MAGNICON

physical research and instrumentation

High Performance dc SQUID Electronics

XXF-1

Manual

09/2015
v3.3.16

Contents
Getting started

Getting started

CAUTION: this electronics contains electrostatic sensitive devices. Avoid electrostatic discharge when handling any part of the electronics!

What you will need

First check if all items listed below are present and not damaged on the transport:

- FLL Electronics
- Connector Box
- Switch-mode power supply
- Power supply adaptor (not for all countries)
- FLL-cable
- Output cable (not for MFFT Systems)
- PC connection cable
- USBC-1 USB to Serial converter (not for MFFT Systems)
- Installation CD or USB flash drive
- Manual

Next you need a standard WINDOWS® based PC with a free RS-232 port, usually called COM port, or with a free USB port.

To familiarize with the hard and software it is helpful to use a two or more channel oscilloscope.

PC Requirements

SQUID*Viewer*™ is a LabView® v2011 application, that should run under MS Windows® XP, VISTA, and 7 (98/ME and 2000 are not supported). You need the SQUID*Viewer*™ software to control the XXF-1.

The PC has to be equipped with a standard RS-232 COM port or a free USB port.

A screen resolution of at least 1024 x 768 is recommended.

Software installation

It is not necessary to connect any part of the electronics to install the SQUID*Viewer*™ software. On the Magnicon CD or USB flash drive, you should find this manual as a PDF file and a folder named *SQUIDViewer Install*. The installation can be performed directly from the CD or USB stick. Read the *Version History* file for latest updates.

Please follow the steps below to install the Software:
1. On Windows® XP, Windows® 7, and Windows® 8 you need administrator rights to install the SQUID*Viewer*™ software. Exit all running programs.

2. Open the folder *SQUIDViewer vX.X.X Install*. Double-click the installer application named *setup.exe*. You are prompted to choose a directory, where the *SQUIDViewer.exe* application should be installed. As a default, the folder *C:\Program Files\Magnicon\SQUIDViewer vX.X.X* is created but you may choose any other location. This will be the directory, where the main components of the SQUID*Viewer*™ software are installed. Click Finish.

3. During SQUIDViewer installation a folder named *MagniconData/SQUIDViewerData* is created on your boot drive. Configuration and setup files will be stored here. You can also store your SQUIDViewer related files in this folder.

4. Reboot your computer! This is necessary to set up the LabView® v2011 runtime environment.

5. Within the *SQUIDViewer* folder, in the *Start* menu (Start - Programs - Magnicon), and on the desktop, you should find the application *SQUIDViewer.exe*. Start the application. If the SQUID*Viewer*™ window opens (together with a warning that no electronics could be found) you have installed the SQUID*Viewer*™ software successfully.

6. If you use the USBC-1 USB-to-Serial converter to connect the SQUID electronics to a PC you need to install the Magnicon USB driver. If you use a COM port (RS-232) connection to connect PC and electronics, please ignore the following section.

USBC–1 Driver Installation

USBC-1 plugged to the optically isolated RS-232 to RS-485 converter of a Magnicon SQUID Electronics. The shape of the converter might have changed.

The following two chapters describe USB driver installation for PCs running WindowsXP, Windows7, and Windows® 8.

WindowsXP installation
Please follow the step-by-step instruction to install the USB driver on Windows XP.

1. Install the latest SQUIDViewer software (v3.2.95 or higher) on your PC. The needed USB driver is saved to your disk during SQUIDViewer installation. The driver is located inside the *C:/MagniconData/Windows_USB_Driver* folder.

2. Connect the USBC-1 converter to a spare USB port of your PC. The *Found New Hardware Wizard* opens automatically. Choose *No, not this time* to prevent Windows from installing any suitable driver it finds. Click *Next.*

3. Select *Install from a list or specific location (Advanced)* as shown below and click *Next*.
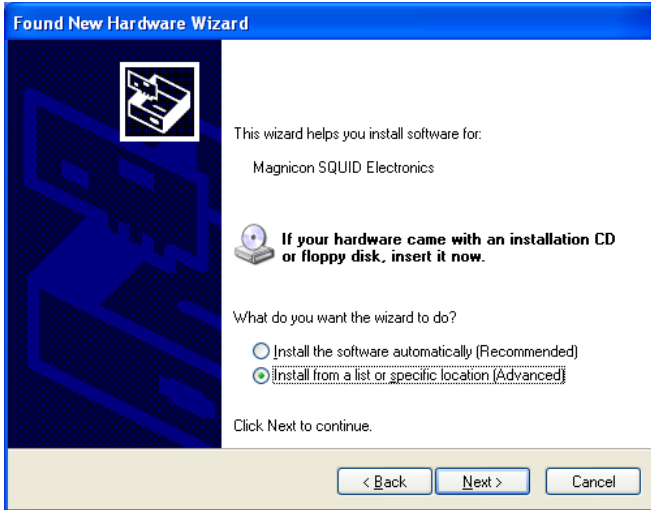
4. Select *Search for the best driver in these locations* and check *Include this location in the search*. Browse to the file path of the *Windows_USB_Driver* folder inside the *MagniconData* folder (usually *C:\MagniconData\Windows_USB_Driver*). If the correct path is displayed in the combo-box, click *Next*.

5. Since the Magnicon USB driver is not WHQL certified, the following screen might

be displayed. Click on *Continue Anyway* to continue with the installation.

Hardware Installation

⚠ The software you are installing for this hardware:

Magnicon SQUID Electronics

has not passed Windows Logo testing to verify its compatibility with Windows XP. ([Tell me why this testing is important.])

Continuing your installation of this software may impair or destabilize the correct operation of your system either immediately or in the future. Microsoft strongly recommends that you stop this installation now and contact the hardware vendor for software that has passed Windows Logo testing.

[Continue Anyway]   [STOP Installation]

6. Please wait as Windows copies the required driver files.

Found New Hardware Wizard

Please wait while the wizard installs the software...

Magnicon SQUID Electronics

[< Back]   [Next >]   [Cancel]
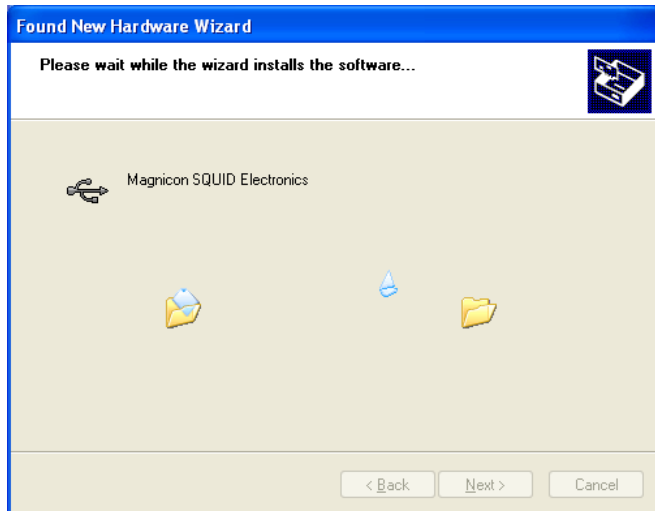
7. Windows should display a message as shown below. Click *Finish* to complete the installation.
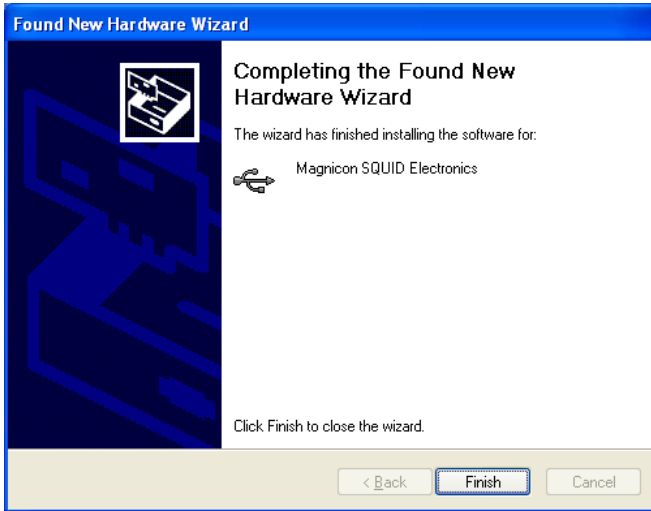
8. Windows should inform you that the new device is ready for use now.

Windows7 installation
Please follow the step-by-step instruction to install the USB driver on Window7.
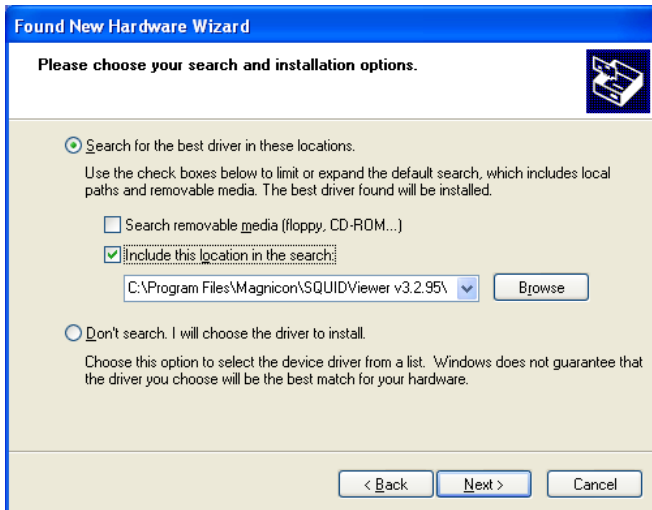
1. Install the latest SQUIDViewer software (v3.2.95 or higher) on your PC. The needed USB driver is saved to your disk during SQUIDViewer installation. The driver is located inside the *C:/MagniconData/Windows_USB_Driver* folder.

2. Connect the USBC-1 converter to a spare USB port of your PC. The *Found New Hardware Wizard* opens automatically. In some cases, the automatic USB driver installation process for Magnicon SQUID electronics and MFFT-1 Systems on Windows7 OS PCs is aborted and you see the following message after you have connected the Magnicon USB-to-Serial converter to your PC.
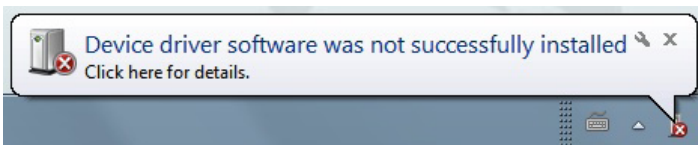
In this case, you have to select the driver files manually.

3. Close SQUIDViewer Software. Open the Windows Control Panel and click on the "Device Manager" link. The following window appears:
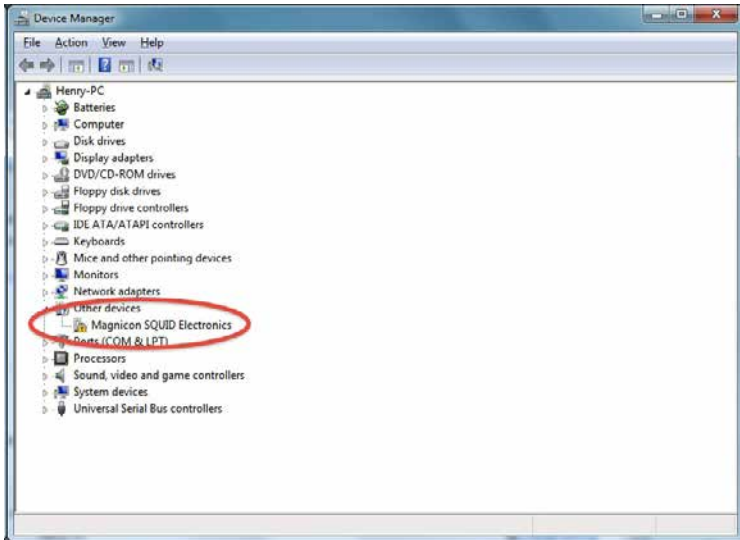
4. Double-click the "Magnicon SQUID Electronics" device in the "Other Devices" section. The following window opens:
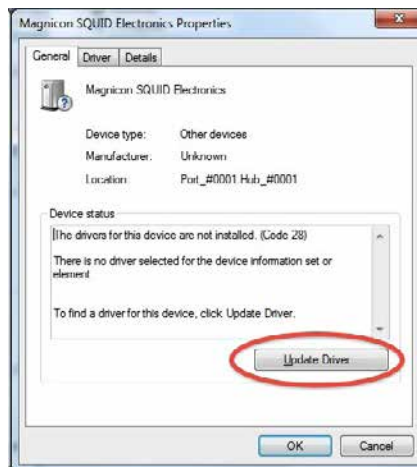
5. Click on the "Update Driver…" button. A new window opens:
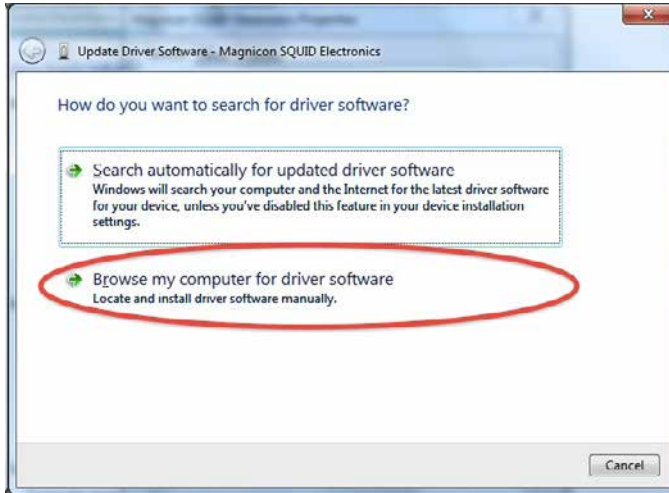
6. Click on the "Browse my computer for driver software" link. A new window opens:

7. Click the "Browse…" button and navigate to the "C:\MagniconData\Windows_ USB_Driver" folder. Be sure that the "Include subfolders" option is checked. Click the "Next" button.

8. An error message appears. Click the "Install this driver software anyway" link. The installation process starts. After the installation is finished you should see a message like this:
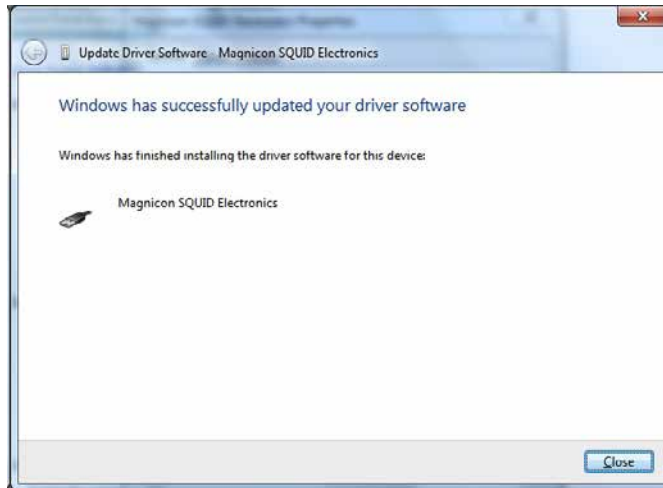
9. You are ready to operate your SQUID electronics now. Be sure that the XXF-1/ SEL-1 electronics is connected and powered. If you start SQUIDViewer software your electronics should be detected and ready to use.

Windows8 and Windows 8.1 installation

Please follow the step-by-step instruction to install the USB driver on Window8. Instructions for Windows8.1 are set in brackets.

Since the Magnicon USB driver is not signed/certified, Windows8 refuses installation. You have to deactivate the Windows8 driver signature enforcement to install the Magnicon USB driver.

1. Install the latest SQUIDViewer software on your PC. The needed USB driver is saved to your disk during SQUIDViewer installation. The driver is located inside the *C:/MagniconData/Windows_USB_Driver* folder.

2. Open the Windows8 *Settings* (move your mouse to the bottom-right-corner of the screen and wait for the pop-out bar to appear, then click the gear icon).

