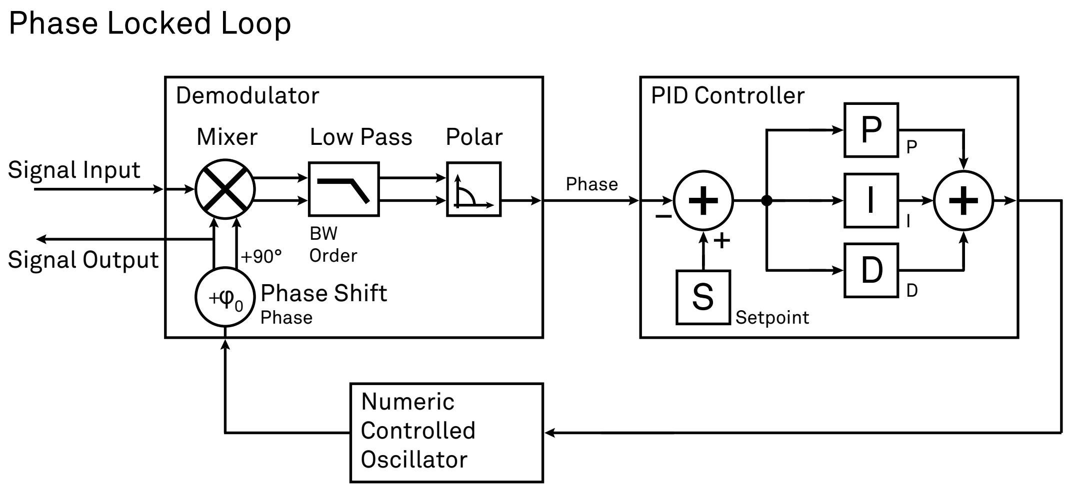


Figure 4.28. Phase Locked Loop block diagram (components simplified)

In a typical work flow to setup a PLL one would first define the center frequency and the setpoint in the left section. These values are often known or can be inferred by using the Sweeper or Spectrum tool. Then a target bandwidth in the PLL Advisor can be set with a subsequent click on the Advise button. The results will be shown in the read only fields just below. Moreover, a graphical representation of the determined transfer function in indicated by the plot on the right. If the resulting values are within the range of expectations one can then copy the values to the Instrument by pressing the To PLL button. Before enabling the PLL one can quickly open the Lock-in tab to check if the right Signal Input is associated with the chosen demodulator. Also the values for the frequency limits given in Hz should exceed the target bandwidth at least by about 5 to 10 times. A successful lock is indicated by the green LED next to the Error/PLL Lock field, which should indicate very low values now. One can now play with the bandwidth in the PLL Advisor and calculate a new set of parameters and copy it to the Instrument in order to improve performance. Displaying the associated demodulator phase in the Plotter along with a Histogram and Math function (e.g. standard deviation) can help to characterize residual phase deviations and further improve lock performance by manual tweaking.

4.17.3. Functional Elements

Table 4.48. PLL tab

Control/Tool	Option/Range	Description
Enable	ON / OFF	Enable the PLL (i.e. the associated PID controller)
Oscillator	oscillator index	Oscillator controlled by the PLL
Center Freq (Hz)	0 to 600 MHz	Center frequency of the PLL oscillator. The PLL frequency shift is relative to this center frequency.
Auto Adjust		Adjust the center so that the frequency shift is zero.
Upper Limit (Hz)	numeric value	Upper frequency limit of the PLL oscillator. The PLL frequency is clamped between Center+Lower Limit and Center+UpperLimit.
Lower Limit (Hz)	numeric value	Lower frequency limit of the PLL oscillator. The PLL frequency is clamped between Center+Lower Limit and Center+UpperLimit.
Demodulator	demodulator index	Select the demodulator that is used as the phase detector of the PLL.
Demod BW (Hz)	numeric value	Filter bandwidth of the input demodulator (advanced mode).
Order	1 to 8	Filter order of the input demodulator
Setpoint (deg)	numeric value	Phase set point in degrees (i.e. PID setpoint). Control the phase difference between the input signal and the generated signal.
P (Hz/deg)	numeric value	PLL proportional gain P
I (Hz/deg)	numeric value	PLL integral gain I
D (Hz/deg*s)	numeric value	PLL differential gain D
D Limit TC	numeric value	Time constant of the low pass filter for the D limitation. When 0, the low pass filter is disabled.
Rate (Hz)	numeric value	Current sampling rate of the PLL control loop. Note: The numerical precision of the controller is influenced by the loop filter sampling rate. If the target bandwidth is below 1 kHz is starts to make sense to adjust this rate to a value of about 100 to 500 times the target bandwidth. If the rate is set to high for low bandwidth applications, integration inaccuracies can lead to non linear behavior.
Error	numeric value	Current phase error of the PLL (Set Point - PID Input).
PLL lock LED	grey/green	Indicates when the PLL is locked. The PLL error is sampled at 5 Sa/s and its absolute value is calculated. If the result is smaller than 5 degrees the loop is considered locked.

Control/Tool	Option/Range	Description
Freq Shift (Hz)	numeric value	Current frequency shift of the PLL (Oscillator Freq - Center Freq).
To Advisor	To Advisor	Copy the current PLL settings to the PLL Advisor.
Phase Unwrap	ON / OFF	Enables the phase error unwrapping up to +/-32pi.
Advanced Mode	ON / OFF	Enables manual tuning of the PID parameters. The stability is reported and the frequency response is shown on the plots.
Application	Open Loop	Select PLL Advisor mode. Currently only one mode is supported.
Target BW (Hz)	0.1 Hz to 84 kHz	Requested PLL bandwidth. Higher loop filter bandwidth can be attained by manual tuning only.
Advise	Advise	Calculate PLL settings based on application mode and given settings.
Demod BW (Hz)	numeric value	Demodulator bandwidth used for the PLL loop filter
Order	1 to 8	Demodulator order used for the PLL loop filter
P (Hz/deg)	numeric value	PLL Advisor proportional gain P
I (Hz/deg/s)	numeric value	PLL Advisor integral gain I
D (Hz/deg*s)	numeric value	PLL Advisor differential gain D
Rate (Hz)	109.9 kHz to 14 MHz	PLL Advisor sampling rate of the PLL control loop
PM (deg)	numeric value	Simulated phase margin of the PLL with the current settings. The phase margin should be greater than 45 deg and preferably greater than 65 deg for stable conditions.
Advisor stability LED	green/red	When green, the PLL Advisor found a stable solution with the given settings. When red, revise your settings and rerun the PLL Advisor.
PLL BW (Hz)	numeric value	Simulated bandwidth of the PLL with the current settings. The bandwidth is roughly equal to the locking range of the PLL.
Model BW LED	green/red	Red indicates the simulated PLL BW is smaller than the Target BW.
To PLL	To PLL	Copy the PLL Advisor settings to the PLL.

4.18. MOD Tab

The MOD tab relates to the UHF-MOD AM/FM Modulation option and is only available if this option is installed on the UHF Instrument (see Information section in the Device tab).

Note

The UHF-MOD AM/FM Modulation option requires that the UHF-MF Multi-frequency option to be activated.

4.18.1. Features

- Phase coherently add and subtract oscillator frequencies and their multiples
- Control for AM and FM demodulation
- Control for AM and narrow-band FM generation
- Direct analysis of higher order carrier frequencies and sidebands

4.18.2. Description

The MOD tab offers control in order to phase coherently add and subtract the frequencies of multiple numerical oscillators. Whenever closed or a new instance is needed the following symbol pressed will generate a new instance of the tab.

Table 4.49. App icon and short description

Control/Tool	Option/Range	Description
MOD		Control panel to enable (de)modulation at linear combinations of oscillator frequencies.

The MOD tab (see Figure 4.29) is divided into two horizontal sections, one for each modulation kit.

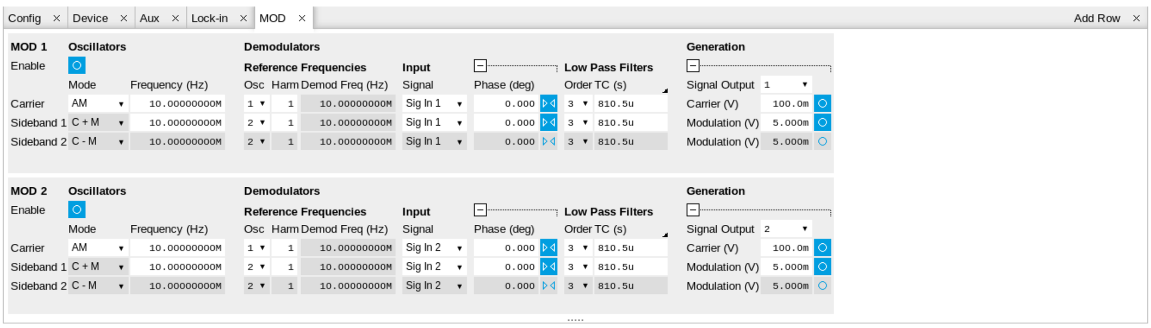


Figure 4.29. LabOne UI: MOD tab

The UHF-MOD option is designed for experiments where multiple frequencies are involved. For many of such experiments the associated spectrum reveals a dominant center frequency, often referred to as carrier, and one or multiple sidebands symmetrically placed around the carrier and termed sidebands. Typical examples are amplitude modulated signals with one carrier component and two sidebands separated by the AM modulation frequency from the carrier. Another example is frequency modulation where multiple sidebands left and right of the carrier can appear. The relative strength of the sideband components for both examples depends on the modulation depth, which is often expressed by the modulation index.

