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BS / BSA Series

Precision Multichannel Voltage Source

BS-Series_Voltage_Source_v3_0.doc
28. Oct 2018

User Manual

Rev. 3.0

Features:

- **Very low-noise DC voltage source, 2 to 16 channels**
- **Few millisec. response time**
- **+/-0.1V to +/-14V versions**
- **Simple plug-and-play USB-connectivity**

Applications:

- **Quantum computing**
- **Solid state physics / semiconductor testing**
- **Cryoelectronic Biasing**

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1. General Information and Overview

1.1 Purpose and Description of the Device

BS and BSA Series devices provide very precise and stable voltages up to +/-14V with internal resolution of 16Bits (BS) or 19Bits (BSA). Unlike DC *power* supplies, the output currents are limited to small values, and the outputs are optimized for high stability (ppm level), low noise and low temperature drift. The typical response time is only a few milliseconds, making it suited for Quantum Computing or precision testing applications. The device is housed in a standard 19-inch rack-mount case. User control of the device is accomplished by PC control programs, utilizing a standard USB connection (USB 2.0 compatible). The programmed voltages and measured output currents are displayed on the front LCD display. The measured output voltages and currents can be read back, which allows the devices to be used as source-meter units.

Typical applications, using the high stability (ppm level) of this devices are

- Quantum Computing
- Nano/Cryo Electronics
- High Precision Experiments

1.2 Functional Principle and Block Diagram

The following picture displays the internal structure. A USB interface receives commands from a PC, which are translated into output voltages on e.g. 4, 8 or 16 channels. Voltages and corresponding output currents are displayed on the front display. In case an output is not able to establish the desired voltage, or if a current overload occurs, indicators on the user interface will signal a fault. All outputs can deliver both voltage and current polarities, negative as positive (4-quadrant operation).

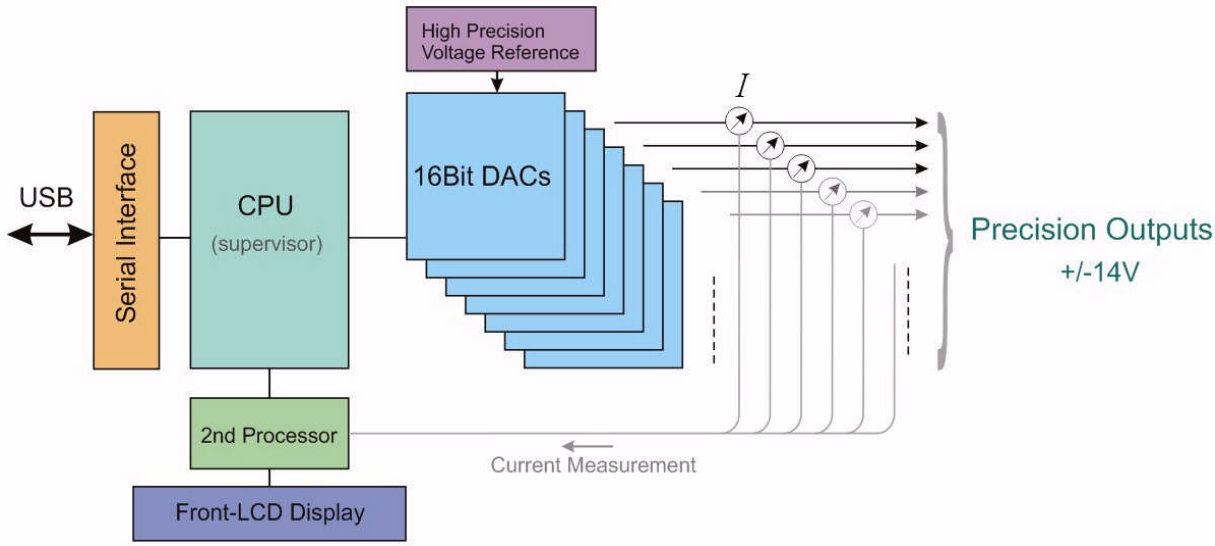

Fig. 1.1: Illustration of internal structure (simplified, BS version, the BSA version has 19Bits of resolution)

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1.3 Device Variety

The following devices are currently members of the BS and BSA series device family.
For higher voltage ranging up to 1000V please refer to HV series (see manufacturers homepage).

BS-series (16Bit resolution):

BS 1-2 (2 channels)
BS 1-4 (4 channels)
BS 1-8 (8 channels)
BS 1-10 (10 channels)
BS 1-16 (16 channels)

each available with fixed range of +/-0.1V, +/-1V, +/-5V, +/-10V, +/-14V

BSA-series (19Bit resolution):

BSA with one, two or four channels and fixed ranges of
+/-2V, +/-5V, +/-10V, +/-14V, +/-40V

2. Safety Hints

Observe installation, operation, and safety instructions	Prior to operation, thoroughly review all safety, installation, and operating instructions accompanying this equipment.
Rear side switch turns device completely off	If the device is not in use for a longer time, it is recommended to turn the mains switch at the *rear* side off, otherwise the device will not be completely separated from the mains supply.
Observe correct Mains Supply voltage	**Attention**: **Apply only correct mains voltage.** Observe supply voltage rating on rear side of device, being either 230Vac or 115Vac of mains supply. Incorrect voltage can destroy this device and can cause overheating and fire !
This equipment must be connected to earth safety ground	This product is grounded through the grounding conductor of the power cord. To avoid electrical hazard, the grounding conductor must be connected to protective earth ground.
Do not modify the unit	Do not make electrical or mechanical modifications to this unit, which are not authorized by the manufacturer.
Do not operate in wet/damp conditions	To avoid electric shock hazard, do not operate this product in wet or damp conditions. Protect the device from humidity or direct water contact.
Disconnect power before servicing	To avoid electric shock, disconnect the main power by removing the power cord prior to any servicing.
Do not block chassis ventilation openings	Slots and openings in the chassis are provided for ventilation purposes to prevent overheating of the equipment. Case vents should continuously be cleared in order to ensure proper operation and to prevent overheating. If mounted in a rack, please allow 2cm clearance at the top cover with respect to the next device above. By means of software, the internal temperature sensor can be read out. A temperature over 55°C indicates inadequate air ventilation. Additionally a second sensor can be read out in the display's protocol mode (see section 4.1).
Beware of external magnetic fields	As it is common for most electronic devices, external magnetic fields can impair, damage or even destroy a device. A maximum external field strength of 5mT is admissible and must never be exceeded. This holds for static as well as alternating fields. If in doubt, check possible external field e.g. with a hall probe before switching the device on. In case an external field strength of 5mT is exceeded, once or permanently, the device may overheat or cause

	excessive power consumption.
Operate carefully with respect to risk of electrical shock	In case the floating ground input is used, the internally produced voltage adds up to the externally applied. Voltages above +/- $100V_{DC}$ therefore may appear at the outputs which are harmful in case of direct touch with the human body, or which may endanger other sensitive devices.
Routinely cleaning from dust	After long operation, or operation in a dusty environment it is strongly recommended to have the internal parts of the device cleaned by the manufacturer, or an appropriately qualified workshop in order to ensure proper operation and reduce the hazard of overheating.
Only operate with working air fan	The ventilation fan located at the rear side of the device always needs to work to ensure proper cooling. Please refer to section 6.
No outdoor operation	Outdoor operation of the device is not admissible.

3. Installation

3.1. Mechanical and Electrical Installation

Positioning: Sufficient air cooling should be provided to the device. Rack mounting into a standard 19" rack is as well possible as resting the device on a table. Case vents must be cleared (fan inlet and air outlet at rear side), in order to prevent overheating or thermal drifts. If in doubt about the sufficiency of air ventilation, provide a software readout of the internal temperature sensor for regular inspection, e.g. every 2 minutes. Alternatively the temperature of a second sensor can be read by switching the display to the protocol mode (see section 4.1, below).

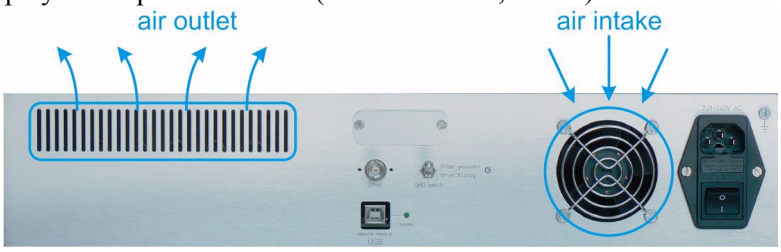


Fig. 3.1 Keep air vents always clear to ensure ventilation

Connecting to mains power:
Connect the device to the mains power supply by using an appropriate power cord, being properly wired and providing a grounded outlet. The power cord must be suited with respect to possible load currents and should be rated to at least 1A current. **Attention**: Observe Supply voltage rating on rear side of device! The voltage rating is either $230V_{ac}$ or $115V_{ac}$ of mains supply. **Apply only correct supply voltage.**

Cabling of voltage outputs:
Always provide appropriate cabling to the device, shielded cables are preferable to ensure avoidance of external noise pickup. In case the reference ground is floated always be aware about the potential hazard of high electrical voltages to human beings and sensitive objects of all kind (see also safety hints in section 2).

USB connection:
Use a standard type-A-B connection cable (USB 2.0 standard) to connect the device to the control computer. After connecting to a PC under Windows, the "Found New Hardware Wizard" should open (see next section for detailed description), regardless if the device is already switched on or not, since the corresponding receiver inside the device is powered by the USB bus itself and therefore autonomous. Cable length can be prolongated using an appropriate USB hub or repeater.