3. Click on the *More PC Settings* button (click on *Change PC settings*).

4. Click on the *General* button (click on *Update and Recovery*, then on *Recovery*).

5. Scroll down, and click *Restart now* under *Advanced startup.*

5. You might have to wait a bit. Then click *Troubleshoot.*

6. Click *Advanced Options.*

7. Click *Windows Startup Settings.*

8. Click *Restart.* After the restart, Windows8/8.1 comes up with a selection screen.

9. Select *Disable Driver Signature Enforcement* with the arrow keys, then hit the *ENTER* key.

10. Connect the Magnicon PC connection cable to a spare USB port of your PC.

11. Now you can install the driver from the *Device Manager* as described in the Windows7 section (steps 3 to 9).

The *Driver Signature Enforcement* is reactivated automatically with the next restart. The Magnicon USB driver will still work. So, you do not have to restart you PC with the *Driver Signature Enforcement* deactivated once you have installed the driver successfully.

Uninstall

To uninstall the SQUID*Viewer*™ software, please use the *Ad/Remove Programs* utility located in the *Control Panel*. Please note, that the program folder will not be removed during an uninstall procedure. So, your saved *Setup* files etc. within the *SQUIDViewer*™ folder are not lost.

Connecting the hardware

Take precautions to avoid electrostatic discharge!

1. Put the black 9-pin SUB-D connector of the RS-485 connection cable to a COM port of your PC or to the USBC-1 converter. Plug the other end of the cable to the Connector Box. The connection will only work if the black plug is connected to the PC COM port or USBC-1 converter. If the COM port is used, please use the following settings at your PC:

57600 Baud / databits: 7 / parity: even / stopbits: 1 / control: none

2. Plug the analog output cable to the connector box and fix it.

3. Because of the switching power supply, an earth connection has to be established somewhere! The PC connection is optically isolated, so there is no earth connection via the RS-232/RS-485 cable. An easy way is to plug one of the analog output cables to a grounded device like an oscilloscope or PC DAQ card. Next to the FLL-cable plug at the connector box housing there is a 5 mm ground plug you might use instead. Normally it is advisable to use only one point of grounding.

4. Fix the screened FLL cable to the connector box and to the FLL Electronics.

5. Connect the power supply to the *Connector Box.*

In *Fig. 1* you find a picture of a correctly connected system. Now you are ready to turn on your electronics. The green LED at the connector box indicates power on. The red LED indicates the state of the integrated 10 kHz low pass output filters. LED on means filters on.
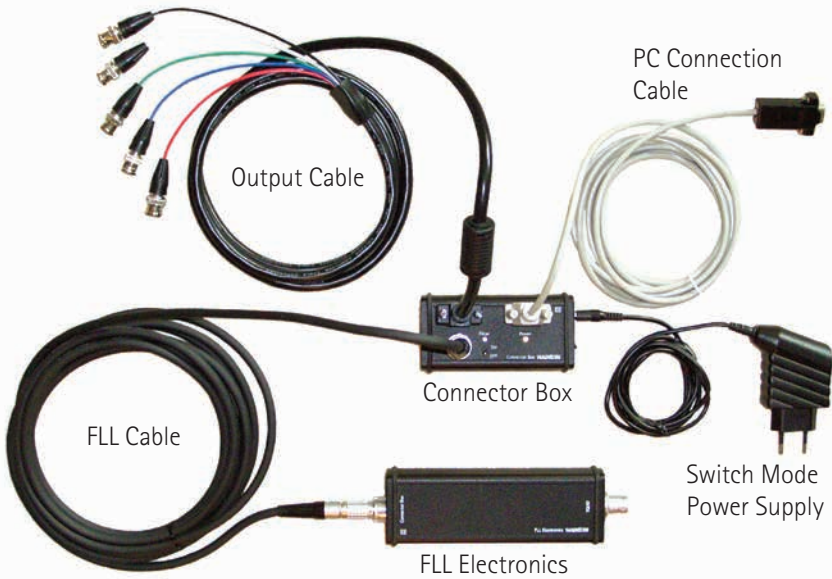
PC Connection Cable

Output Cable

FLL Cable

Connector Box

Switch Mode Power Supply

FLL Electronics

Fig. 1: Connected hardware components of XXF-1 electronics
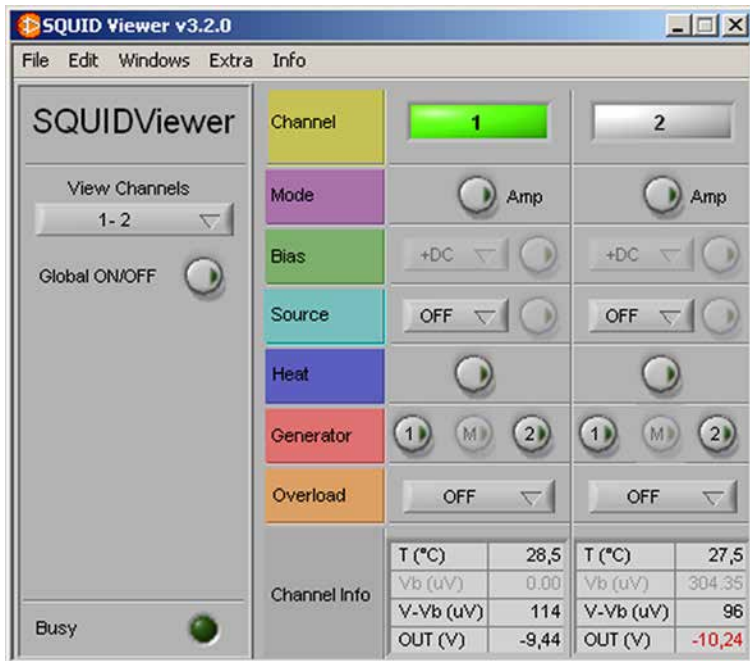
First contact

Fig. 2: SQUIDViewer™ software main window

Please be sure that all connections are provided as described in the previous section and that the electronics is powered and the SQUIDViewer™ software is installed.

A double-click on the *SQUIDViewer.exe* application starts the program. At every activation, the software scans the COM port for any connected and powered SQUID electronics.

The default COM port is COM 1. If the electronics is connected to another COM port or if you would like to change the baud rate please select the *COM* tab in the *Settings* palette (in the *EDIT* menu). After changing the COM port, you can perform a *System Scan* (in the *File* menu) to find SQUID electronics with the new COM port settings.

The SQUID*Viewer*™ window as depicted in *Fig. 2* appears. This is the main window, that groups some of the most important controls and indicators. In the upper left corner, you find a control named *View Channels*. This pop-up menu shows the channel number of each recognized electronics, bundled in groups of three

numbers. So, if you are the owner of a two-channel system, you should see two numbers (usually 1 and 2) in the control and there is no pop-up functionality.

You should see one, two or three columns (depending on the number of channels you have) with several buttons and indicators. The topmost display (named *Channel*) shows the channel number, to which the values displayed in the column belong.

First draw your attention to the indicator titled *Channel Info* at the bottom of the SQUID*Viewer*™ window. Here you find some readouts of the on-board AD converter. The top item mirrors the actual temperature of the FLL electronics board. After a cold start up of your electronics the board temperature will increase slightly with time until it settles. You can update the display by a click on the *Channel Info* text left of the indicators.

If you are able to observe the electronics temperature your system is installed correctly and the communication between SQUID electronics and SQUID*Viewer*™ is working. Now you can start experiencing the great features of your SQUID electronics.

Explore some system basics

Before connecting a real SQUID to your electronics it is advisable to experiment with a *SQUID dummy* first to familiarize with hard and software. In this section some examples are given. Just follow this short step-by-step introduction to learn some basic concepts of the electronics.

The *SQUID Dummy* replaces the SQUID with a resistor and allows testing of some basic electronics functions. The *SQUID Dummy* is activated as a default setting. To view the state of the built-in *SQUID Dummy*, you have to open the *Hardware Palette*.

All *SQUIDViewer* controls are bundled in different palette windows. There are three ways to open a palette window. Firstly, you can choose the palette you want to open in the *Window* menu. Secondly, you can click on the text fields at the left side of the main *SQUIDViewer* window. If you click, e.g., on the *Mode* text, the *Mode Palette* will open. Another click on the *Mode* text field will close the *Mode Palette* again. Alternatively you can open a palette window by use of the corresponding shortcut (displayed if you open the *Window* menu)

The *Hardware Palette* will open with a click on the *Channel* text field. Open the *Hardware Palette*. In the upper left corner of the palette you will find the channel selector. In a multichannel system you select the electronics channel which parameters you want to see or change. The selected channel is called *active* channel. Within the main *SQUIDViewer* window, the active channel is indicated by a green light behind the channel number. You can also change the active channel by a click on the corresponding channel number in the main window.

Choose the channel you want to experiment with and find the *SQUID Dummy* button in the *Hardware Palette*. If the button is red, the *SQUID Dummy* is activated. You will notice a red warning light below the channel number in the main window. This light indicates, that you have selected a setting, that is unfavorable for regular SQUID measurements.

Please connect the output of the channel you are experimenting with to an oscilloscope. If you use the delivered output cable, red is for channel 1, green for channel 2 and blue for channel 3. Set the scope to 1 V/div., dc coupling and a time base of 1 ms/div.

Open the *Bias Palette* with a click on the *Bias* text field or by choosing *Bias Palette* in the *Window* menu. The bias palette will open and you will see the three sliders

for bias current *Ib*, bias voltage *Vb* and bias flux *Phib*.

Each slider has a main slider (on the left) and two sub-sliders. With the main slider you can roughly set the corresponding value. The two sub-sliders allow a more precise adjustment.

Now, move the main bias current slider up and down between 0 and 50µA and watch the flat line on the scope moving up and down. Try to set the bias current to 25µA by use of the sub-sliders. The output voltage should be around 1.2V. You can check the output voltage in the *Channel Info* section in the main window. The row named OUT(V) displays the output voltage measured with the on-board ADC. You can update the channel info values by clicking on the *Channel Info* text field.

What do you see: The electronics is set to *Amp* mode (see *Mode Palette* or main window), i.e., it acts as an amplifier. The bias current is fed through the *SQUID Dummy* which replaces the SQUID. The voltage drop at the *SQUID Dummy* is amplified and output. Note, that the *SQUID Dummy* resistance is realized by transistors. So, the *SQUID Dummy* resistance depends on the given bias values. To change the amplification you can open the *Mode Palette*. Find the pop-up menu named *Amp Gain* and change the value to *1100*. The output voltage will decrease to about 0.8V. Set the *Amp Gain* back to *2000* and close the *Mode Palette*.

Now increase the bias voltage *Vb*. The output voltage will decrease to zero at a bias voltage of about 600µV (this equals the output voltage divided by the amplification factor of 2000). If you press the button below the *Vb* slider, the bias voltage is set to zero. If you press the button again, *Vb* is set to the previous value.

Since the *SQUID Dummy* also connects the flux leads, you can change the output voltage by changing *Phib*.

Now we want to try the internal generator. Therefor, please set the system back to the *Factory Default* state. Open the *Extra* menu and then the *Factory Default* submenu. Select *Reset Active Channel To Factory Default*. Answer the following warning with *Reset*. Now, the active channel is set back to the default state. Your adjusted bias current and bias voltage values are overwritten. The output voltage should be around zero.

Close all palettes by choosing *Hide All* in the *Window* menu. Open the *Generator Palette*. The electronics has two internal generators to modulate different current and voltage values. This is uefull for device characterization and calibration.

Set the peak-to-peak value of generator 1 to 25µA. Set the *Frequerncy Divider* of

Generator 1 to *OFF*. Press the *ON/OFF* button to activate generator 1 (left of the *M* button). On your scope you should see a triangular shaped output voltage with 1.1Vpp. Maybe you have to adjust the trigger settings of your scope to see a reasonable signal.

What have we done: The source of generator 1 is set to *Ib*, i.e., the bias current is modulated with the *Base Frequency* (400 Hz default). Try another waveform with the corresponding pop-up menu. Change the *Base Frequency* to the maximum value of about 2003Hz. You will see a quite ugly signal because the quality of the output signal depends on the selected frequency due to limitations of the on board microprocessor. Change the *Base Frequency* back to 400Hz and the waveform back to triangle.

The *Offset 1/2 pp* button above the *ON/OFF* button is activated. Deactivate it. On the scope you see, that the signal clips at negative voltages and you only see the positive part of the triangle because *Ib* is a unipolar current source. The *ON/OFF* button indicates a clipped generator signal by its red color (see main window as well). Open the *Bias Palette* again. Set the bias current *Ib* to 12.5µV.

Now, the generator signal is shifted by half of the peak-to-peak value and there is no clipping anymore.

What we have learned: The generators always generate a signal symmetrically around the adjusted source value (e.g. *Ib*). If the generated signal exceeds the source range, the signal clips. The *Offset 1/2 pp* button ads half of the peak-to-peak value to the output signal.

With activation of generator 1, the button with the *M* was activated too. *M* stands for *monitoring* output. The monitoring output is a mirror of generator 1 with a fixed peak-to-peak value of 0.5V. You get access to the monitoring output signal via the black BNC connector of the VGA cable or via the Mon./*BRC* output of the *Connector Box (Mon./BRC* at the *BreakoutBox BOB-1 or the BreakoutCable BOC-1)*.

Set the second channel of your scope to 1V/div and DC coupling and connect the monitoring output to the scope. You should see a second triangular shaped signal with 1Vpp. If you change the waveform of generator 1, the monitoring output will follow this setting. The monitoring output is usefull for sensor characterizations in the oscilloscopes *xy*-mode.

Now you have learned some basic concepts of the XXF-1 SQUID electronics. Please read the whole manual before connecting a real sensor to the electronics.

Connecting a sensor

LEMO®
plug
socket

LEMO®
plug
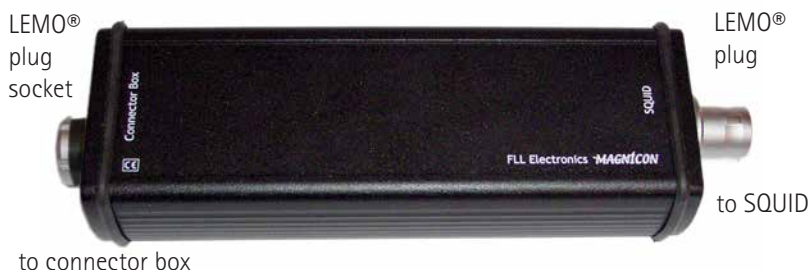
to SQUID

to connector box

Fig. 3: FLL electronics

The main electronics where all signals from and to the SQUID are controlled and amplified is the so-called *FLL Electronics* shown in *Fig. 3*.

The male input connector plug of the electronics is a 24 pin LEMO connector with LEMO part number FAG.3B.324.CLA, which preferably should be plugged directly on top of the cryostat. The connection between this LEMO plug and the sensor should be as short and direct as possible. The corresponding plug socket part number is EGG.3B.324.CLL. This socket is available as a vacuum tight version too. Please check the current LEMO catalog (www.lemo.com). Part numbers may have changed!

Magnicon offers vacuumtight and screened cryocable solutions for single channel and multi channel systems.

