Nanonis™

Signal Output SO5

User Manual

January 2018 (R7636)

Contents

Conventions

The following signal words and symbols appear in this manual:

Danger: Indicates a hazardous situation which, if not avoided, will result in death or major injury.

Warning: Indicates a hazardous situation which, if not avoided, could result in death or major injury.

Caution: Indicates a hazardous situation which, if not avoided, could result in minor or moderate injury.

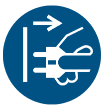
High voltage: Risk of electric shock. Lethal voltages present.

Hot surface: Indicates that the surface of the instrument might become hot. Avoid coming into contact with the hot surface.

Static sensitive devices: Observe precautions for handling electrostatic sensitive devices.

Note: Indicates a situation which, if not avoided, could result in damage or a malfunction of the instrument.

Refer to instruction manual: The instruction manual mentioned in the text must be read before operating the instrument.



Disconnect mains plug from electrical outlet: The mains plug must be disconnected from the electrical outlet before proceeding.

Italic *Commands, programs, menu items, functions, field names and product names are shown in italic characters.*

Safety information

- Carefully read this manual and all related documents before installing and using the instrument.
- The safety notes and warnings have to be obeyed at all times.
- The SO5 may only be installed and used by authorized and instructed personnel who have read this manual.
- The SO5 is designed for indoors dry laboratory use only.
- The SO5 may only be used as specified in this manual, otherwise it may not fulfill safety requirements.
- Do not install substitute parts or perform modifications to this instrument. No user serviceable parts inside.
- Do not operate the SO5 if it is damaged or not functioning properly. Never use damaged accessories.
- Do not operate the instrument during electrical storms, in order to avoid damaging the instrument.
- Never use corrosive or abrasive cleaning agents or polishes. If necessary, clean the instrument with a soft and dry cloth, and make sure that it is completely dry and free from contaminants before returning it to service.

Warning: Lethal voltages are present inside the instrument. Disconnect the mains plug from the electrical outlet before opening the instrument

About this Manual

This manual is intended as a reference tool for users of the Nanonis SO5 signal output interface. It covers the functionality of the instrument and explains its installation and operation.

This manual is not a service manual for the SO5.

Revision history

January 2018 (R7636) Initial release of the SO5 manual

The SPECS order number for this manual is: 2100011430

Introduction

The Nanonis Signal Output interface (SO5) is a high-performance voltage source designed for applications requiring high resolution, high precision, low noise, low drift, the highest DC and AC performance, and multiple-channel functionality within a single enclosure. With 20-bit resolution, 1-ppm precision, and an output bandwidth of 40 kHz, the SO5 is the ideal driver for multi-terminal quantum devices, simultaneous characterization of mutliple devices and multi-probe scanning probe microscopy (SPM).

The SO5 features sixteen single-ended outputs with ±10 V signal range and 40 kHz bandwidth. Digital to analog conversion is achieved by using high-performance 20-bit, 1 MS/s R2R DACs, allowing for 1 ppm precision and ultra-low noise. All outputs are short-circuit proof, and clamped to GND when the instrument is switched off.

For optimal temperature stability, the SO5 uses a custom temperature-stabilized, and thermally and mechanically isolated precision voltage reference. Each function group has its own low-noise voltage regulators, and crosstalk is minimized further by separately shielding the inputs, outputs, voltage reference, and digital processing circuits from each other and from the power supply.

The instrument is powered by an internal linear power supply with automatic line voltage detection and overtemperature protection. No switching power supplies or DC-DC converters are used. A separate winding of the power transformer is used for the auxiliary ±15 V power supply, which can feed external instruments (e.g. preamplifiers) with a current load of up to 300 mA.

The SO5 allows for a flexible electrical ground concept, which minimizes sources of noise and hum without sacrificing safety of operation. The user can choose whether the reference ground of the analog electronics should be connected to the experiment or to protection earth (PE). Protection earth is provided over the supply voltage connector and is connected to the metallic enclosure of the SO5.

Computer control of the SO5 is achieved using the *Nanonis RC5* real-time controller, to which the SO5 is connected with a dedicated digital cable. Up to two SO5s can be connected to one RC5, therefore allowing data acquisition systems with up to 16 input and 48 output channels with two SO5s and two SC5s, or 24 input and 40 output channels with one SO5 and three SC5s. The SO5 should be connected only to the *Nanonis RC5*, and throughout this manual it will be assumed that this is the case. For more details about the *Nanonis RC5*, please refer to the *RC5 User Manual.*

Please note that at least one SC5 needs to be connected to the RC5 in order to operate the SO5. It is not possible to operate only the RC5 and SO5 without an SC5.

Instrument Overview

Block diagram

The block diagram of the SO5 is shown in the picture below.

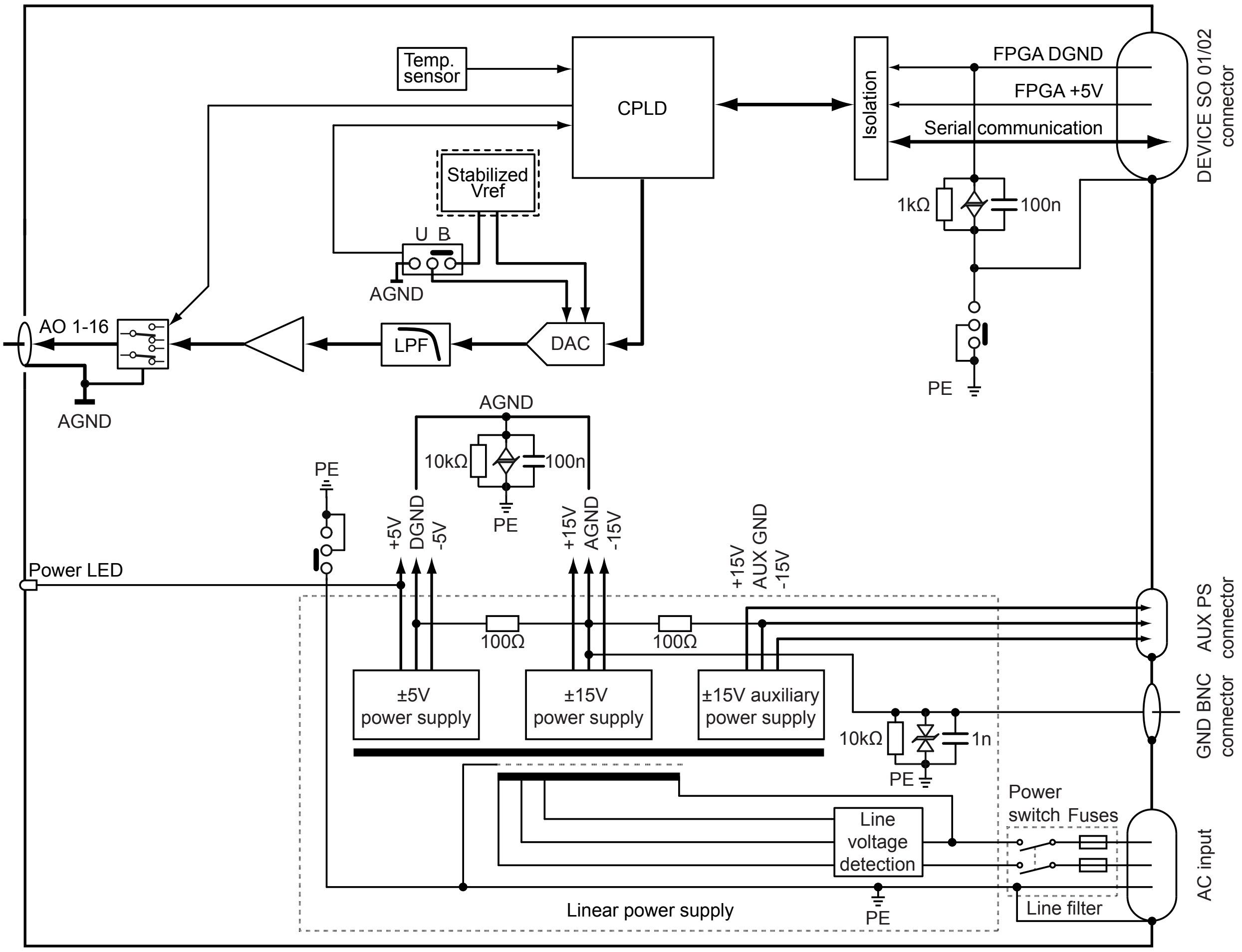


Figure 1: Block diagram of the SO5. Only one analog output is shown for clarity.

The SO5 can be divided into the following functional blocks: Analog outputs, logic, and power supply.

The sixteen analog outputs (AO) on the front panel consist of a 20-bit 1 MS/s DAC, followed by a 5^{th} order low-pass filter with a corner frequency of 40 kHz (-3 dB). Bipolar (-10 V to +10 V output range) or unipolar (0 V to +10 V output range) can be set individually for each channel by adjusting a jumper placed close to the DAC. The jumper setting is detected by software. The reference voltage for all DACs is provided by a single precision, temperature stabilized voltage reference. When the SO5 is switched off, all outputs are clamped to AGND. The output stage is disconnected from the outputs with software-controlled relays during calibration and start-up. The shield of the output BNC connectors is connected to AGND.

The logic section consists of a complex programmable logic device (CPLD) which takes care of preparing and transferring digital data between DACs in the SO5 and the FPGA in the Nanonis RC5. It also controls the output relays, monitors the status of the bipolar/unipolar jumpers of the outputs, and the temperature inside the instrument. A clock-cleaning circuit provides a clean, low-jitter reference clock for the digital section and the DA converters.

The SO5 linear power supply generates three preregulated voltages: ±5 V for the digital circuits (and for the *power LED* (3) on the front panel), ±15 V for the analog circuits, and ±15 V for the auxiliary power supply. Each supply branch uses separate secondary windings of the power transformer. The first two power supplies are connected to protection earth (PE = chassis of the instrument) by two 10 kΩ resistors in parallel. The GND of the auxiliary power supply is connected to AGND over a 100 Ω resistor. DGND, AGND and AUX GND are connected to each other with 100 Ω resistors. The line voltage is selected automatically.

Front panel

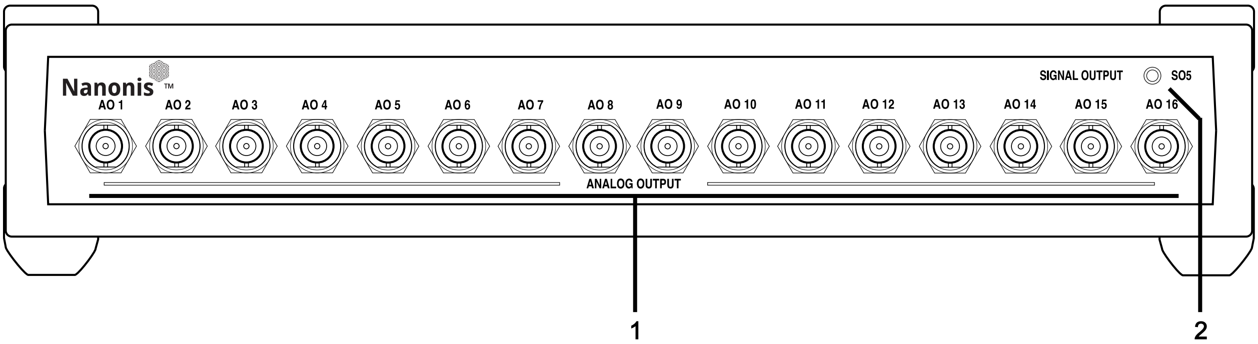


Figure 2: SO5 front panel.

1. **Analog Outputs:** The sixteen BNC plugs AO1 to AO16 are the analog outputs of the SO5. All outputs can deliver voltages up to ±10 V and currents up to ±20 mA. The shields of the output BNCs are connected to AGND. The analog bandwidth is 40 kHz (-3 dB). Please refer to the *Analog Outputs* section for more details about the output stage.
2. **Power LED (blue):** Indicates that the instrument is powered on.