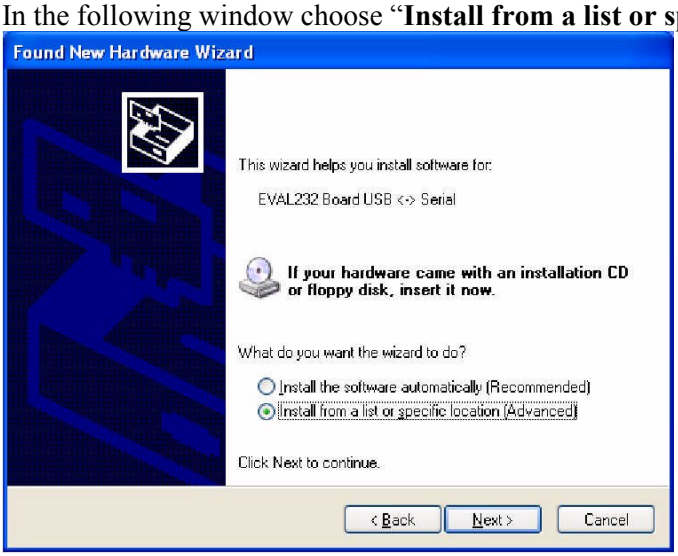
3.2. Software installation

3.2.1 USB-Driver

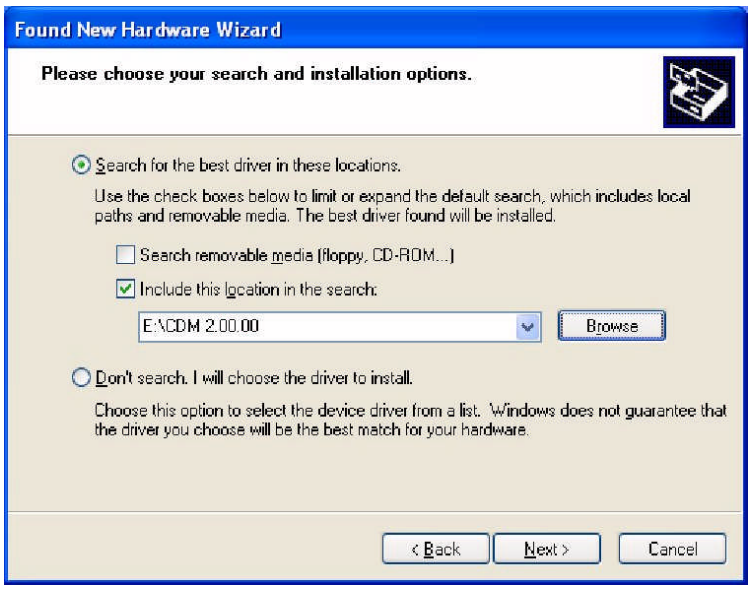
The device uses the USB bus for connecting to a control PC. After proper cabling of the USB connection (see section before) the "Found New Hardware Wizard" under Windows should open up. Depending on the Windows version allow a few seconds to automatically identify the connected device and install drivers, or follow the described steps below. The automatic or manual installation will install the USB-CDM drivers from FTDI Ltd., which is the manufacturer of the USB bus interface circuitry.
The supplied installation CD provides suitable drivers for operation under Windows XP. Latest drivers, also for different other operating systems (Linux, Mac OS, other Windows versions) can be downloaded from http://www.ftdichip.com/FTDrivers.htm. Note that the device appears as a RS232-controlled device, communicating with standard settings (9600 Baud, 8N1 protocol, no handshake) or 115200 Baud, or others on request (see also appendix).

Execute the following steps after start of the "Found New Hardware Wizard":

In this screen activate the last button "**No, not this time**" and continue with "**Next**".
In the following window choose "**Install from a list or specific location**" => "**Next**"



Afterwards choose "Search for driver in these locations" and "Include this location in the search". Browse now to the provided Installation CD and select the appropriate path with the USB drivers.

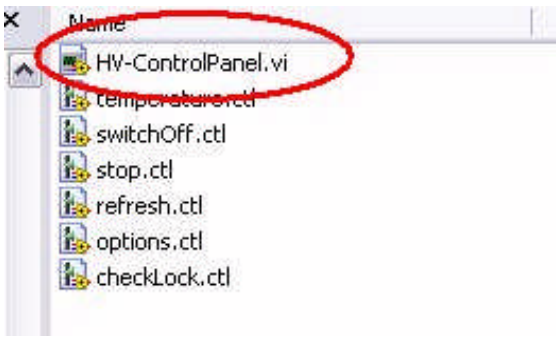


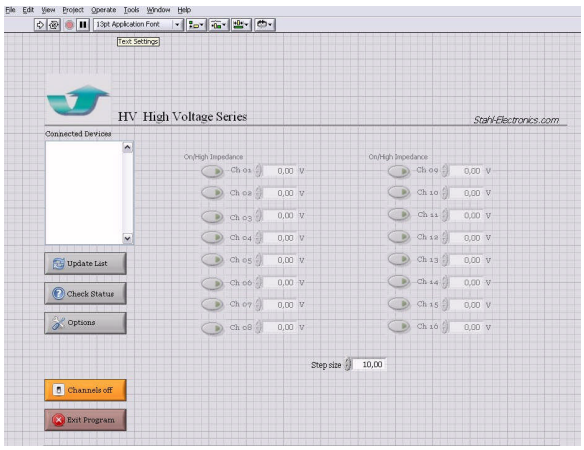
Click “OK” and “Finish” to complete the first driver installation.

After a few seconds the first window will show up **again** (“Found New Hardware Wizard”). This is because the drivers come in two separate parts, which **both** have to be installed. Go through the installation steps in the same way as before. After completion, the USB drivers are ready for use and Windows indicates this by showing “Device Ready” (or similar) in the lower right screen corner for a couple of seconds.
Windows usually recommends to restart Windows now, but normally one can skip this point. Nevertheless note that the PC should be restarted *before* installing any other piece of hardware or software.

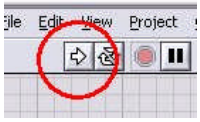
3.2.2 LabVIEW™ control program

A LabVIEW™ based control program is used to operate the device. Its operation is described in section 4.2. Its installation assumes that the LabVIEW™ development environment in Version 8.2 or higher is available on the target PC (if this is not the case, please see below). Copy the path containing the LabVIEW™ source code VI’s from the installation CD to a proper place of your choice on a local drive. To start it, double-clicking on the file





"ControlPanel.vi" in the path "ui" ("User Interface") the control panel for HV and BS Series devices will open, which can immediately be started by clicking on the



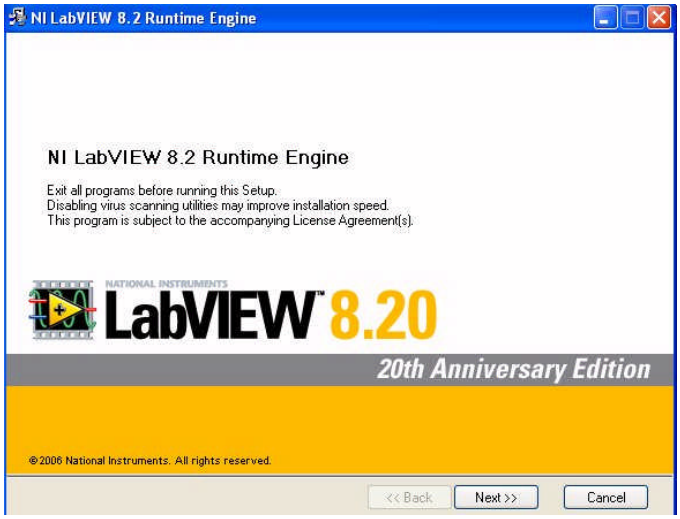
start-arrow in the upper left corner.

→ For details see also section 4.2.

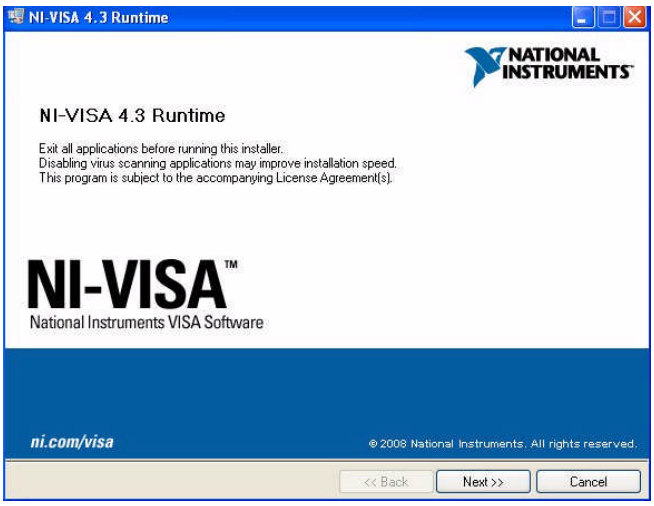
In case that the LabVIEW™ development software in version 8.2 or higher is **not** available on the PC, which controls the device, there is a second option. The "LabVIEW™ run time engine" can be installed from the installation CD and the application program (containing the control software for the HV-Series and BS-Series devices) can be run subsequently as stand-alone program. In this case modifications of the control software or implementation in own programs are not possible but the completed software can be used unchanged in the version as it is. Please contact manufacturer for more details and possibilities, in case any changes of the program are desired.
To install, launch the **LabVIEW™ Runtime Installer Wizard**, and follow the instructions.

RuntimeEngine File Icon

You will be requested to choose an installation directory and location for unzipping the required files.



Furthermore (in case not installed before) the **National Instruments VISA drivers** need to be



installed, which enable the LabVIEW™ software easy access to the PCs hardware resources. After completion of these two installations, the control program can be run in the executable file version without having the LabVIEW™ development environment installed.

3.2.3 Self-written Code

It is easy to access the device by self-written program code, simple commands in plain text style (ASCII) can be used to set voltages, query the status of the device, retrieve voltages and currents and so on. These commands are described in the appendix (see end of this manual), are simple, and can be sent using own programs (apart from LabVIEW™) via e.g. C++, Python, BASIC or Pascal/Delphi dialects. The physical connection to the device needs to be established beforehand, like described above, section 3.2.1 .

Typical execution times for commands are in the order of 1 to 30ms, depending on the chosen speed rate (COM port settings), but also limited by the PC operating system and USB latency times (see also Appendix Section for further details).