Standard pin assignment and wiring

In this section, pin assignment and wiring for all applications except TES applications is described. Please check, if your electronics source mode is *normal* or *TES*. To do so, connect the electronics to your PC and start the SQUID*Viewer*™ software. Open the *Hardware Palette* and find the *Source Mode* button. If it is set to *normal*, wire the electronics as described in this section, if it is set to *TES*, wire the electronics as described in the next section. If you want to change the source mode, please contact Magnicon.
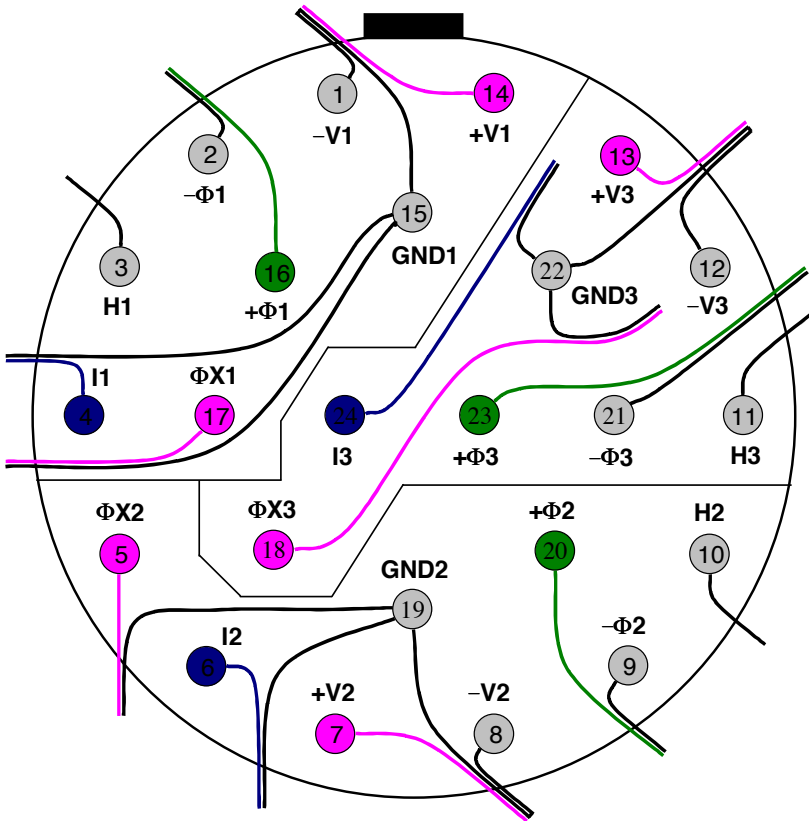
Fig. 4: Standard pin assignment for the connection to the SQUID for all applications except TES applications. Solder side of plug inside the FLL electronics housing is shown, i.e., top view on the corresponding plug socket at the cryostat.

Fig. 4 shows pin numbers and the pin assignment of the input connector. The numbers behind the abbreviations (V1, I1 etc.) indicate the electronics channel number inside the housing. The following list gives a description of the used abbreviations:

- $\pm$V   current and voltage connections to the SQUID
- $\pm\Phi$ connections to the feedback loop
- H   active lead to optional heater (13.5 V while heating)
- GND   ground connection to SQUID, heater and current sources
- I   output of the first additional current source
- ΦX   output of the second additional current source

Single-stage wiring

Fig. 5 shows an example connection scheme for SQUID applications. The two auxiliary current sources can be connected, e.g., to coils. Twisted pairs of copper wires (a twisted triple for the three SQUID wires) are recommended for the connection from warm to cold. The resistance of the three SQUID wires should be kept below a few ohms to avoid excess noise. The twisted pairs/triples should have a few turns per cm. It is recommended to twist the whole cable harness loosely to avoid large loops. If you need to use wires with higher resistances (like manganine) please contact Magnicon®. Magnicon offers vacuum tight and screened cryocable solutions.
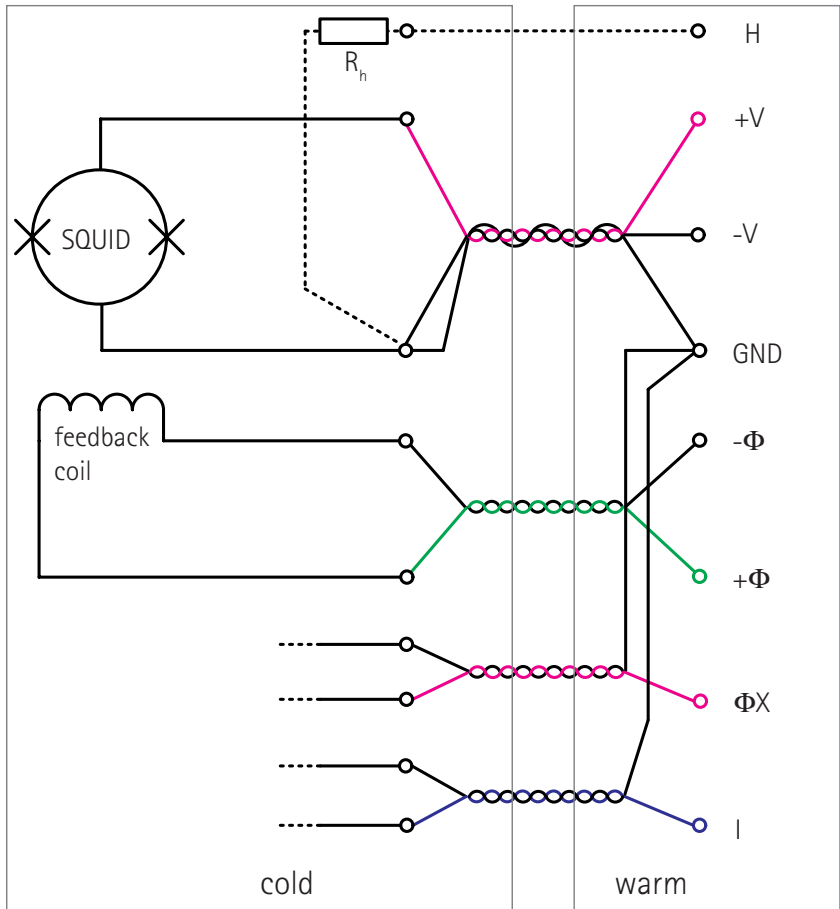

Fig. 5: Standard connection scheme for SQUID applications. The auxiliary current sources I and ΦX can, e.g., be connected to additional coils.

Two-stage wiring

Fig. 6 shows a standard connection scheme for two-stage SQUID applications.
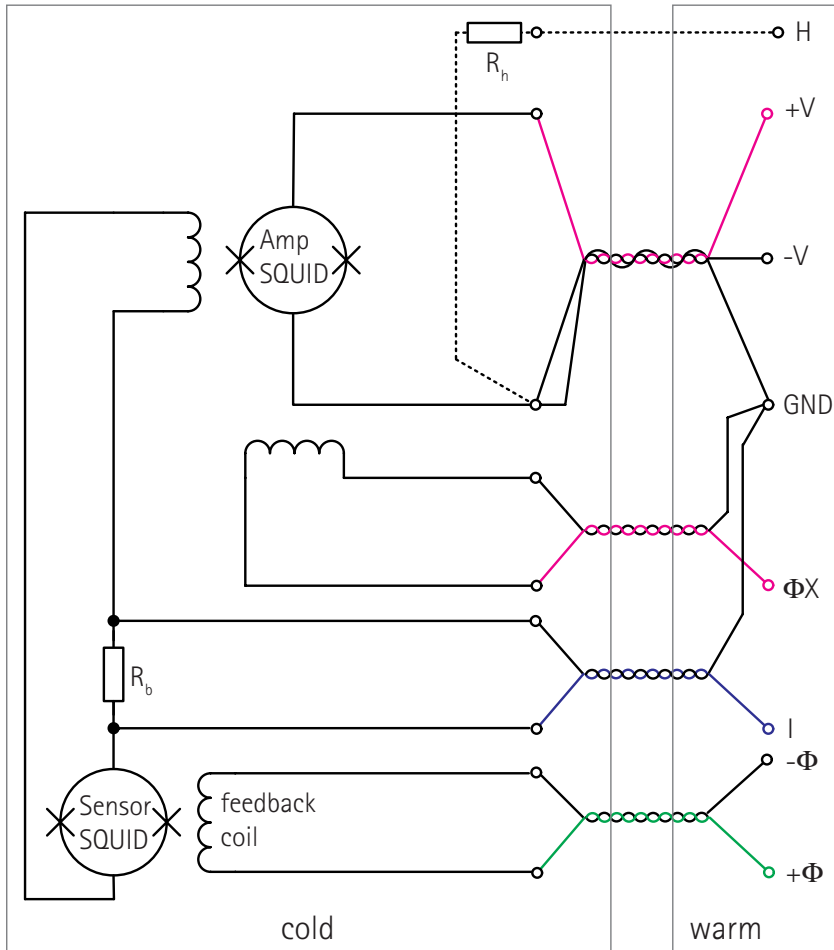

Fig. 6: Standard connection scheme for two-stage SQUID applications

If you need to reduce the number of wires between warm and cold, the ground return lines of I and ΦX can be omitted for two-stage configurations (see *Fig. 7*). Since V, I, and ΦX then have the same return line, any current change at I or ΦX leads to a voltage drop that may disturb the other signals. The common ground wire (GND) should have low resistance. In usual two-stage applications, I and ΦX are static signals and would not lead to any interferences in the V wires. Please twist I and ΦX loosely with the V triple (indicated by the dashed line) as well as the whole cable harness should be twisted loosely to avoid large loops.
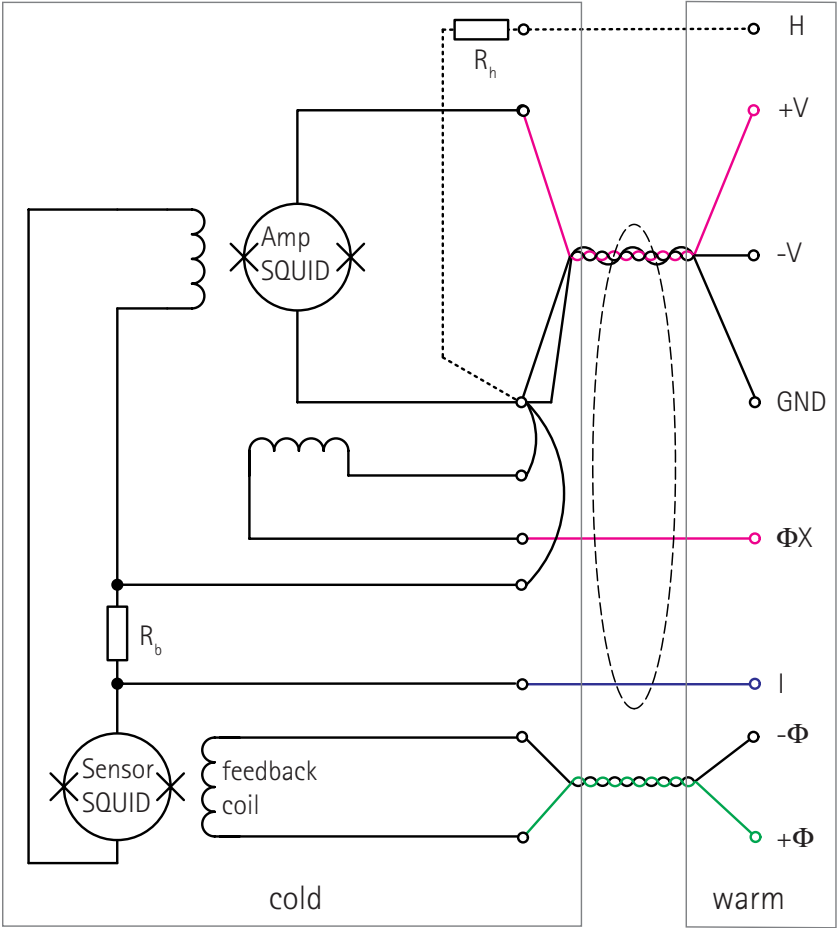

Fig. 7: Connection scheme for two-stage SQUID applications with reduced number of wires from warm to cold.

Pin assignment and wiring for TES applications

In this section, pin assignment and wiring for TES applications is described. In *TES mode*, the outputs of the two auxilliary current sources are added and fed to the I and IGND pins. Then you can use the *I* current source for TES bias current and the *Pulse Ampl.* current source to provide calibration pulses. *Fig. 8* shows pin numbers and the pin assignment of the input connector. The numbers behind the abbreviations (V1, I1 etc.) indicate the electronics channel number inside the housing. The following list gives a description of the used abbreviations:

- $\pm$V   current and voltage connections to the SQUID
- $\pm\Phi$ connections to the feedback loop
- H   active lead to optional heater (13.5 V while heating)
- GND   ground connection to SQUID, heater and current sources
- I   output of both additional current source
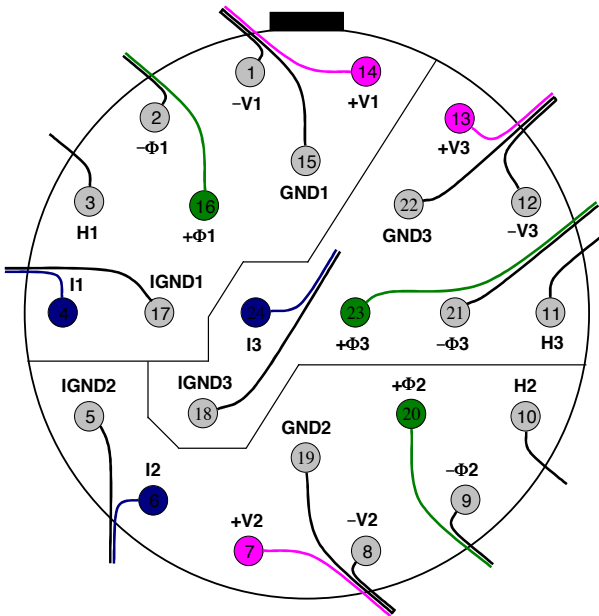- IGND   ground return of the additional current sources

Fig. 8: Pin assignment for the connection to the SQUID for TES applications. Solder side of plug inside the FLL electronics housing is shown, i.e., top view on the corresponding plug socket at the cryostat.

Fig. 9 shows an example connection scheme for TES applications. Twisted pairs of copper wires (a twisted triple for the three SQUID wires) are recommended for the connection from warm to cold. The resistance of the three SQUID wires should be kept below a few ohms to avoid excess noise. The twisted pairs/triples should have a few turns per cm. It is recommended to loosely twist the complete cable harness to avoid large loops.

If you need to use wires with higher resistances (like manganine) please contact Magnicon®.
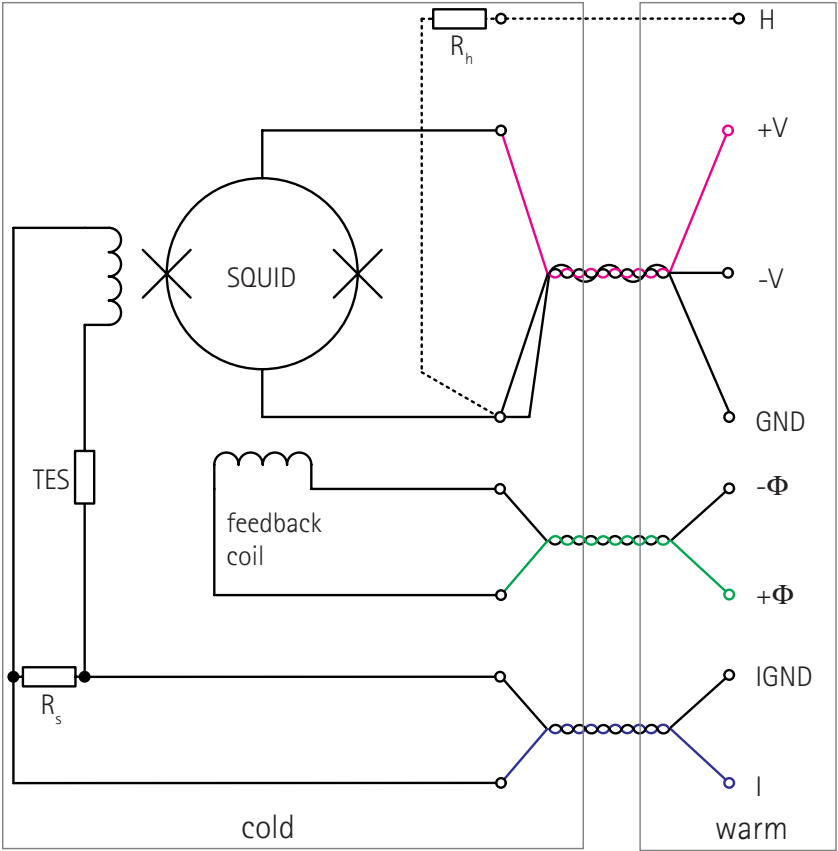

Fig. 9: Example connection scheme for TES applications

SQUID operation

This chapter gives a brief description on how to operate the electronics with a SQUID sensor. Keep in mind, that due to the large variety of existing SQUID sensors, only some basic operation principles can be described. The behavior of your sensor might differ from the described reactions. Please read the entire manual before connecting a SQUID sensor.