Rear panel

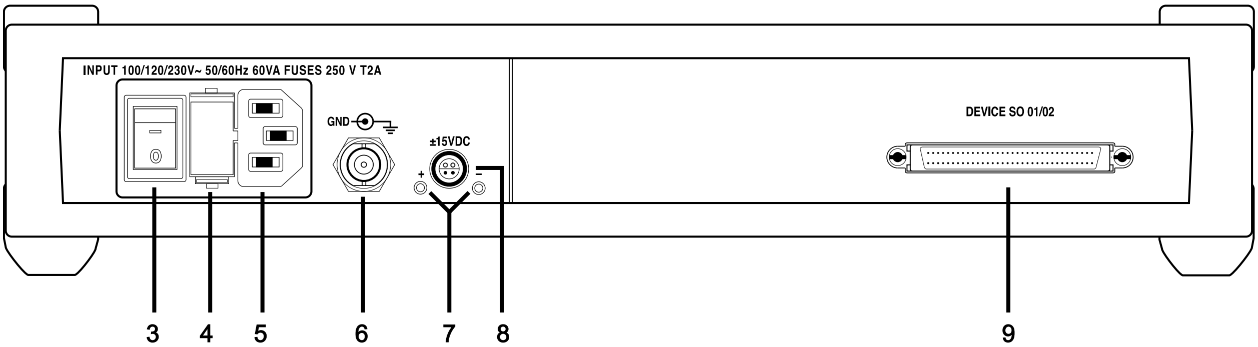


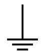
Figure 3: SO5 rear panel.

3. **Power switch:** Turns the SO5 on and off.
4. **Fuse holder:** Contains two identical slow blowing fuses, each one connected to line and neutral of the power supply transformer. Slow blowing 2A fuses (2AT, rated 250 VAC, 5×20 mm) should be used regardless of the line voltage.
5. **IEC power socket.**
6. **GND BNC connector:** The shield of this connector is connected to protection earth (PE), and therefore also to the SO5 chassis. The inner conductor is connected to the GND reference of the analog electronics (AGND). See the *Electrical ground* section for details.
7. **Status LEDs (green):** Indicate that the positive and negative rails of the auxiliary power supply are providing the correct voltages (+15 V and -15 V respectively), and are not overloaded. If the external device connected to the *auxiliary power supply connector* (9) is drawing too much current (more than 300 mA per rail), the LED of

the overloaded rail will start flashing with a frequency of 5-10 Hz. See the *Auxiliary Power Supply* section for details.

8. **Auxiliary power supply connector:** This connector supplies ±15 V with a maximum current of 300 mA per rail. It can be used to power external devices like preamplifiers. See the *Auxiliary Power Supply* section for details.
9. **DEVICE SO 01/02:** This connector is used for the communication between the SO5 and the *Nanonis RC5*. The cable for the connection between the two instruments is provided with the SO5.

Symbols:



Earth

Protection Earth

GND **Analog Ground**

Installation Guide

This installation guide shows how to prepare and power-up the SO5. Following these instructions ensures that the instrument is working correctly, and that it can be connected to the experiment. Further steps will be explained in detail in the chapters following this guide.

It will be assumed that the SO5 is controlled using a *Nanonis RC5*. Please read the RC5 manual carefully before proceeding.

Content of delivery

When first unpacking the SO5, please check for the following items:

1. Nanonis SO5
2. BNC grounding plug
3. DEVICE RDIO cable
4. Power cord
5. Test protocol
6. User manual

These items are shown in the picture below. Note that the power cord appearance will depend on the country where the SO5 is used (type J power cord shown).

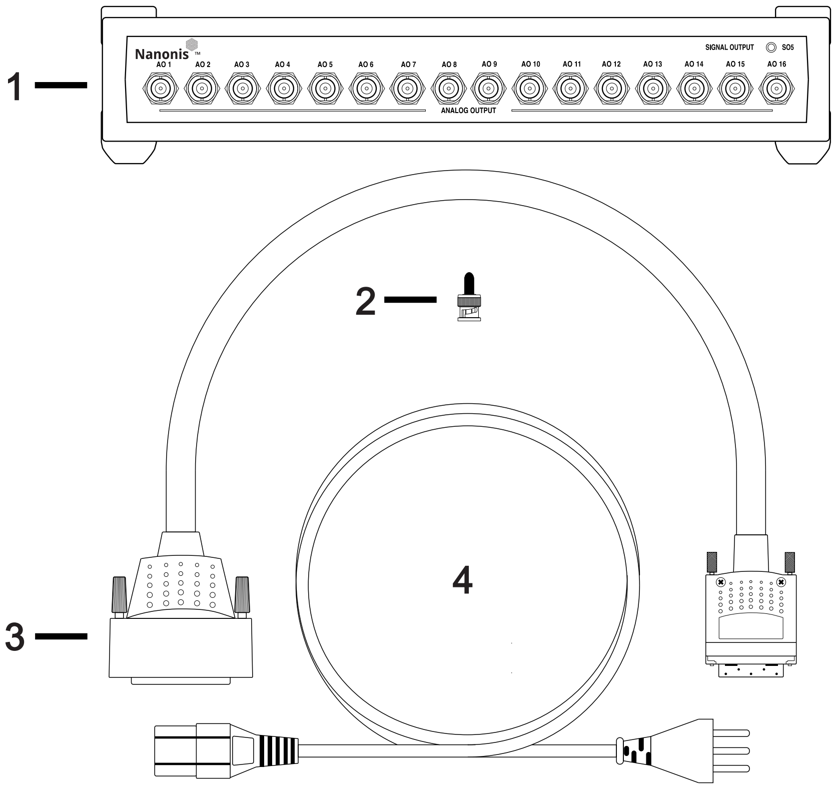


Figure 4: These items are delivered with the SO5.

Setup

To properly set up the instrument, a square space of at least 40 cm × 50 cm × 10 cm (W × D × H) is required. The *Nanonis RC5* needs an additional height of 25 cm. The SO5 weighs approximately 4.4 kg, and stability of its supporting table must be guaranteed. It must be possible to access the hardware from the front and the rear in order to connect all necessary cables. The space has to be dry and kept within the specified temperature range.

Note: Make sure that the power cord is accessible at all times. It must be possible to disconnect the power cord immediately in case of emergency.

The SO5 requires one power socket (35 VA typical, 60 VA max at 100/120/230 V ±10%, 50/60 Hz ±5%) with proper grounding. The SO5 is powered by a linear power supply with automatic line voltage selection.

Note: The power cord must be connected to a properly wired and earthed socket.

Note: Use only the provided power cord or power cords conforming to IEC60227 with a connector conforming to IEC60320.

Connection to RC5

Only one single cable, supplied with the SO5, is needed as a connection between the SO5 and the real-time controller RC5. The DEVICE RDIO cable is labelled as *SHC68 – 68 – RDIO*. Place the SO5 and RC5 at the desired location, and make sure that the space requirements listed in the previous section are fullfilled.

Note: Please carefully read the RC5 user manual delivered with the Nanonis RC5 before proceeding!

Note: Do not connect the SO5 to a Nanonis RC4. Although no damage to the instruments will occur, the SO5 will not function.

Note: Only use the supplied DEVICE RDIO cable for the connection between the SO5 and RC5. Do not use cables labelled as *SHC68 – 68 – RMIO* or the SO5 will not function.

Make sure that both the SO5 and the RC5 are switched off, but connected to the mains. Connect the *DEVICE RDIO cable* to the *DEVICE SO 01/02 port* (9) of the SO5 first, then to the SC 03 / SO 01 port of the RC5, as shown in the figure below. Always tighten the screws at either side of the connectors.

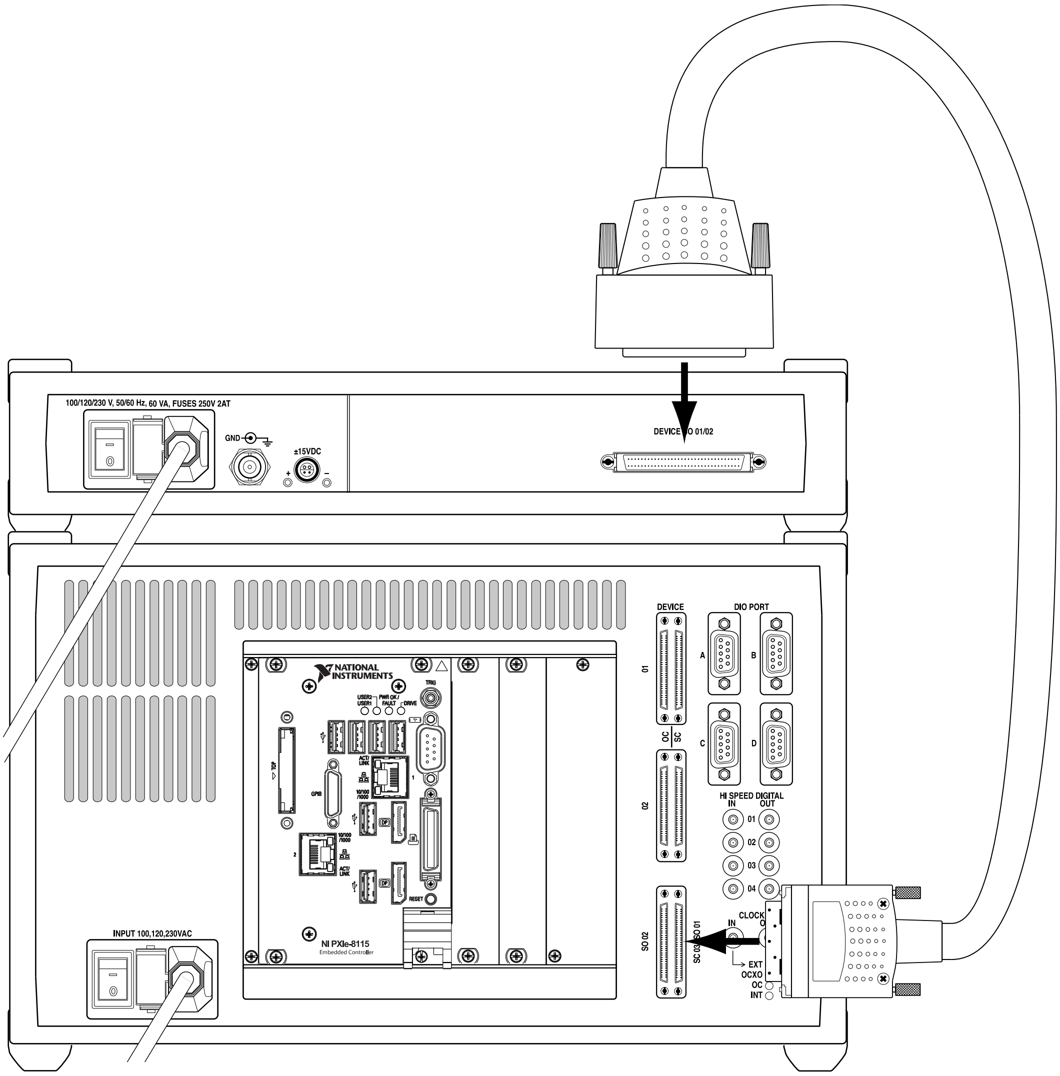


Figure 5: Connection of the SO5 to the RC5 when only one SO5 has to be connected. The power cords of both intsruments have to be connected to the mains first. Note that the SO5 can also be placed below the RC5.

Note: Connect both the SO5 and the RC5 to the mains using the supplied power cords before connecting the instruments together!

Note: Make sure that the screws of the DEVICE RDIO cable connectors are tightened, otherwise the connectors might be damaged. Do not overtighten the screws!

Note: If a single SO5 is connected to the RC5, it must be connected to the SC 03 / SO 01 port at the back of the RC5. Do not connect it to the SO 02 port.

Multiple SO5 connection

Up to two SO5s can be connected to a single Nanonis RC5. Follow the instructions given in the previous section for the connection of the additional SO5 unit.

Since the different SO5s are addressed by their port number in the Nanonis software, make sure to label the instruments on the front panel in order to recognize which instrument is connected to which port.

Note: The SO5 must be able to dissipate a large amount of heat. It is not recommended to stack more than two SC5s or SO5s on top of the RC5 unless an external source of forced cooling provides a stream of air towards the SC5 and SO5 enclosures. It is recommended to use a mixed arrangement with SC5s and SO5s placed below and above the RC5.

Caution: Avoid touching the instrument and the BNC connectors if multiple SC5s and SO5s are stacked on top of each other since the surface of the instruments and the connectors may become very hot. Switch off the instrument and let it cool down before touching it.