4. Operation and Control Elements

4.1 Elements on the front plate

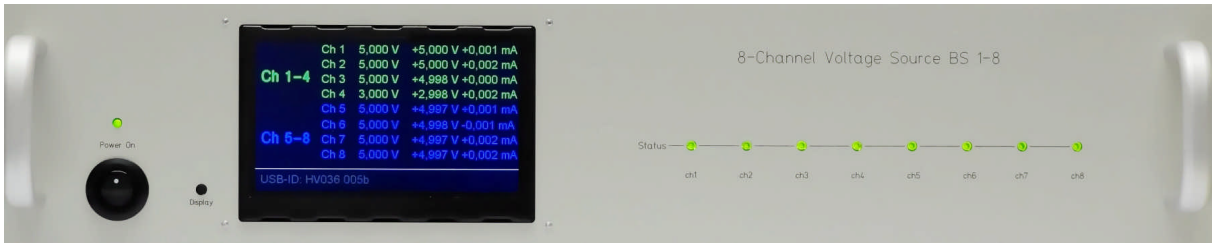


Fig. 4.1: Front side of device

The device is powered up after flipping the power-switch on the rear-side and also the **mains-button** on the front plate. The **Power-on-LED** (green) indicates proper operation of the internal supply circuitry. If the device is not in use, it is recommended to use the rear side mains switch to cut it completely off from mains supply for safety reasons.

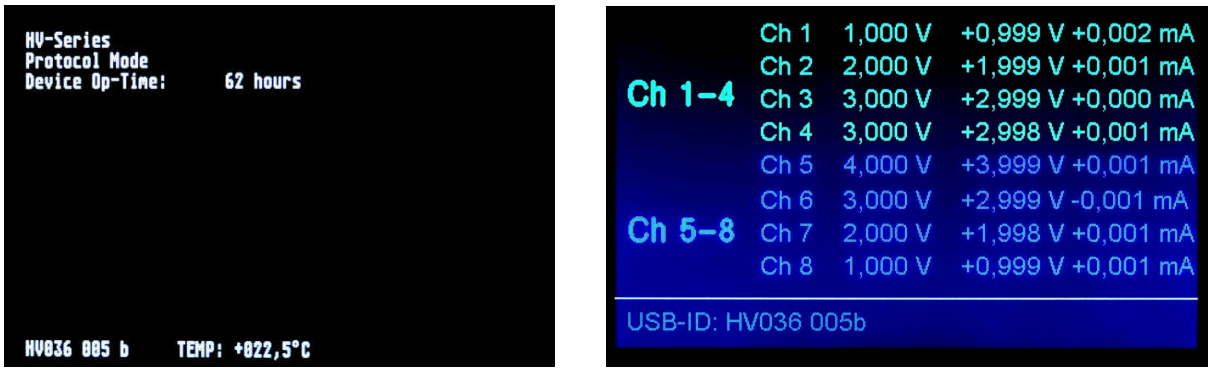


Fig.4.2:
Pressing the "LCD-display key" toggles the display view between two possible states: Protocol Mode (left) and Voltage Mode (right). As an example the right pictures shows an 8-channel BS-device. Screen appearance differs slightly depending on device variant.

The **LCD display** shows information about received commands and the latest voltage settings for the output channels. It can be run in two modes: In the "Protocol Mode" all commands, which are received via the USB connection are listed, subsequently one after another. Also the device's internal temperature, the total operating hours, device type and USB identifier string are shown. The latter string is sent on request to an interrogating PC in order to state the devices identity. In the "Voltage Mode" all programmed voltages are listed and furthermore all corresponding output voltages and currents, which are measured at the output lines. Please note that the output accuracy surpasses the accuracy of the read-back values shown in the right part of the display. Please see accuracy specifications in section 7 for details. The two display modes are toggled (alternated) by pressing the **LCD-display key** on the front plate. Note that in the protocol mode of the front display a screen contents may need up to 500ms to be updated. In case of frequently sent commands this can result in some commands to be 'swallowed' and not displayed correctly. The LCD display enters a power-save mode after roughly 60 minutes using dimmed backlight intensity. Any press on the LCD-display key reactivates the full backlight again. The programmed voltages are provided on BNC, SMA or Sub-D output connectors on the front or rear plate, depending on the chosen option. Please note that the floating GND option can shift (offset) the output voltages by using the offset input at rear side. The display shows only the internally created voltages, and does not take into account any externally added offset voltage.

In case an overcurrent condition occurs (threshold is normally set at a current limit value of about 7.9mA) this is indicated by highlighting the value of electrical current in the corresponding display line (see picture below). In devices with LED status indicators on the front plate, the corresponding

LED will turn red. These LED indicators are normally green and only become red in case of an internal malfunction or in case of an output current exceeding the set limit. Please note that the LED indicators are an additional option. The overload status is also displayed in the window of the device control program (see section below) and can be interrogated by a dedicated software command.

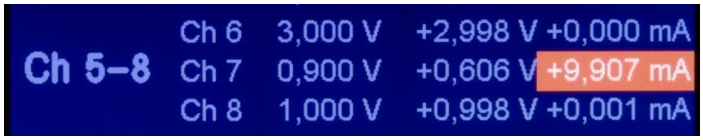


Fig. 4.3: In case an output current exceeds the defined limit, the corresponding current value is highlighted in red. If installed, additional LED indicators show each channels status. E.g. ch7 is ”red”, indicating an exemption.

A **manual (digital) control wheel** may be used to set voltages, in case this option is installed.

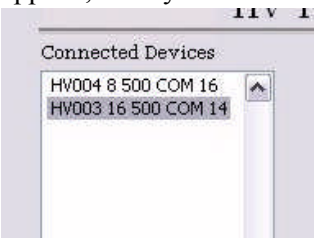
Fig. 4.4: An optional manual control wheel may be used to change voltages

In order to change the voltage of a channel manually, just press the corresponding channel button and change the voltage by rotating the wheel (rotate to the right => voltage more positive, vice versa) in digital steps. The digit to be changed is selected with the buttons below the wheel and indicated at the LEDs above the wheel. Pressing the wheel (instead of rotating) has the same effect as selecting the next *right* digit (i.e. selecting higher resolution).
Note that this manual mode can be operated completely in parallel with commands sent by a PC. Therefore there is no dedicated mode-selection (manual/remote) as can be found in many other instruments. This feature allows for setting a voltage by the PC, and subsequent ‘fine-tuning’ by hand (or vice versa).
In case the control PC overwrites a channel, which was changed manually before, the LED of selected channel will become dark, to indicate that a change has been established remotely.
To ensure, that the control PC is aware of changes done by the user locally at the device, there are several query commands (see appendix), with which the latest voltage settings can be read back by self-written programs.
Note that the function button has currently the following meaning: Once pressed, a ‘speedy mode’ is enabled, and the manual control will <u>not</u> resume at the last voltage being set by the PC (see also detailed description in appendix). This additional mode has been implemented in favour of even faster control operation, but likely is not needed in most standard application. The 6 LED indicators are illuminated all at the time in this fast mode. Pressing ‘function’ again resets this mode.

4.2 LabVIEW™ Control Software

After starting the LabVIEW™ main VI or application program the following user surface will appear, which can be operated in a mostly intuitive style. Controls for 2, 4, 8, 10, 12 or 16 channels, depending on device version are visible. By modifying the open source code the user can easily change the appearance and functionality.

While starting up, a list of connected devices (upper left corner) will be updated and the program will list all recognized HV- and BS-Series devices inside the window. Please note, that before taking any action the user needs to click once on a listed device to select this one for further operation. This also applies, if only one device is listed but not highlighted (marked in the list).



picture shows a list with two recognized devices inside the displayed list.

The information about the listed devices shows:

- device serial number (e.g.: HV121, for a device with serial number 121)
- the number of available channels on that specific device
- the voltage rating (e.g. 10V), including overrange
- the COM port number, under which the device will be accessible in Microsoft Windows from the PC.

Note, that the driver software on a Windows™ PC will enumerate detected USB devices automatically. This COM port number may vary from PC to PC and does not depend on the connected device itself.

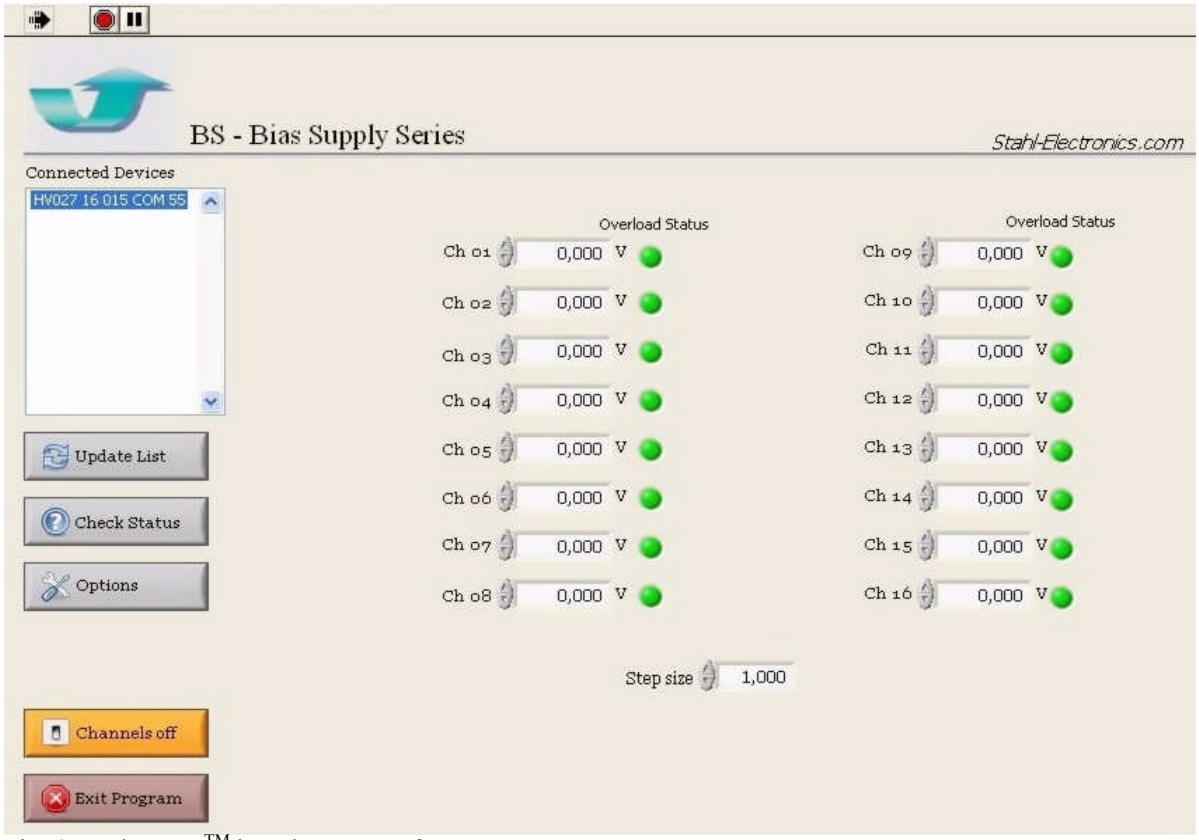


Fig. 4.5 LabVIEW™ based User Interface

If a new device is connected while the program is already running, the list can be forced any time to be updated by pressing the 

button.