If you switch on the electronics when your SQUID sensor is at room temperature, note that currents of up to 180µA can be applied to the SQUID. Your sensor should be suitable to be charged with such currents at room temperature. Otherwise, be sure to set the bias current Ib to appropriate values (the offset current $I0$ should have the factory default value printed on the last side of the manual).

Some general remarks at first: The bias values Ib and Vb are unipolar, Φb is bipolar with the following standard ranges:

- Ib: 0...180µA
- Vb: 0...1300µV
- Φb: ±125µA

rf Interferences

One of the main problems in a lot of SQUID measuring setups are rf interferences. Sources of rf interferences can be e.g. television towers, cell phones, and electrical devices. All kind of SQUID sensors are more or less sensitive to such kind of disturbances. The I-V curve can be somewhat rounded and the SQUID modulation may be reduced or even fully suppressed if rf interferences reach the SQUID.

In all cases, even if your sensor can be operated magnetically unshielded, you need a good electrical rf shield around your sensor (Faraday cage). Furthermore it is important, to have a good connection between the plug socket of the *FLL Electronics* and the Faraday cage of your Dewar.

It is recommended to have only one single ground connection at the whole setup. This can be a connection to a scope, a spectrum analyzer, or a data acquisition. Multiple ground connections lead to large ground loops and may cause serious interferences.

If you get unsatisfying results at the first measurements, please check the rf shielding of your setup.

Display the I–V curve

To display the I-V curve of the Josephson-junctions of your device, the internal generator has to be used. The I-V curve can be displayed in *xy* mode of the scope by use of the monitoring output of generator 1 (*Mon./BRC)* at the Breakout Box and Breakout Cable or v-sync wire at the VGA cable).

Since the bias current *Ib* is unipolar, you can only see the I-V characteristics for positive currents. If you are using a two-stage sensor, the I-V curve of the amplifier SQUID (see *Fig. 6*) will be displayed.

Some remarks about the internal generator (see *Software reference* section as well): If a bias or source value in the *Bias* palette or *Source* palette is set to a value other than zero, the corresponding generator signal is superimposed to that value. If this superimposition exceeds the range of the corresponding bias or source values, the amplitude is cut off at the maximum/minimum value and the generator on/off button turns to red.

Please note, that the input range of the preamplifier is limited to about $\pm2\text{mV}$. If you have input voltages exceeding this range, the output signal will clip, independently from the selected amplifier gain.

If your SQUID is cold and wired correctly, the electronics is connected, and the SQUID*Viewer*™ software has scanned the COM/USB port successfully, please check the following settings:

- make the channel you want to observe the *active* channel by clicking into the corresponding channel number in the SQUID*Viewer*™ main window
- reset the active channel to Factory Defaults (*Factory Defaults* in the *Extra* menu)
- open the *Hardware* palette by a click in the channel text field or by selecting *Hardware Palette* in the *Windows* menu or by pressing *CTRL+H* on the keyboard
- deactivate the *SQUID Dummy* and close the *Hardware* palette
- open the *Generator* palette by a click in the generator text field or by selecting *Generator Palette* in the *Windows* menu or by pressing *CTRL+G* on the keyboard
- set *Base Frequency* to about 22 Hz
- select *Ib* as source for generator 1
- set *Waveform* to *triangle* for generator 1
- *Frequency Divider* and *Phase Shift* should be *OFF*

- turn *Offset 1/2 pp* on
- activate the *ON/OFF* button and the monitoring output button (*M*)
- generator 2 should be *OFF*
- set the oscilloscope to *xy* mode
- the electronics output of the channel with the SQUID you want to measure is connected to the *y* input of the oscilloscope
- the *MON./BRCLK* output (v-sync line at the VGA cable) is connected to the *x* input of your scope
- set the *y* input of your scope to 50 mV / division as a start value. The optimum value depends on the sensor you use.
- set the *x* input of your scope to 100 mV / division to use the full screen range with the 1 Vpp monitoring output
- to reduce possible rf interferences in the output signals, you can activate the 10 kHz output filter at the *Connector Box.*
- you should see a more or less flat line on the scope.
- Now you have to adjust the offset voltage *Vo* at the *Hardware* palette. Adjust *Vo* to have zero voltage at the output signal. Due to thermoelectric effects, this value depends on the setup and wiring

If you now enter a value into the Peak-to-peak field of generator 1, the corresponding bias current is fed through your device. If you, e.g., set the Peak-to-peak value to 50 µA, a triangular shaped bias current from 0 µA to 50 µA with 22 Hz frequency is applied.

Now increase the peak-to-peak value of I_b, until the critical current of the Josephson-junctions is reached and the I-V characteristics can be viewed on the oscilloscope. Choose an appropriate *y* sensitivity for your scope. Note, that XXF-1 SQUID electronics does not provide a 4-point measurement, i.e., asymmetries in the $\pm$V wire resistances appear as an additional voltage drop at the output signal (see *Fig. 10*).

The voltage in *x* direction of the scope can easily be scaled to a current through your device. Just multiply the peak-to-peak value of generator 1 with the sensitivity/division of your scope in *x* direction (e.g. 100mV/div.) and divide the result by 1 V (peak-to-peak value of the monitoring output) and you have the current per division in *x* direction.
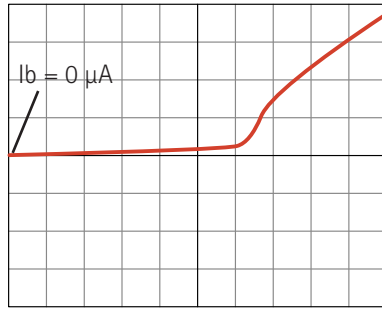
Fig. 10: Appearance of I-V characteristics

SQUID modulation (V–Φ characteristics)

Once you have seen the V-I characteristics of your device, you can go on and view the V-Φ characteristics. If you are using a two-stage sensor, the V-Φ curve of the amplifier SQUID will be displayed. Follow the steps below, starting from a situation as displayed in *Fig. 10*:

- deactivate the *Offset 1/2 pp* button of generator 1
- change the *Source* of generator 1 from *Ib* to *Phib* (for two-stage devices from *Ib* to *PhiX*). If a warning appears, that the disconnect switch is active, press *OK*, open the *Bias* palette and deactivate the *Disconnect* switch at the *Phib* slider (for two-stage devices, open the *Source* palette and deactivate the *Disconnect* switch at the *PhiX* slider).
- set the *Peak-to-peak* current of generator 1 to a value, where you expect to produce at least one flux quantum with the feedback coil of your device (depends on the feedback sensitivity of the sensor).
- if closed, open the *Bias* palette

Now, slowly increase the bias current *Ib*. Until the critical current of your device is reached, you should see more or less no change on the oscilloscope screen. If the critical current is reached, the SQUID modulation should start to appear. With increasing bias current, the SQUID modulation increases and moves to higher positive voltages. Find the bias current with the maximum voltage swing of your device. To reduce possible high frequency noise at the modulation curve, you can turn on the 10kHz anti alias filter at the connector box. If the voltage drop across the sensor exceeds the range of your oscilloscope, you can switch the scope to AC coupling for more convenient bias current adjustment.

Working point adjustment

Once you see the SQUID modulation, you can start to adjust the working point for proper FLL operation.

The working point *W* of your sensor will be at the decreasing or increasing side of the V-Φ curve, where the zero voltage line is intersected (e.g. see black point in *Fig. 11*a). If *SQUID Gain* is positive (see *Mode* palette), the electronics will lock at the increasing slope of the V-Φ curve, if *SQUID Gain* is negative, the electronics will lock at the decreasing slope of the V-Φ curve (set *Amp Gain* to *positive* to see the "real" SQUID modulation polarity).

Right now, it is possible, that your modulation curve has no intersection with the zero voltage line (see dotted line in *Fig. 11*a) and therefore the electronics has no locking point in FLL mode. Please be sure that your scope is not ac coupled.
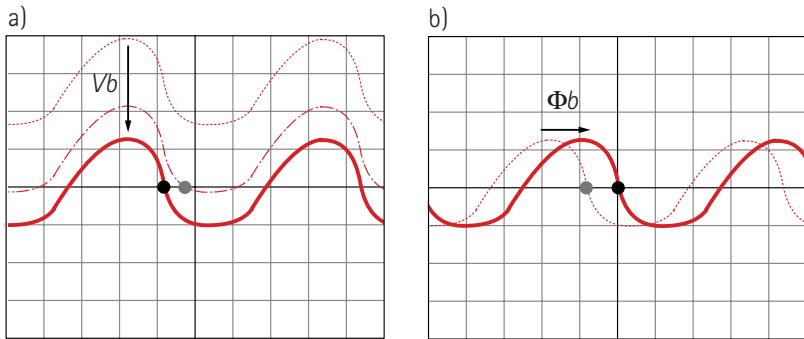
a)

b)

Fig. 11: Influence of adjusting a) bias voltage Vb and b) bias flux Φb on the V-Φ curve

By increasing bias voltage *Vb*, you can compensate the offset voltage caused by the resistance of your sensor to get an intersection between modulation curve and zero voltage line. The dash-dotted line in *Fig. 11*a) shows such an intersection (grey point). In this condition, the electronics would be able to lock in *FLL* mode, but it would be an unfavorable working point because the transfer function (i.e. the ratio of a resulting voltage change due to an applied flux change) has a very low value.

By further increasing the bias voltage *Vb*, you can find an intersection point of the decreasing/increasing side of the modulation with the zero voltage line with a better transfer function (e.g. black point in *Fig. 11*a).

Now you can start the fine tuning of the working point. Try to increase and decrease the bias current I_b to find a bias current where the decreasing/increasing side of the SQUID modulation has its steepest value. This does not necessarily have to be the bias current with the maximum modulation depth of the V-Φ characteristic.

Additional working point adjustment of two-stage devices

You can skip the following paragraph, if your sensor is not a two-stage device.

The sensor SQUID of a Magnicon two-stage device is voltage biased. The sensor bias current is controlled by the current I (*Source* palette). The flux bias Φx of the amplifier SQUID array has to be adjusted to operate the amplifier array in a low-noise and linear region of its V-Φ characteristics.

Follow the steps below, to adjust the working point:

- open the *Mode* palette
- activate the *input termination @ Amp* button
- open the *Generator* palette
- change the *Source* of generator 1 from *PhiX* to *Phib*.
- set the *Peak-to-peak* current of generator 1 to a value, where you expect to produce at least one flux quantum with the feedback coil of your device
- switch to the *Source* palette
- refer to the sensor datasheet and set I and Φx to the given values

Now, the overall characteristics of the device should appear as depicted in *Fig. 12* (red curves). The flux bias Φ*x* is almost constant, independent of magnetic background and thermal cycling. But sometimes a fine tuning is necessary. *Fig. 12* shows the behaviour of the V-Φ characteristic in dependence of Φ*x*. Adjust Φ*x* to get the optimum characteristics similar to *Fig. 12*a with the steepest part on the rising V-Φ characteristic.
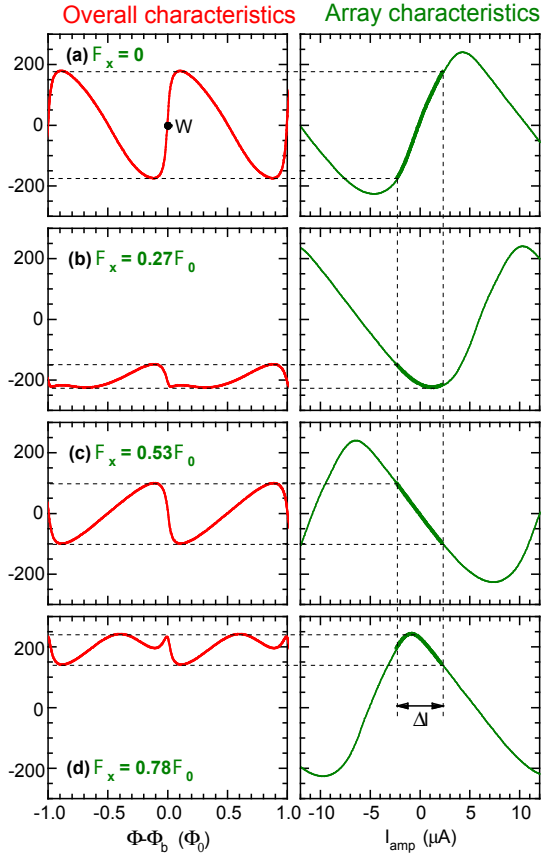
Fig. 12: Overall V-Φ characteristics (left) and amplifier characteristics (right) of a two-stage sensor for four representative values of the amplifier array flux bias Φx. The optimum working point W is indicated by a circle. Dashed lines show the output current swing of the front-end SQUID. The array is loaded by the 50 Ω input termination of the XXF-1 electronics leading to a nearly triangular amplifier array characteristic (see also: Drung, et.al., IEEE Transactions on Applied Superconductivity, Vol. 17, No. 2, pp. 699-704, June 2007).

FLL mode

If the working point is adjusted as described in the previous pages, the electronics is ready to be switched to FLL mode. It will lock to the adjusted working point and the flux locked loop will shift the working point to zero flux in the SQUID, resulting in an offset voltage at the electronics output. To avoid this offset voltage, you can shift the V-Φ modulation by means of the bias flux Φb. Just increase or decrease Φb and watch the SQUID modulation shift along the x axis of your scope until your working point is at zero flux (see *Fig. 11*b). The bias flux Φb has a range of ± 125 μA. So your feedback coil should produce at least half a flux quantum in your sensor to allow proper bias flux adjustment. Note, that the bias flux Φb is not required for proper FLL operation, it is just to provide zero FLL output without signal applied to the SQUID.

Now you can change the electronics mode to Flux Locked Loop (*FLL*) mode. This mode is commonly used for measurements. In *FLL* mode, the SQUID voltage is amplified, integrated and fed back into the feedback coil via the feedback resistor *Rf* to linearize the SQUID modulation. You can switch to *FLL* mode by selecting *FLL* with the *Amp/FLL* button in the *Mode* palette and in the main window. Before changing the mode to *FLL*, check the following setting:

- set *Rf @ FLL* to *10kΩ* (*Mode* palette)
- set *Gain Bandw. Prod.* to *0.23 GHz* (*Mode* palette)
- turn off the generator (*Generator* palette)

Now select *FLL* with the *Amp/FLL* button. Watch the output voltage at the *Channel Info* section (*OUT*) of the active electronics to see if the electronics locks stable with your working point settings. If the output voltage is close to zero, everything should work properly. If the output voltage is at plus or minus 10 V, the electronics could not lock or is unlocked due to interferences in your measurement setup. The output voltage can easily be controlled via the *OUT(V)* value in the *Channel Info* sector of the SQUID*Viewer*™ main window (press the *Channel Info* text to update the display). Note, that the gain of the electronics may decrease if you reach the output voltage limit and therewith you may get output signals that appear quite reasonable although they are not.

Now you can change the feedback resistor and the gain bandwidth product to values you want to use (see section *Estimation of the system bandwidth*).

Estimation of the system bandwidth

To estimate the 3dB system bandwidth, you need an adjusted working point as described in the previous sections. The electronics has to be set to *Amp* mode to visualize the V-Φ characteristics with an oscilloscope. You should see the SQUID modulation as depicted in *Fig. 13*a).