Electrical ground

The SO5 allows for different configurations of the electrical ground. The enclosure of the SO5 is connected to the protection earth (PE) provided by the AC power line. The ground reference for the analog electronics (AGND) is not directly connected to PE, but instead is separated by two 10 kΩ resistors in parallel. If necessary, AGND can be shorted to PE by connecting a BNC short plug to the *GND BNC connector* (6) on the rear panel. By shorting AGND and PE, all shields of the analog output connectors *AO1-AO16* (1) are also connected to PE. Note that all analog outputs are referenced to the same electrical ground (AGND) and are not floated with respect to each other.

If the experimental setup requires AGND and PE to not be connected together, the *GND BNC connector* (6) on the rear panel of the SO5 should be left open. AGND and PE are then separated by two 10 kΩ resistors in parallel. In this case a GND reference for the SO5 electronics must be provided from the experiment over the shield of the coaxial cables connected between *AO1-AO16* (1) and the experiment. The maximum voltage difference between AGND and PE should never exceed 5 V. The two configurations for the *GND BNC connector* (6) are shown in the picture below.

The reference ground of the digital electronics (DGND) and AGND are connected together only at the GND star point. The reference GND of the Auxiliary Power supply is separated from AGND by a 100 Ω resistor. This resistor cannot be bridged.

The digital GND of the RC5 is completely separated from the GND of the SO5. It is connected to PE of the RC5 by a 1 k Ω resistor, but PE of the two instruments is connected together only over the power cord, not over the *DEVICE RDIO cable*.

The best electrical ground setup depends on the characteristics of the experimental setup, and has to be determined experimentally. However, a good starting point is to keep the BNC short plug connected at the back of the SO5.

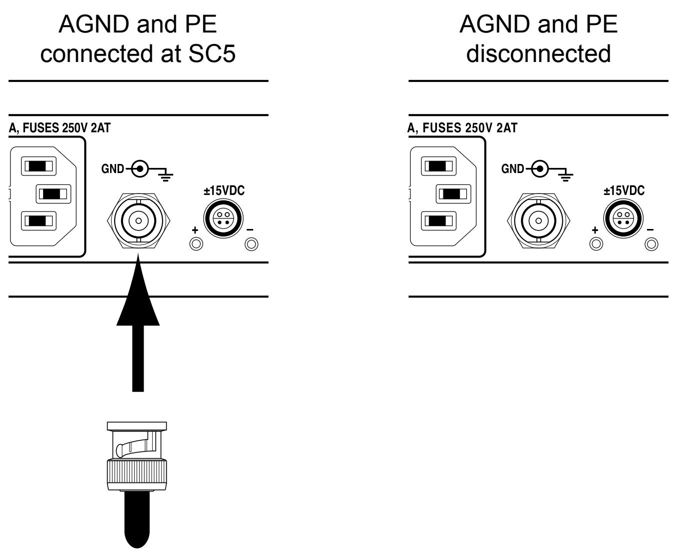


Figure 6: Electrical GND options for the SO5 depending on the GND BNC connector (7) on the rear panel of the instrument. Left: BNC short plug connected, AGND and therefore the shields of the analog outputs AO1-AO16 (2) are connected to PE. Right: No BNC short plug connected, AGND and PE are separated by two 10 kΩ resistors in parallel.

Note: The *GND BNC connector* should not be used for applying offset voltages to AGND. The maximum potential difference between AGND and PE should never exceed 5 V, or the power supply of the SO5 will be damaged.

Powering

Make sure that the SO5 is connected to the Nanonis RC5 as described in the previous section. Turn on the SO5 with the mains switch (4) located at the back of the unit (see picture below). The power LED (3) will turn on.

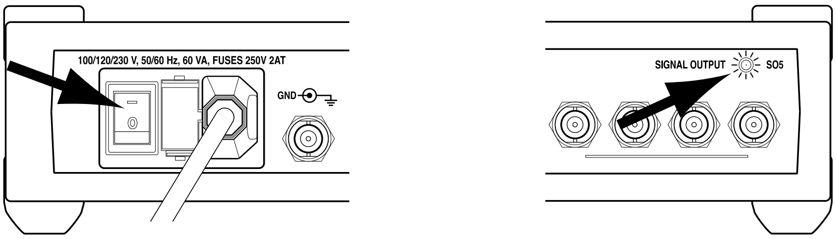


Figure 7: Powering of the SO5. Left side: Location of the power switch at the back of the SO5. Right side: LED which will turn on after powering the unit.

The SO5 is now ready for use. Should the SO5 not turn on as described above, please refer to the *Troubleshooting* section before proceeding. If a solution to the unexpected behavior is not listed there, please contact SPECS before taking any further action.

How to proceed

- Make sure that the SO5 is connected to the Nanonis RC5 as explained in the *Connection to RC5* section. Otherwise switch off the SO5, connect it to the RC5, then switch it on again.
- Turn on the Nanonis RC5
- Start the Nanonis software and make sure that all output voltages are set to 0 V
- Connect the analog outputs of the SO5 as described in the *Analog Outputs* section

Analog Outputs

This chapter explains how to connect the SO5 analog outputs AO1 – AO16 (1) to other equipment, and explains in more detail the output stages of the instrument.

Analog outputs connection

The analog outputs of the SO5 can be connected to the experiment using BNC cables, as shown in the picture below.

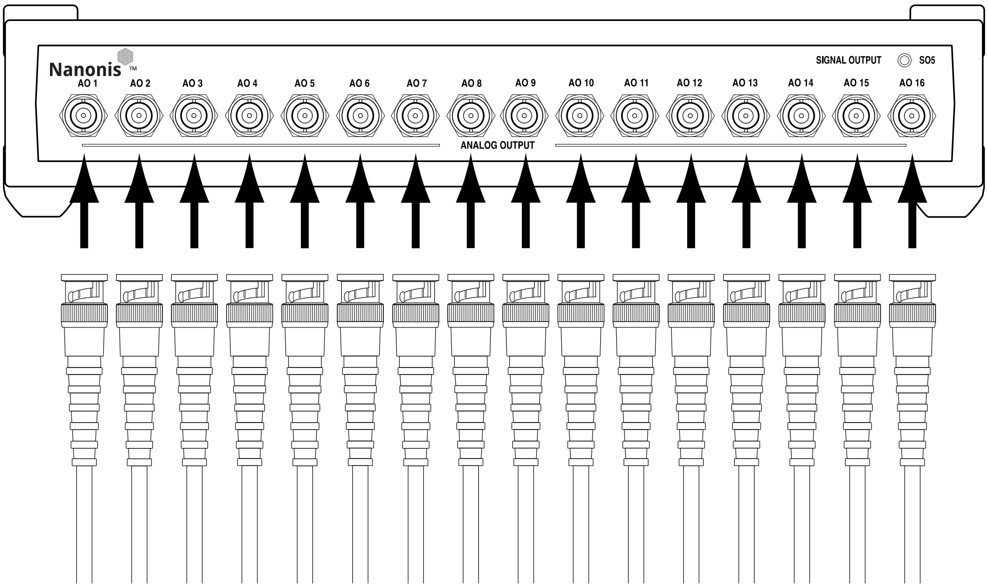


Figure 8: Connection of the analog output BNC cables.

There are no external controls for the analog outputs. The output relays (see the *Analog outputs schematic* section for details) are controlled by software during the calibration procedure. The outputs are configured for bipolar operation (output voltage range: -10 V to +10 V) by default. They can be configured for unipolar operation (output voltage range: 0 V to +10 V) by changing the position of jumpers inside the SO5, as explained in the *Bipolar and unipolar operation* section below.

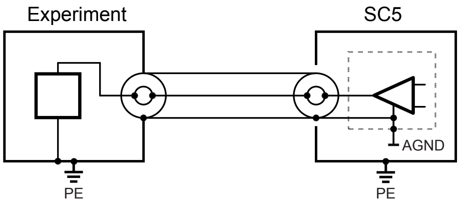
Note: The maximum output current is limited to ± 20 mA. Although the outputs are short-circuit proof, make sure that this value is not exceeded, otherwise the output drivers will exceed their rated operating temperature, and their lifetime will be reduced.

Specific connection options

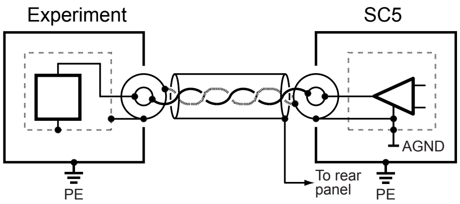
Connection using shielded twisted-pair cables: The use of coaxial BNC cables as a standard connection is dictated by their widespread use and general availability in research laboratories. Coaxial cables are, however, not the ideal solution for low-frequency signals in the frequency range that the SO5 operates. Shielded twisted-pair cables would be the best solution, followed by triaxial cables, but both require dedicated connectors, which would not be compatible with standard BNC connectors, and would also be more expensive.

Depending on the signal input at the experiment, the shortcomings inherent to the use of coaxial cables can be reduced by preparing shielded twisted-pair cables according to the general rules discussed below. These are suggestions; improvements will depend on the measurement set-up, and have to be determined experimentally.

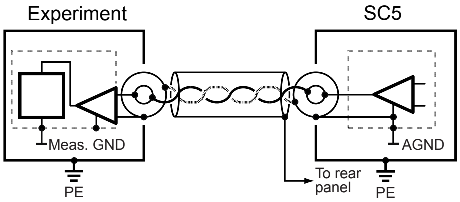
Shielded twisted-pair cables should not be used if the signal input is single-ended and referenced to PE, or a BNC connector with the shield connected to PE is used at the experiment. Note that in this case AGND and PE will be connected together at the experiment. The situation is depicted below:



Shielded twisted-pair cables can be used when the signal input is single-ended, but the device the voltage is applied to is referenced to a GND connected to the shield of the experiment input BNC as shown below. The GND can be either a larger part of the experiment, or just the return path for the applied signal.

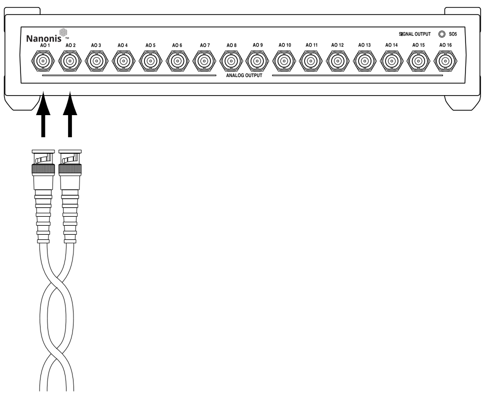


Shielded twisted pair cables should be used if there is a differential buffer after the input connector at the experiment as shown below. This solution can lead to best results, but only if the specifications of the buffer and its associated circuitry are at the same level as those of the analog outputs of the SO5, and if the buffer provides sufficient CMRR. The input impedance of the buffer should not be below 1 kΩ.



Differential mode connection: The outputs of the SO5 can easily be paired, thereby increasing the (differential) voltage range to ±20 V, and allowing a differential connection to the experiment. However, the total number of outputs is then decreased by one for each pair of differential signals. The number of paired outputs is user selectable, but only nearby outputs should be paired, and only if at least one of the outputs is not assigned to a specific function by the software as default. A differential pair of outputs is defined in the software by setting the negative output as a "Monitor" channel of the positive output, with a negative (-1) calibration.

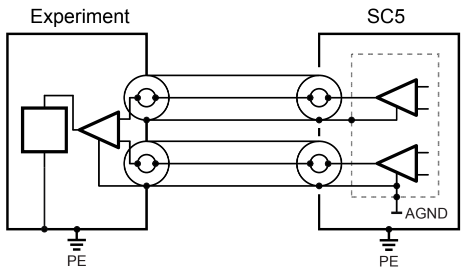
A typical connection situation (AO1 and AO2 shown) is depicted below. The cables can be twisted in order to reduce magnetic pick-up:



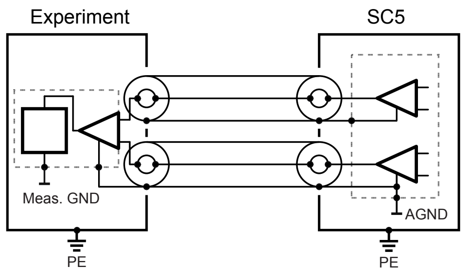
Note: In order to operate correctly in differential mode, both paired outputs must be set to bipolar operation.