The classical approach of analysing such signals (in particular when only analog instruments are available) is to use a configuration called tandem demodulation. This is essentially the serial concatenation of lock-in amplifiers where the first device is referenced to the carrier frequency and outputs the in-phase component which is then fed into the subsequent lock-in amplifiers in order to extract the different sideband components. There are several downsides to this scheme:

- The quadrature component of the first lock-in tuned to the carrier has to be continuously zeroed out by adjusting the reference phase. Otherwise a serious part of the signal power is lost for the analysis which usually leads to a drop in SNR.
- The scheme scales badly in terms of the hardware resources needed, in particular if multiple sideband frequencies need to be extracted.
- Every time a signal enters a new Instrument or is output from an Instrument after analysis is associated with a loss of SNR (e.g. by the Instruments inputs noise). Multiple such steps can deteriorate signal quality significantly.

All these shortcomings are nicely overcome by providing the ability to generate linear combinations of oscillator frequencies and base demodulation on that. To do so, the MOD option provides two sections MOD 1 and MOD 2. Both are identical in all aspects other than the fact that MOD 1 is hard wired to demodulators 1,2 and 3, whereas MOD 2 has a permanent assignment to demodulators 5,6 and 7. Each of them can make use of up to 3 independent numerical oscillators, which can be even referenced to an external source by using ExtRef or a PLL on demodulators 4 and 8 respectively. Figure 4.30 gives an overview of the different components involved and their interconnections.

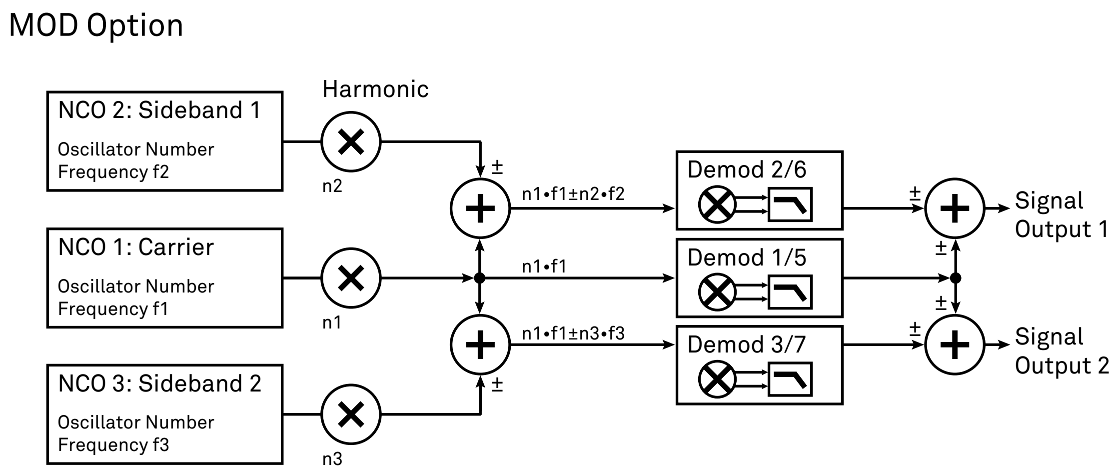


Figure 4.30. Modulation Option block diagram

For convenience the UI provides access to presets for AM and FM in the Mode column. In the Manual Mode all settings can be chosen freely. When there is more than three frequencies present on a single signal one can even associate both sections MOD 1 and 2 to the same Signal Input.

Note

Whenever MOD 1/2 are enabled, all the associated settings in the Lock-in tab that are controlled by the MOD Option will be set to read only.

On top of signal analysis the MOD option can also be utilized for signal generation. The Generation section provides all the necessary controls to adjust for the amplitudes and modulation properties.

Note

FM signals are generated by coherent superposition of the carrier signal with two sideband frequencies on either side that have the same amplitudes but opposite phases. The phase shift is achieved by using negative amplitudes as displayed in the lock-in tab. This FM generation method approximates true FM as long as the modulation index is well below 1, i.e. higher order sidebands can be neglected. For a modulation index of 1 true FM provides more than 13% of signal power in the second and higher order sidebands.

More details regarding AM and FM signal analysis and generation can also be found on the Zurich Instruments web page, e.g. http://www.zhinst.com/blogs/sadik/2014/02/sideband-analysis/ .

4.18.3. Functional Elements

Table 4.50. MOD tab

Control/Tool	Option/Range	Description
Enable	ON / OFF	Enable the modulation
Mode	AM/FM/manual	Select the modulation mode.
Mode	Off	Sideband is disabled. The sideband demodulator behaves like a normal demodulator.
	C + M	Sideband right to the carrier
	C - M	Sideband left to the carrier
Mode	Off	Sideband is disabled. The sideband demodulator behaves like a normal demodulator.
	C + M	Sideband right to the carrier
	C - M	Sideband left to the carrier
Carrier	oscillator index	Select the oscillator for the carrier signal.
Sideband 1	oscillator index	Select the oscillator for the first sideband.
Sideband 2	oscillator index	Select the oscillator for the second sideband.
Harm	1 to 1023	Set harmonic of the carrier frequency. 1=Fundamental
Harm	1 to 1023	Set harmonic of the first sideband frequency. 1 = fundamental

Control/Tool	Option/Range	Description
Harm	1 to 1023	Set harmonic of the second sideband frequency. 1 = fundamental
Channel	Signal Inputs, Ref / Trigger, Auxiliary Inputs, Auxiliary Outputs	Select Signal Input for the carrier demodulation
Channel	Signal Inputs, Ref / Trigger, Auxiliary Inputs, Auxiliary Outputs	Select Signal Input for the sideband demodulation
Phase	-180° to 180°	Phase shift applied to the reference input of the carrier demodulator and also to the carrier signal on the Signal Outputs
Phase	-180° to 180°	Phase shift applied to the reference input of the sideband demodulator and also to the sideband signal on the Signal Outputs
Zero		Adjust the carrier demodulator phase automatically in order to read zero degrees. Shifts the phase of the reference at the input of the carrier demodulator in order to achieve zero phase at the demodulator output. This action maximizes the X output, zeros the Y output, zeros the Θ output, and leaves the R output unchanged.
Zero		Adjust the sideband demodulator phase automatically in order to read zero degrees. Shifts the phase of the reference at the input of the sideband demodulator in order to achieve zero phase at the demodulator output. This action maximizes the X output, zeros the Y output, zeros the Θ output, and leaves the R output unchanged.
Order	1 to 8	Filter order used for carrier demodulation
Order	1 to 8	Filter order used for sideband demodulation
TC/BW Value	numeric value	Defines the low pass filter characteristic in the unit defined above for the carrier demodulation
TC/BW Value	numeric value	Defines the low pass filter characteristic in the unit defined above for the sideband demodulation
Frequency (Hz)	0 to 600 MHz	Sets the frequency of the carrier.
Frequency (Hz)	0 to 600 MHz	Frequency offset to the carrier from the first sideband.
Frequency (Hz)	0 to 600 MHz	Frequency offset to the carrier from the second sideband.
Demod Freq (Hz)	0 to 600 MHz	Carrier frequency used for the demodulation and signal generation on the carrier demodulator.
Demod Freq (Hz)	0 to 600 MHz	Absolute frequency used for demodulation and signal generation on the first sideband demodulator.

Control/Tool	Option/Range	Description
Demod Freq (Hz)	0 to 600 MHz	Absolute frequency used for demodulation and signal generation on the second sideband demodulator.
Signal Output	1, 2 or both	Select Signal Output 1, 2 or none
Carrier (V)	-range to range	Set the carrier amplitude
On	ON / OFF	Enable the carrier signal
Modulation (V), Index, Amplitude (V)	-range to range	Set the amplitude of the first sideband component.
Modulation (V), Peak Dev (Hz), Amplitude (V)	-range to range	Set the amplitude of the second sideband component.
Enable FM Peak Mode	ON / OFF	In FM modulation, choose to work with either modulation index or peak deviation. The modulation index equals peak deviation divided by modulation frequency.
Enable	ON / OFF	Enable the signal generation for the first sideband
Enable	ON / OFF	Enable the signal generation for the second sideband

4.19. Boxcar Tab

The Boxcar tab relates to the UHF-BOX Boxcar option and is only available if this option is installed on the UHF Instrument (see Information section in the Device tab).

4.19.1. Features

- 2 equivalent boxcar units with up to 450 MHz repetition rate
- Baseline suppression for each Boxcar unit
- up to 450 MHz repetition rate
- Dead time free operation for frequencies below 450 MHz
- Period waveform analyzer (PWA) allows display of waveform and convenient graphical setting of Boxcar averaging windows
- PWA frequency domain view allows for simultaneous analysis of up to 512 harmonics of the reference frequency

4.19.2. Description

The Boxcar tab provides access to the gated averager functionality of the UHF Instrument. Whenever closed or a new instance is needed the following symbol pressed will generate a new instance of the tab.

Table 4.51. App icon and short description

Control/Tool	Option/Range	Description
Boxcar		Boxcar settings and periodic waveform analyzer for fast input signals.

Each Boxcar unit is shown in a separate sub-tab (see Figure 4.31) that consists of a plot area and three control tabs on the right hand side.