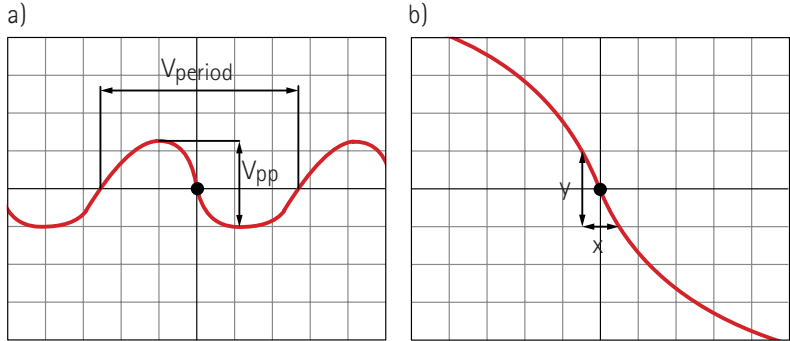a)   b)

Fig. 13: Values needed to estimate the system bandwidth. In b), the range of the oscilloscope is decreased to enlarge the SQUID modulation curve near the working point.

The first value to measure, the reciprocal of the mutual inductance $1/M_f$, is the current needed in the feedback coil to produce one flux quantum in your sensor. Measure the voltage in *x* direction for one period of your SQUID modulation (V$_{period}$ in *Fig. 13*a). This voltage, divided by 1 V and multiplied by the peak-to-peak value of the generator gives you the current per flux quantum for your sensor/feedback coil combination.

The second needed value is the transfer coefficient V_Φ. The transfer coefficient is the slope of the V-Φ curve at the working point in units of Volt per flux quantum. To measure this slope you should increase the sensitivity of your scope in *x* and *y* direction to enlarge the linear region of the SQUID modulation near the working point. Now measure the slope by writing down a x value and the corresponding y value as depicted in *Fig. 13*b). Then, the transfer coefficient V_Φ can be calculated using:

$$V_\phi = \frac{y}{x} \cdot \frac{V_{period}}{2000}$$

The multiplication with V$_{period}$ scales the x value to one flux quantum, the division of the y value by 2000 takes the amplification in *Amp* mode into account.

The SQUID gain G_S can be calculated using the mutual inductance, the transfer coefficient, and the FLL feedback resistor *Rf*:

$$G_S = \frac{V_\phi M_f}{\text{Rf}}$$

The SQUID gain defines the total gain between FLL output and preamplifier input. The feedback resistor in *FLL* mode can be set in the *Mode* palette. Now, you are able to calculate the unity-gain frequency f_1, which determines the 3dB system bandwidth f_{3dB}:

$$f_{3dB} \geq f_1 = G_S \cdot GBP$$

thereby GBP is the FLL gain-bandwidth product (set in the *Mode* palette). For unity-gain frequencies up to about 1MHz, the 3dB system bandwidth is approximately equal to f_1. At higher unity-gain frequencies f_{3dB} becomes larger than f_1 up to about a factor of 2.

In the following, an example calculation with realistic values is shown. If the generator source is set to Phib with a p-p value of 33.3uA, a V_{period} of 0.6V leads to the reciprocal value of the mutual inductance of:

$$1\big/M_f = \frac{33.3\mu A \cdot 0.6}{\phi_0} = 20\mu A/\phi_0$$

If the ratio of y value to x value is about 1, the transfer function is:

$$V_\phi = 300\mu V / \Phi_0$$

With a feedback resistance Rf = 30kΩ, this leads to a SQUID gain of:

$$G_S = 5 \cdot 10^{-4}$$

Setting the gain-bandwidth product to GBP = 5GHz, the system bandwidth is:

$$f_{3dB} \approx f_1 = 2.5\text{MHz}$$

The transfer coefficient V_Φ can be alternatively measured in an elegant way by using the internal generator in FLL mode. Set your scope to *y(t)* mode and the electronics to *Amp* mode. Choose *Phio* as signal with the *Source* selector in the *Generator* palette to display the V-Φ characteristic as described above. Now, you have to measure the voltage swing V_{pp} of your device as depicted in *Fig. 13*a) (you have to divide the voltage measured at your scope by a factor of 2000 due to the

amplification in *Amp* mode!). Turn off the internal generator, switch to *FLL* mode and then choose *Vb* as generator source. Set *Waveform* to a symmetrical square wave. Choose a generator peak-to-peak value V_{gen} that corresponds to a value of about 10% of the V_{pp} signal you have measured before. If, e.g., $V_{pp} = 15\mu V$ you need a generator amplitude of $V_{gen} = 1.5\mu V$.

You should see a weak square wave on the oscilloscope screen. Measure the amplitude V_{out} of this square wave. The transfer function then can be calculated with:

$$V_\phi = \frac{V_{gen}}{V_{out}} \cdot \frac{\text{Rf}}{M_f}$$

whereas *Rf* is the feedback resistor in FLL mode (set in the *Mode* palette). The *Vb* square wave signal is compensated by the electronics via a flux generated in the feedback loop. So, the electronics output (V_{out}) corresponds to a flux applied to the SQUID caused by a voltage change (V_{gen}) at the SQUID.

Now you can calculate the SQUID gain and therewith the unity-gain frequency as described in the above paragraphs.

If you vary *Ib* instead of *Vb* with the internal generator, the current sensitivity M_{dyn} can be estimated in a comparable way.

To subtract the noise contribution of the electronics from the total system noise in FLL mode, the following equation can be used:

$$S_{\Phi,\text{System}} = S_\Phi + \frac{S_{V,\text{Electronics}}}{V_\Phi^{\;2}} + S_{I,\text{Electronics}} M_{dyn}^2 \, .$$

S_Φ is the intrinsic SQUID noise density, $S_{V,\text{Electronics}}$ the electronics voltage noise density and $S_{I,\text{Electronics}}$ the electronics current noise density. V_Φ is the transfer function at the working point and M_{dyn} is the corresponding current sensitivity.

A more detailed description of SQUID electronics principles and explanations of the used definitions can, e.g., be found in:

Dietmar Drung, *High-T$_C$ and low-T$_C$ dc SQUID electronics*, Supercond. Sci. Technol., **16** (2003), 1320-1336
or
John Clarke, Alex I. Braginski, *The SQUID Handbook: Volume 1: Fundamentals and Technology of SQUIDs and SQUID Systems*,
Wiley, Chapter 4, June 2004

Hardware reference

Fig. 1 shows all parts of the hardware of the direct coupled dc SQUID electronics XXF-1. In this chapter, you will find descriptions of the components like pin assignment of plugs or functions of devices.

FLL electronics

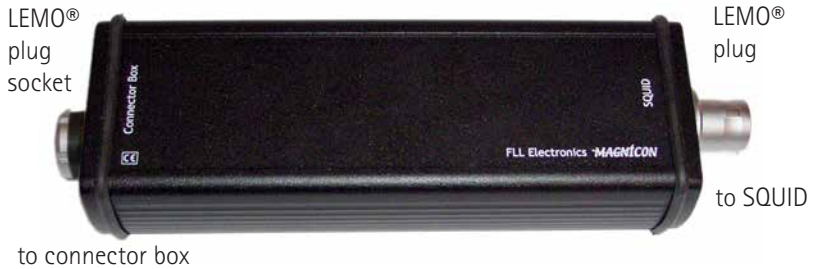LEMO®
plug
socket

LEMO®
plug

to SQUID

to connector box

Fig. 14: FLL electronics

The box with the integrated male and female LEMO plugs houses the FLL electronics unit (see *Fig. 14*). This is the main electronics where all signals from and to the SQUID are controlled and amplified. The male input connector plug of the electronics is a 24 pin LEMO FGG.3B.324.CLA or FAG.3B.324.CLA, which should be plugged directly on top of the cryostat.

For details of pin assignment and wiring, please see section *Connecting a sensor*.

FLL cable: Connection between FLL electronics and connector box

Fig. 15: FLL cable

The used plug socket for the FLL cable at the FLL electronics is a LEMO ECG.2B.319. CLN. The plugs of the FLL cable are LEMO FGG.2B.319.CLAD72 types. The FLL cable provides a 1 to 1 connection between both plugs (pin 1 to pin 1, pin 2 to pin 2, and so on…). The cable is available in lengths of 2.5 m, 5 m, 11 m, and 21 m (please note, that the maximum bandwidth may be decreased with long cables).
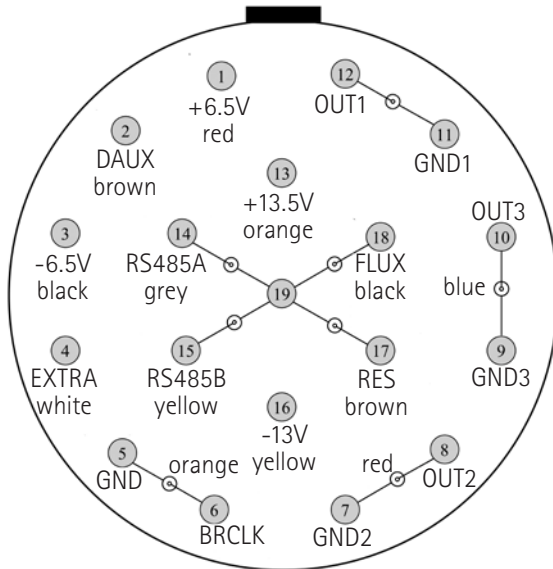

Fig. 16: Pin assignment of FLL cable plugs. View on solder side of plug is shown (i.e. up view on the Connector Box plug socket).

Fig. 16 shows the pin assignment of the FLL cable plugs. The used coax cables have 50Ω impedance. If you need a through-connection, e.g. into a shielded chamber,

you can use two FLL cables and two LEMO plug sockets. The plug sockets should be connected using 50Ω coax cables as denoted in *Fig. 16*. Be sure to provide good rf-shielding performance.
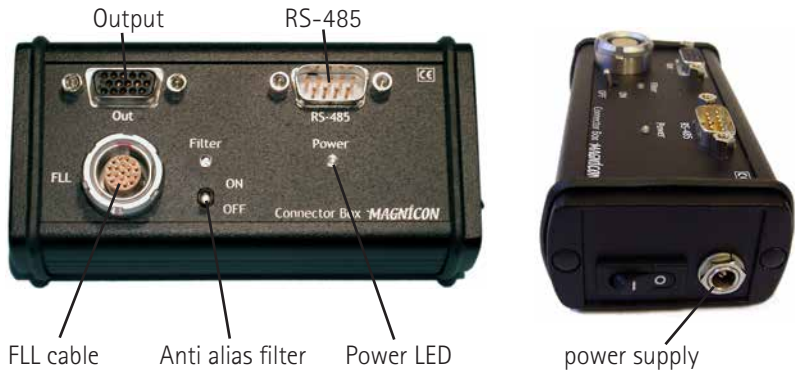
The connector box

Fig. 17: Connector box

The connector box is the device, where all components of the electronics are connected to each other. It provides plug sockets for the FLL cable from the FLL electronics (LEMO ECG.2B.319.CLN), a socket for the optically isolated connection to the control computer (SUB-D09, male), a socket for the output signals including additional inputs/outputs like overload detection and reset (SUB-HD15, female), a 4mm ground socket for a central ground connection, and a socket for power supply (Type T421). The switch on top activates an anti-alias filter to the output signals of 10 kHz bandwidth, indicated with a LED.

RS-485 connection

The electronics is controlled via a RS-485 connection and LabView® Software. To use a standard RS-232 COM-port, one has to use an appropriate converter (e.g. USB to serial converter). The RS-232 cable which is delivered with the electronics is equipped with such an optically isolated converter. Although both ends of the RS-485 cable have the same type of plug it can not be used in either direction. The black housing labeled „PC" must be put to the COM port of a PC or to a USB to serial converter for a working connection. The default COM port settings are:

- 57600 Baud
- data bits 7

- parity even
- stop bits 1
- control none

If you need a longer cable from your control PC to the *Connector Box*, you can use a standard one-to-one RS-232 extension cable.

Fig. 18: RS-485 connection. The black plug has to be connected to the COM port of a PC or to an appropriate USB-to-serial converter. Pin assignment shows top view on the connector box.

Depending on the system it can be necessary to provide a termination resistor for the RS-485 connection. This can be soldered on the backplane board within the FLL-electronics housing. Please ask Magnicon for details before changing this resistor.

Analog output / control signals

Despite the analog output signals (1 up to 3) in a range of ± 10 V, the female SUB-HD15 socket provides several different input and output signals. With the delivered VGA cable, you do not have access to all of the control signals. So, you have to design your own cable, in order to use features like external reset and external overload detection (Magnicon offers a *Breakout Box* and a *Breakout Cable* with some unique features to make all signals available. Find further information at www.magnicon.com).
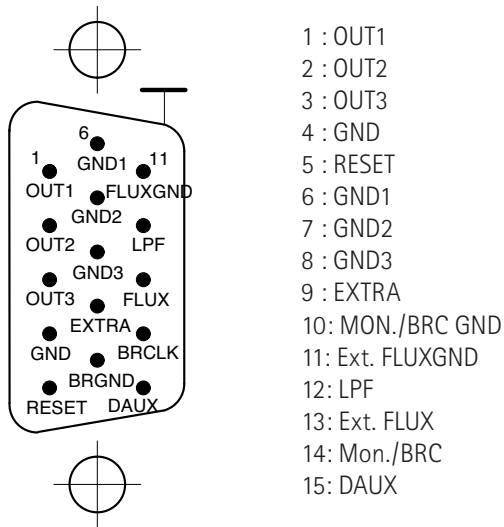
1 : OUT1
2 : OUT2
3 : OUT3
4 : GND
5 : RESET
6 : GND1
7 : GND2
8 : GND3
9 : EXTRA
10: MON./BRC GND
11: Ext. FLUXGND
12: LPF
13: Ext. FLUX
14: Mon./BRC
15: DAUX

Fig. 19: Pin assignment of the output plug at the connector box. Top view on the connector box is shown.

- <u>1-3 / OUT1-OUT3</u>: The analog output signals of the electronics.
- <u>4 / GND</u>: General ground connection.
- <u>5 / RESET</u>: If this lead gets an active-low signal for at least 1 µs, an integrator reset is carried out, i.e., the integrator is reset by discharging the integration capacitor. Works only if FLL mode is chosen with the *Amp/FLL* button within the *Mode Palette*. The 1 µs is needed to fully discharge the capacitor. An active high signal changes the electronics mode back to FLL. So, a TTL signal can be used to trigger the external reset. Alternatively you can shorten the *RESET* pin to ground to perform a reset. Note, that an external reset is unobservable for microcontroller and SQUIDViewer software, i.e., you get no notice within the SQUIDViewer window if an external reset is carried out or not.
- <u>6-8 / GND1-GND3</u>: Ground leads for OUT1-OUT3.
- <u>9 / EXTRA</u>: An extra lead from the connector box to the FLL electronics boards. Can be used for user specific applications.
- <u>10 / MON./BRC GND</u>: Ground lead of the internal generator monitor output.
- <u>11 / Ext. FLUXGND</u>: Ground lead of the FLUX input.
- <u>12 / LPF</u>: To turn the anti-alias filter (low-pass filter) on and off, without using the switch at the connector box, this lead can be used (see section *Anti alias filter* below).
- <u>13 / Ext. FLUX</u>: The Ext. FLUX signal is an input. This signal is fed to all channels where it is connected to the $+\Phi$ signal via a resistor. The resistor can be set

within the *Mode Palette*. By this means you are able to provide additional currents to the SQUID feedback coils. Please note that the applied voltage should not exceed ±10V.

- 14 / MON./BRC: Monitoring output of the internal generator. Provides a 1Vpp (±0.5V) signal with the waveform and frequency of generator 1. This output can be used to display SQUID characteristics in xy mode on an oscilloscope.
- 15 / DAUX: The *Digital Aux* output has two possible functions, which can be selected within the *Hardware Palette*. Either a 3V square wave signal is generated each time the *OVL threshold* set in the *Overload Palette* is reached (if *Overload Detection*, *Auto Reset* or *Dynamic Field Compensation* are active) or the generator clock (3V) can be monitored to provide a trigger signal that can be used as an external scope trigger . You have to insert a pull-down resistor to get a clean digital 1/0 signal.