Connection options: As for shielded twisted pair cables, there are different options for connecting the SO5 to the experiment when using the outputs in differential mode.

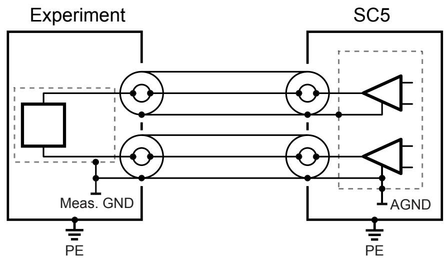
When the connectors' shields at the experiment are connected to PE, the following connection scheme should be used:



If the shields are separated from PE, the following wiring configuration should be used:



The following configuration should be used if a symmetric biasing of the measured device is required:



Use of external attenuators and low-pass filters: The analog outputs of the SO5 have a fixed voltage range of ± 10 V (or 0 to 10 V in unipolar operation), and the corner frequency of the output low-pass filters cannot be changed from its 40 kHz (-3 dB) setting. Although the output noise of the SO5 is very low, additional reduction of the noise using attenuation might be desired. However, in most cases, the experiment is placed at a considerable distance from the SO5 (up to 10 m). Over such distances, the signal will be prone to common-mode noise pick-up, and to other effects due to the long cabling (e.g. triboelectric effects), which will become more significant with a smaller signal amplitude. Therefore, attenuators should be placed as close to the experiment as possible, allowing large amplitudes to be carried over the long distance, and also allowing attenuation of external interference.

If passive attenuators (voltage dividers) are used, the total resistance to AGND (both divider resistors) should not have a value below 1 kΩ, in order to minimize current consumption. Note that a 1 kΩ resistor will have a thermal noise contribution of slightly more than 4 nV/√Hz. It is important to use AGND for the resistor to ground of the voltage divider, and not a different GND.

Active attenuators should also not have input impedances below 1 kΩ.

For the same reasons as above, if a lower cut-off freqency than the 40 kHz cut-off of the analog outputs is required, low-pass filters should be placed as close as possible to the experiment. They would make little sense if placed inside the SO5. If only DC, or very slow varying signals are necessary, a low-pass filter with sufficiently low cut-off frequency placed close to the experiment will also guarantee that line frequency components picked-up from the cabling between SO5 and experiment can be filtered effectively.

For purely capacitive loads, optimum frequency response of the SO5 output stage is only guaranteed if the capacitance to AGND does not exceed 500 pF (including cable capacitance). For passive RC-filters, there is no limitation on the value of the capacitor. The resistor should not have a value below 1 kΩ.

Active filters should not have input impedances below 1 kΩ.

Analog outputs schematic

Each one of the sixteen analog outputs *AO1 – AO16* (1) is referenced to AGND. This means that the shield of the output BNC is not connected to PE, unless a BNC short plug is connected to the *GND BNC connector* (6) at the back of the SO5 as described in the *Electrical ground* section. An output relay shorts the output connector to AGND when the instrument is switched off or has not yet initialized. During normal operation this relay connects the output stage with the output connector. The output stage consists of a 20-bit, 1 MS/s DAC, followed by a 5th order (Butterworth) active low-pass filter with a corner frequency of 40 kHz (-3 dB) as well as a buffer, which is shown in the picture below.

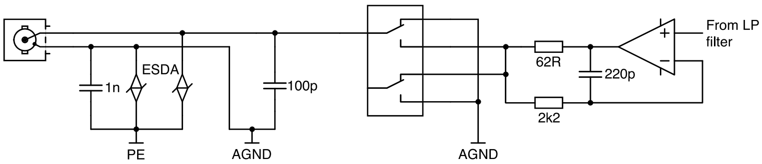


Figure 9: Schematic of the output stage of the SO5 analog outputs. The output relay is shown in the position when the SO5 is not powered up.

Bipolar and unipolar operation

The analog outputs of the SO5 are configured by default for bipolar operation, meaning that the output voltage can be set between -10 and +10 V. If only positive voltages from 0 to 10 V are required, each output channel can be individually switched to unipolar operation. This requires changing the position of two jumpers per channel, which are placed on the main circuit board of the SO5. One jumper connects the negative reference voltage input of the DAC to AGND (instead of -10 V) while the other jumper is read out by the logic of the SO5 in order to automatically adjust the signal calibration in the SO5 control software. Therefore, the position of both jumpers must be changed for correct unipolar operation.

In order to perform this change, the following tools are required:

- 3 mm hex scredriver
- #0 Phillips screwdriver
- Small metallic tweezers with flat but roughened tips

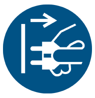
Note: Changes between bipolar and unipolar operation require the SO5 to be opened, and the process also requires the removal and replacement of relatively small objects close to electronic components sensitive to electrostatic discharge (ESD). Make sure to follow all directives for handling ESD sensitive components before proceeding. A wrist strap connected to ground must be worn when performing the modification. Please send the SO5 back to SPECS for the modification if there is any doubt about making the modification.

Before proceeding with the change of jumper positions, please make sure that:

- All *analog outputs* (3) are disconnected from the experiment.
- The SO5 is disconnected from the RC5
- The SO5 is disconnected from the mains.

Once the above conditions are fulfilled, put the SO5 on a stable and sufficiently large surface. Remove the four plastic caps covering the screws which hold the top cover of the instrument as shown in the figure below, and remove the screws by turning them CCW using the 3 mm hex screwdriver. Make sure not to lose the lock washers placed below the screws. The top cover can now be carefully lifted, and should be put on the side of the instrument. Note that there is a grounding wire connecting the top cover with the rest of the instrument, and therefore the top cover cannot be lifted by more than 10 cm or removed completely.

Warning: Lethal voltages are present inside the SO5.



Note: If a change of jumper position is required, make sure that the SO5 is disconnected from the mains.

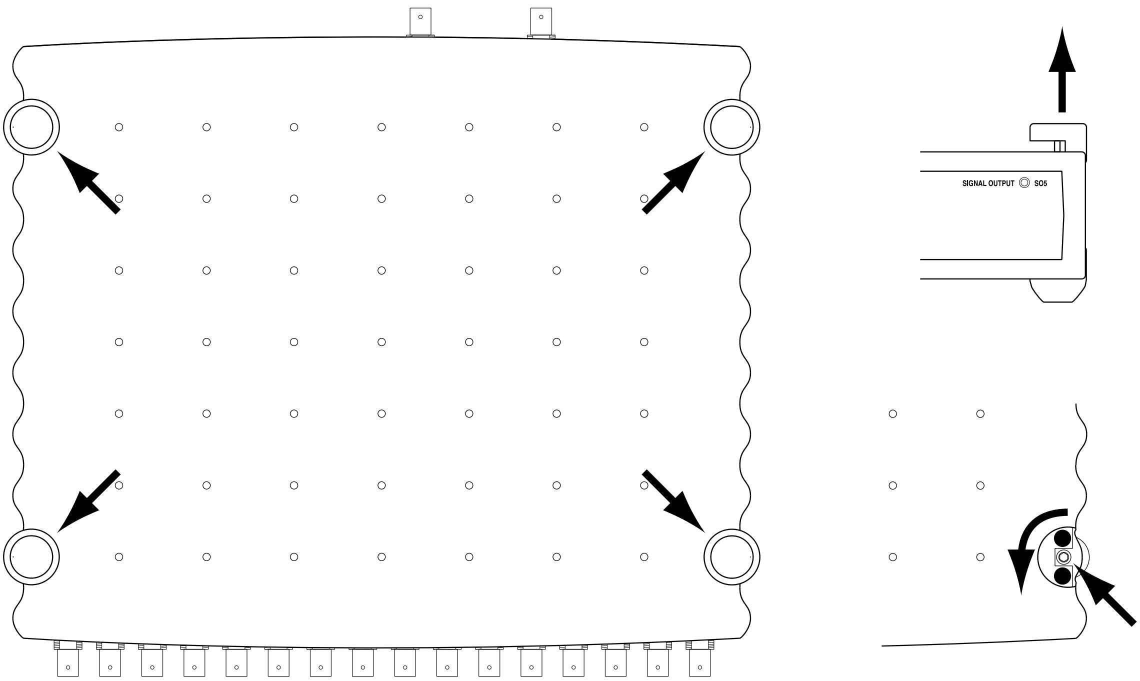


Figure 10: Removing the top cover of the SO5: First remove the four plastic caps covering the screws by lifting them, then remove the four screws by turning CCW with a 3 mm hex screwdriver.

After removal of the top cover an additional internal shield has to be removed. The shield covers the entire analog output section, and is located as indicated in the figure below. Remove the three Phillips screws keeping the shield in position, and then remove the shield.

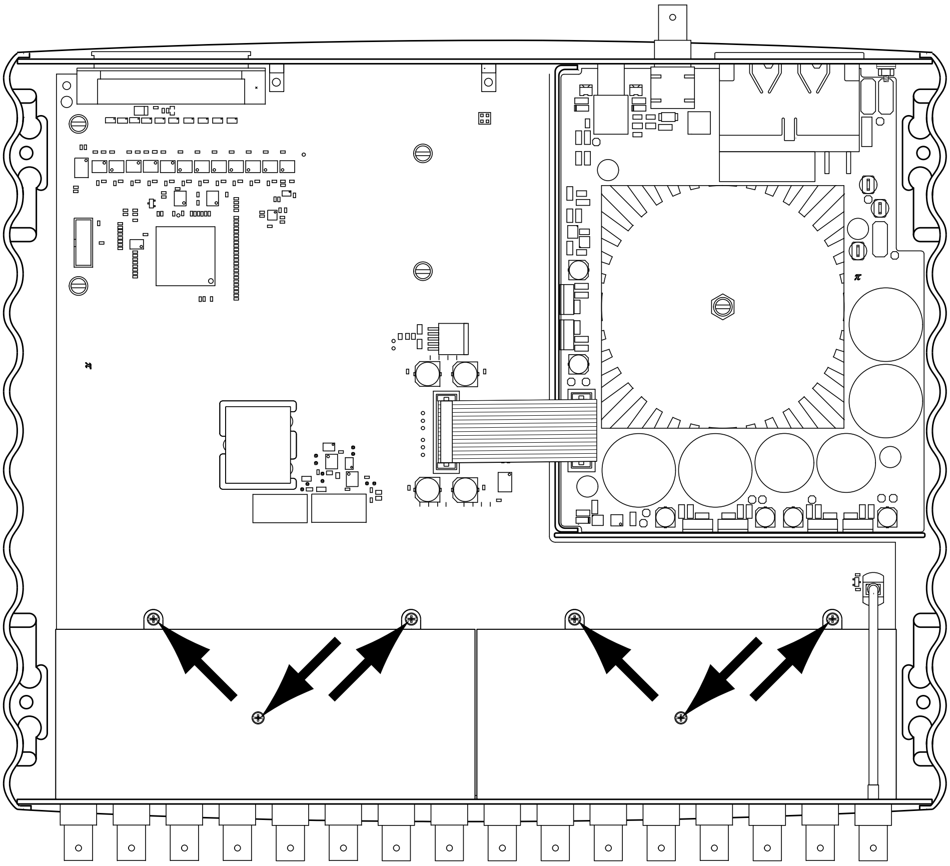


Figure 11: Internal view of the SO5. The six screws indicated by the arrows need to be removed in order to detach the metallic shields covering the analog outputs sections.

The position of the jumpers is indicated in the figure below. The jumpers can be removed and placed at the desired position by using small metallic tweezers. The position is marked by a “B” (bipolar) and “U” (unipolar) on the printed circuit board. Make sure to wear a wrist strap properly connected to ground. Make sure to change the position of both jumpers of each channel requiring a change of the bipolar/unipolar setting.