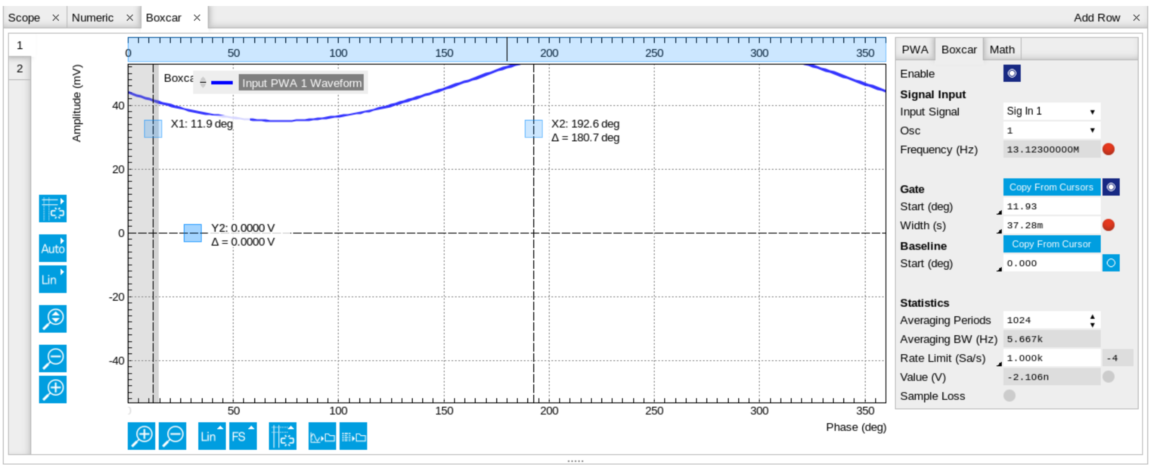


Figure 4.31. LabOne UI: Boxcar tab

Similar to the lock-in amplifier functionality the Boxcar offers a large reduction of the incoming signal bandwidth sampled with 1.8 GSa/s to a regime where much lower sampling rates suffice that can easily be transfered to a PC over USB or Ethernet cable for further analysis and post processing. For both methods ideally no piece of signal information is lost during the data reduction but huge parts if the initial signal are discarded that contain no or a negligible piece of relevant information. The operation of the lock-in amplifier can most easily be understood considering the inputs signal in the frequency domain where the lock-in acts as a sophisticated bandpass filter with adjustable center frequency and bandwidth (if we generously ignore phase sensitivity here for the sake of simplicity). In contrast, the Boxcar does a very similar thing in the time domain where it allows to cut out only the signal components that contain information. A very common use case are experiments with pulsed lasers. In particular when duty cycles are low, the fraction of the time domain signal where there is actual information can be quite small and so the idea is to record only the parts when for instance the laser is on.

In classical analog instruments this is typically realized by a switch, that can by triggered externally, and a subsequent integrator. Most often the trigger functionality also allows to configure a time delay and a certain window for as long as the switch shall open up for each trigger and the signal will be integrated. The signal output from the integrator is then passed through an adjustable low pass filter for further noise reduction.

One of the biggest limitations of analog boxcar instruments is their trigger re-arm time (caused by the finite time required to erase the integrator) which is usually several 10 ms long. During that time no signals can be acquired. For periodic signals this means a limitation to frequencies of a few 10 kHz when signal loss cannot be afforded, measurement time needs to be minimized while high SNR is crucial.

Note

The Zurich Instruments Boxcar uses a synchronous detection approach instead of the traditional triggering method described above. A reference frequency has to be provided - either from external or an internal oscillator can be used - instead of a trigger signal and the Boxcar window is defined in terms of the phases of that reference frequency.

Note

Using a synchronous detection scheme in combination with a fixed input sampling rate of 1.8 GSa/s excludes all commensurate signal frequencies from proper analysis. The UI provides warnings whenever the reference frequency is anywhere close to any of these. Potential issues can be easily quantified by displaying the bin counts in the PWA sub-tab.

Figure 4.32 shows a detailed block diagram how signal processing is performed.

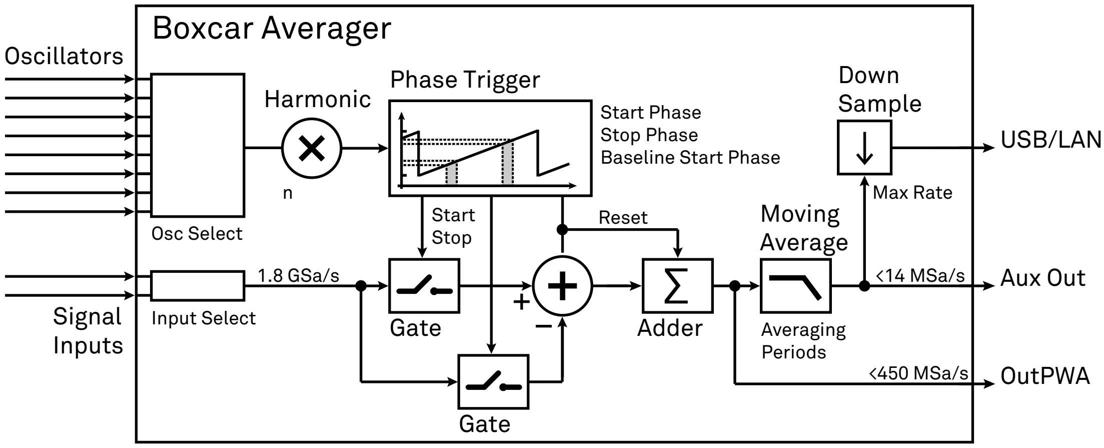


Figure 4.32. Boxcar block diagram

The input signal is sampled at a rate of 1.8 GSa/s. Depending on the phase of the reference oscillator and the set Start Phase and Window Width each of these samples is added up and output from the Adder after each period. From there one branch is directly connected to the outPWA (see Section 4.20) for a further step of synchronous detection. The other signal path way is subject to a Moving Average filter that allows to average over an adjustable number of reference oscillator periods.

Note

The moving average filter provides up to 512 intermittent results. That means if Averaging Periods is set to 1024 the Output is updated with a new value every second oscillator period whereas for smaller numbers of averaging Periods this update is performed on every cycle.

Another big advantage of the Zurich Instruments Boxcar is the graphical display of the input signal termed Periodic Waveform Analyzer. Each Boxcar unit is equipped with a PWA unit that can be either bound to the Boxcar settings or used on any other signal input and oscillator independently. Figure 4.33 shows a block diagram of the PWA.

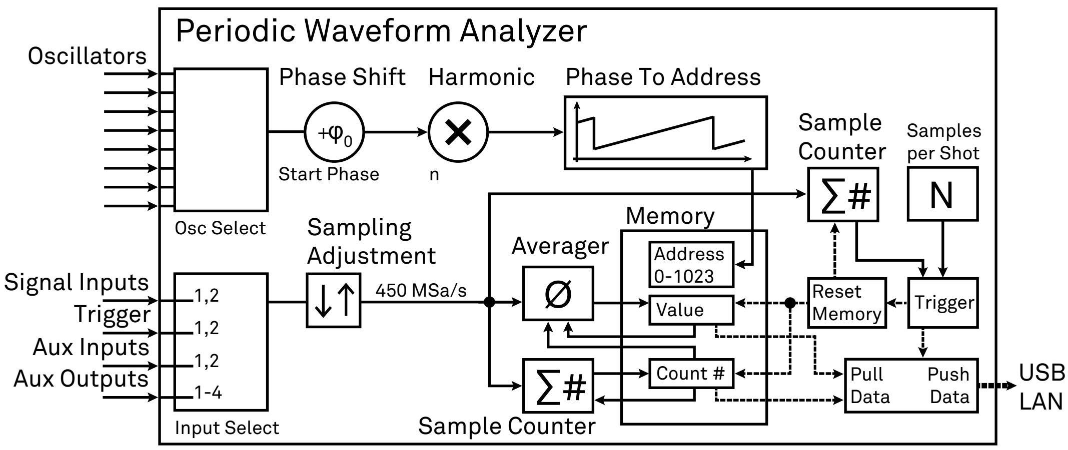


Figure 4.33. Periodic Waveform Analyzer block diagram

The user can select from a variety of different input signals, all of which will be re-sampled - either up or down, where no averaging is provided - at the input to a sampling rate of 450 MSa/s. Depending on the phase of the reference oscillator each data sample is associated to one of 1024 memory units which records the average values and the number of samples. These 1024 can be spread over the entire 360 degree of the reference oscillator period or a smaller span by using the Zoom mode. After an adjustable number of total input samples the entire memory is transfered to the PC and the memory is reset.

Each shot of data contains 1024 average values and sample counts each associated to a certain phase window. In case the reference frequency is sufficiently stable over the course of one shot it makes perfect sense to switch from the phase domain view to the time domain, which for some experiments might be the more natural way of consideration.

4.19.3. Functional Elements

Table 4.52. Boxcar tab: PWA sub-tab

Control/Tool	Option/Range	Description
Run/Stop	Run/Stop	Continuously run and stop PWA acquisition.
Single	Single	Single acquisition of a PWA data set.
Osc	oscillator index	Select reference oscillator for PWA signal acquisition.
PWA Frequency	numeric value	Actual frequency at which the PWA operates based on set oscillator frequency and harmonic scaling factor.
Commensurability	grey/red	Traffic light showing whether the number of samples acquired is evenly distributed over all bins.
Input Signal	Signal Inputs, Ref/Trigger, Auxiliary Inputs, Auxiliary Outputs	Select PWA input signal.
Input Interlock	ON / OFF	Interlock PWA and Boxcar Input settings
Mode	Phase	Measurement data can be interpreted in four different modes and displayed over either phase (native), time, frequency (FFT) or harmonics of the base frequency (FFT).
	Time	
	Freq Domain (FFT)	
	Harmonics (FFT)	
Copy from range	Copy From Range	Change PWA start and span according to plot range.
Reset	R	Reset the start and width value to show the full 360 deg.
Start	numeric value	Defines the start of PWA range in time or phase.
Width	numeric value	Defines width of PWA range in time or phase.
Samples	1 to 2^47	Defines the number of samples acquired of each PWA data set (450 MSa/s).