Note also, that the correct device communication speed (mostly 9600 or 115200 Baud, see rear side label on device) must be selected with the corresponding selection tab. In case the communication speed has been changed one may also press the 'Update List' button again in order to check the physical connections at the PC. Next right to the list of connected devices, the user can set the voltages of each channel in the numerical control field, either manually by entering numbers or by clicking on

the up/down arrows. A step size can be defined in the control field underneath the voltage input controls for convenience .

At right hand side besides the numerical control field for the voltages, the "Overload Status Indicators" appear. They indicate the status of the circuitry for every channel. As long as the set voltage can be held, the indicator is green. If the pre-defined over-current value of approx. +/-8.6mA is exceeded, it will lighten up red. Depending on LabVIEW settings the control program reads the actual status over the USB bus roughly once per second. A forced and immediate status check is possible, if the user clicks on the 

button.

By pressing the Options Button 

, the user can manually read the device's internal temperature in the subsequent window or enter manually commands to the device (for advanced users, see also the list of commands in the appendix).

4.3 Output Characteristics

General properties

The device features highly stable bipolar low-current DC voltage outputs with low noise, ripple and low temperature drifts. The outputs are of four-quadrant-type, i.e. they can both sink and source currents regardless of the output polarity. Heavy external loads should be avoided, which reach or exceed the device's nominal output current of 10mA on a longer time scale (minutes, hours).
The outputs feature an internal programming resolution of 16 Bits (BS series) or 19 Bits (BSA series). This translates into these approximate resolutions:

output range	approx. resolution **BSA** series	approx. resolution **BS** series
+/-14V	50µV	500µV
+/-10V	40µV	300µV
+/-5V	20µV	150µV
+/-1V	4µV	30µV
+/-100mV		3µV

The output reacts on voltage change commands after a delay (see appendix) depending on the communication speed and with an analog signal rise time (10%-90%) of typically 20µs to 100µs (BS devices) or approx. 1ms to 2ms in case of BSA devices.

Output accuracy, fluctuations and loads

Precision components ensure a very good base accuracy and very low long-term drift, both on a 10^{-5} level and better. Intrinsic short term stability is on a level of several µVolts, corresponding to only a few ppm's (parts per million) with respect to the full voltage span (applies for devices with span greater +/-1V). For details about 12h and 24h-fluctuations see also technical data in section 8 and fluctuation data in section 9, showing the behaviour of the +/-10V-version. Devices featuring other output voltages behave similar, fluctuations essentially scale with the output voltage span.
All outputs feature protection resistors serially to the internal output amplifiers (effectively 50Ω, others on request) which will cause a voltage drop as soon as current is drawn from any output. Please take into account that voltage drop (according to Ohms law) for operation with considerable load currents or for high precision measurements. Heavy capacitive loads (>1µFarad) should be avoided for

stability reasons, especially in conjunction with very long cabling (> 20meters). In cases where higher capacitive loads or longer cabling is required, the addition of about 20 Ohms in each line will ensure better stability. You may also contact manufacturer in cases with longer cabling or heavier loads in order to adapt the output properties accordingly.

Short cuts or other heavy loads at the outputs

Generally all outputs are short-cut proof, with respect to GND-short cuts or short cuts to any voltage between the specified min./max. voltage. Nevertheless shortcuts represent a thermal load on the internal output stages and may impair their life expectance, in case present for longer times. This holds especially, when the optional floating offset input is used (see chapter below), which may increase the current flowing in case of a short cut event considerably. Externally applied offsets larger than +/-5 V therefore may damage the outputs in case of a short cut event, due to excessive thermal load on the output stages.
It is recommended to check the status indicators on a regular base, e.g. latest every 10 seconds by software means (see appendix for software commands). In case of an overcurrent exemption, the corresponding indicator will become "red" indicating a problem and a countermeasure like putting all relevant voltages to safe values is recommended.

5. Floating Ground Option

Using the Floating Ground Option

In case the option for floating ground is installed, the user has the possibility to float the reference ground by a certain amount with respect to the metal case (housing). Two options are available: BNC output sockets floating or non-floating (see diagram below). In first case the BNC shields are connected to the floating GND, in the second case they are connected to the case.

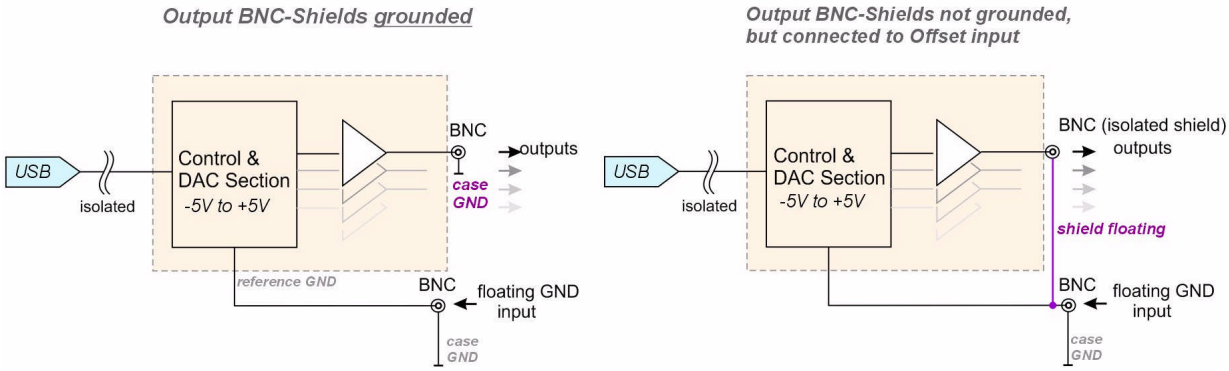


Fig. 5.1 Two floating GND versions are available, with BNC sockets floating or non-floating

Depending on purpose of the device the first or second option may be preferable. Please note that the voltage settings given from the control program refer always to the internal reference ground. The *absolute* value of voltage at any output with respect to the case ground is therefore given by the *sum* of the externally applied voltage at the floating ground input and the programmed value, as mentioned above. The device does not measure the externally applied voltage explicitely. Any voltage on the "floating GND/Offset GND" input places a common offset to all of the voltage values, which are programmed by the user. Voltages within the maximum range of up to +/-100V (damage limit) are applicable to the floating ground input, however +/-30V should not be exceeded normally in favor of least noise, and also dur to safety issues. Please note that the offset input is not indended for applying fast pulses (this can damage the device). A maximum voltage slope of +/-2V/µs is admissible and must not be exceeded.

Fig. 5.2 Rear side view on offset input. In case no external offset is applied, the user should switch the GND selector switch to "Offset

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grounded". This GND selector switch is for safety reasons mechanically locked (unlock by carefully pulling the lever handle).

Please note that if there is no intention to commonly shift all output values by using the Offset-GND input, the respective BNC-plug must be shorted, or the GND selector switch changed to position "offset grounded" (see picture above) in order to force the added voltage to be zero. Care has to be taken in case the reference ground is floated accidentally, since high voltages might charge up and could damage this device and all connected devices/experiments.
Note that the GND selector switch is for safety reasons mechanically locked, and its position can be changed only by carefully pulling the lever a few millimeters outwards before moving.

6. Maintenance and Calibration

The BS and HV Series Voltage Sources are designed for years of reliable operation. Under normal operating conditions, they do not require electrical maintenance, but routinely cleaning of dust, and in longer time intervals, replacement of rear fan (see below).

Routine cleaning

All ventilation openings – top, bottom, sides, and rear panel – should be checked periodically and kept free of dust and other obstructions. A vacuum cleaner may be used to clean these vents when the unit is powered off. Do not use compressed air to clear the vents. The front panel may be cleaned periodically with a clean cloth and alcohol solution, when the unit is powered off. It is recommended to send the device to the manufacturer routinely in 5-year intervals for internal cleaning from dust.

Fan life time and temperature monitoring

The ventilation fan at the rear side of the housing is a part which shows deterioration and finally failure in time. Exchange of this part is recommended after latest 50.000 hours of operation. Please contact manufacturer for replacement after long term operation. Complete failure may severely impair the accuracy specifications due to overheating of the device. Temperature fuses and other protection measures ensure a certain degree of safety against fire hazard in this case. Nevertheless, it is strongly recommended to read out regularly the device's temperature by software means in order to monitor the internal temperature and therefore to ensure avoidance of damage to the device. In the "protocol mode" of the front display the user can also visually check the internal temperature. Values above 55 degree Celsius indicate a possible problem.