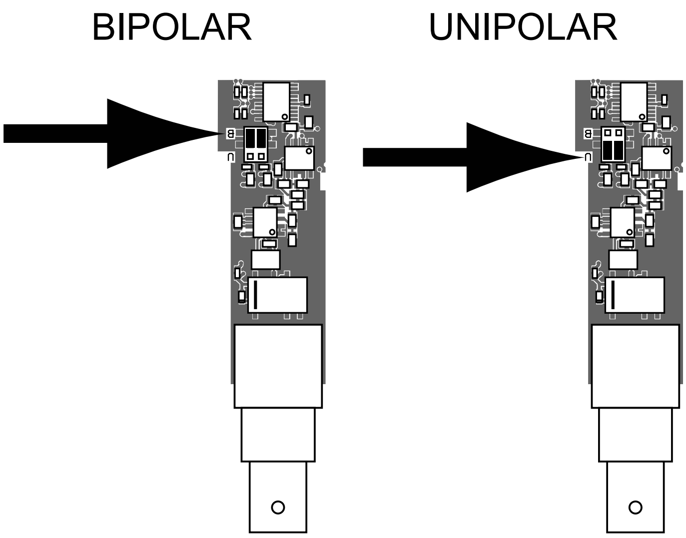


Figure 12: Location and setting of the jumpers for the selection between bipolar and unipolar operation. A single channel including output BNC connector is shown.

Note: Make sure to change the position of both jumpers of each channel requiring a change of the bipolar/unipolar setting. Changing the position of only one jumper will lead to a wrong output calibration. Do not turn the jumpers by 90°, or the instrument will not work properly.

Warning: Avoid any physical contact with or modification of the areas of the instrument marked by the high voltage warning sign, as this might impair the safety of the instrument.

Note: Make sure that the grounding wire is still firmly connected to the top cover and to the rear panel before closing the instrument. A loose grounding wire will impair safety of the instrument. Also make sure that no shields, screws, tools, or other objects have been dropped or forgotten inside the instrument. Any object left inside the instrument might impair safety of the instrument.

Specifications (outputs)

Connectors	16 × BNC
Coupling	DC, referenced to AGND
Output voltage range	±10 V into 1 kΩ or larger (0 to 10 V per internal jumper per channel)
Output impedance	< 1 Ω, short circuit safe
Analog bandwidth	DC - 40 kHz (-3 dB)
Analog filter type	5^{th} order Butterworth
DA converter	20-bit, monotonic, 1 MS/s
Effective resolution	20-bit
DNL	± 0.5 LSB (bipolar) typical, ± 0.75 LSB (unipolar) typical @ 20 bit
INL	± 2 LSB typical @ 20 bit
Output noise density	< 23 nV/sqrt(Hz) @ 1 kHz, ±10 V output range
RMS noise 0.1 – 10 Hz	< 165 nV rms, ±10 V output range
Peak-peak noise 0.1 – 10 Hz	< 920 nV p-p, ±10 V output range
RMS noise 10 Hz – 300 kHz	< 10.5 µV rms, ±10 V output range
Peak-peak noise 10 Hz – 300 kHz	< 95 µVp-p, ±10 V output range
Temperature coefficient	< 3 µV/K @ 0 V output, <30 µV/K @ 9.9 V output
SINAD	>96 dB @ 100 Hz, 9 V
THD+N	>115 dB @ 100 Hz, 9 V (FFT bandwidth 1 kHz)
Maximum output current	±20 mA
Maximum slew rate	2.5 V/µs into 10 kΩ
Offset	< 500 µV uncalibrated at 0V
EMC protection	According to EN61326-1, Table-1

Auxiliary Power Supply

The SO5 is equipped with an auxiliary ±15 V power supply, which can be used to power external instruments like preamplifiers. It can supply up to ±300 mA, and is fed from a dedicated winding of the power transformer. The *auxiliary power supply connector* (8) is located at the back of the instrument, and is a LEMO receptacle model EPL.0S.304.HLN. The corresponding plug can be obtained from LEMO (model FFA.0S.304.CLAC42, with "CLAC42" defining the cable diameter range, and therefore depending on the cable used when assembling the connector).

The auxiliary power supply provides a pre-regulated supply voltage. Since most instruments powered by the auxiliary power supply will be placed at relatively large distances from the SO5, it is recommended to use local voltage regulators if these instruments require very low-noise supply voltages.

The auxiliary power supply is protected against overcurrent by a current detection circuit, which disables the output when the connected instrument draws more than 300 mA per supply rail. In that case, the *status LED* (8) of the overloaded rail will start to flash with a frequency of about 5-10 Hz. The complete power supply of the SO5 is additionally protected by a thermal fuse in the main transformer, which irreversibly disconnects its primary winding if the temperature of the core exceeds 115°C.

Connection

The plug of the instrument to be powered can be simply inserted into the auxiliary power supply socket, as shown below. It is possible to insert the connector both with the SO5 switched on or off. Should the *status LEDs* (8) start flashing when the connector is plugged in, disconnect the connector, and make sure that there are no short circuits in the power supply path to the external instrument. If there are no short circuits, the instrument is drawing too much current, and a different power supply should be used. For more details, refer to the *Troubleshooting* section.

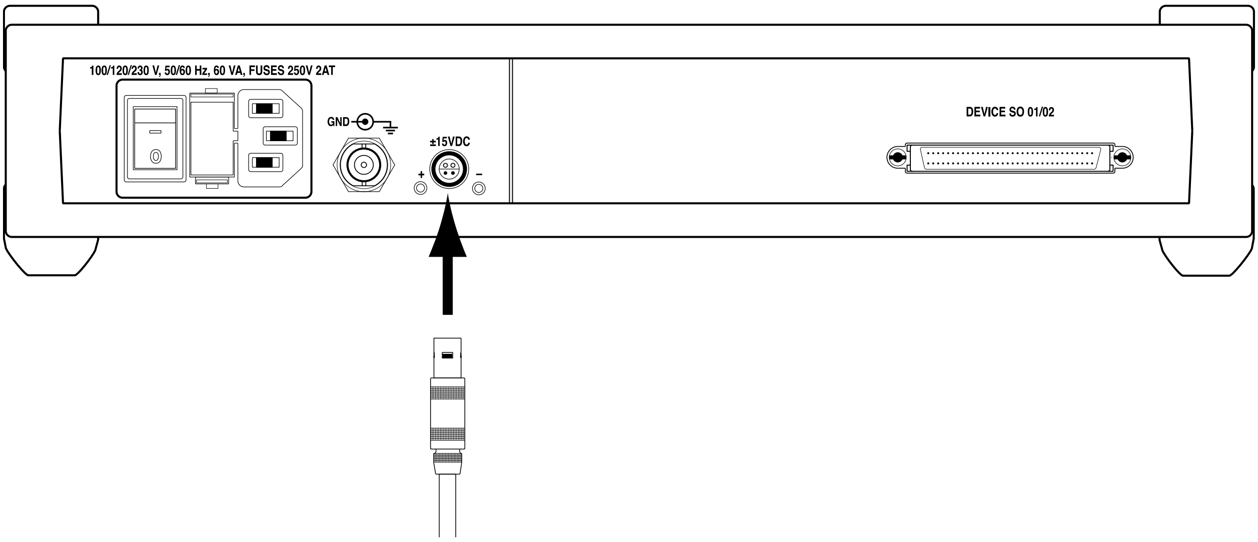


Figure 13: Connection of an external device to the auxiliary power supply on the back of the SO5.

Connection using Y-splitter

The Y-splitter (optional item) allows two instruments to be powered from the auxiliary power supply connector. The two output connectors of the Y-splitter are wired in parallel, and the Y-splitter is inserted between the SO5 and the instruments to be powered. The Y-splitter is shown in the picture below.

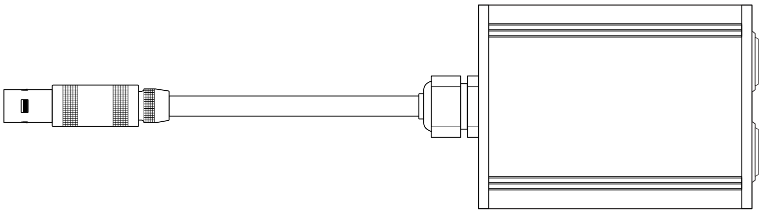


Figure 14: SO5 auxiliary power supply Y-splitter.

The schematic of the splitter is shown below:

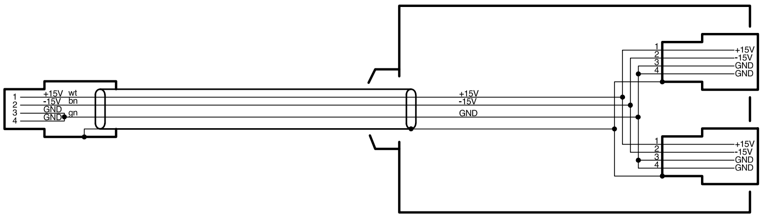


Figure 15: Schematic of the Y-splitter for the auxiliary power supply.

Note: Make sure that the sum of current consumption of the two instruments connected to the AUX power supply output of the SO5 over the Y-splitter does not exceed 300 mA.

Note: Large power consumption from the auxiliary power supply will increase the temperature of the SO5 due to additional thermal dissipation of the power supply. Make sure that the SO5 is operated within the specified *temperature range* and that there is enough space for airflow around the instrument.

Schematic and connector pin layout

A schematic of the auxiliary power supply is shown in the picture below.

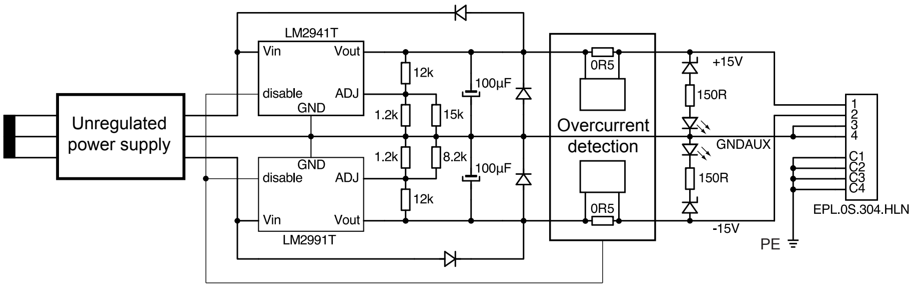


Figure 16: Schematic of the auxiliary power supply.

The auxiliary power supply is fed by a dedicated winding of the main power transformer. The unregulated part uses ultrafast soft-recovery diodes for rectification followed by a large capacitor reservoir. The following two low-noise, low drop-out regulators can be disabled by the overcurrent detection circuit if the current should exceed ±300 mA. The two *status LEDs* (7) indicate whether the output voltage of the power supply is ±15 V (LEDs on), the device connected to the power supply is drawing too much current (LEDs flashing), or the power supply is faulty and does not supply enough voltage (LEDs off).

The connector pin configuration is shown in the picture and table below.

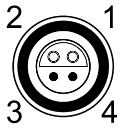


Figure 17: Auxiliary power supply receptacle pin layout.

PIN	Signal
1	+15 V
2	-15 V
3	AUX power supply GND
4	AUX power supply GND

Table 1: Pin assignment of the auxiliary power supply receptacle.

Note that the casing of the receptacle is connected to PE (in contrast to the Nanonis SC4 and OC4, where the casing is connected to AUX power supply GND).

Specifications (auxiliary power supply)

Connector	LEMO EPL.0S.304.HLN
Voltage	±15 V
Maximum asymmetry	< 750 mV (5%)
Maximum current	±300 mA (current limiter)
Minimum load	0 mA
Noise (0.1 Hz – 25 kHz)	< 2 mV RMS
Mains transient rejection	< 500 ppm @ 10% line voltage change
Load transient rejection	< 600 ppm @ 100% load change
Temperature coefficient	< 500 ppm/K typical
Hold-up time	3.5 s (idle), 60 ms (50% load), 5 ms (100% load)

Troubleshooting

Instrument doesn't power up correctly

SYMPTOM: **The *Power LED* (2) does not light up AND the auxiliary power supply status LEDs (7) do not light up.**

REASON: Fuses blown.

SOLUTION: Disconnect the SO5 from the mains. Remove and check the *fuses* (4). If the fuses are blown, replace them with fuses of the same rating (2AT, rated 250 VAC, 5×20 mm), and try powering up the SO5. Should the fuses blow again, please contact SPECS.

REASON: SO5 damaged.

SOLUTION: Disconnect the SO5 from the mains. Remove and check the fuses (4). If the fuses are intact, but the unit is still not working, please contact SPECS.

Auxiliary power supply doesn't work correctly

SYMPTOM: **When connecting the external device to the auxiliary power supply receptacle, the *status LEDs* (7) start flashing with a frequency of about 5-10 Hz.**

REASON: There is a short circuit in the power supply wiring of the external device.