Control/Tool	Option/Range	Description
Overflow	grey/red	Indicates whether the number of samples collected per bin or the amplitude exceeds the numerical limit. Reduce number of samples and/ or change frequency.
Acq Time (s)	numeric value	Estimated time needed for recording of the specified number of samples.
Infinite Acq Time	string	The signal source of this unit (Boxcar) is not producing any data. Once it is configured and enabled, this field will indicate the duration of a single measurement.
Progress (%)	0 to 100%	Show state of the PWA acquisition in percent.
Resolution	numeric value	FFT resolution (bin width) in Hz.
Max Harmonics	numeric value	Maximum number of displayed harmonics.
Signal	Waveform	Select signal to be displayed.
	Count	

Table 4.53. Boxcar tab: Boxcar sub-tab

Control/Tool	Option/Range	Description
Enable	ON / OFF	Enable the BOXCAR unit
Input Signal	1/2	Select Signal Input used for the boxcar analysis.
Osc	oscillator index	Selection of the oscillator used for the boxcar analysis
Frequency (Hz)	frequency value	Oscillator frequency used for the boxcar analysis.
Too high frequency	grey/red	Frequency for the boxcar is above or equal 450MHz. Sticky flag cleared by restarting the boxcar. The boxcar output may not be reliable any more.
Copy from cursors	Copy From Cursors	Take cursor values to define Window Start and Window span values.
Start Mode	Start (deg)	Native definition of the boxcar averaging gate start as phase.
	Start (s)	Definition of the boxcar averaging gate start as time. Due to the conversion to phase on the device a small uncertainty window exists.
Start (deg)	0 to 360	Boxcar averaging gate opening start in degrees. It can be converted to time assuming 360 equals to a full period of the driving oscillator.
Start Time (s)	0 to period	Boxcar averaging gate opening start in seconds based on one oscillator frequency period equals 360 degrees.
Width Mode	Width (deg)	Definition of the averaging gate width as phase.
	Width (s)	Native definition of the averaging gate width as time.
	Width (pts)	Definition of the averaging gate width in samples.

Control/Tool	Option/Range	Description
Width (deg)	0 to 360	Boxcar averaging gate opening width in degrees based on one oscillator frequency period equals 360 degrees.
Width (s)	555 ps to period	Boxcar averaging gate opening width in seconds. It can be converted to phase assuming 360 equals to a full period of the driving oscillator.
Width (pts)	Integer value	Boxcar averaging gate opening width in samples at 1.8 GHz rate.
Too large gate width	grey/red	Boxcar averaging gate opening width is more than one cycle of the signal and should be reduced.
Copy from cursor	Copy from cursor	Take cursor value to define Baseline Start value.
Start Mode	Start (deg)	Native definition of the boxcar baseline suppression gate start as phase.
	Start (s)	Definition of the boxcar baseline suppression gate start as time.
	Offset (deg)	Definition of the boxcar baseline suppression gate start relative to the gate opening start as phase.
	Offset (s)	Definition of the boxcar baseline suppression gate start relative to the gate opening start as time.
Start (deg)	0 to 360	Boxcar baseline suppression gate opening start in degrees based on one oscillator frequency period equals 360 degrees.
Start (s)	0 to period	Boxcar baseline suppression gate opening start in seconds based on one oscillator frequency period equals 360 degrees.
Start (deg)	0 to 360	Boxcar baseline suppression gate opening start in degrees relative to the gate opening start.
Start (s)	0 to period	Boxcar baseline suppression gate opening start in seconds relative to the gate opening start.
Enable	ON / OFF	Enable Baseline Suppression
Show Gate Opening	ON / OFF	Show gate opening on the PWA plot.
Averaging Periods	1 to 2^20	Number of periods to average. The output will be refreshed up to 512 times during the specified number of periods. This setting has no effect on Output PWAs.
Averaging BW	10 μHz to 7 MHz	The 3 dB signal bandwidth of the Boxcar Averager is determined by the oscillation frequency and the Number of Averaging Periods set. Note: internally the boxcar signal is sampled at a rate of 14 MSa/s and the signal bandwidth of the auxiliary output is 7 MHz.
Rate Limit (Sa/s)	1 to 14.06 MSa/s	Rate Limit for Boxcar output data sent to PC. This value does not affect the Aux Output for which the effective rate is given by min(14 MSa/s , Frequency / max(1, Averaging Periods/512)).

Control/Tool	Option/Range	Description
Rate (Sa/s)	1 to 14.06 MSa/s	Display of the currently effective rate used for data transfer to the PC given by min(14 MSa/s , Frequency / max(1, Averaging Periods/512)). This value is read-only.
Rate Limit (Sa/s) or Rate (Sa/s)	Rate Limit (Sa/s)	Display of the Rate Limit which defines the maximal transfer rate.
	Rate (Sa/s)	Display of the currently active transfer rate.
Oversampling	Integer value, ideally 0	Indicates, in powers of 2, the number of averager outputs sent to the PC while Averaging Periods Boxcar integrations are obtained. Positive integer values indicate oversampling. Negative integer values indicate undersampling. Examples for oversampling values: 0 : 2^0 = 1 averager output is sent to the PC during Averaging Periods Boxcar integrations. 2 : 2^2 = 4 averager outputs are sent to the PC during Averaging Periods Boxcar integrations. -1 : 2^-1 = 0.5, only every other Averaging Periods Boxcar integrations an averager output is sent to the PC.
Value	numeric value	The current boxcar output.
Value Overflow flag	grey/red	Overflow detected. Sticky flag cleared by restarting the boxcar. The boxcar output may not be reliable any more.
Sample Loss	grey/red	Data lost during streaming to PC. Sticky flag cleared by restarting the boxcar.

For the Math sub-tab please see Table 4.7 in the section called “Cursors and Math” .

4.20. Out PWA Tab

The Out PWA tab relates to the UHF-BOX Boxcar option and is only available if this option is installed on the UHF Instrument (see Information section in the Device tab).

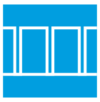
4.20.1. Features

- Period waveform analyzer for boxcar output samples (multi-channel boxcar, deconvolution boxcar)
- Support signals derived from asynchronous optical sampling

4.20.2. Description

The Out PWA tab provides access to the period waveform analyzer that acts on boxcar output samples. This feature is also called multi-channel boxcar or deconvolution boxcar. Whenever closed or a new instance is needed the following symbol pressed will generate a new instance of the tab.

Table 4.54. App icon and short description

Control/Tool	Option/Range	Description
Out PWA		Multi-channel boxcar settings and measurement analysis for boxcar outputs.

The Out PWA tab (see Figure 4.34) consists of a plot and a control tab on the right hand side.

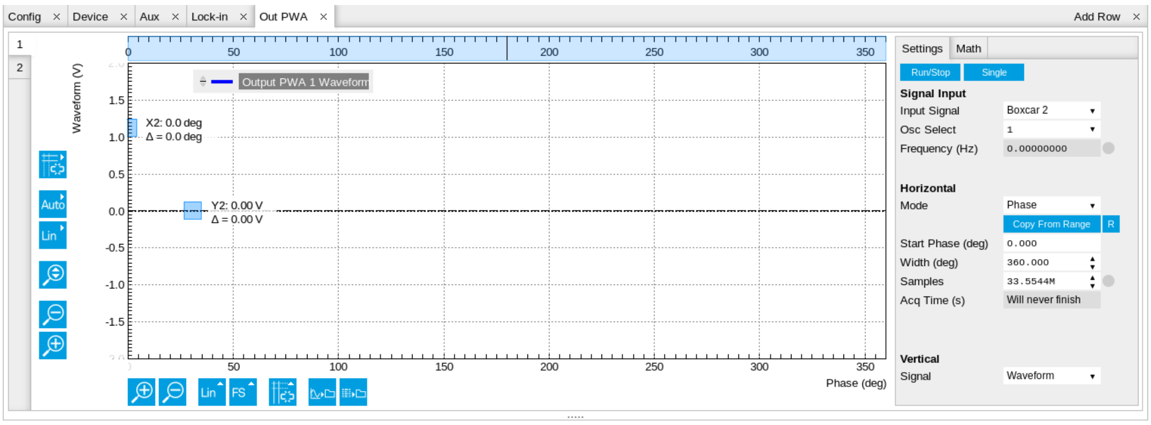


Figure 4.34. LabOne UI: Out PWA tab

Note

The Out PWA works exactly the same way as the PWA supplied in the Boxcar tabs (see Figure 4.33) except that its inputs are limited to the output of the two Boxcar units. It is important to understand that the Boxcar results are directly connected to the input of the Out PWA, in particular that there is now averaging or down sampling applied in between.

4.20.3. Functional Elements

Table 4.55. Out PWA tab: Settings sub-tab

Control/Tool	Option/Range	Description
Run/Stop	Run/Stop	Continuously run and stop PWA acquisition.
Single	Single	Single acquisition of a PWA data set.
Input Signal	Boxcar 1	Select PWA input signal.
	Boxcar 2	
Osc Select	oscillator index	Select reference oscillator for PWA signal acquisition.
Frequency	numeric value	Actual frequency at which the PWA operates based on set oscillator frequency and harmonic scaling factor.
Commensurability	grey/red	Traffic light showing whether the number of samples acquired is evenly distributed over all bins.
Mode	Phase	Measurement data can be interpreted in four different modes and displayed over either phase (native), time, frequency (FFT) or harmonics of the base frequency (FFT).
	Time	
	Freq Domain (FFT)	
	Harmonics (FFT)	
Copy from range	Copy From Range	Change PWA start and span according to plot range.
Reset	R	Reset the start and width value to show the full 360 deg.
Start	numeric value	Defines the start of PWA range in time or phase.
Width	numeric value	Defines width of PWA range in time or phase.
Samples	1 to 2^47	Defines the number of samples acquired of each PWA data set (450 MSa/s).
Overflow	grey/red	Indicates whether the number of samples collected per bin or the amplitude exceeds the numerical limit. Reduce number of samples and/or change frequency.
Acq Time (s)	numeric value	Estimated time needed for recording of the specified number of samples.
Infinite Acq Time	string	The signal source of this unit (Boxcar) is not producing any data. Once it is configured and enabled, this field will indicate the duration of a single measurement.
Progress (%)	0 to 100%	Show state of the PWA acquisition in percent.
Resolution	numeric value	FFT resolution (bin width) in Hz.
Max Harmonics	numeric value	Maximum number of displayed harmonics.
Signal	Waveform	Select signal to be displayed.
	Count	

For the Math sub-tab please see Table 4.7 in the section called “Cursors and Math” .

Chapter 5. Specifications

Important

Unless otherwise stated, all specifications apply after 30 minutes of instrument warm-up.

Important

10 minutes after power-up of the Instrument, an internal calibration is performed. This internal calibration is essential to achieve the specifications of the system. Further it is required to perform the internal calibration after 7 days of instrument use. This auto calibration is turned-on per default and can be configured in the Device tab.