Fan speed monitoring

A fan speed monitoring circuit routinely checks the fan rotation speed and gives an acoustic warning signal (intermittent sound) in case of low rotation speed and in case of a fatal failure (permanent warning sound). A few seconds after turning the device on, the warning sounder is shortly active demonstrating proper operation.

Calibration

Under normal operating conditions, the BS Series Voltage Sources will not require regular calibration. However, they can be returned to factory for complete electrical and mechanical inspection and calibration purposes. Calibration by user is also possible using special commands (see appendix).

7. Special Functions

The BS series devices can be equipped with special functions, like supplying cryogenic electronics with PID regulation loops. These functions are defined separately and not inside this manual.

8. Specifications

Output Specifications		
Output Voltage Range	Versions: +/-100mV +/-1V +/-5V +/-10V +/-14V	depending on version: single fixed range +/-100mV to +/-14V, bipolar Note, that approx. 1V of overrange is provided in some devices, e.g. a +/-14V device actually delivers (at low output current) up to +/-15V
Number of Outputs		1, 2, 4, 8, 10, 12 or 16 output lines, depending on device configuration
Output Connectors		BNC sockets (standard), SubD 25pole female, others on request
Output Current	per output	approx. +/-10mA (4-quadrant operation, $\lvert U_{OUT} \rvert$ < 10V) Overload-indication above +/-8.6mA
Output Reference Ground		All outputs share a common GND, which can be floated up to +/-30V vs. case ground (max. +/-100V temporarily); voltage changes must be slower than +/-2V/µs to avoid damage.
Output resistance		50 Ohm +/-3% , at I < 2mA, versions +/-5V to +/-14V 2 Ohm +/-15% , at I < 6mA, version +/-100mV. Special output resistance available on request.
Programming Resolution		BS series: 16 Bits BSA series: 19 Bits

Accuracy	typical error	maximum error	typical drift
% of Setting	0.014%	0.02%	0.001% per day
Offset error Version +/-5V to +/-14V +/-1V +/-100mV	 ±0.9mV ±0.45mV ±15µV	 ±1.8mV ±0.9mV ±50µV	 ±0.05mV per day ±0.01mV per day ±4µV per day
Temperature drift Version +/-1V to +/-14V related to Span related to Offset Version +/-100mV related to Span related to Offset	 BS: 5ppm/K BSA: 2.5ppm/K 15µV/K 20ppm/K 4µV/K		

Output Fluctuations (applies for devices produced after June 2018)	typical	maximum	conditions
Ripple (50Hz, 100Hz) Version +/-5V to +/-14V Version +/-100mV	 BS: < 5µV rms BSA: < 1µV rms < 2µV rms	 18µV rms 11µV rms 4µV rms	 no output current no output current no output current
Noise, 10kHz…10MHz Version +/-5V to +/-14V Version +/-100mV	 ≤ 0.5mV rms ≤ 0.06mV rms		
Low-Frequency Noise, 1Hz…10kHz BSA Version +/-14V	 10µVrms		 50ms internal filter activated
Short/Mid Term Fluctuations @ output voltage 10V, any channel vs. GND, Version ±10V Short Term 1 day Version ±100mV Output at 100mV, Short Term 1 day Offset 1 day	 BS: 21µV pp BSA: 8µV pp 80µV pp 0.9µV pp 20µV pp 4µV pp	 BS: 45µV pp BSA: 20µV pp 150µV pp	-sampling interval 1s- observation period 100s observation period 100s observation period 24h observation period 100s observation period 24h observation period 24h

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Channel separation Version +/-5V to +/-14V Version +/-100mV	typ. BS: 1.2ppm BSA: 0.6ppm 250ppm	max. BS: 2ppm BSA: 1.5ppm 350ppm	static channel crosstalk, no output current drawn
Front Plate LCD Screen, Digital Amperemeter and Voltmeter (Voltage Check)			
Range	+/-100mV or +/-20V, depending on device version and +/-10mA Full Scale		
Accuracy:	typical	maximum	
Scale error	0.5%	1%	
Offset error Version +/-5V to +/-14V Version +/-100mV	50mV or 1µA 50µV or 1µA	75mV or 4µA 90µV or 4µA	
Fluctuations	0.2%	0.3%	observation interval ΔT = 10s
Remote Control / Communication Parameter			
Remote Connection	USB 2.0 compatible connection to PCs, fully galvanic isolation provided. The device acts as RS232-controlled device (8N1 protocol, no handshake), communicating with wither 9600 Baud, 115200 Baud or customized values. Remark: '8N1' = **8** data bits, **n**o parity check, **1** stop bit.		
USB Isolation Rating	max. +/-300V on USB socket vs. case GND		
Command Language	clear ASCII code command codes see Appendix		
Device Response Time	see Appendix		
Software Support	USB drivers are required. Free LabVIEW™ 8.2 based user surface and executable program is provided		
Power Supply			
AC Supply Rating (country depending)	Attention: fixed AC input voltage 230V_{AC} at 50Hz; Fuse: medium fast blow 1A or: AC input voltage 115V_{AC} at 50 to 60Hz; Fuse: medium fast blow 2A Power Consumption typ. 15.6W Note that application of wrong mains supply voltage damages the device. The device contains linear regulators only, no power switchting circuitry.		
Environmental Conditions			
Storage Temperature	-55C° to +105C°.		
Magnetic Field	max. 5 mT admissible		
Humidity & Temperature	non-condensing humidity, temperatures between +10°C and +40°C		
Miscellaneous			
Fan	life time typ. 50'000 to 100'000 hours; acoustic warning in case of failure and low speed.		
Case dimensions	standard rack mount 19.00" wide x 10" deep. Front-panel mounting holes are configured for M6 rack bolts.		
Weight	approximately 3.0 kg, configuration dependent		

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9. Fluctuation Data

Output voltage stability at selected voltages over time periods of seconds, minutes and hours.

9.1 BSA Series

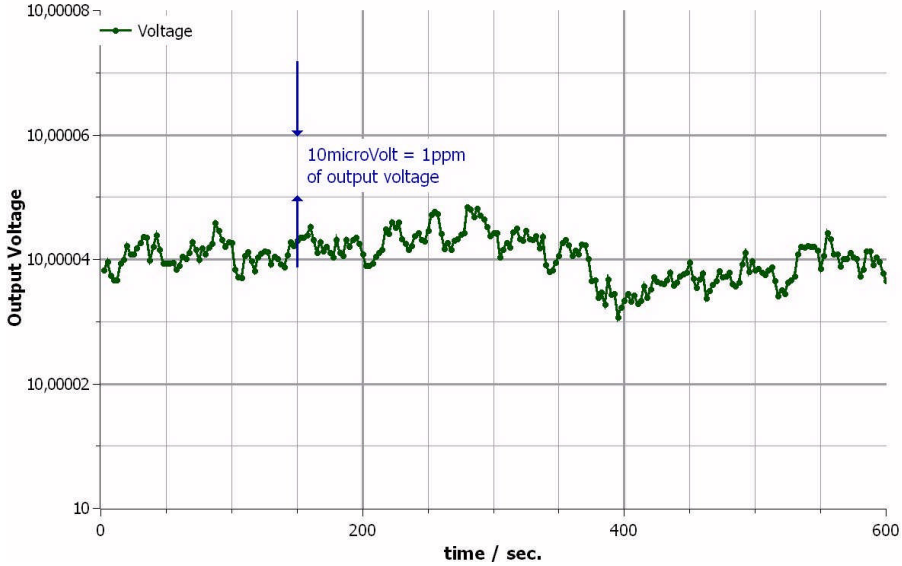


Fig. 9.1: This figure illustrates the stability of an output channel at +10V, BSA series, over a **10-minute** interval. Measurement device was a Keithley 7725 multimeter, 2 sec. averaging per data point. The room temperature has been determined to be constant within +/-0.5K during the measurement.

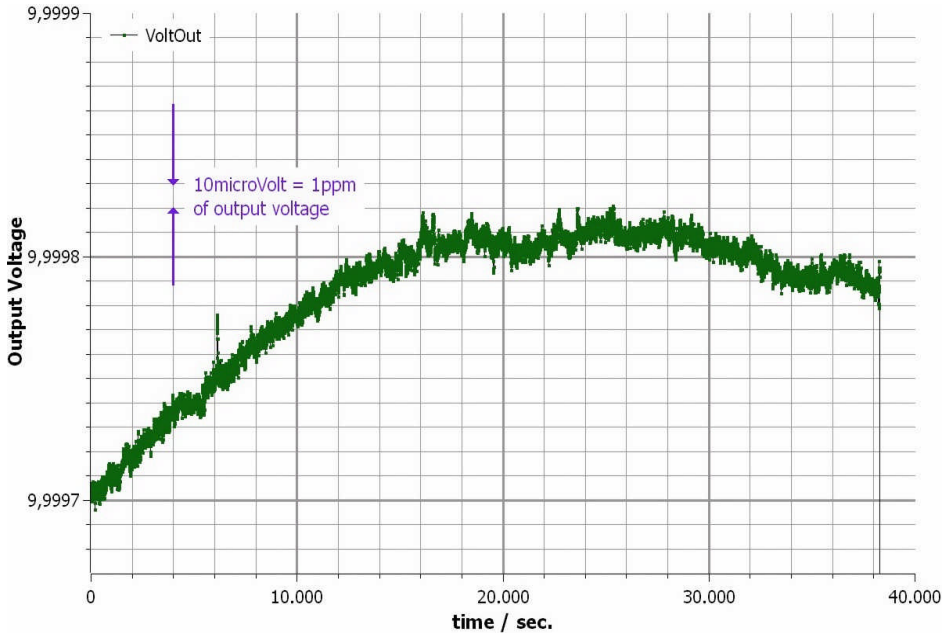


Fig. 9.2: This figure illustrates the stability of an output channel at +10V, BSA series, over a **12 hour** interval. Measurement device was a Keithley DMM7510 multimeter, 2.5 sec. averaging per data point. The room temperature has been determined to be constant within +/-2K during the measurement. The voltage rise in the first third of time period is mainly due to a temperature rise of approx. 2K