SOLUTION: Unplug the external device and check if the positive and negative power supply rails of the external device are shorted with respect to each other or to GND. If a short circuit is detected, locate the source of the short circuit, and power the external device with the SO5 only when the short circuit has been removed.

REASON: The external device is drawing too much current.

SOLUTION: Check for a short circuit as above. If there is no short circuit, the external device is drawing more than 300 mA per rail from the SO5 auxiliary power supply, and should therefore be powered from another power supply.

REASON: More than one device connected to the auxiliary power supply, and the total current consumption exceeds 300 mA per rail.

SOLUTION: Connect only one external device to the SO5, or a number of devices whose current consumption does not exceed 300 mA per rail.

SYMPTOM: **There is a voltage offset between the GND of the power supply and PE or the experiment.**

REASON: The device powered by the SO5 is not connected to any GND source.

SOLUTION: Make sure that the external device is connected to GND correctly. The auxiliary power supply of the SO5 is fed from a dedicated winding of the power transformer, and the GND pins of the output connector correspond to the center tap of that winding. These pins are referenced to GND over either 5.1 kΩ, or 100 Ω (depending on the GND BNC connector) and the GND level can have an offset of up to 6.5 V maximum with respect to PE (limited by a transient voltage suppression diode).

SYMPTOM: **The *status LEDs* (7) do not turn on, but the *power LED* (3) does.**

REASON: The auxiliary power supply has been damaged.

SOLUTION: Please stop operating the instrument and contact SPECS.

Specifications

General

Casing	Wavetronics, stackable
Power	Internal linear power supply
Power consumption	Approx. 35 VA typical, 60 VA maximum
Power supply	100/120/230 V ±10%, 50/60 Hz ±5%, Fuses 250 V 2AT
Outputs	16
EMC-Protection	According to EN61326-1, Table-1, for cable length < 3 m
Operating temperature	+5 ˚C to +35 ˚C
Dimensions	33.0 × 26.5 × 5.4 cm (W×D×H)
Weight	Approx. 4.4 kg

Analog outputs specifications

Connectors	16 × BNC
Coupling	DC, referenced to AGND
Output voltage range	±10 V into 1 kΩ or larger (0 to 10 V per internal jumper)
Output impedance	< 1 Ω, short circuit safe
Analog bandwidth	DC - 40 kHz (-3 dB)
Analog filter type	5^{th} order Butterworth
DA converter	20-bit, monotonic, 1 MS/s
Effective resolution	20-bit
DNL	±0.5 LSB (bipolar) typ., ±0.75 LSB (unipolar) typ. @ 20 bit
INL	±2 LSB typical @ 20 bit
Output noise density	< 23 nV/sqrt(Hz) @ 1 kHz, ±10 V output range
RMS noise 0.1 – 10 Hz	< 165 nV rms, ±10 V output range
Peak-peak noise 0.1 – 10 Hz	< 920 nV p-p, ±10 V output range
RMS noise 10 Hz – 300 kHz	< 10.5 µV rms, ±10 V output range
Peak-peak noise 10 Hz – 300 kHz	< 95 µVp-p, ±10 V output range
Temperature coefficient	< 3 µV/K @ 0 V output, <30 µV/K @ 9.9 V output
SINAD	>96 dB @ 100 Hz, 9 V
THD+N	>115 dB @ 100 Hz, 9 V (FFT bandwidth 1 kHz)
Maximum output current	±20 mA
Maximum slew rate	2.5 V/µs into 10 kΩ
Offset	< 500 µV uncalibrated at 0V
EMC protection	According to EN61326-1, Table-1

Auxiliary power supply specifications

Connector	LEMO EPL.0S.304.HLN
Voltage	±15 V
Maximum asymmetry	< 750 mV (5%)
Maximum current	±300 mA (current limiter)
Minimum load	0 mA
Noise (0.1 Hz – 25 kHz)	< 2 mV RMS
Mains transient rejection	< 500 ppm @ 10% line voltage change
Load transient rejection	< 600 ppm @ 100% load change
Temperature coefficient	< 500 ppm/K typical
Hold-up time	3.5 s (idle), 60 ms (50% load), 5 ms (100% load)

Operating conditions

Environment	The SO5 is designed for indoors dry laboratory use only
Ambient temperature	15 ˚C to 35 ˚C in accordance with IEC-60068-2-1 and IEC-60068-2-2
Humidity	10-50% relative humidity, non-condensing in accordance with IEC-60068-2-56
Maximum altitude	2000 m
Pollution degree	2 (indoor use only)
Installation category	II
Mains supply voltage fluctuations	Are not to exceed ±10% of nominal supply voltage

Storage and transportation conditions

Ambient temperature	-20 ˚C to 70 ˚C in accordance with IEC-60068-2-1 and IEC-60068-2-2
Humidity	5-95% relative humidity, non condensing in accordance with IEC-60068-2-56
Pollution degree	2 (indoor use only)

Performance Measurements

Analog outputs noise performance measurements

All measurements of the analog outputs, if not otherwise specified, were performed with hrDAC™ switched off.

Spectral noise

The noise spectrum of the analog outputs is measured with AO1 connected to a battery-powered Stanford Research Systems SR560 low-noise differential preamplifier set to gain 1000, and the spectrum is recorded using a *National Instruments 4071* PXI digital multimeter operated in digitizer mode. The pictures below show the noise spectrum for the range of 1 kHz (0 V and +9 V DC output). The low frequency range up to 50 Hz and the high frequency range up to 300 kHz is shown in separate plots below. Note that line voltage frequency and harmonic components strongly depend on the measurement set-up. Also, the amplitude of these components can vary from output to output.

The following settings have been used for the measurement:

SO5		DMM	
Measured output:	AO1	Mode of operation:	Digitizer, DC volts
Output amplitude:	0 V and 9 V	Range:	100 mV
		Resolution:	22 bit
		FFT resolution	20’000 points

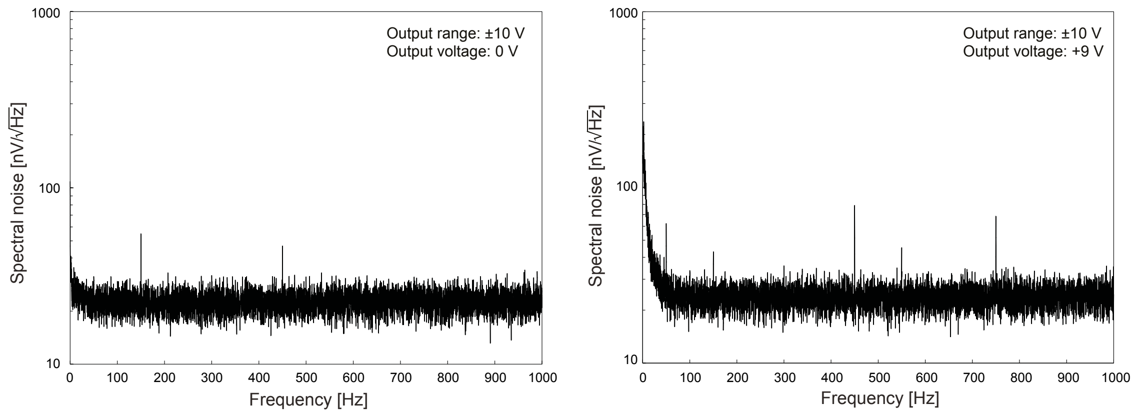
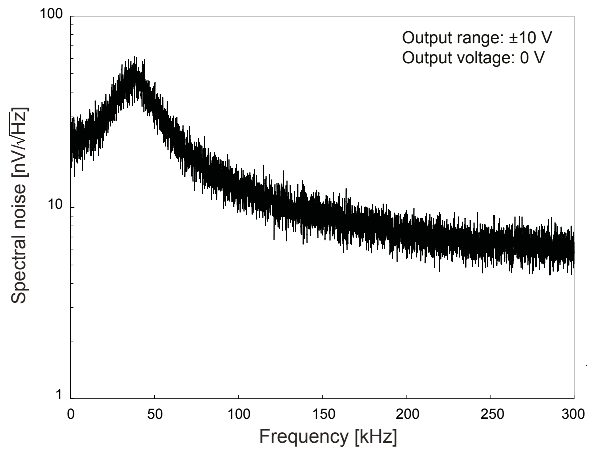


Figure 18: Spectral noise of the analog outputs up to 1 kHz. The left picture is for 0 V output voltage, the right picture for +9 V output voltage.



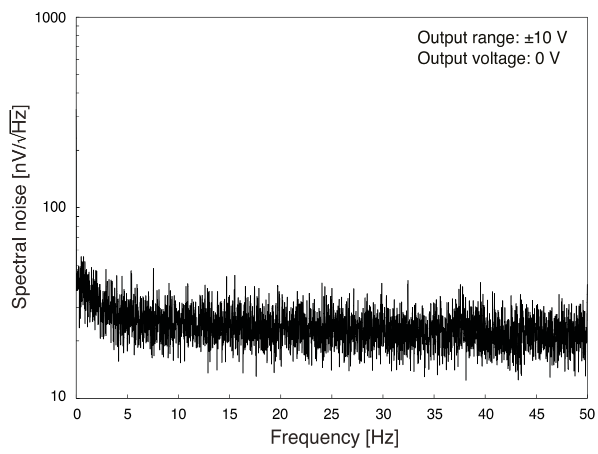


Figure 19: Spectral noise of the analog outputs up to 300 kHz (left) and 50 Hz (right) at 0 V output.

The following table shows typical spectral noise values for selected frequencies. Note: The measurement was performed with 50 Hz line voltage frequency.

Frequency	Spectral noise (nV/√Hz)
1 Hz	38
10 Hz	24
50 Hz	< 35
100 Hz	32
150 Hz	< 40
1 kHz	22
10 kHz	23
40 kHz	45
100 kHz	13
1 MHz	45

Table 2: SO5 output spectral noise density measured at AO1 for different frequencies, including line frequency (50 Hz) and its second and third harmonic, as well as sampling frequency.

Noise 0.1 Hz – 10 Hz

The low-frequency noise of the SO5 outputs is measured with the same set-up as described in the previous section.

The following settings were used for the measurement:

SO5

Measured output:	AO1
Output amplitude:	0 V

DMM

Mode of operation:	Digitizer, AC volts
Range:	100 mV
Sample rate:	100 S/s
Resolution:	22 bit

The following graph shows a typical trace for the output noise in the 0.1 to 10 Hz range:

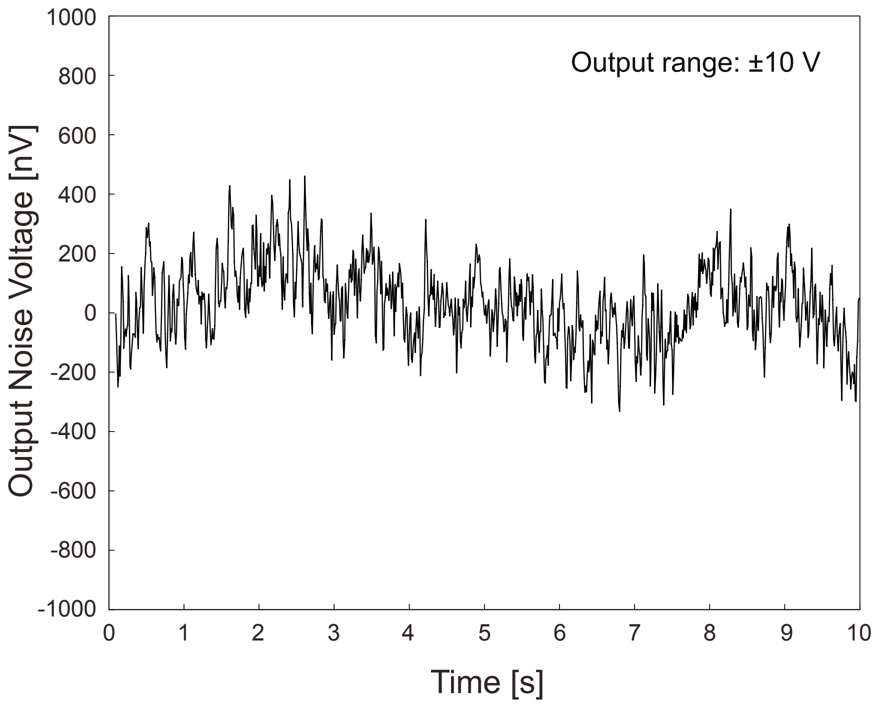


Figure 20: SO5 output noise 0.1 - 10 Hz.