Important

Changes in the specification parameters are explicitly mentioned in the revision history of this document.

5.1. General Specifications

Table 5.1. General and storage

Parameter	min	typ	max
storage temperature	-25 °C	-	65 °C
storage relative humidity (non-condensing)	-	-	95%
operating temperature	5 °C	-	40 °C
operating relative humidity (non-condensing)	-	-	90%
specification temperature	18 °C	-	28 °C
power consumption	-	-	150 W
power inlet support	100-240 V, 50/60 Hz, multi-mains operation		
power inlet fuses	250 V, 2 A, fast acting, 5 x 20 mm		
environmental policy	RoHS compliant		
dimensions with handles and feet	45.0 x 34.5 x 10.0 cm, 17.7 x 13.6 x 3.9 inch, 19 inch rack compatible		
weight	6.4 kg		
recommended calibration interval	2 years		

Table 5.2. Maximum ratings

Parameter	min	typ	max
damage threshold Signal Input 1 and 2	-5 V	-	5 V
damage threshold Signal Output 1 and 2	-2.5 V	-	2.5 V
damage threshold Ref / Trigger 1 and 2	-6 V	-	6 V
damage threshold Trigger Out 1 and 2	-1 V	-	6 V
damage threshold Trigger In 1 and 2	-6 V	-	6 V
damage threshold Aux Output 1, 2, 3, 4	-12 V	-	12 V
damage threshold Aux In 1 and 2	-12 V	-	12 V
damage threshold DIO (digital I/O)	-1 V	-	6 V
damage threshold Clk In and Clk Out	-5 V	-	5 V

Table 5.3. Host computer requirements

Parameter	Description
supported Windows operating systems	32-bit and 64-bit versions of XP, Vista, Windows 7, Windows 8
supported Linux distribution	32-bit and 64-bit of Linux, Ubuntu 12.04 LTS (i386, AMD64), 64-bit systems require the IA32 extension
minimum host computer requirements (for low bandwidth data transfer)	Windows XP 32-bit

Parameter	Description
	Dual Core CPU with SSE2 support 4 GB DRAM 1 Gbit/s Ethernet controller
recommended host computer requirements	Windows 7 64-bit or Linux 64-bit Quad Core CPU (i7) or better 8 GB DRAM or better 1 Gbit/s Ethernet controller with receive side scaling and Jumbo Frame support (9k); high data transfer rates can be obtained by using for instance Intel Ethernet Server Adapter I210-T1 SSD HD drive (for high-bandwidth data saving)
supported processors (requiring SSE2)	AMD K8 (Athlon 64, Sempron 64, Turion 64, etc.), AMD Phenom, Intel Pentium 4, Xeon Celeron, Celeron D, Pentium M, Celeron M, Core, Core 2, Core i5, Core i7, Atom

Table 5.4. Demodulator output sample rate to host computer.

Host computer connection	Active demodulators	Maximum sample rate per demodulator	Comments
1 GbE	1	1.6 MSa/s	to achieve highest rates, it is advised to remove all other data transfer that loads the LAN/USB interface - it is recommended to check the sample loss flag (in the status tab) from time to time when using high readout rate settings
	2 - 4	800 kSa/s	
	5 - 8	400 kSa/s	
USB 2.0	1 - 2	400 kSa/s	
	3 - 6	200 kSa/s	
	7 - 8	100 kSa/s	
10GbE	1	3.2 MSa/s	

Note

The sample readout rate is the rate at which demodulated samples are transferred from the Instrument to the host computer. This rate has to be set to at least 2 times the signal bandwidth of the related demodulator in order to satisfy the Nyquist sampling theorem. As the maximum rate is limited by the USB/LAN protocol and by the performance of the host PC, less maximum rate is provided for more active demodulators. This table summarises the capability of the UHFLI (6 or 8 demodulators).

The maximum achievable rate requires the connection of performing, up-to-date, host computer hardware.

5.2. Analog Interface Specifications

Table 5.5. UHF signal inputs

Parameter	Conditions	min	typ	max
connectors	-	BNC, front panel single-ended		
input impedance	low value	-	50 Ω	-
	high value	-	1 MΩ // 16 pF	-
input frequency range	50 Ω termination	DC	-	600 MHz
input frequency range	1 MΩ termination	DC	-	100 MHz
input A/D conversion	-	12 bit, 1.8 GSa/s		
input noise amplitude	> 100 kHz, 10 mV range, 50 Ω termination	-	4 nV/√Hz	-
input bias current	50 Ω termination	-	10 µA	-
	1 MΩ termination	-	-	1 nA
input full range sensitivity (10 V lock-in amplifier output)	-	1 nV	-	1.5 V
input AC ranges	-	10 mV	-	1.5 V
input range (AC + common mode)	DC coupling	-1.5 V	-	1.5 V
	AC coupling	-3.5 V	-	3.5 V
AC coupling cutoff frequency	50Ω termination	-	320 kHz	-
	1MΩ termination	-	80 Hz	-
input amplitude accuracy	< 100 MHz	-	3 %	-
	> 100 MHz	-	10 %	-
input amplitude stability	-	-	0.1 %/°C	-
input offset amplitude	with respect to range	-	-	5%
input harmonic distortion (HD2/HD3)	1 Vpp, 50 Ω termination, 10 minutes after manual input calibration < 1 MHz	-	-75 dB	-
	< 10 MHz	-	-70 dB	-
	< 100 MHz	-	-60 dB	-
	> 100 MHz	-	-50 dB	-
dynamic reserve		-	90 dB	100 dB

Table 5.6. UHF signal outputs

Parameter	Conditions	min	typ	max
connectors	-	BNC, front panel single-ended		
output impedance	-	-	50 Ω	-
output frequency range	-	DC	-	600 MHz

Parameter	Conditions	min	typ	max
output frequency resolution	-	-	6 µHz	-
output phase range	-	-180 °	-	180 °
output phase resolution	-	-	1.0 µ°	-
output D/A conversion	-	14 bit, 1.8 GSa/s		
output amplitude ranges	-	±150 mV, ±1.5 V		
output power	-	-	-	7.5 dBm
output amplitude accuracy	< 100 MHz	-	2%	-
	> 100 MHz	-	5%	-
output harmonic distortion (HD2/HD3)	1 Vpp, 50 Ω termination, < 1 MHz	-	-70 dB	-
	< 10 MHz	-	-70 dB	-
	< 100 MHz	-	-55 dB	-
	> 100 MHz	-	-42 dB	-
output noise amplitude	> 100 kHz	-	25 nV/√Hz	-
output phase noise	10 MHz, BW = 0.67 Hz, offset 100 Hz	-	-120 dBc/Hz	-
	10 MHz, BW = 0.67 Hz, offset 1 kHz	-	-130 dBc/Hz	-
output offset amplitude	-	-5 mV	-	5 mV
output drive current	-	-	-	100 mA

Table 5.7. Reference signals and reference modes.

Parameter	Conditions	min	typ	max
connectors	-	BNC, front panel bidirectional SMA, back panel input SMA, back panel output		
input impedance (front and back panel)	low value	-	50 Ω	-
	high value	-	1 kΩ	-
input level at Ref / Trigger (front panel) and Trigger In (back panel)	low input impedance	-2.5 V	-	2.5 V
	high input impedance	-5 V	-	5 V
output impedance (front and back panel)	-	-	50 Ω	-
output level (front and back panel)	-	-	-	3.3 V TTL
input trigger hysteresis	-	-	100 mV	-
internal reference mode, output of reference on UHF outputs	frequency range	1 mHz	-	600 MHz
	reference orthogonality	-	0 °	-
	reference acquisition time, lock time	instantaneous		

Parameter	Conditions	min	typ	max
internal reference mode, output of reference on Ref / Trigger	frequency range	1 mHz	-	200 MHz
	reference orthogonality	-	0 °	-
	reference acquisition time, lock time	instantaneous		
external reference mode and auto reference mode, reference input at Signal Input 1 and 2	frequency range	10 Hz	-	600 MHz
	amplitude, note: for low-swing input signals the gain should be set to full-swing range to achieve best performance	100 mV	-	-
	amplitude (using UHF-PID option), note: for low-swing input signals the gain should be set to full-swing range to achieve best performance	10 mV	-	-
	reference acquisition time, lock time	-	-	100 reference cycles or 1.2 ms whatever is larger
external reference mode, reference input at Ref / Trigger	signal type	arbitrary, active at rising edge		
	frequency range	10 Hz	-	600 MHz
	amplitude	250 mV	-	-
	reference acquisition time, lock time	-	-	100 reference cycles or 3 ms, whatever is larger

Note

The UHF Instrument permits to input external references and triggers on the same connectors. At the same time it is possible to output triggers and synchronization signals, partially on the same connectors. For this purpose, 2 bidirectional, 2 output, and 2 input connectors are provided.