The pin assignment is depicted in *Fig. 19*. If one uses a standard VGA RGB-Video cable (as delivered with the electronics), the following assignments are used:

- red: OUT1 (Channel 1)
- green: OUT2 (Channel 2)
- blue: OUT3 (Channel 3)
- v sync: MON./BRC
- h sync: Ext. FLUX

Note that the video-cable has 75 Ohm impedance and might not be suitable for optimum performance. There are some VGA RGB Video cables on the market with pin 5 connected to ground. If such a VGA cable is plugged to the Connector Box, the electronics will not work properly, since the intergator capacitor is shortened all the time.

Anti-alias filter

The connector box provides three filters (for the three possible output channels) of second order Bessel type with a cutoff frequency set to 10 kHz ±2.5%. They can be used to limit the bandwidth of the one to three output signals. The state of the filters is controlled by the switch on top of the connector box or by the pin LPF (pin 12, DB-15 connector). If pin LPF is left open, the filters are directly controlled by the switch. On power up the correct position of the switch is recognized. If LPF is connected to a low impedance signal like a digital output, the switch position is overwritten by the pin state. The polarity is negative. That means a low voltage at LPF (logic zero) turns the filters on. The LED at the connector box always shows the actual state of the filter (on/off).

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Heater

The heater voltage is +13.5 V. If R_H is the resistance of the heater including the connecting wires, the heater current I_H and heater power P_H are:

$$I_H = \frac{13.5\text{V}}{R_H}, \qquad P_H = 13.5\text{V} \cdot I_H = \frac{182.25\text{V}^2}{R_H}$$

The maximum current of 300mA requires a minimum heater resistance of 45Ω.

Electronics power supply

The electronics requires a single dc voltage between $\pm$15 V and $\pm$18 V with a current of approximately 120 mA per channel. The polarity of the power input socket is depicted in *Fig. 20* (Type T421).
A switch-mode power supply, a battery pack or any other voltage source with the required parameters can be used. Note that an earth connection is necessary when using a switch-mode power supply.

Switch-mode power supply

The switch-mode power supply delivered with the SQUID electronics is specified for input ac voltages of 100 V to 240 V with 50 to 60 Hz. The output is 15V dc and 800 mA maximum current.

Fig. 20: Polarity of the power supply input socket.

Software reference

The Software which controls all functions of the electronics is called SQUID*Viewer*™, and is delivered on a CD or USB flash disk. See the *Software installation* section for installation instructions.

The latest SQUID*Viewer*™ version is available at *http://www.magnicon.com/down-loads/customer-area/* . The required username and password are printed on the *DefaultValues* data sheet of your electronics. You will find the data sheet at the end of your printed manual and on the CD/USB flash drive. You can also use the *Check For Updates* menu entry in the *Info* menu to see if updates are available at the Magnicon website.

Please read the *Explore some system basics* section to get used to some basic software and hardware concepts.

At start-up and at every *System Scan*, SQUID*Viewer*™ scans the selected COM port for channel numbers from zero to nine. If you have electronics with higher channel numbers, you can increase the numbers to scan within the *SQUIDViewer Config* file in the SQUID*Viewer*™ application folder: Find the file named *SQUIDViewer Config* in the folder where the SQUID*Viewer*™ application is located. Open the file with a text editor. Below the entry *[General Settings]* you will find the line "*COM IDs To Scan=10*". Change the number right of the equals sign to the highest channel number you wish to scan plus one. Note, that the start-up time and the *System Scan* time increases with higher numbers.

Firmware updates

At every startup, SQUID*Viewer*™ compares the electronics microcontroller software version number with the latest version number available with this SQUID*Viewer*™ version. If old or damaged microcontroller software is detected, SQUID*Viewer*™ offers a firmware update. It is recommended to perform the firmware update to the latest version.

The firmware update process lasts up to about 1 minute per connected channel. Do not abort the update process. It is recommended to quit all other running Windows® applications before updating. SQUID*Viewer*™ quits after the update. If there is an error message after the update process, turn electronics off and on again and restart SQUID*Viewer*™.

SQUID*Viewer*™ main window

Fig. 21: SQUIDViewer™ software main window

The SQUID*Viewer*™ main window, that opens every time you start the software is depicted in *Fig. 21*. With this window you have access to the most important and mostly used settings of your electronics. Furthermore you can open and close the control palettes to reach all the other controls of the electronics.

The meaning of the controls is described in the section of the corresponding control palette.

View Channels selector
The information of up to three channels, separated in three columns, can be displayed at once. *Fig. 21* shows a two channel system. At systems with more than three channels, you can switch between the channels by use of the *View Channels* selector in the upper left side of the main window.

Global ON/OFF button

Only active in multi channel systems. If the *Global ON/OFF* button is pressed, every command is send to all connected electronics of the same type, i.e., to all SEL-1 electronics or to all XXF-1 electronics. Some commands are grayed out if the *Global ON/OFF* button is pressed because the specific command could lead to problems if send as global command. The channel buttons of the non-active channels are colored dark green if *Global* is active.

If you just want to send a single command as a global command, you can use the right mouse button together with the left mouse button. Press the right mouse button and hold it. You will notice that the *Global* buttons of all open palettes turn to red. Then click on a SQUID*Viewer*™ button or slider by use of the left mouse button to send this command as a global call. This is useful, e.g., if you want to set the complete system quickly from *Amp mode* to *FLL mode* or vice versa.

Palette buttons

The column with the text entries like *Channel*, *Mode*, *Bias*, *Source*, etc. can be used to open and close the corresponding control palette. If you, e.g., click on the *Bias* text field, the *Bias* palette opens and is the frontmost window. Another click will close the palette. A click on the *Channel* text field opens and closes the *Hardware* palette.

Active Channel buttons

The first row of the main window (*Channel*) displays the channel numbers of the connected electronics. The channel number with a green background is the active channel. You can change the active channel by a click on the channel number. If you press a button or change a pop-up window of a channel in the SQUID*Viewer*™ main window, this channel becomes the active channel.

If you open a control palette, always the settings of the active channel are displayed. Some functions like *Load Setup*, *Save Setup,* or *Save to EEPROM* refer to the active channel.

Channel Info

The *Channel Info* table at the bottom of the SQUID*Viewer*™ main window displays some information from the on-board analog-to-digital converter (ADC). These informations are updated every time a command is send to the electronics. You can manually update the information by a click on the *Channel Info* text field.

- T(°C): This is the board temperature.
- Vb(uV): Shows the bias voltage Vb, that is set in the *Bias* palette (this is not an ADC value).

- **V-Vb(uV)**: This is the amplifier input voltage with a range of $\pm1022\mu$V. If this value exceeds 1020µV, the text color turns to red to indicate a range exceeding.
- **OUT(V)**: This is the output voltage with a range of ±10.24V. If 10.22V is reached, the text color turns to red to indicate a range exceeding.

Menus

This section describes the different menu entries of the SQUID*Viewer*™ main window.

File

- **System Scan (Ctrl+Shift+S)**: Lets you perform a system scan to find electronics connected to the COM/USB port of your control PC and to reload the electronics state to the SQUID*Viewer*™ software. If you have turned off and on the electronics you have to perform a system scan to synchronize electronics and SQUID*Viewer*™.
- **Load Setup:** Please note, that setup files of different electronics types (SEL-1 and XXF-1) are not compatible with each other. The *Integrator Reset* is activated at the beginning of the load procedure. At the end of the load operation, the *Integrator Reset* is set back to the saved value. If the loaded setup file was saved with the electronics in *FLL* mode, the above procedure leads to a more reproducible locking process.
  - **Load Active Channel... (Ctrl+O)**: Loads a setup you stored with the *Save Setup* command into the active channel (the active channel is the one with a green indicator at the top of the SQUID*Viewer*™ main window). The current settings in the electronics FlashROM are overwritten. Some hardware settings (offsets) are not loaded because they belong to one specific electronics hardware. The following parameters are not changed by a *Load Active Channel...* operation: *Io, Vo, VoTC, IoTC, AC gain* and *Source mode*.
  If the chosen setup file contains more than one parameter sets (created with the *Save System* command), the first parameter set is loaded into the active channel.
  - **Load System... (Ctrl+Shift+O)**: Loads setups from a setup file into the connected electronics. If the number of saved channels in the setup file differs from the number of channels in system, a warning will occur. The parameter sets from the setup file are loaded to the channels in system in ascending order. If, e.g., two parameter sets from a two channel system are saved in a setup file, and this file is loaded to a three channel system, the third channel in the system will not be changed. The offset parameters are never loaded with a *Load System...* operation.
- **Load Active Channel with Offsets...**: This operation is identical to the *Load*

Active Channel… operation except, that the hardware specific values are also loaded. Use this command carefully. Wrong offset settings may affect measurement signals and electronics performance. You can return to the factory default values with the *Reset To Factory Default* commands in the *Extra* menu.

- Load Setup With View
  - Load Active Channel With View…: Same as a *Load Active Channel…* operation except that the view (open palettes and their positions) which is saved together with the setup file is restored.
  - Load System With View…: Same as a *Load System…* operation except that the view (open palettes and their positions) which is saved together with the setup file is restored.
- Save Setup: Note, that the electronics has to be powered during the *Save Setup* procedure to build a reloadable setup file. If problems occur with you electronics, please save a setup file and send it togehter with other useful informations to Magnicon.
  - Save Active Channel…(Ctrl+S): Saves the actual setup of the active channel into a text file. As a default the file name has the format *Date_Time.stp*. The setup file can be opened with any text editor. It is divided in two sections, a text section with all parameters as readable text and a parameter section which is used by SQUID*Viewer*™ during the *Load Setup…* operation. The entries in the text section are separated by tabs. So you can paste the information directly into text editor or spreadsheet oriented programs. It can be useful to save data settings before every measurement to simplify troubleshooting.
  - Save System…(Ctrl+Y): Saves the setups of all connected electronics into a single setup file. You can reload these setups with the *Load system…* operation.
  - Exit (Ctrl+Q): Quits the SQUID*Viewer*™ application. Informations about opened control palettes and their window positions are stored and recalled at the next start-up.

Edit
- Undo (Ctrl+Z): The last five commands can be reversed with the *Undo* command. Changes like window positions can not be recalled.
- Redo (Ctrl+Shift+Z): This reverses up to five *Undo* operations.
- Settings:
  - Enable Tip Strips: If checked, the tip strips are enabled. Just move the cursor above an object of the SQUID*Viewer*™ Software and a tip strip appears with additional informations.
  - Colored Palettes: If this option is checked, the SQUID*Viewer*™ palettes have colored backgrounds for better overview.
  - Digital Aux Automatic: If this box is checked and *Generator Clock* is selected

as *Digital Aux* output in the *Hardware* Palette, *Digital Aux* of all other electronics in the same FLL case is set to *OFF*. If it is unchecked, you can set the *Digital Aux* output of multiple electronics in one case to *Generator Clock*.

- Palette Transparency*:* The trancparency of the palettes can be set with the slider. Zero means opaque palettes, 100 means invisible palettes. The SQUID*Viewer* main window is always opaque.
- COM: You can set the COM port number and the baud rate that will be used for communication between electronics and PC. The baud rate setting is changed within the electronics and the SQUID*Viewer*™ software. Default COM port is the one with the lowest number, default baud rate is 57600 baud. If not all connected channels are recognized by SQUID*Viewer*™, you can try to change the baud rate and perform a *System Scan*.

- *Remote*: On the left side of the window, you can enter settings for use of this SQUID*Viewer*™ as a server (with the electronics connected to the COM port). On the right side you can enter settings if this SQUID*Viewer*™ should act as a client (running away from the electronics).
  - Approved IP Numbers: In the *Approved IP Numbers* list you can enter IP addresses of client PCs. If a client PC tries to connect to your server PC and the IP address of the client is not on the list, the connection is denied automatically. If the clients IP address is on the list, you are prompted to accept or deny the connection. If you enter an asterisk (*) into the first row of the list, every IP address is accepted.
  - Server Port Number: You can enter the port number at which the server listens to remote calls. Default is 54242. Please contact your system administrator to get free and open port numbers.
  - Connect to server IP: If you want to connect to a server PC, you have to enter the IP address of this server PC. If you choose the *Connect To Server* command, SQUID*Viewer*™ tries to connect to this IP.
  - ...via Port Number...: Enter the same port number that is set in the *Server Port Number* input field at the server PC SQUID*Viewer*™.

- *WebServer*: You can use the LabView web server to control SQUIDViewer via a web browser on a client PC. You have to install the LabView 2011 minimum runtime engine on the client to enable web browser support.
  - *Web Server Active?*: Turn on/off the web server engine on the server PC. If activated, Windows firewall might ask you if SQUIDViewer is allowed to connect to client machines.
  - HTTP Port: You can set the HTTP port for communication between client and server. Default is 8000.
  - Web Server Root Path: Set the path to the file named *magniconsquidviewer.html*. This file is saved into the *C:\MagniconData\web* folder from the SQUIDViewer installer as a default
  - *Save*: You have to save changes before you close the *Settings* window.

Windows

- <u>Show All (Ctrl+A)</u>: Opens all palettes.
- <u>Hide All (Ctrl+X)</u>:Closes all windows.
- <u>Stack Windows</u>: Stacks all open windows at the top left corner of the screen. If, for whatever reason, a palette is displayed outside the monitor range, you can get it back with a *Show All* and *Stack Windows* command.
- <u>Load View (Ctrl+1...5)</u>: You can load five different *views*. A *view* restores information about opened palettes, their positions on the screen, and if they were colored. With the shortcuts CTRL+*view-number* you can change easily between different views.
- <u>Save View</u>: Define the five different view settings with this command. You are prompted to name each view you save. Note, that these view settings are independently saved from the views stored in the *Setup* files (see *File* menu).
- <u>Hardware Palette (Ctrl+H)</u>: Opens the *Hardware Palette*.
- <u>Mode Palette (Ctrl+M)</u>: Opens the *Mode Palette.*.
- <u>Bias Palette (Ctrl+B)</u>: Opens the *Bias Palette*.
- <u>Source Palette (Ctrl+U)</u>: Opens the *Source Palette*.
- <u>Heater Palette (Ctrl+T)</u>: Opens the *Heater Palette*.
- <u>Generator Palette (Ctrl+G)</u>: Opens the *Generator Palette*.
- <u>Overload Palette (Ctrl+R)</u>: Opens the *Overload Palette*.

Extra

- <u>Auto Voltage Offset:</u> Sets the offset voltages *Vo(μV)* of all connected channels. This function uses the internal 10Bit ADC to measure the output voltage and sets *Vo* to obtain zero output voltage. Please note that due to the limited ADC resolution, the *Vo* values are just a rough setting and might need to be readjusted.
- <u>Recall From EEPROM</u>:
  - <u>Recall Active Channel From EEPROM</u>: Recalls the saved EEPROM settings of the active channel.
  - <u>Recall System From EEPROM</u>: Recalls the saved EEPROM settings of all connected channels.
- <u>Save To EEPROM</u>: At every power-on of the electronics, the state from the on board EEPROM is loaded. With the *Save To EEPROM* command, you can store the actual settings to the EEPROM.
  - <u>Save Active Channel To EEPROM</u>: Saves the active channel to the on-board EEPROM.
  - <u>Save System To EEPROM</u>: Saves the state of all connected channels to the on-board EEPROMs.
- <u>uC Reset</u>: A uC reset is a warmboot, i.e., the uC reacts as if it was powered down. The setup stored in the EEPROM is reloaded, actual settings are lost.