Typical RMS and peak-to-peak noise values in the 0.1 Hz to 10 Hz range are listed below:

RMS noise	p-p noise
< 165 nV	< 920 nV

Table 3: Typical maximum output noise level in the 0.1 to 10 Hz range.

Noise 10 Hz – 300 kHz

The noise of the SO5 outputs above 10 Hz is measured with the same set-up as described in the previous section. The upper frequency limit is given by the analog bandwidth of the multimeter.

The following settings have been used for the measurement:

SO5

Measured output:	AO1
Output amplitude:	0 V

DMM

Mode of operation:	Digitizer, AC volts
Range:	100 mV
Sample rate:	1.8 MS/s
Resolution:	10 bit

The following graph shows a typical trace for the output noise in the 10 Hz to 300 kHz range:

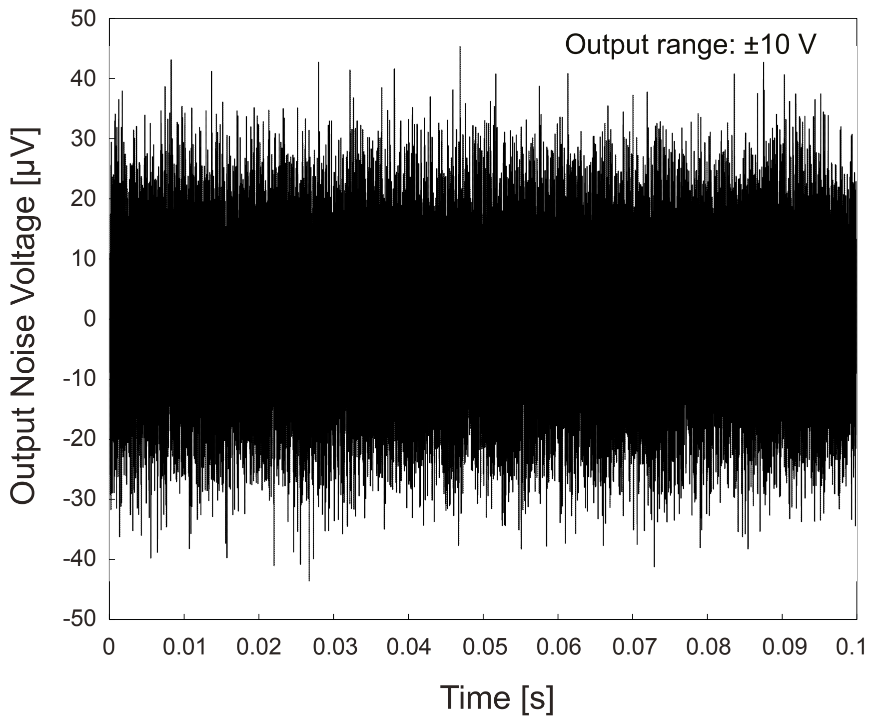


Figure 21: SO5 output noise 10 Hz - 300 kHz.

Typical RMS and peak-to-peak noise values in the 10 Hz to 300 kHz range are listed below:

RMS noise	p-p noise
< 10.5 µV	< 95 µV

Table 4: Typical maximum output noise level in the 10 Hz to 300 kHz range.

Noise using external filters

The output noise can be further reduced by using external low-pass filters. The output noise above 0.1 Hz for different cut-off frequencies is listed in the table below, for first and second order active filters (built-in filters of the SR560 preamplifier). The sampling frequency of the measurement is set to twice the filter cut-off frequency.

Cut-off frequency	6 dB/Oct.		12 dB/Oct.	
	RMS noise	p-p noise	RMS noise	p-p noise
100 kHz	< 8 µV	< 75 µV	< 7.2 µV	< 66 µV
10 kHz	< 1.9 µV	< 17 µV	< 1.7 µV	< 16 µV
1 kHz	< 605 nV	< 4.8 µV	< 560 nV	< 4.4 µV
100 Hz	< 210 nV	< 1.5 µV	< 195 nV	< 1.3 µV

Table 5: Output noise above 0.1 Hz when using external 1st or 2nd order low-pass filters with the indicated cut-off frequencies.

Analog outputs DC performance measurements

DNL and INL

Note: The INL and DNL measurements are done with a SC5, which uses identical DA converters to the SO5.

The differential (DNL) and integral nonlinearities are measured with the SC5 connected directly to a *National Instruments 4071* PXI digital multimeter operated in DMM mode (7.5 digits). During these measurements the environment temperature was not kept constant, meaning that in a constant-temperature environment the results for the INL would show a lower INL than in the measurement below. The following settings have been used for the measurement:

SO5		DMM	
Measured output:	AO1	Mode of operation:	DMM, DC volts
		Range:	10 V
		Resolution:	26 bit

The first plot shows the differential nonlinearity, the second the integral nonlinearity. In both cases the error is below ±1 LSB at 20 bit, meaning below ±20 µV absolute voltage error. The SC5 achieves therefore ppm-precision on its analog outputs.

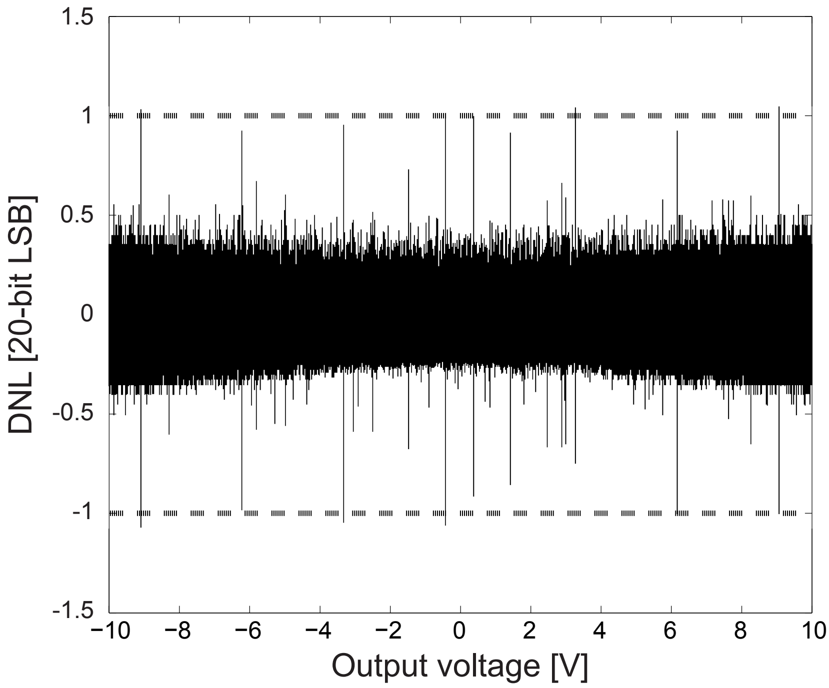


Figure 22: Differential nonlinearity of the analog outputs. The dashed lines indicate the ±1 LSB range.

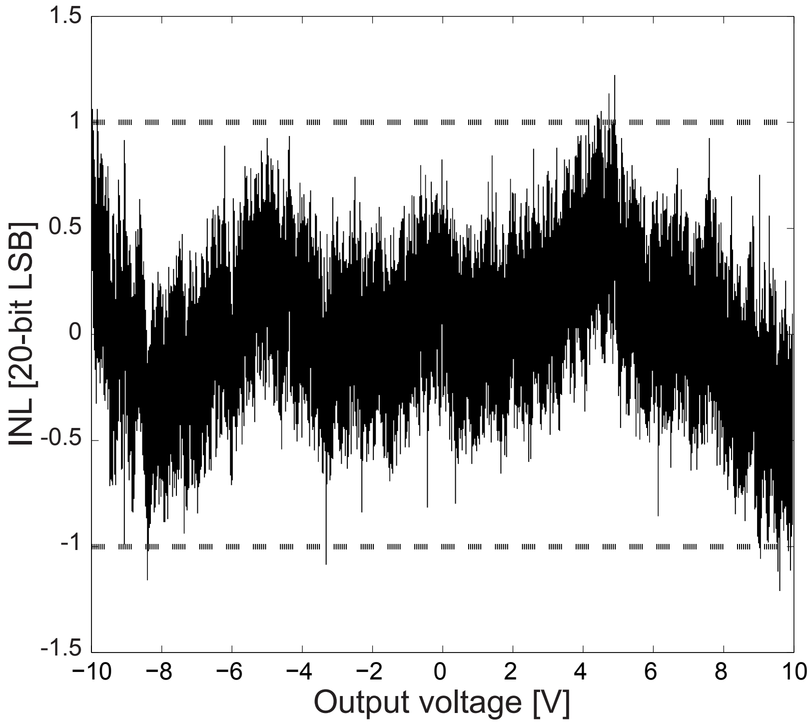


Figure 23: Integral nonlinearity of the analog outputs. The dashed lines indicate the ±1 LSB range. The INL is below ±1 LSB at 20 bit, meaning that the outputs achieve 1-ppm precision.

Offset and gain error

The offset of the SO5 outputs set to 0 V is measured with the SO5 connected directly to a *National Instruments 4071* PXI digital multimeter operated in DMM mode (7.5 digits). The maximum absolute offset compared to the DMM, and the maximum relative offset between channels is shown in the table below. Note that in contrast to the SC5, the SO5 cannot be automatically calibrated as there are no input channels. The following settings have been used for the measurement:

SO5		**DMM**	
Measured output:	AO1	Mode of operation:	DMM, DC volts
Output amplitude:	0 V, ±10 V	Range:	100 mV and 10 V
		Resolution:	26 bit

Output voltage	Typ. max. absolute offset	Typ. max. relative offset
0 V	± 500 µV	250 µV

Table 6: maximum absolute and relative offsets of the SO5 analog outputs.

Gain error is measured at output voltages on -10 V and +10 V.

Output voltage	Typ. Gain error	Typ. max. relative offset
-10 V	< 0.5 ‰ of setting	250 µV
+10 V	< 0.5 ‰ of setting	250 µV

Table 7: maximum gain error and relative offsets of the SO5 analog outputs at ±10 V.

Accuracy

The accuracy of the analog outputs can be deduced from the offset and gain error measurements. The result for uncalibrated and calibrated outputs is summarized below:

Typ. Accuracy error	Typ. Abs. Accuracy at 0 V	Typ. Abs. accuracy at ±10 V
< ± 0.5‰ of setting ±500 µV	< ±500 µV	< ±5 mV

Table 8: Accuracy of the analog outputs.

Resolution

In contrast to the SC5, the SO5 cannot make use of the hrDAC™ algorithm as the outputs cannot be calibrated without beaing measured 1:1 with an input channel. The maximum resolution of the SO5 outputs is therefore 20 bit.

Output stability and temperature dependence

12 hour stability

The stability of the output voltage is measured over 12 hours at a 10 seconds interval with AO1 connected to a *National Instruments 4071* PXI digital multimeter operated in DMM mode (7.5 digits). The measurement is performed for output voltages of 0 V and +9.9 V. The internal temperature of the SO5 is also recorded, in order to compare the drift of the output signal with the temperature coefficient determined below. The results of the 12 hour measurement are shown below. The following settings were used for the measurement:

SO5		DMM	
Measured output:	AO1	Mode of operation:	DMM, AC volts
Output amplitude:	0 V and +9.9 V	Range:	100 mV and 10 V
		Resolution:	26 bit

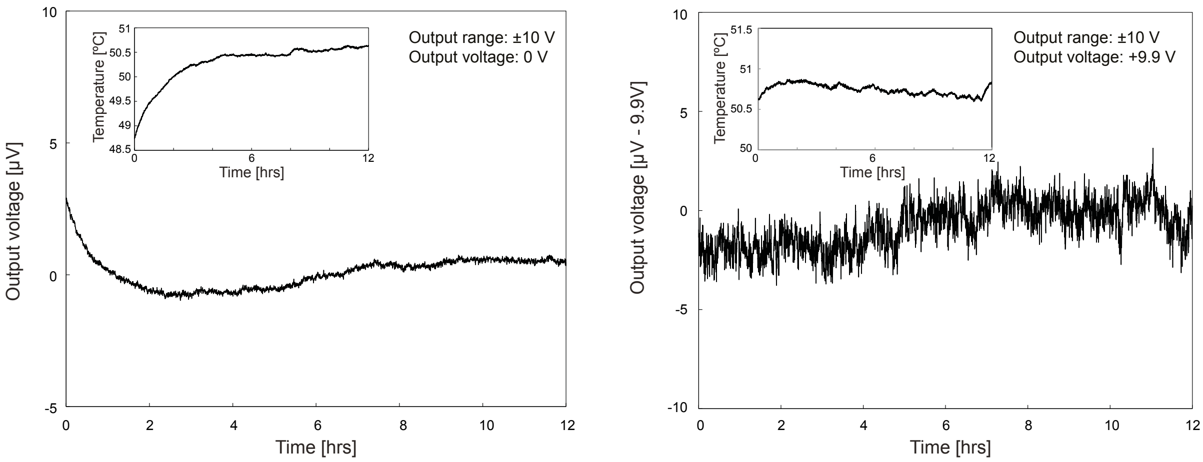


Figure 24: Output drift measurement over 12 hours. The left plot is for 0 V output voltage, the right plot for +9.9 V. The 9.9 V offset has been subtracted in the right plot. Insets show the internal temperature of the SO5, not the ambient temperature. Larger noise in the right plot is due to a different sensitivity setting of the DMM.