Table 5.8. Demodulators

Parameter	Details	min	typ	max
demodulator number	-		8	
demodulator harmonic setting range	-	1	-	1023

Parameter	Details	min	typ	max
demodulator filter time constant	-	30 ns	-	76 s
demodulator measurement bandwidth	-	80 μHz	-	5 MHz
demodulator filter slope / roll-off	-	6, 12, 18, 24, 30, 36, 42, 48 dB/oct, consisting of up to 8 cascaded critical damping filters		
demodulator output resolution	-	X, Y, R, Θ with 64-bit resolution		
demodulator output sample rate (readout rate), for detailed specifications refer to Table 5.4	on auxiliary outputs	-	-	28 MS/s
	USB 2.0 high speed	-	-	400 kSa/s
	1GbE, 1 Gbit/s LAN	-	-	1.6 MS/s
	10GbE, 10 Gbit/s LAN	-	-	3.2 MS/s
demodulator harmonic rejection	-	110 dBc	-	-
group delay (lag time from Signal Input to Aux Output)	30 ns time constant and 1st order filter	-	-	3 μs

Table 5.9. Auxiliary Inputs and Outputs

Parameter	Details	min	typ	max
auxiliary output	connectors	BNC, 4 outputs on front-panel		
	sampling	28 MSa/s, 16-bit		
	bandwidth	-	-	7 MHz
	impedance	-	50 Ω	-
	amplitude	-10 V	-	10 V
	resolution	0.3 mV	-	-
	drive current	-	-	100 mA
auxiliary input	connectors	SMA, 2 inputs on back-panel		
	sampling	400 kSa/s, 16-bit		
	bandwidth	-	-	100 kHz
	impedance	-	1 MΩ	-
	amplitude	-10 V	-	10 V
	resolution	0.3 mV	-	-

Table 5.10. Oscillator and clocks

Parameter	Details	min	typ	max
internal clock (ovenized crystal)	initial accuracy	-	-	±0.5 ppm
	long term accuracy / aging	-	-	±0.4 ppm/year
	short term stability (1 s)	0.00005 ppm	-	-
	short term stability (100 s)	0.0005 ppm	-	-

Parameter	Details	min	typ	max
	temperature coefficient (23° ± 5°)	-	-	±0.03 ppm/°
	phase noise (at 100 Hz)	-	-130 dBc/Hz	-
	phase noise (at 1 kHz)	-	-140 dBc/Hz	-
	warm-up time	-	-	60 s
UHF-RUB Rubidium clock (option)	initial accuracy at 25°	-	-	±0.0005 ppm
	long term accuracy / aging	-	-	±0.000005 ppm/day ±0.0005 ppm/year
	short term stability, AVAR (1 s)	0.00008 ppm	-	-
	short term stability, AVAR (100 s)	0.000008 ppm	-	-
	temperature coefficient (25° ± 25°)	-	-	±0.0005 ppm/°
	phase noise (at 100 Hz)	-	-	-
	phase noise (at 1 kHz)	-	-140 dBc/Hz	-
	warm-up time	-	-	300 s @ 25°
clock input	connector	SMA, on back-panel		
	impedance	-	50 Ω	-
	amplitude	200 mV	320 mV	1 V
	frequency	9.98 MHz	10 MHz	10.02 MHz
clock output	connector	SMA, on back-panel		
	impedance	-	50 Ω	-
	amplitude, 50 Ω	250 mV	500 mV	1 V
	frequency	-	10 MHz	-

5.3. Digital Interface Specifications

Table 5.11. Digital interfaces

Parameter	Description
host computer connection	USB 2.0 high-speed, 480 Mbit/s
	1GbE, LAN / Ethernet, 1 Gbit/s
	10GbE, LAN / Ethernet, 10 Gbit/s (option)
DIO port	4 x 8 bit, general purpose digital input/output port, 5V TTL specification
ZCtrl peripheral port	2 connectors for ZI proprietary bus to control external peripherals

5.3.1. DIO Port

The DIO port is a VHDCI 68 pin connector as introduced by the SPI-3 document of the SCSI-3 specification. It is a female connector that requires a 32 mm wide male connector. The DIO port features 32 bits that can be configured byte-wise as inputs or outputs.

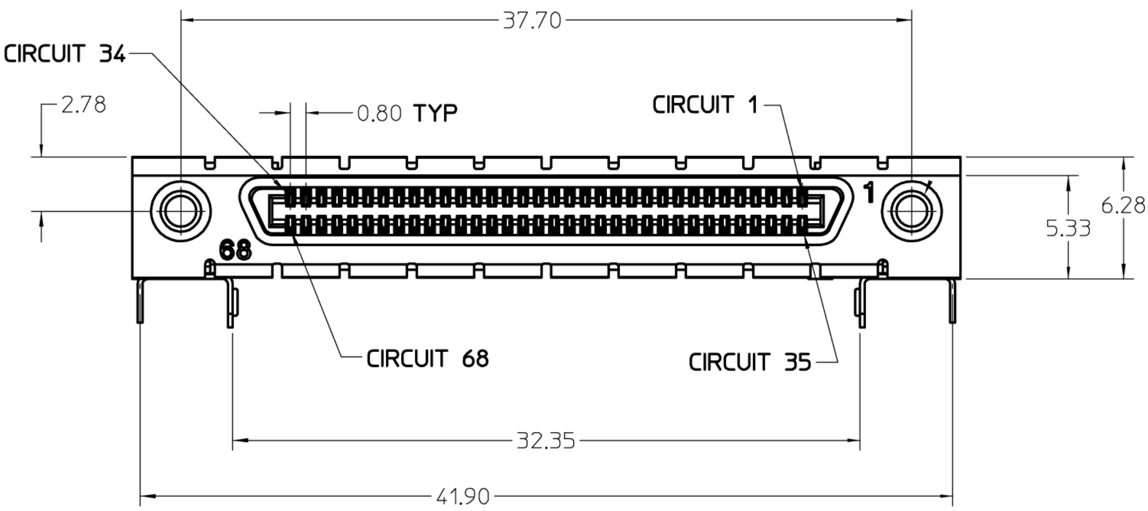


Figure 5.1. DIO HD 68 pin connector

Table 5.12. DIO pin assignment

Pin	Name	Description	Range specification
68	CLKI	clock input, used to latch signals at the digital input ports - can also be used to retrieve digital signals from the output port using an external sampling clock	5 V CMOS/TTL
67	DOL	DIO output latch, 56.25 MHz clock signal, the digital outputs are synchronized to the falling edge of this signal	5 V CMOS
66-59	DI[31:24]	digital input or output (set by user)	output CMOS 5 V, input is CMOS/TTL

Pin	Name	Description	Range specification
58-51	DIO[23:16]	digital input or output (set by user)	output CMOS 5 V, input is CMOS/TTL
50-43	DIO[15:8]	digital input or output (set by user)	output CMOS 5 V, input is CMOS/TTL
42-35	DIO[7:0]	digital input or output (set by user)	output CMOS 5 V, input is CMOS/TTL
34-1	GND	digital ground	-

The figure below shows the architecture of the DIO input/output. The DIO port features 32 bits that can be configured byte-wise as inputs or outputs by means of a drive signal. The digital output data is latched synchronously with the falling edge of the internal clock, which is running at 56.25 MHz. The internal sampling clock is available at the DOL pin of the DIO connector. Digital input data can either be sampled by the internal clock or by an external clock provided through the CLKI pin. A decimated version of the input clock is used to sample the input data. The Decimation unit counts the clocks to decimation and then latches the input data. The default decimation is 5625000, corresponding to a digital input sampling rate of 1 sample per second.

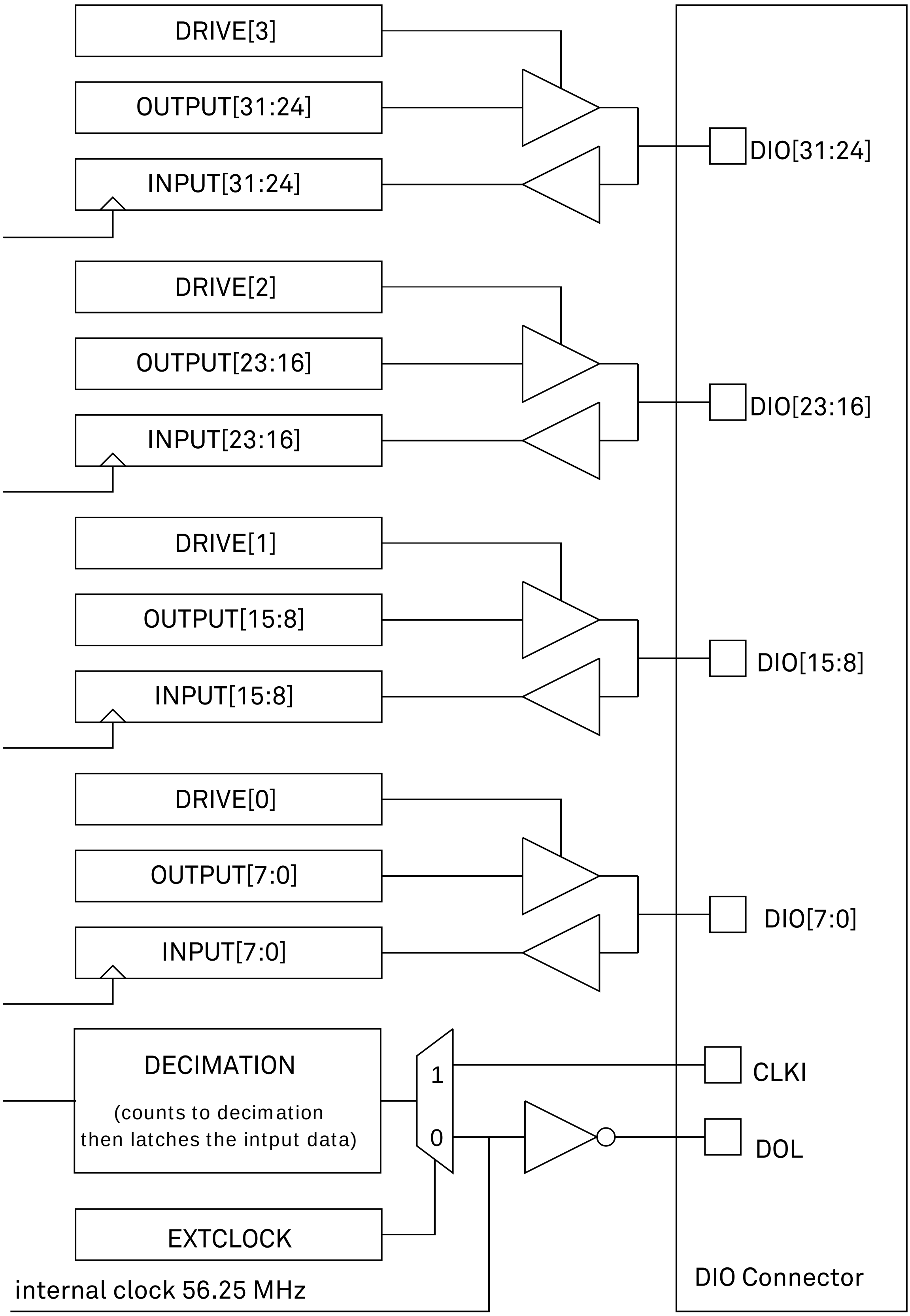


Figure 5.2. DIO input/output architecture

5.3.2. ZCtrl Peripheral Port

The ZCtrl port serves to power and communicate to external equipments, such as pre-amplifiers: the port provides a floating power supply with ±14.5 V and 100 mA per port. After Instrument power-on, the port is not active and must be switched on in order to be used. Two activation methods are supported:

- Manual switch in the user interface
- Manual switch by shorting the ZCtrl_Detect and Device_Ground - these pins should be floating against ZCtrl_GND and ZCtrl_PWR

Th ZCtrl port can be connected with an RJ45 connector, therefore non-crossed Ethernet cables can be used for convenient interfacing.