- *Reset Active Channel*: Performs a uC reset of the active channel.
- *Reset All*: Performs a uC reset of all connected channels.
- Factory Default: Factory default is the *as delivered* state of the electronics including all channel specific settings like offsets, *AC Gain*, *VoTC* and *IoTC*.
  - Reset Active Channel To Factory Default: Recalls the factory default state of the active channel.
  - Reset System To Factory Default: Recalls the factory default states of every connected channel.
- Remote Control: SQUID*Viewer*™ gives you the possibility to remotely control and supervise a SQUID electronics via a TCP connection. The server PC is the one that controls the SQUID electronics via the RS-232 COM port or USB port. The client PC is the remote machine that controls the SQUID electronics via the server PC.
  - Enable Remote Control: Check this menu entry to allow remote connections from other client PCs to control the electronics via this SQUID*Viewer*™. If this entry is not checked, other PCs have no possibility to take control over your SQUID*Viewer*™ and electronics. If the item is checked and a remote client PC tries to connect to your server PC, an information window opens. You have the possibility to deny the connection. After 20 seconds the connection will be established automatically. If you have a firewall running, you have to enable the port set in the *Remote* tab of the Settings window (*Edit* menu).
  - Connect To Server: Choose this command if you would like to take control of a SQUID*Viewer*™ running on a server PC. A window opens to inform you about the connection status. If the connection to the server is successfull, you are prompted to perform a system scan to synchronize your SQUID*Viewer*™ with the electronics state. A grey *R* in the menu bar indicates a connection to a server. Please note, that a system scan on a client PC lasts much longer than a system scan on a directly connected electronics. To cancel the connection just uncheck the *Connect To Server* menu entry.
- Run Macro: Sets the command changes saved with a *Record Macro* operation. Please note, that the changes are performed in a fix command order that may be different from the recording command order. The macro informations are stored within the *SQUIDViewer Config* file and not in the electronics memory. A macro can be usefull, e.g., to set all bias values and current sources to zero with a single command.
- Record Macro: If you choose this menu item, a *Recording Macro* note appears in the SQUID*Viewer*™ main window. The macro function compares the two electronics states at the time you choose *Record Macro* and at the time you select *Stop Recording*. Every change of the electronics state between these two commands will be saved under this macro name. Note, that a twofold button press does not change the electronics state and therefor will not be saved.

- <u>Stop Recording</u>: Only active if *Record Macro* was chosen. To stop the recording of a macro, you have to select this menu item.

Info
- <u>System Info...</u>: Opens a window with information about all connected electronics like board ID, board number, case ID, firmware version and SQUID*Viewer*™ version.
- <u>www.magnicon.com</u>: Opens the Magnicon homepage in your default internet browser.
- <u>Check For Updates</u>: Connects to the Magnicon website and looks for the latest SQUID*Viewer*™ version number available in the customer area.
- <u>About...</u>: Opens a window with copyright, credits, and contact information.

Hardware Palette
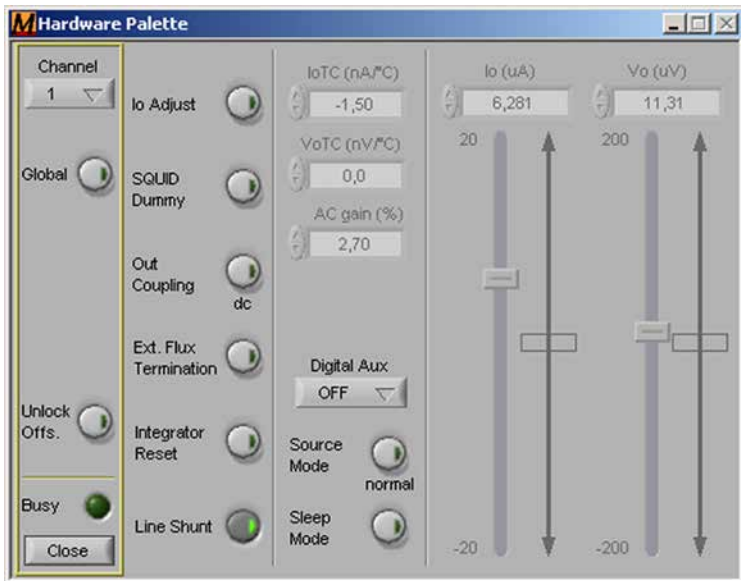
Fig. 22: Hardware palette

The *Hardware* palette includes controls that are related to basic hardware settings. Some of these settings can falsify the output signal without having any other remarkable consequence. If one or more of these controls is chosen, a red warning light appears below the channel number in the main window. The "warning" controls are *Io Adjust*, *SQUID Dummy*, *Out Coupling*, *Ext. Flux Termination* and *Integrator Reset.*

- <u>Unlock Offsets</u>: To change some hardware related values like I0, Vo, and IoTC you have to press this button first.
- <u>Unlock Io</u>: This is just an extra safety button to prevent Io changes by error.
- <u>Io Adjust</u>: A 1 kOhm resistor is switched into the +V lead at the amplifier input to adjust the offset current *Io*. During normal operation and measurements, *Io Adjust* should be turned off. There is a voltage limitation of 0.7V if you use the Josephson junction heater (*JJ Heater*). If *Io Adjust* is turned on, this voltage limitation is deactivated and the full heater voltage is applied to the ±V lines (see *Heater Palette* section too).
- <u>SQUID Dummy</u>: The *SQUID Dummy* basically replaces the SQUID with a resistor and allows testing of some basic electronics functions. Since the *SQUID Dummy* resistor is realized by use of a transistor circuit, the resistance depends on the bias current and bias voltage values. So, the resulting output voltage does not depend linear with the current through the *SQUID Dummy*. If you have problems with your setup you can check the electronics behaviour (like *Ib, Vb, Phib, Amp* mode, *FLL* mode, *Generator*, etc.) with the SQUID dummy. Please note that the *I* and *PhiX* current sources are affected by the *SQUID Dummy* setting. If *SQUID Dummy* is active, the current source outputs are shorted by a FET and the output impedance is reduced from $10k\Omega$ to about 27.6Ω.
- <u>Out Coupling</u>: Changes the output coupling between ac or dc. The cut-off frequency for ac coupling is defined by a 1μF capacitor and $1M\Omega$ internal impedance leading to 0.16Hz.
- <u>Ext. Flux Termination</u>: Activates a 50Ω termination of the external flux line. In one FLL electronics case, only one *Ext. Flux Termination* can be active.
- <u>Integrator Reset</u>: Shortens the integration capacitor and therewith keeps the output near zero voltage. If you have electronics channels in your system, that are not connected to a sensor it is recommended to activate the integrator reset to avoid interferences.
- <u>Line Shunt</u>: Activates line shunts for *I*, *PhiX(IX)*, and the feedback flux lines. An active line shunt leads to a slightly increased electronics current noise above frequencies of 5MHz. Since *Line Shunt* reduces possible line resonance effects, you should activate it if you can accept the higher noise value. If unused wires cause interferences of the output signal, you can try to activate *Line Shunt*.
- <u>IoTC</u>: Temperature correction for the offset current *Io*. This value is set by Magnicon (factory defaults) and should not be changed.
- <u>VoTC</u>: Temperature correction for the offset voltage *Vo*. This value is set by Magnicon (factory defaults) and should not be changed.
- <u>AC gain</u>: Correction of the gain for the ac amplifier. This value is set by Magnicon (factory defaults) and should not be changed.
- <u>Digital Aux</u>: The *Digital Aux* selector lets you control the digital aux output *DAUX* (pin 15 of the output connector). If *Digital Aux* is activated for more

than one channel, the *DAUX* signals of all channels (1 to 3) overlay as a logical *or*. Note, that you have to use a pull-down resistor to get a digital 1/0 signal. If you use the Magnicon *Breakout Box* BOB-1, this pull-down resistor is already implemented.

- OFF: No signal at the *Digital Aux* output.
- OVL: If overload is chosen, the *DAUX* output gets a 3V square wave signal each time the corresponding threshold (set within the *Overload* palette) is reached and if *Overload Mode* is not set to off.
- Gen. Clock: The generator clock as a 3V square wave signal is fed through the *DAUX* output and can be used to trigger a scope. Only one generator *DAUX* signal in one FLL case should be active at one time. Otherwise the different generator clocks will result in a confused output signal. *Gen. Clock* is disabled if *Global* is active. You can use the *Monitoring Output* (*Generator* palette) as trigger source of the generator too.

- Source Mode: The *Source Mode* is set by Magnicon to *TES* or *normal mode* with this button. In *normal* mode, the two auxiliary current sources *I* and *PhiX* can be independently controlled and wired. In *TES* mode, *PhiX* is renamed to *IX* and the signals of both current sources are added inside the XXF-1 electronics case. The wiring of the current sources changes as described in the *Connecting a sensor* section. See the *Source* palette chapter for more informations. The case of the FLL Electronics has to be opened to change the *Source Mode* hardware setting. Please contact Magnicon if you want to change the *Source Mode*.

- Sleep Mode: You can set the active channel or the complete system (if *Global* button is on) into *Sleep Mode*. In *Sleep Mode*, the electronics stops executing all commands and enters an energy save mode. The internal microcontroller clock pulse will stop (the external clock is always on). So, functions like generators or overload detection will stop working whereas standard FLL and AMP mode operation . If you press the *Wake Up* button of the appearing window, the electronics continue working. Note, that any write activity on the serial port will wake up all connected electronics.

  The *Sleep Mode* can be useful do temporarily deactivate one electronics to identify causes of interference.

- Io (µA): Range ±20µA. Slider for offset current adjustment. This value is set by Magnicon (factory defaults) and should not be changed.

- Vo (µA): Range ±200µV. Slider for offset voltage adjustment. Due to thermoelectric effects, each setup has its own offset voltage, that can be compensated with this slider. You might have to readjust the offset voltage after you have switched from *Amp* mode to *FLL* mode. The factory default value is adjusted with a room temperature short at the electronics in *Amp* mode.

Mode palette

Fig. 23: Mode palette

In the *Mode* palette you find all settings depending on wether the electronics is in *Amp* mode or in *FLL* mode. On the left side of the palette you find all settings regarding the *Amp* mode, on the right side the settings for the *FLL* mode.

- <u>Rf @ Amp</u>: Possible values in kΩ

OFF	0.70	0.75	0.91	1.00	2.14
2.31	2.73	3.00	7.00	7.50	9.10
10.0	23.1	30.0	100		

Defines the feedback resistor *Rf* for *Amp* mode. For SQUID characterization *Rf* should be usually turned off in *Amp* mode.

- <u>Rf @ FLL</u>: Possible values in kΩ

OFF	0.70	0.75	0.91	1.00	2.14
2.31	2.73	3.00	7.00	7.50	9.10
10.0	23.1	30.0	100		

Defines the feedback resistor *Rf* for *FLL* mode. In FLL mode, the feedback resistor, among other parameters, defines the sensitivity of your system and

therewith the system bandwidth.

- RfX @ Amp: Possible values in kΩ

OFF	2.5	10

This pop-up menu lets you activate an additional feedback path in *Amp* mode. If one of the resistors is chosen, *RfX* is connected to the amplifier output via this resistor to build an additional feedback. In a 2-stage SQUID configuration, the output of the amplifier SQUID then is linearized and you can observe the V-Φ characteristics of the sensor SQUID without the need to change the wiring.

- RfX @ FLL: Possible values in kΩ

OFF	2.5	10

This pop-up menu lets you activate an additional feedback path in *FLL* mode (see above).

- Ext. Flux @ Amp: Possible values in kΩ

OFF	2.0	2.5	10

The external flux line is connected to the *Phi* line via a resistor or is not connected at all (OFF). Note, that the input voltage at the *Ext. Flux* input should not exceed 10V. You can connect an external waveform generator to your feedback loop with the *Ext. Flux* input of the electronics.

- Ext. Flux @ FLL: Possible values in kΩ

OFF	2.0	2.5	10

See above.

- Input Termination @ Amp: Terminates the amplifier input with 50Ω in *Amp* mode. It is recommended always to activate *Input Termination* in *Amp* mode. To get the undamped SQUID charachteristics for SQUID characterization in *Amp* mode, *Input Termination* can be turned off.

- Input Termination @ FLL: Terminates the amplifier input with 50Ω in *FLL* mode. It is recommended always to activate *Input Termination* in FLL mode. Although the output signal might be reduced with active input termination, the signal-to-noise ratio is not degraded.

- Amp Gain: Possible gain settings

1100/220	1400/280	1700/340	2000/400

You can change the amplifier gain in *Amp* mode with this pop-up menu. For the XXF-1-20 version, the *Amp Gain* is reduced if *Amp Bandwidth* is set to *Full* (values behind the slash).

- Amp Bandwidth: Possible bandwidths in MHz. Values in brackets are only available in XXF-1-20 systems with 20MHz maximum FLL bandwidth.

ac amp OFF	0.2	0.7	1.4 (1.5)
(3.5)	(20)	Full	

You can set the amplifier bandwidth with this selector. For SQUID characterization, *ac amp OFF* should be used. I.e. the fast ac amplifier is inactivated and only the slower, so called, dc amplifier with a maximum bandwidth of about 30kHz is used. This is helpful, since only the dc amplifier has true differential inputs and therewith possible wire resistances are compensated. For XXF-1-6 electronics versions, *Full* means about 6MHz bandwidth. For XXF-1-20 electronics versions *Full* means about 50MHz bandwidth. If *Amp Bandwidth* is set to *Full*, the *Amp Gain* is reduced in the XXF-1-20 version.

- Gain Bandw. Prod.: Possible gain bandwidths products in GHz

0.23	0.27	0.30	0.38	0.47	0.55
0.66	0.82	1.04	1.28	1.50	1.80
2.25	2.80	3.30	4.00	5.00	6.20
7.20					

The gain bandwidth product defines, together with the feedback resistance *Rf* and the SQUID characteristics, the system bandwidth in *FLL* mode.

- Mode: Change between *Amp* and *FLL* mode. In *FLL* mode, the feedback loop is closed and the SQUID V-Φ characteristics is linearized. Usual mode for experiments. In *Amp* mode, the electronics acts as a simple amplifier with adjustable gain (*Amp Gain*) and a selectable bandwidth (*Amp Bandwidth*). There is no linearization of the SQUID modulation or any other feedback coupling in *Amp* mode. *Amp* mode is usually used to visualize the characteristic curves of the sensor and to set the working point. It can also be used for a readout of the SQUID in a small-signal open-loop mode.

- Amp Gain: Changes the amplifier gain between *positive* and *negative* for *Amp* mode. For positive *Amp Gain*, a positive input signal (e.g. from the SQUID) results in a positive output signal. For negative *Amp Gain*, a positive input signal results in a negative output signal. So, with positive *Amp Gain* you see the "real" SQUID characteristics.

- SQUID Gain: Change the SQUID gain between *positive* and *negative* for *FLL* mode. The SQUID Gain lets you select wether to lock on the increasing edge or decreasing edge of the SQUID V-Φ characteristics in *FLL* mode. If *SQUID Dummy* is turned on, *SQUID Gain* is automatically set to *positive* since the *SQUID Dummy* resistor has a positive edge only.

Bias palette
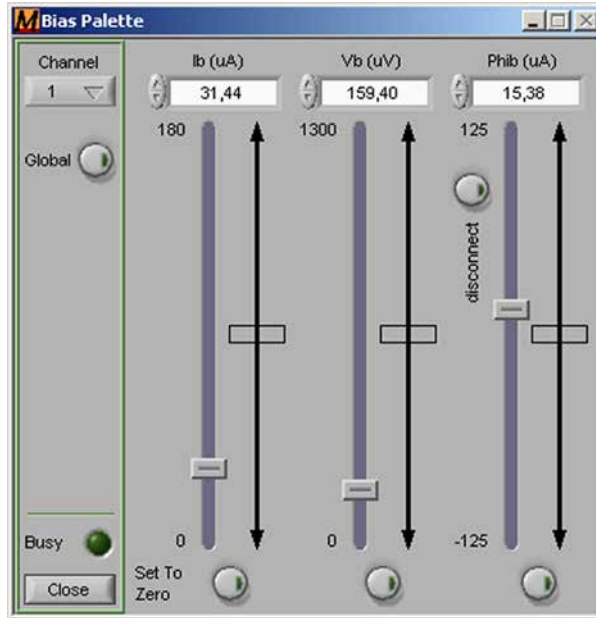
Fig. 24: Bias palette

In the *Bias* palette you can set the bias current *Ib*, bias voltage *Vb*, and bias flux *Phib*. The *Set To Zero* buttons simply set the corresponding value to zero and return to the adjusted value after deactivation. In a multichannel system it is recommended to set all unused current and voltage sources to zero and to activate the disconnect button if possible.