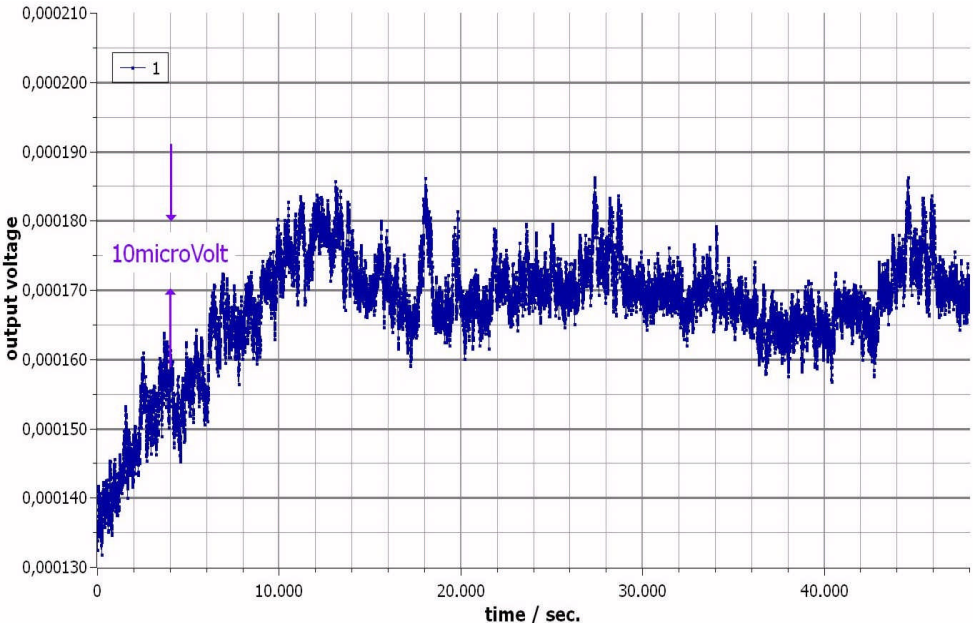


Fig. 9.3: This figure illustrates the stability of an output channel at zero volts, BSA series, over a **12 hour** interval. Measurement device was a Keithley DMM7510 multimeter, 2.5 sec. averaging per data point. The room temperature has been determined to be constant within +/-2K during the measurement.

9.2 BS Series

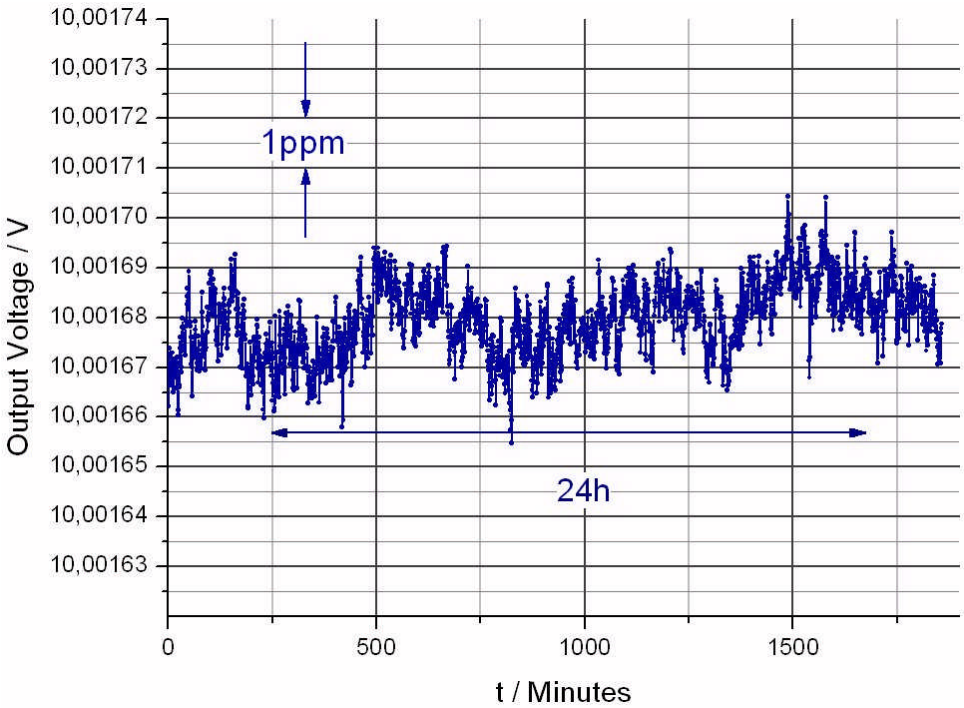


Fig. 9.4: This figure illustrates the stability of an output channel at +10V, BS series, over a 1-day interval. Measurement device was a Fluke 8846A multimeter, 30sec. averaging per data point. The room temperature has been determined to be constant within +/-0.7K during the measurement.

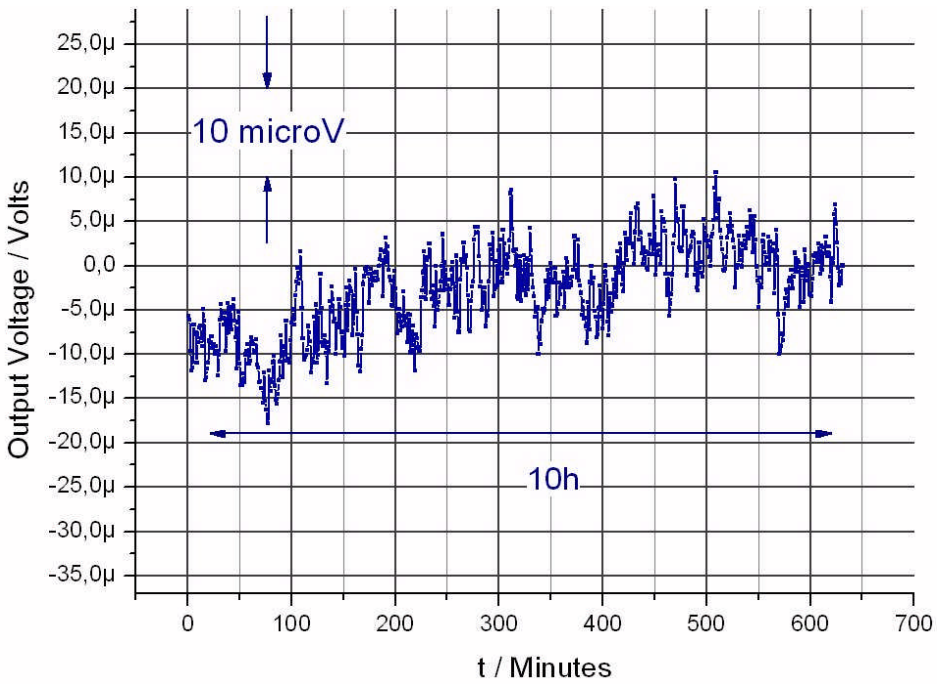


Fig. 9.5: This figure shows a typical offset behaviour (BS series) over a 10-hour interval (output voltage nominally at zero volts). Measurement device was a Fluke 8846A multimeter, 30sec. averaging per data point. Ambient temperature has been determined to be constant within +/-0.7K.

Fluctuation Data (continued)

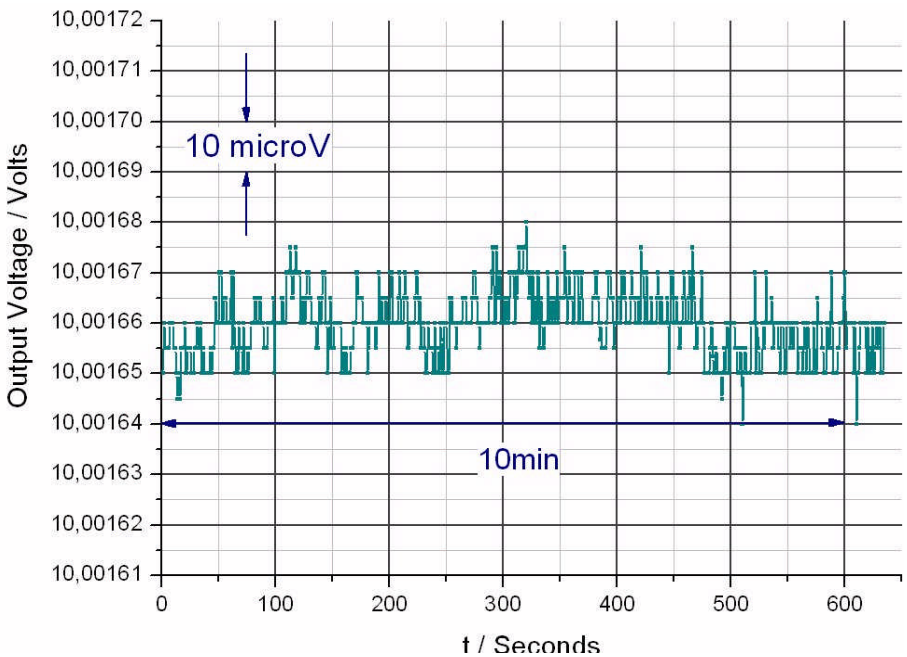


Fig. 9.6: This figure illustrates the short term stability of an output channel at +10V, BS series, over a 10-minute interval. Measurement device was a Fluke 8846A multimeter, 0.5sec. averaging per data point. One measurement point was taken every second.