Note that the general signal drift reflects changes of the internal temperature of the SO5, with an increase in temperature leading to a slight decrease of the output voltage. The DMM has a temperature coefficient of (0.3 ppm of reading + 1 ppm of range)/°C in the 100 mV input range setting (left image above) and (0.3 ppm of reading + 0.1

ppm of range)/°C in the 10 V input range setting (right image above), meaning about 100 nV/°C and 4 µV/°C resp. for the above measurements. The DMM contributes therefore to up to about 4% and 20% of the temperature drift of the above measurements. However, most of the drift for 0 V and 9.9 V output is determined by the change in internal temperature.

Additionally, the drift of the output voltages has been measured over a period of 48 hours. The data are also included in the table below.

Output voltage	**12 h**			**48 h**		
	drift	**Max. internal ΔT**	**T-induced drift**	**drift**	**Max. internal ΔT**	**T-induced drift**
0 V	< 1.5 µV*	0.6 °C	≅ 1.56 µV	< 3 µV	1 °C	≅ 2.6 µV
9.9 V	< 6 µV	0.3 °C	≅ 9 µV	< 13 µV	1.4 °C	≅ 42 µV

*after reaching a stable temperature state

Table 9: Drift of the SO5 outputs measured during 12 and 48 hours. The T-induced drift column indicates the maximum drift expected from the temperature coefficient.

Temperature coefficient

The temperature coefficient is determined by changing the environment temperature and recording both the output voltage (AO1) and the internal temperature of the SO5. The measurement is performed for 0 V, +9.9 V and -9.9 V output (not shown for -9.9 V output). For negative voltages the temperature coefficient is negative, while for positive voltages it is positive.

Note: The temperature coefficient is determined with respect to the internal temperature of the instrument. The internal temperature varies considerably less than the external temperature, meaning that the temperature coefficient is smaller when based on the environment temperature.

Note: During normal operation, the SO5 reaches a typical operating temperature of 38 – 45 °C. The temperature coefficient around the operating temperature is lower than the worst-case value given below.

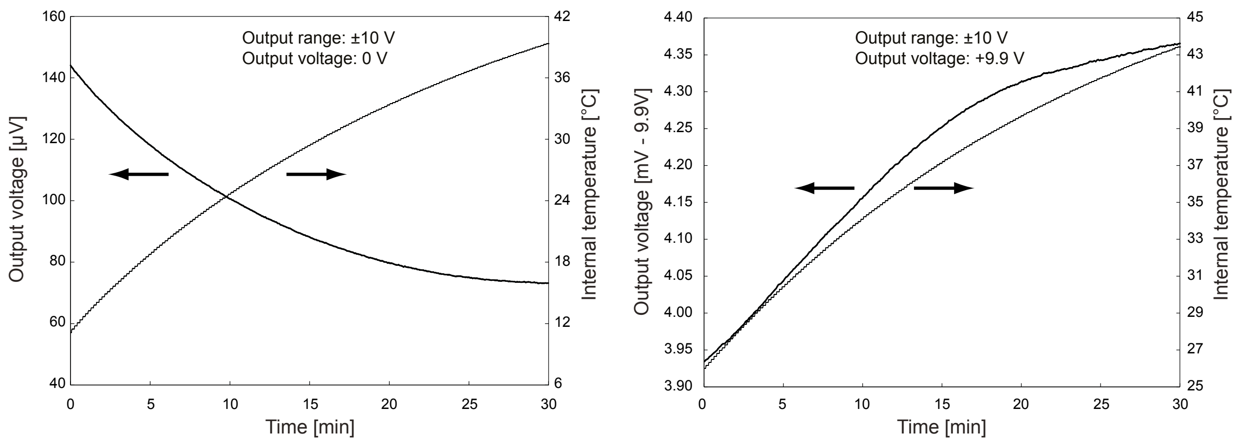


Figure 25: Temperature dependence of the output voltage on the internal temperature of the SO5. The left plot is for 0 V output voltage, the right plot for +9.9 V.

Output voltage	**ΔT**	**ΔV**	**Tc**
0 V	28 °C	< -72 µV	< -2.6 µV/°C
9.9 V	15 °C	< 0.45 mV	< 30 µV/°C
-9.9 V	22 °C	< -0.46 mV	< -21 µV/°C

Table 10: Temperature coefficient of the analog outputs.

Analog outputs AC performance measurements

Frequency response

The frequency response of the analog outputs is measured with AO1 of the SO5 connected directly to a *National Instruments 4071* PXI digital multimeter operated in DMM mode, which has an analog bandwidth of 300 kHz.

The following settings were used for the measurement:

SO5		**DMM**	
Measured output:	AO1	Mode of operation:	DMM, AC volts
Output amplitude:	1 V	Range:	5 V
Output waveform:	Sine wave	Resolution:	22 bit

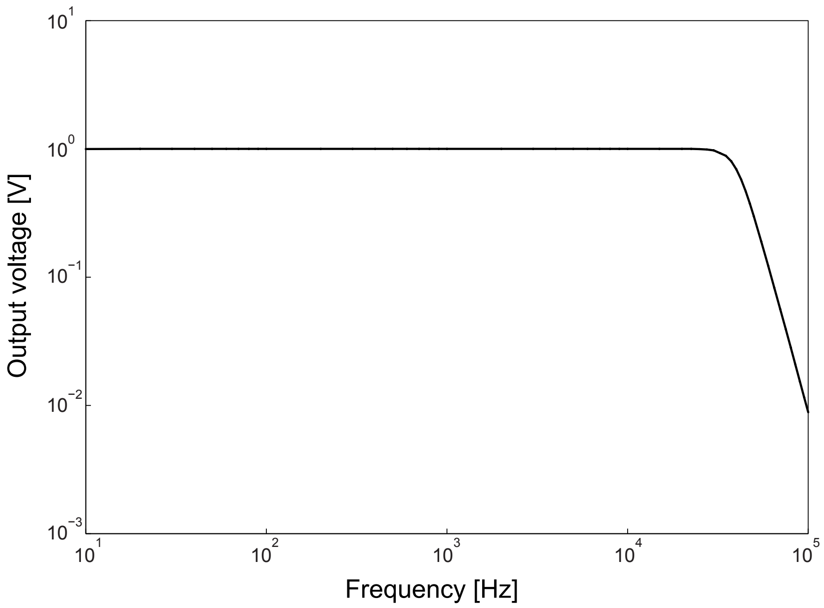


Figure 26: Frequency response of the SO5 analog outputs from 10 Hz to 100 kHz.

Linearity

Linearity is measured with a *National Instruments 4071* PXI digital multimeter operated in digitizer mode at 5 kS/s connected to AO1. The sinewave has a frequency of 100 Hz and amplitudes ranging from 10 V (0 dBFS) to 10 µV (-120 dBFS). The following settings were used for the measurement:

SO5		**DMM**	
Measured output:	AO1	Mode of operation:	Digitizer, AC volts
Output signal:	Sine wave	Range:	10 V, 1 V, 100 mV
Frequency:	20 Hz	Sampling rate:	5 kS/s and 100 S/s
		Resolution:	18 bit and 22 bit

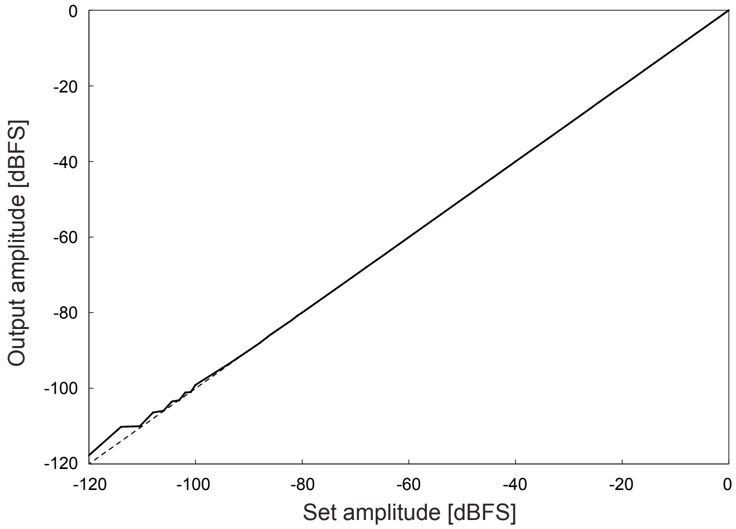


Figure 27: Linearity of the analog outputs of the SO5. The dotted line corresponds to ideal linearity.

Crosstalk

Crosstalk between two adjacent output channels is measured with one output connected to a battery-powered Stanford Research Systems SR560 low-noise differential preamplifier set to gain 1000 and to a *National Instruments 4071* PXI digital multimeter operated in digitizer mode for recording the spectrum, while the adjacent output is set to 1 V and 10 V output amplitude. The following settings were used for the measurement:

SO5

Measured output:	AO1
Driven output:	AO2
Output amplitude:	1V and 10 V

DMM

Mode of operation:	Digitizer, AC Volts
Range:	1 V and 100 mV
Samplig rate:	100 S/s - 40 kS/s
Resolution:	18 bit, 22 bit

Frequency	Crosstalk amplitude (1 V)	Crosstalk amplitude (10 V)	FFT resolution
10 Hz	< 50 nV/√Hz	< 50 nV/√Hz	25 mHz
100 Hz	< 50 nV/√Hz	< 50 nV/√Hz	50 mHz
1 kHz	< 50 nV/√Hz	< 50 nV/√Hz	50 mHz
10 kHz	< 200 nV/√Hz	< 2000 nV/√Hz	0.25 Hz

Table 11: Crosstalk signal amplitude of the analog outputs of the SO5 for a signal amplitude of 1 V and 10 V on the output adjacent to the measured channel.

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1.1 Manufacturer: SPECS GmbH
Voltastraße 5
13355 Berlin / Germany

1.2 Designation of the products: Nanonis Signal Output
Nanonis Tramea Signal Output

1.3 Model: SO5, TSO

1.4 Part Number: 2100011428, 2100011429

We declare under our sole responsibility that the product mentioned above fulfills all the relevant provisions of following EC directives:

- 2014/30/EU Electromagnetic Compatibility
- 2014/35/EU Low Voltage Directive
- 2011/65/EU RoHS 2

Applied harmonized standards:

EN 61326-1: 2013	Electrical equipment for measurement, control and laboratory use - EMC requirements - Part 1 : General requirements.	
Emission:	EN 55011, CISPR 16-2-1	Conducted Emission
	EN 61000-3-2	Harmonics
	EN 61000-3-3	Voltage changes, fluctuations and flicker
Immunity:	EN 61000-4-2	Electrostatic discharge
	EN 61000-4-3	Radiated rf electromagnetic field
	EN 61000-4-4	Burst immunity test
	EN 61000-4-5	Surge immunity
	EN 61000-4-6	Immunity to conducted disturbances
	EN 61000-4-11	Voltage dips and interruptions
EN 61010-1: 2010	Safety requirements for electrical equipment for measurement, control, and laboratory use - Part 1: General requirements.	

Berlin, 17.07.2017 ppa. Ol Schaff
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