- Ib (uA): Range 0...180µA (other ranges on request). Set the bias current *Ib* with this slider.
- Vb (uA): Range 0...1300µV. Set the bias voltage *Vb* with this slider.
- Phib (uA): Range ±125µA (other ranges on request). Set the bias flux *Phib* with this slider. The *disconnect* button physically disconnects the bias flux current source from the *Phi* lines.

Source palette
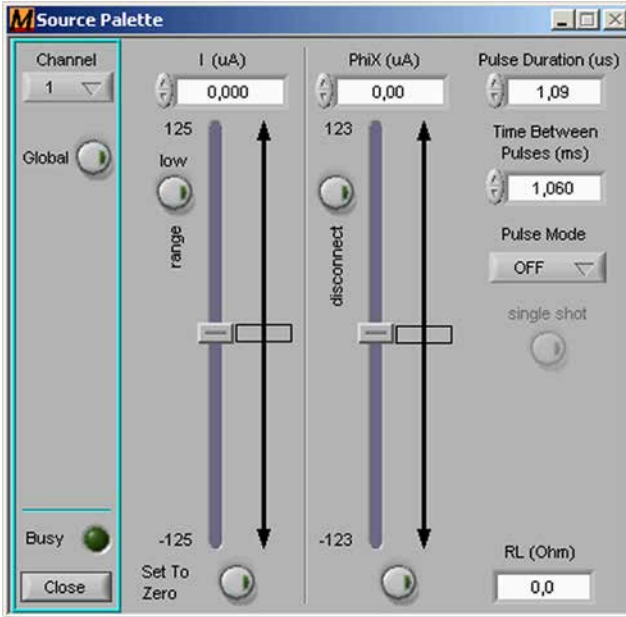
Fig. 25: Source palette

In the *Source* palette you can set the auxiliary current sources *I* and *PhiX* (*Pulse Ampl.* if *Source Mode* is *TES*). The *Set To Zero* buttons simply set the corresponding value to zero and return to the adjusted value after deactivation. In a multichannel system it is recommended to set all unused current sources to zero and to activate the disconnect button if possible.

Please note that the current sources are affected by the *SQUID dummy* setting. If *SQUID dummy* is active, the current source outputs are shorted by a FET and the output impedance is reduced from 10kΩ to 27.6Ω.

- I (uA): Range *low* is ±125µA, range *high* is ±500µA (other ranges on request). Set the current source current *I* with this slider. You can change the *I* range with the *range* button. Note, that the current noise of this source is increased by a factor of 4 if you change from *low* range to *high* range.
- PhiX(uA)/Pulse Ampl.: Range ±123µA (other ranges on request). If *Source Mode* is set to *normal*, *PhiX* is just another auxiliary current source. If you have the two-stage SQUID wiring scheme, *PhiX* can be used as additional feedback

path to view the sensor SQUID characteristics (see *RfX @ Amp / RfX @ FLL* in the *Mode* palette section).

If *Source Mode* is set to *TES* (*Hardware* palette*)*, *PhiX* is renamed to *Pulse Ampl.* (pulse amplitude). In *TES Mode*, the *Pulse Ampl.* current source can not be used as a dc current source anymore, but as a source to generate current pulses for TES calibration and testing. The currents for *I* and *Pulse Ampl.* are superimposed on the electronics PC board in *TES* mode.

- <u>disconnect</u>: The *disconnect* button disconnects the *PhiX/IX* current source from the *PhiX/I* lines. It is recommended to disconnect unused current sources to avoid current noise contributions from these sources.
- <u>Pulse Duration (us)</u>: Range is 1.09...1995.64µs. The *PhiX/Pulse Ampl.* current source can be used to generate current pulses with a definite duration e.g. for TES calibration. The rise/fall time of the pulses is below 100ns.
- <u>Time Between Pulses (ms)</u>: Range is 0.096...6258.566ms. If *Pulse Mode* is set to *continuous*, *Time Between Pulses* defines the time between the end of one pulse and the beginning of the next pulse.
- <u>Pulse Mode</u>:
  - <u>OFF</u>: If *Pulse Mode* is set to *OFF*, no current pulses are generated.
  - <u>continuous</u>: If it is set to *continuous* (*cont.*), a continuous sequence of pulses is generated. The amplitude of the pulses is defined by the *PhiX/Pulse Ampl.* slider. Pulse duration and the time between pulses are defined by the corresponding controls.
  - <u>single</u>: If *Pulse Mode* is set to *single*, the *Single Shot* button becomes active. In this mode, each click on the *Single Shot* button generates one current pulse with the set duration and amplitude.

    Note, that every time you set *Pulse Mode* to *cont.* or *single*, the *disconnect* button of the *PhiX* slider is activated automatically. This has to be done because the pulse generation is realized by use of this disconnect switch.
- <u>RL (Ohm)</u>: Range is 0...6259Ω. You can enter a load resistance for the *I* current source here. If the electronics is set to *TES* mode, the *RL* value affects *Pulse Ampl.* too. The *I* current source is realized by use of a voltage source and a fixed (large) series resistance. If you apply large load resistances to the current source (e.g. high-ohmic wires), the current range as well as the minimum step width of the current source will decrease. To take this into account, you can enter the load resistance of the *I* wires of your setup into the *RL* entry field. Please note, that the *RL* values for all channels are stored into the *SQUIDViewer Config* file and not in the electronics ROM. If you use the electronics at another setup with another PC, the *RL* values stored in the corresponding *Config* file are read. The *RL* values are not loaded during a *Load Setup File* procedure.

Heater palette

Fig. 26: Heater palette

In the *Heater* palette you can set all values regarding the integrated heater. The heater voltage indicates the voltage that is used by the heater to generate the needed power.

- Heating Time (s): Range is 0.001...4s. Sets the heating time. If *PWM* is activated, the minimum heating time is 0.002s.
- PWM (%): With the pulse-width modulation you can set the heater power in % of the maximum value.
- PWM: This button turns the pulse-width modulation on and off. With *PWM* you can control the heater power. In a time interval of 550 μs, the heater voltage is switched off for a time, specified with the *PWM (%)* field. If you, e.g., set *PWM (%)* to 20%, the heater voltage is turned on every 550 μs for a duration of 110 μs. The time averaged heater power then is 20% of the maximum heater power.
- Junction Heater: By use of the *Junction Heater*, the heater voltage is fed through a resistor into the ±V lines during heating. Therewith you can heat your device directly without the need of an external heater resistor. Be sure, that your device is appropriate to be heated that way. The junction heater current can be set to 35mA, 70mA, and 105mA (by use of the standard Connector Box and the delivered switch-mode power supply). The pop-up window shows the junction heater current I_J dependent from the heater voltage V_H like $I_J(mA) = (V_H(V)-1)1000/R_J$. whereas R_H is set by the Junction Heater pop-up window to 345Ω, 180Ω, or 120Ω. If *Io Adjust* is off, the voltage at the ±V lines is lim-

ited to 0.7V. If *Io Adjust* is on, the full heater voltage is applied to the ±V lines. Note, that in any case the full heater voltage is applied to the heater leads. You can automatically switch off the voltage limitation by use of the *JJ Voltage Limit OFF* automatic.

- <u>Heat</u>: Starts the heating process. An alert box appears. The heating process is indicated by a window with a progress bar and red *Abort* button. The heating process aborts immediately if this button is pressed. You are not allowed to send any commands during the heating process. Note, that any write activity on the serial bus (COM port) will abort the heating process.
  If *Wait (s)* is not zero, a wait window replaces the heating window after the heating process is over.

- <u>Automatic</u>: The heater automatic functions activate some usefull settings before the heating starts. After the heating process and the *Wait* time, these settings are revoked automatically.
  - <u>Bias OFF:</u> All bias currents and bias voltages are set to zero.
  - <u>Other Signals OFF</u>: Both generators and both current sources are set to zero. Additionally the *External Flux* is disconnected (off).
  - <u>JJ Voltage Limit OFF</u>: *Io Adjust* is switched on. If *Io Adjust* is turned off, the heater voltage applied to the ±V leads is limited to about 0.7V.
  - <u>Amp Mode</u>: Electronics is switched to *Amp* mode and *Input Termination* is switched off.
  - <u>Wait (s)</u>: Range 0...15s. Defines the time between the end of the heating process and revoke of the automatic settings. This waiting time can be usefull to allow the sensor to cool down and settle after heating.

- <u>Heater Voltage</u>: This is the heater voltage at the *FLL Electronics* board. The final heater voltage at the cold side of the connection to the SQUID depends on the cable length between *FLL Electronics* and SQUID. Typically, about 0.5 V are lost resuling in a heater voltage of about 13 V.

Generator palette
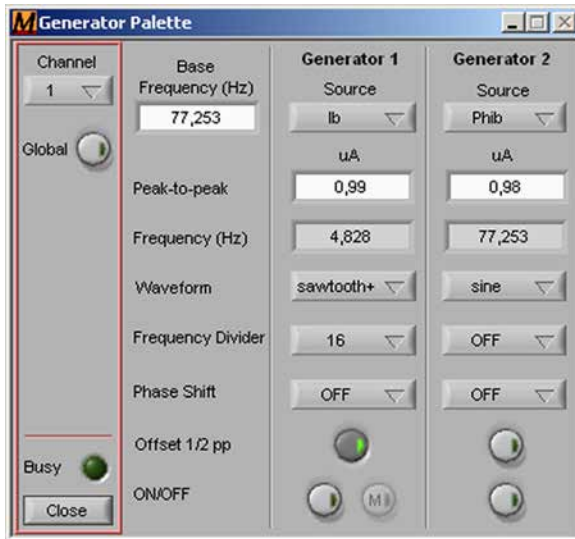
Fig. 27: Generator palette

In the *Generator* palette you can set all values regarding the internal generator functions. With the internal generators, you can modulate all necessary signals for sensor characterization and calibration. Note, that the resolution of the generator signal depends on the generator frequency. Lower frequency means smoother signals.

All generator signals are superimposed to the corresponding source, i.e., the source value you set with the slider is like an offset value for the generator signals.

- Base Frequency (Hz): Range is 0.027...2076.923Hz. Sets the base frequency for both generators.
- Source: Here you can select the signal source that you want to be modulated. Generator1 and Generator2 can not have the same source. Possible sources are *Ib*, *Vb*, *Phib*, *I*, and *PhiX*. SQUID*Viewer*™ remembers the generator settings of all sources.
- Peak-To-Peak: This is the peak-to-peak value of the selected signal. The range depends on the selected source.
- Frequency (Hz): This is an indicator of the generator frequency depending on the *Base Frequency* and the *Frequency Divider*.

- Waveform: Possible waveforms

triangle	sawtooth+	sawtooth-
square	sine	noise

You can select different waveforms for both generators. Note, that all waveforms are symmetrical around the corresponding value of the source. If noise is selected, *Frequency (Hz), Frequency Divider*, and *Phase Shift* are invisible. The bandwidth of the noise approximates the *Base Frequency*.

- Frequency Divider: Possible values

OFF	2	4	8	16	32
64	128	256	512	1024	

You can reduce the frequency of a generator by a factor indicated with the *Frequency Divider* pop-up menu based on the *Base Frequency*.

- Phase Shift: Possible phase shifts

OFF	90°	180°	270°

This setting can be used to produce a phase shift between Generator1 and Generator2.

- Offset 1/2 pp: If this button is activated, half of the *Peak-to-peak* value of the corresponding generator is added as an offset to the signal. This is useful for unipolar signals like *Ib*. If you, e.g., choose *Ib* as source and a peak-to-peak value of 50uA, you will get a signal between 0 and +25µA (if *Ib* is set to zero in the *Bias* palette) because all signals are symmetrical around the corresponding slider value and the 0 to -25µA part of the waveform is clipped. If you now press the *Offset 1/2 pp* button, 25µA are added to your signal and you get a signal between 0 and 50µA without clipping.
- ON/OFF: The *ON/OFF* button turns the corresponding generator on and off. If the set generator values lead to a clipped signal, this button turns red.
- M button: The monitoring button of Generator1 activates a mirror signal at the *Mon./BRC* output of the *Connector Box* with 1Vpp ($\pm$0.5V) signal with the waveform and frequency of generator 1. This output can be used to display SQUID characteristics in x-y mode (as x input) on an oscilloscope. For one FLL electronics case, only one monitoring output can be activated.

Overload palette

Fig. 28: Overload palette

In the *Overload* palette you can choose between several overload functionalities. Any overload activity can be monitored by use of the *Digital Aux* output (see *Hardware* palette).

- Mode: Choose the overload mode.
  - OFF: No overload detection.
  - OVL Detect.: If overload detection is active, the electronics counts up/down, every time the output voltage exceeds the *OVL Detection* threshold for positive or negative values, respectively.
  - Auto Res.: If auto reset is active, the electronics performs an integrator reset every time the output voltage exceeds the *Auto Res.* threshold. The red warning LED in the SQUID*Viewer* main window turns to red if this mode is active.
  - DFC: In the *dynamic field compensation* mode, the output current of the *I* current source (*Source palette*) is increased every time the *DFC threshold* is reached. The step size and sign of each increment can be set in the *DFC Step Size* input. By use of a field coil, this mode can be used to compensate external field changes. It was originally developed for use with the SEL-1-CS SQUID electronics high-range low-noise current source. Althoug the comparable low range of the XXF-1 current source restricts this application it might be a usefull tool in some cases.

    To calculate useful parameters for a field compensation using *DFC* you need to know some essential quantities. If you, e.g., want to have a threshold of 10 Volt output signal above that the present field is canceled by means of the current source and field coil and your feedback resistor is set to 30 kΩ, the feedback current is

$$\frac{10V}{30\text{k}\Omega} = 333\mu\text{A}$$

With a SQUID feedback coil constant of 14 µA/Φ_0 and a SQUID sensitivity of 5.6 nT/Φ_0 your present field to compensate is

$$\frac{333\mu A}{14\mu\text{A}/\Phi_0} = 23.8\Phi_0$$

$$23.8\Phi_0 \cdot \frac{5.6\text{nT}}{\Phi_0} = 133.3\text{nT}$$

Now you have to know the field coil constant of your compensation coil. E.g., the field coil constant of the PTB capsule is 2.8 mT/A. With this device you will need

$$\frac{133.3\text{nT}}{2.8\text{mT/A}} = 47.6\mu\text{A}$$

to compensate the actual field to zero. So with this configuration you would enter 10 V as *DFC threshold* and 48 µA as *DFC Step Size* in the corresponding digital field.

If you store your actual settings into the EEPROM with *DFC* on, be aware that *DFC* is still activated after the next boot process. At the next power up, *DFC* may react on possible switching voltages.

- <u>Thresholds</u>: Range is 0.08...10.24V. Here you can set the different threshold values for the different overload functionalities.
- <u>Clear Counter</u>: Clears all overload counters of the active channel.
- <u>Read Counter</u>: Reads the counters for all overload functionalities. The counter distinguishes between counts for positive and negative exceedings of the threshold value as indicated by the "+" and "-" signs above the counter indicators.

Technical specifications

General
1 to 3 Channels per electronics unit
optically isolated PC connection
selectable noiseless 50Ω input impedance
optional anti-alias filter: 10 kHz ±2.5 %
power consumption per channel: typical 1.8 W @ 15 V

Bias
bias current range   0-180 μA (other ranges on request)
bias voltage range   0-1300 μV

Preamp
low noise bipolar/JFET input stage

input range	±2 mV
white voltage noise	0.32 nV/√Hz
voltage noise @ 0.1 Hz	0.8 nV/√Hz
white current noise	2.7 pA/√Hz
current noise @ 0.1 Hz	40 pA/√Hz

FLL Mode

maximum FLL bandwidth	20 MHz
fast external integrator reset	<1 μs
output coupling ac or dc	
analog output signal range	±10 V

Amp Mode

adjustable gain	1100 to 2000
adjustable bandwidth	0.2-50 MHz

Heater

voltage	+13 V
maximum current	300 mA

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MAGNICON
physical research and instrumentation

Barkhausenweg 11
22339 Hamburg
Germany

phone: +49-40-788922-11
fax: +49-40-788922-12
info@magnicon.com
www.magnicon.com