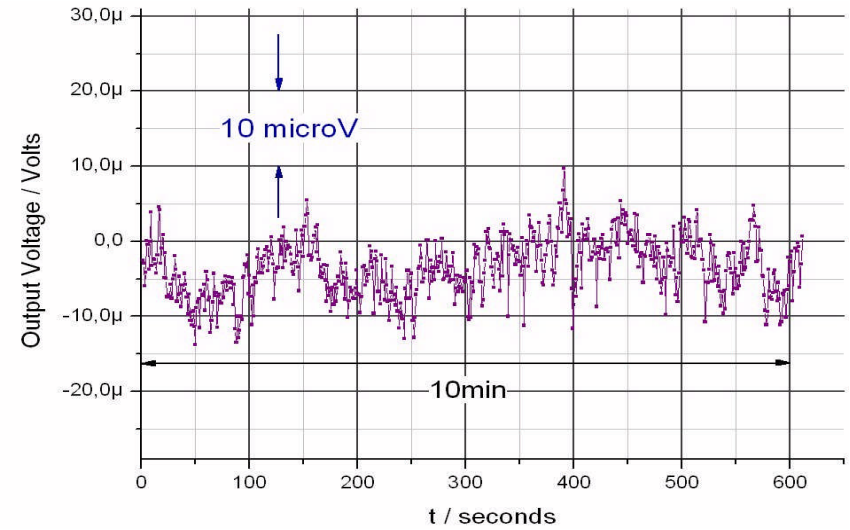


Fig. 9.7: The typical short term stability of an output channel at 0V is shown here (BS series). Measurement device was a Fluke 8846A multimeter, 0.5sec. averaging per data point. One measurement point was taken every second.

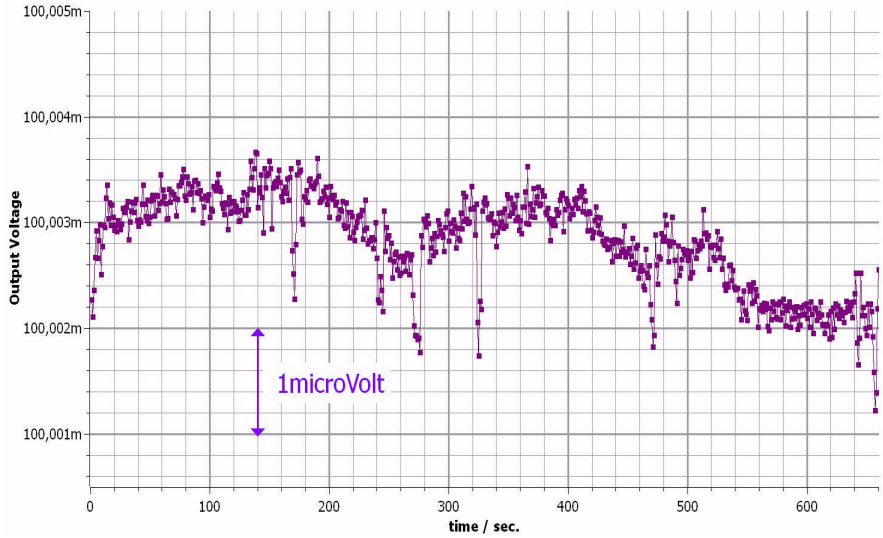
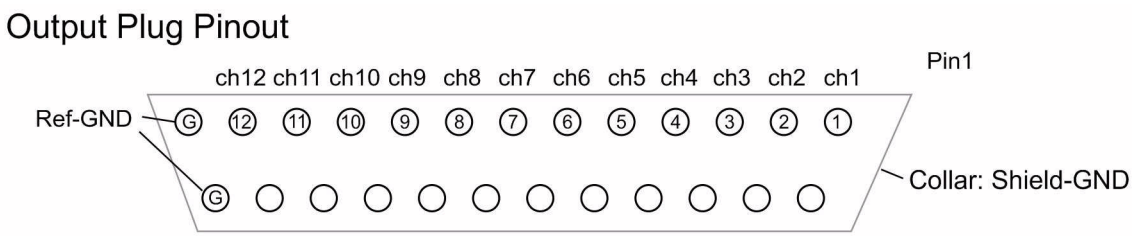


Fig. 9.7: The typical short term stability of a 100mV device, at 100mV is shown here (BS series). Measurement device was a Keithley DMM7510 multimeter, 1sec. averaging per data point.

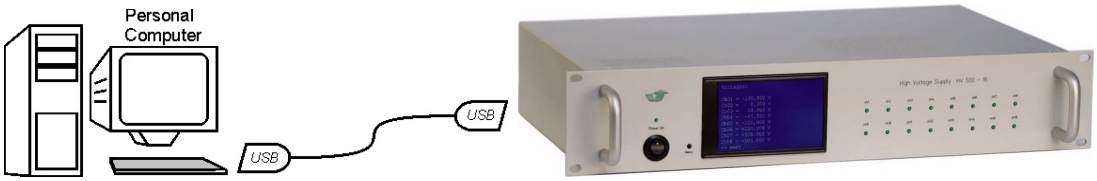
10. Output Connector Pinout (SubD)

(available as special ordering option, other pinouts or connectors on request)



25pole SubD-Pinout, female

Appendix



User-Defined Remote-Control

The device can be controlled in an easy way using the provided LabVIEW™ source code blocks, or by self-written program code. Standard program compilers/interpreters like C++, BASIC or Pascal/Delphi dialects may be used for own code writing, also generic command-line terminal programs (e.g. HyperTerminal™) will do. However, the physical line connection to the device (USB-connection) needs to be established beforehand, like described in section 3.2.1. USB-drivers for Windows™ versions, Mac OS and Linux are readily provided. Please check eventually the USB-manufacturers homepage (www.ftdichip.com) for latest updates.

Note that the physical communication behaves like a traditional RS232 device, communicating with standard settings (9600 Baud, 8N1 protocol, no handshake) or with faster settings (like 115200 Baud, others in case customized). If a faster speed option is installed (denominated as 'fast mode' in the table below), the latter is marked with a label at the rear side USB socket. In self-written code the 115200 Baud rate parameter (or faster) needs to be set explicitely, since 9600 Baud is Windows standard otherwise. In Windows™ operating systems the device appears on a 'COM'-port (VCP = virtual COM port), as soon as connected to the control PC after driver installation. The COM-Port number is assigned by Windows upon connecting the device by USB cable and may change from time to time. The COM-Port settings may be checked inside the Windows™ system control panel .

Command List

In the table below the abbreviation "DDDDD" represents the name of the device including its serial number, e.g. "HV099" means a device with serial number "099". All commands must be terminated with an CR ('carriage-return') symbol "↵" (13 in ASCII code). After establishing the USB link to the device and turning it on, the IDN identifier should be sent in order to retrieve the serial number, since this serial number will be used to address the device correctly during the subsequent commands. See also examples and more details after the table.

Command Function	**ASCII Strings** sent to device or received + CR ('carriage-return') at string ends	**Observations and comments**
Identify device	sent IDN received DDDDD … … …	The device replies with its name, serial number (DDDDD) and further information. See also examples below this table.
Set voltage	sent DDDDD CHXX Y.YYYYYY received (normal mode) CHXX Y.YYYYYY received (fast mode) [ACK-Symbol]	An output voltage is set. XX is the adressed channel number (01 up to 16), Y.YYYYYY is a decimal number between 0.000000 and 1.000000 which represents the scaled voltage. I.e. 0.000000 represents the minimum voltage (e.g. -14V), 1.000000 the maximum value (e.g. +14V). 5 or 6 or 7 digits after the decimal point are required. In normal mode operation the command sent to the device is reflected (echoed) back. In fast mode operation the command sent to the device is not echoed back but only the acknowledge symbol (ASCII symbol 6) + CR

Query voltage and current	sent DDDDD QXX received +/-yy,yyy V +/- z,zzz mA	Requests read-back of internally measured voltage and current of channel XX (e.g. XX is 01 up to 16 for a 16 channel device, note that XX needs to be a two-digit number). The returned string contains voltage and current including dimensions (voltage/current units). Note 1. The real output values are more precise and stable than the read-back values. 2. For this command, the read-back voltages and currents are updated approx. every 500ms
Query voltage	sent DDDDD UXX received +/-yy,yyy V	Returns the (immediate and forced) read-back voltage of channel XX in Volts. Execution time of this commands is approx. 5 to 6 ms.
Query current	sent DDDDD IXX received +/-yy,yyy mA	Returns the (immediately) measured current of channel XX in milliAmpere. Execution time of this commands is approx. 5 to 6 ms.
Read temperature	sent DDDDD TEMP received TEMP XXX.XºC	XXX.X is the temperature in degrees Celsius, measured at an internal temperature sensor. This value should be regularly checked (e.g. once per minute) while the device is in operation. Temperatures above approx. 55°C indicate a possible ventilation problem or other malfunction. The device should be switched off in this case to prevent serious damage or fire hazard
Check lock status of all channels	sent DDDDD LOCK received $B_3B_2B_1B_0$	Probes all channels to see if any is overloaded. The response is coded into 4 bytes (B_3 to B_0), see also definitions below. If a Bit is zero, then locking is ok, if = 1 then an overload occurred in the respective channel.
String to LCD-display	sent DDDDD DIS L “string” or DDDDD DIS L CHXX “string” received [ACK-Symbol]	Sends a “string” (arbitrary chain of ASCII characters, max. 16 characters long) to the front LCD display of the device. If a channel number XX is transmitted the string will be placed in the line of the corresponding channel XX. Otherwise the string will only be visible in the ‘Protocol Mode’ of the front display. Note that the provided LabVIEW source code uses this command to indicate the set voltages, since the ‘Set Voltage’ command only transmits a scaled voltage, which is not easily readable ASCII text.
Digital Control Wheel (in case installed):		
Request Set Voltage	sent DDDDD Vxx received CHxx y.yyyyyy	Returns the currently set (programmed) voltage: returns CHxx y.yyyyyy, where xx = channel number and y.yyyyyy = scaled Voltage String between 0.000000 and 1.000000, corresponding to min. / max. possible voltage
Identify	sent	Returns an ASCII character for each