Warning

Connection to a Ethernet might damage the UHF Instrument.

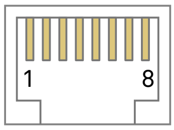


Figure 5.3. The pinout of the ZCtrl port

Table 5.13. DIO port pin assignment

Pin	Name	Description	Range specification
1	ZCtrl_Power+	power pin, for external use	14.5 V, 100 mA
2	ZCtrl_Detect	connection detection	-
3	Device_Ground	ground of UHF Instrument, connected to earth pin	-
4	ZCtrl_Power-	power pin, for external use	-14.5 V, 100 mA
5	ZCtrl_D	proprietary function	-
6	ZCtrl_C	proprietary function	-
7	ZCtrl_GND	floating input	-
8	ZCtrl_GND	reference ground pin for ZCtrl_Power+ and ZCtrl_Power-	-

5.4. Performance Diagrams

Many of the parameters mentioned in Section 5.2 are valid without specific conditions. Other parameters instead are typical specifications, because they depend on several parameters, such as the current range setting, the input termination and/or the frequency. This section completes the previous chapters with detailed performance diagrams in order to support the validation of applications.

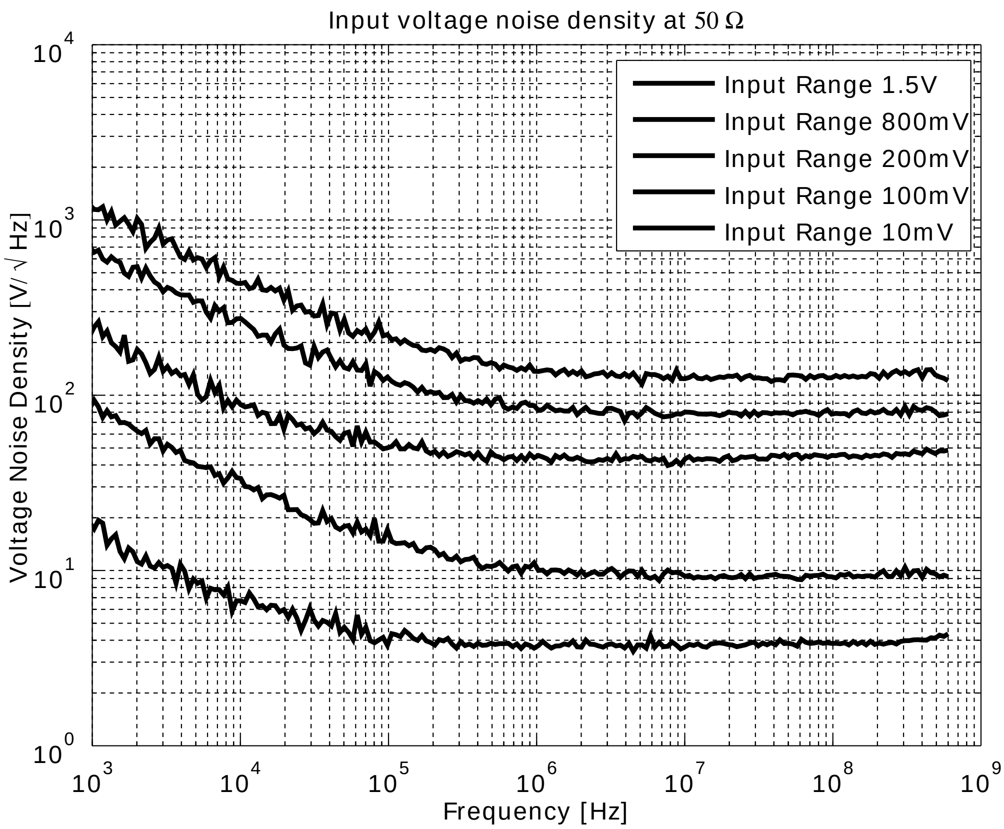


Figure 5.4. Input noise with 50Ω input impedance

Input noise amplitude depends on several parameters, and in particular on the frequency and the setting for the input range. The input noise is lower for smaller input ranges, and it is recommended to use small ranges especially for noise measurements. Only the noise with DC input coupling is shown here as the input noise with AC coupling is the same, as long as the frequency is above the AC cutoff frequency (see Table 5.5). The corner frequency of the 1/f noise is in the range of 100 kHz and the white noise floor is around 4 nV/√Hz for the smallest input range.

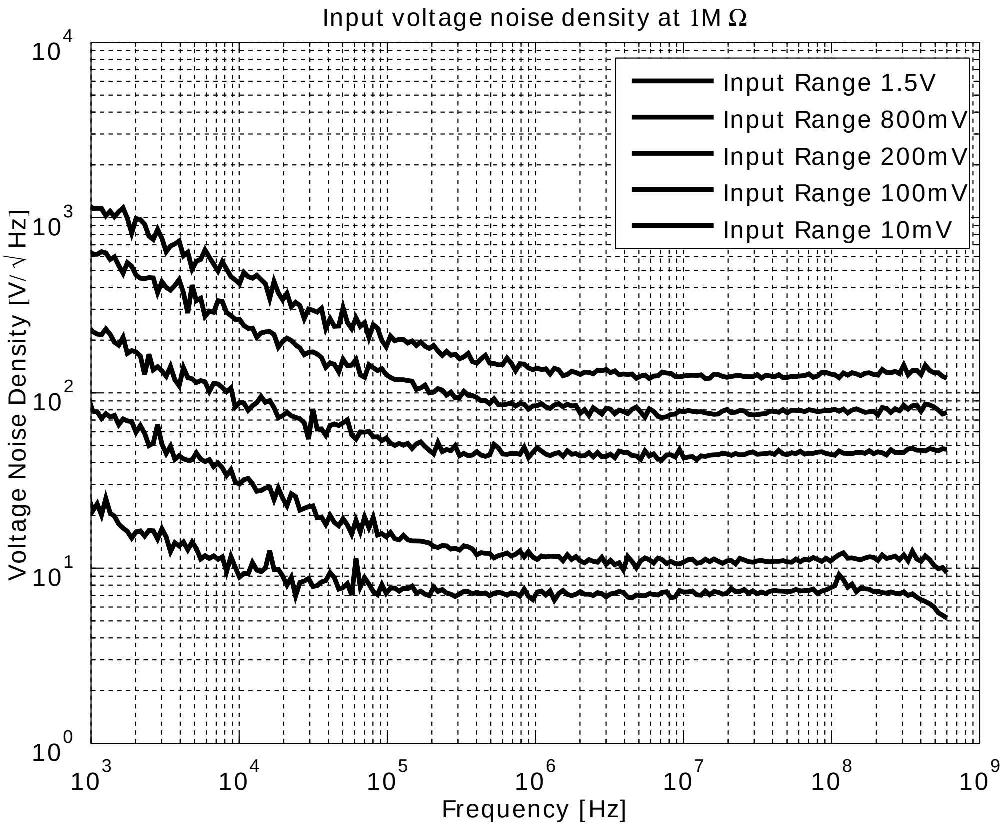


Figure 5.5. Input noise with 1MΩ input impedance

Input noise amplitude depends on several parameters, and in particular on the frequency and the setting for the input range. The input noise is lower for smaller input ranges, and it is recommended to use small ranges especially for noise measurements. Only the noise with DC input coupling is shown here as the input noise with AC coupling is the same, as long as the frequency is above the AC cutoff frequency (see Table 5.5). The corner frequency of the 1/f noise is in the range of 100 kHz and the white noise floor is below 8 nV/√Hz for the smallest input range.

5.5. Clock 10 MHz

A 10 MHz clock input and output is provided for synchronization with other instruments. The figure explains the internal routing of the different clock signals. An internal clock generation unit receives a 10 MHz clock reference and generates all necessary device internal sampling clocks. The clock reference either comes from the internal quartz/Rubidium oscillator or from an external clock source connected to the Clock 10 MHz In connector. The user can define if the clock is taken from the internal or external source. The Clock 10 MHz Out connector always provides the 10 MHz clock of the internal quartz/Rubidium oscillator.

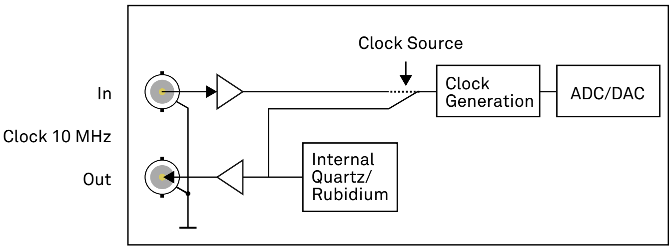


Figure 5.6. Clock routing

5.6. Device Self Calibration Procedure

The device requires a self calibration after a short warm-up period to ensure operation according to specifications. During this self calibration process, components of the sensitive analog front-end are calibrated to account for temperature variations and drift. It is worth noting, that self calibration has nothing to do with the device calibration, which is done at the manufacturer site. The self calibration lasts about one second and only applies a fine-tuning.

The first self calibration after warm-up is executed automatically. Any further self calibration needs to be manually executed by the user. The self calibration process can be executed by means of clicking the "Run" button of the Auto Calibration in the Device tab of the user interface.

The user can disable the calibration procedure completely if necessary. This can be done by changing the Enabled button of the Auto Calibration in the device tab. If this flag is disabled, no calibration is executed after warm-up time.

The default self calibration procedure can be divided into three different states, which are also indicated by the CAL flag in the footer of the user interface. The CAL flag can be either yellow, gray/off, or red.

- Yellow: The yellow CAL flag indicates, that the calibration has not been executed yet. After a warm-up and temperature settling period of approximately 16 minutes, a self calibration is executed and the CAL flag turns gray. If the self calibration is disabled, the CAL flag turns red after the warm-up period to indicate that no calibration was run.
- Gray/off: The gray CAL flag indicates, that the device is self calibrated. The CAL flag turns red when the temperature change is larger than a given threshold or the time since the last calibration is longer than a given time interval. The values of these thresholds are indicated in the device tab.
- Red: The red CAL flag indicates, that it is recommended to run a self calibration. The self calibration is never executed automatically in this state. The CAL flag is red, either, when the device experienced a temperature change, which is larger than a given threshold, or, when the time since the last calibration is longer than a given time interval. By executing a self calibration, the CAL flag will turn gray.

Glossary

This glossary provides easy to understand descriptions for many terms related to measurement instrumentation including the abbreviations used inside this user manual.

A

A/D	Analog to Digital See Also ADC.
AC	Alternate Current
ADC	Analog to Digital Converter
AM	Amplitude Modulation
Amplitude Modulated AFM (AM-AFM)	AFM mode where the amplitude change between drive and measured signal encodes the topography or the measured AFM variable. See Also Atomic Force Microscope.
API	Application Programming Interface
ASCII	American Standard Code for Information Interchange
Atomic Force Microscope (AFM)	Microscope that scans surfaces by means an oscillating mechanical structure (e.g. cantilever, tuning fork) whose oscillating tip gets so close to the surface to enter in interaction because of electrostatic, chemical, magnetic or other forces. With an AFM it is possible to produce images with atomic resolution. See Also Amplitude Modulated AFM, Frequency Modulated AFM, Phase modulation AFM.
AVAR	Allen Variance

B

Bandwidth (BW)	The signal bandwidth represents the highest frequency components of interest in a signal. For filters the signal bandwidth is the cut-off point, where the transfer function of a system shows 3 dB attenuation versus DC. In this context the bandwidth is a synonym of cut-off frequency $f_{cut-off}$ or 3dB frequency f_{-3dB}. The concept of bandwidth is used when the dynamic behavior of a signal is important or separation of different signals is required. In the context of a open-loop or closed-loop system, the bandwidth can be used to indicate the fastest speed of the system, or the highest signal update change rate that is possible with the system. Sometimes the term bandwidth is erroneously used as synonym of frequency range. See Also Noise Equivalent Power Bandwidth.
BNC	Bayonet Neill-Concelman Connector

C

CF	Clock Fail (internal processor clock missing)
Common Mode Rejection Ratio (CMRR)	Specification of a differential amplifier (or other device) indicating the ability of an amplifier to obtain the difference between two inputs while rejecting the components that do not differ from the signal (common mode). A high CMRR is important in applications where the signal of interest is represented by a small voltage fluctuation superimposed on a (possibly large) voltage offset, or when relevant information is contained in the voltage difference between two signals. The simplest mathematical definition of common-mode rejection ratio is: CMRR = 20 * log(differential gain / common mode gain).
CSV	Comma Separated Values

D

D/A	Digital to Analog
DAC	Digital to Analog Converter
DC	Direct Current
DDS	Direct Digital Synthesis
DHCP	Dynamic Host Configuration Protocol
DIO	Digital Input/Output
DNS	Domain Name Server
DSP	Digital Signal Processor
DUT	Device Under Test
Dynamic Reserve (DR)	The measure of a lock-in amplifier's capability to withstand the disturbing signals and noise at non-reference frequencies, while maintaining the specified measurement accuracy within the signal bandwidth.

E

XML	Extensible Markup Language. See Also XML.

F

FFT	Fast Fourier Transform
FIFO	First In First Out
FM	Frequency Modulation
Frequency Accuracy (FA)	Measure of an instrument's ability to faithfully indicate the correct frequency versus a traceable standard.
Frequency Modulated AFM (FM-AFM)	AFM mode where the frequency change between drive and measured signal encodes the topography or the measured AFM variable. See Also Atomic Force Microscope.

Frequency Response Analyzer (FRA)	Instrument capable to stimulate a device under test and plot the frequency response over a selectable frequency range with a fine granularity.
Frequency Sweeper	See Also Frequency Response Analyzer.

G

Gain Phase Meter	See Also Vector Network Analyzer.
GPIB	General Purpose Interface Bus
GUI	Graphical User Interface

I

I/O	Input / Output
Impedance Spectroscope (IS)	Instrument suited to stimulate a device under test and to measure the impedance (by means of a current measurement) at a selectable frequency and its amplitude and phase change over time. The output is both amplitude and phase information referred to the stimulus signal.
Input Amplitude Accuracy (IAA)	Measure of instrument's capability to faithfully indicate the signal amplitude at the input channel versus a traceable standard.
Input voltage noise (IVN)	Total noise generated by the instrument and referred to the signal input, thus expressed as additional source of noise for the measured signal.
IP	Internet Protocol

L

LAN	Local Area Network
LED	Light Emitting Diode
Lock-in Amplifier (LI, LIA)	Instrument suited for the acquisition of small signals in noisy environments, or quickly changing signal with good signal to noise ratio - lock-in amplifiers recover the signal of interest knowing the frequency of the signal by demodulation with the suited reference frequency - the result of the demodulation are amplitude and phase of the signal compared to the reference: these are value pairs in the complex plane (X, Y), (R, Θ).

M

Media Access Control address (MAC address)	Refers to the unique identifier assigned to network adapters for physical network communication.
Multi-frequency (MF)	Refers to the simultaneous measurement of signals modulated at arbitrary frequencies. The objective of multi-frequency is to increase the information that can be derived from a measurement which is particularly important for one-time, non-repeating events, and to increase the speed of a measurement since different frequencies do not have to be applied one after the other. See Also Multi-harmonic.

Multi-harmonic (MH)	Refers to the simultaneous measurement of modulated signals at various harmonic frequencies. The objective of multi-frequency is to increase the information that can be derived from a measurement which is particularly important for one-time, non-repeating events, and to increase the speed of a measurement since different frequencies do not have to be applied one after the other. See Also Multi-frequency.

N

Noise Equivalent Power Bandwidth (NEPBW)	Effective bandwidth considering the area below the transfer function of a low-pass filter in the frequency spectrum. NEPBW is used when the amount of power within a certain bandwidth is important, such as noise measurements. This unit corresponds to a perfect filter with infinite steepness at the equivalent frequency. See Also Bandwidth.
Nyquist Frequency (NF)	For sampled analog signals, the Nyquist frequency corresponds to two times the highest frequency component that is being correctly represented after the signal conversion.

O

Output Amplitude Accuracy (OAA)	Measure of an instrument's ability to faithfully output a set voltage at a given frequency versus a traceable standard.
OV	Over Volt (signal input saturation and clipping of signal)

P

PC	Personal Computer
PD	Phase Detector
Phase-locked Loop (PLL)	Electronic circuit that serves to track and control a defined frequency. For this purpose a copy of the external signal is generated such that it is in phase with the original signal, but with usually better spectral characteristics. It can act as frequency stabilization, frequency multiplication, or as frequency recovery. In both analog and digital implementations it consists of a phase detector, a loop filter, a controller, and an oscillator.
Phase modulation AFM (PM-AFM)	AFM mode where the phase between drive and measured signal encodes the topography or the measured AFM variable. See Also Atomic Force Microscope.
PID	Proportional-Integral-Derivative
PL	Packet Loss (loss of packets of data between the instruments and the host computer)

R

RISC	Reduced Instruction Set Computer
Root Mean Square (RMS)	Statistical measure of the magnitude of a varying quantity. It is especially useful when variates are positive and negative, e.g., sinusoids, sawtooth,

square waves. For a sine wave the following relation holds between the amplitude and the RMS value: $U_{RMS} = U_{PK} / \sqrt{2} = U_{PK} / 1.41$. The RMS is also called quadratic mean.

RT — Real-time

S

Scalar Network Analyzer (SNA) — Instrument that measures the voltage of an analog input signal providing just the amplitude (gain) information.
See Also Spectrum Analyzer, Vector Network Analyzer.

SL — Sample Loss (loss of samples between the instrument and the host computer)

Spectrum Analyzer (SA) — Instrument that measures the voltage of an analog input signal providing just the amplitude (gain) information over a defined spectrum.
See Also Scalar Network Analyzer.

SSH — Secure Shell

T

TC — Time Constant

TCP/IP — Transmission Control Protocol / Internet Protocol

Thread — An independent sequence of instructions to be executed by a processor.

Total Harmonic Distortion (THD) — Measure of the non-linearity of signal channels (input and output)

TTL — Transistor to Transistor Logic level

U

UHF — Ultra-High Frequency

UHS — Ultra-High Stability

USB — Universal Serial Bus

V

VCO — Voltage Controlled Oscillator

Vector Network Analyzer (VNA) — Instrument that measures the network parameters of electrical networks, commonly expressed as s-parameters. For this purpose it measures the voltage of an input signal providing both amplitude (gain) and phase information. For this characteristic an older name was gain phase meter.
See Also Gain Phase Meter, Scalar Network Analyzer.

X

XML — Extensible Markup Language: Markup language that defines a set of rules for encoding documents in a format that is both human-readable and machine-readable.

Z

ZCtrl	Zurich Instruments Control bus
ZoomFFT	This technique performs FFT processing on demodulated samples, for instance after a lock-in amplifier. Since the resolution of an FFT depends on the number of point acquired and the spanned time (not the sample rate), it is possible to obtain very highly resolution spectral analysis.
ZSync	Zurich Instruments Synchronization bus

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Symbols