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altered channels	DDDDD OW - received "$x_{16}x_{15}x_{14}x_{13}x_{12}x_{11}x_{10}x_9x_8x_7x_6x_5x_4x_3x_2x_1$"	Channel, which was recently changed "$x_{16}x_{15}x_{14}x_{13}x_{12}x_{11}x_{10}x_9x_8x_7x_6x_5x_4x_3x_2x_1$", where x_n : x = "0" or "1", n = Channel number, meaning "0": channel was not manually overwritten "1": channel was overwritten by manual controls. If a channel was manually overwritten the command returns "1" for this Channel until the channel is overwritten by remote control.
Set Fast Mode	sent DDDDD FAST received Fastmode	Sets the fast mode with reduced response time. The manual controls no longer store the voltage send by remote control (PC) in this case. When turning the manual knob the manual voltage will resume at voltage which was set last by manual controls
Set Manual Mode	sent DDDDD MANUAL received Manualmode	Returns from Fastmode to Manualmode. This is the normal operating mode. So, turning the manual knob the voltage will resume at the last manual or remote voltage.
Special Commands for Device Calibration **(**for advanced users only, available as device option)		
Set correction parameters (on an output channel)	sent DDDDD CORR …….. received CORR ……..	Changes the output channel calibration of a certain channel, setting internal correction parameters, in a dedicated LabVIEW control, coding details see below. For adjustment during manufacturing process and later re-adjustment only.
LDC screen and readback calibration	sent DDDDD CUxx yyyy zzzz received CUxx yyyy zzzz (further commands see text below)	These parameters set the span and offset for read-back values of voltage and current. It applies for the values displayed on the front LCD screen as well as for those values retrieved by the Query commands (see above). Details see text below.
The device may reply the following **Error codes:** ERROR01 ERROR02 ERROR03		 - Command not recognized - if channel number out of range - scaled voltage bigger than 1.0000

<u>Hints for digital control wheel operation:</u>

-Normal Operation (Device is in Manual mode):

The user may set voltages via the manual controls. When setting the voltage via remote control the application may take the following steps to retrieve the latest manual setting:

- Send the "DDDDD OW" command and parse the string for a selected channel.
- If the channel returned a "0" no voltage was set manually and the application may send a new Set Voltage command (DDDDD CHyy z.zzzzzz) based on the last known voltage.
- If the channel returned a "1" the application may use the DDDDD Vyy command to retrieve the latest voltage and send a new channel command accordingly.

-Fast mode:

Fast mode may be used to set voltages quicker, since the voltage information is not parsed and stored inside the device. After going back to manual controls, the latter will therefor not resume at the latest voltage, set in fast mode, but at the voltage set last in manual mode or by the manual controls.

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Further explanations and examples

Device identifier, sent back from a device upon request by the "IDN" command:

The identifier string consists of several parts, returning information about the device. Every part is separated from the next by a normal "space"-character:
Example:
"HV023 5 16 b" = "HV" + "003" + " 5" + " 16" + " b"
That means: a HV-series or BS-series device answers, serial number is 023, voltage range +/-5V, 16 channels, and having **b**ipolar outputs. This identifier string is programmed into the FlashRom of every HV / BS series device by factory.
The different string options are:

first string part:	always "HV", also for BS devices
2nd part:	serial number between "001" and "999"
3rd part:	voltage in volts, can be any (integer) number between 1 and 100000
4th part:	number of channels, presently either "2", "4", "8", "10", "12" or "16"
5th part:	"b" like bipolar or "u" like unipolar "q" like quadrupole lens supply, "s" like steerer supply, "m" repesents a bipolar device with 1/1000 ('m' like 'milli' of

the stated number, e.g. 100 m means range of +/-100mV

Command Examples for setting a voltage:

Example a:
The command "HV014 CH02 0.00000" puts channel number 2 on minimum voltage, i.e.
-10V for a device with +/-10V outputs (assuming the devices serial number is 014).

Example b:
The command "HV014 CH02 1.00000" puts channel number 2 on maximum voltage, i.e. +10V for a device with +/-10V outputs

Example c:

The command "HV014 CH02 0.50000" puts channel number 2 on half span between minimum and maximum, which is zero voltage.
All other voltages between "0.00000" and "1.00000" are scaled linearly, e.g. "0.75000" represents 75% of full span above minimum voltage, which is +2.5V for a +/-5V device.

The user is free to choose the number of digits sent after the decimal point from 5 to 7; however, for exploiting the devices internal resolution of 16 Bits (or higher in customized version) at least 6 digits should be used.

Display Command:

The display command shows clear (ASCII) text strings on the front panel LCD display. This is specially of relevance for self-written programs, since the set voltage (command see above) is not automatically displayed as clear visible text on the display. A control device should therefor send two comands if a voltage is changed: the 'set voltage' command (see above) and the 'display command' subsequently. The latter brings clear text to a specified line, e.g. 'HV014 DIS L CH01 10.000V' will show the text string '10.000V' in the line associated with channel number 1. The user may create this string to be sent and also eventually scale it, as certain applications may require. Note that the provided LabVIEW™ program automatically sends this string, each time a voltage is changed.

Coding of the 16 channels/bits into the control 4 bytes $B_3B_2B_1B_0$:

The following encoding is used for the "Check Lock" command.
The first 4 bits (= upper nibble) of every Byte is always 0001 = 16_{dec}. This is in order to avoid certain bit-combinations, which could cause trouble to USB/RS232-based communication (like "enter", "escape").
Next 4 bits (=lower nibble):

in B_3: ch16 ch15 ch14 ch13
in B_2: ch12 ch11 ch10 ch09
in B_1: ch08 ch07 ch06 ch05
in B_0: ch04 ch03 ch02 ch01
For instance B_0 = 0001 0011 means, that 3 and 4 are ok, 1 and 2 not locked (or overloaded).

Output Calibration (advanced users only)

The correction command 'CORR' for output correction is primarily used within the manufacturing process and adjusts correction routines inside the HV or BS series devices for voltage output. The format of the correction command looks like

"HV084 CORR02 0.12345 +0.54321",

which means that the device with (as example) serial number 084 is changed, specially channel number 2 in this case. Both parameters (span, offset) refer to a linear correction, in which the sent voltage is processed and converted to the output voltage of a certain channel. The span correction comes first (0.12345), then the offset correction (+0.54321). These both numbers represent the linear correction. The span correction ranges from 0.00000 to 1.99999 (always 5 digits after the decimal point), and the offset correction ranges from -0.49999 up to +0.49999. For the offset the sign "-" or "+" always has to be sent as well. The decimal point always must be a point and not a comma (". " and not ","). Please contact manufacturer in case correction commands were sent in error, to retrieve the original factory settings, or check calibration settings, being documented in a calibration file.

Readback Calibration (advanced users only, available as additional device option)

In a similar way like the output channels are calibrated (see above), all readback values (voltage, current, being actually measured for each channel) can be adjusted.

There are the following commands available:

HVdddd CUxx yyyy zzzz *device reply*: CUxx yyyy zzzz
This command **calibrates** Span and Offset of **voltage** read back for a certain channel
-"xx" is the channel number (1 to 16)
-"yyyy" is the Span Parameter in Hexadecimal notation (e.g."3DO1")
-"zzzz" is the Offset Parameter in Hexadecimal notation (e.g. "000A")

HVdddd CIxx yyyy zzzz *device reply*: CIxx yyyy zzzz
This command **calibrates** Span and Offset of **current** read back for a certain channel.
-"xx" is the channel number (1 to 16)
-"yyyy" is the Span Parameter in Hexadecimal notation (e.g."3DO1")
-"zzzz" is the Offset Parameter in Hexadecimal notation (e.g. "000A")

HVdddd RUxx *device reply*: yyyy zzzz
This command **retrieves** the **voltage** readback calibration command, being sent before for a certain channel
-"xx" is the channel number (1 to 16)
-"yyyy" is the Span Parameter in Hexadecimal notation (e.g."3DO1")
-"zzzz" is the Offset Parameter in Hexadecimal (e.g. "000A")

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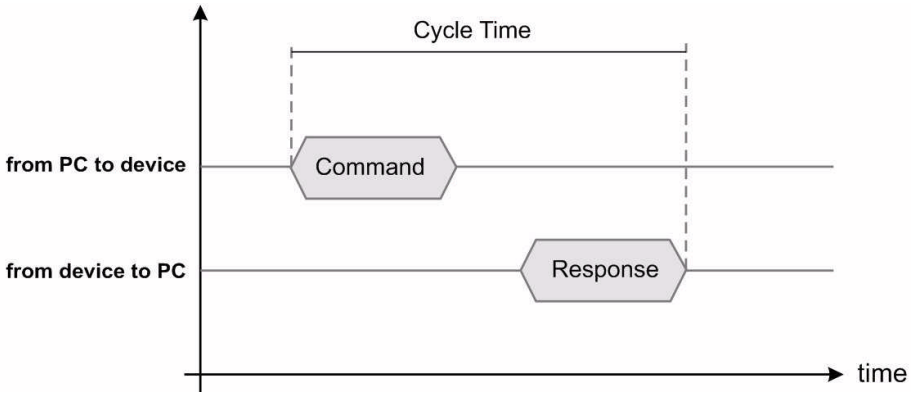
HVdddd RIxx *device reply*: yyyy zzzz“
This command **retrieves** the **current** readback calibration command, being sent before for a certain channel

-“xx“ is the channel number (1 to 16)
-“yyyy“ is the Span Parameter in Hexadecimal notation (e.g.“3DO1“)
-“zzzz“ is the Offset Parameter in Hexadecimal (e.g. “000A“)

In order to apply this readback value calibration it is useful to start with the parameters (factory settings) at time of delivery of the device. These values can be retrieved using the retrieving commands (see above) or checking the calibration file, being shipped with the device (see documentation on CD/memory stick).
The **span** parameter scales (magnifies) the voltage/current values, whereas the **offset** parameters shifts their values; both paramters act in a linear way. Note that the offset parameter is understood as 2-complement after converting the Hexadecimal value into binary notation.

USB Communication Speed

The device is shipped with a certain speed mode installed. Most commonly a transmission speed of 115200 Baud is set.



High speed modes are better suited for quick communication with the device (e.g. for biasing quantum computing experiments or STM/AFM setups), the cycle times for individual commands are listed below for 115200 Baud.

Command	**Cycle Time, 115200 Baud**	
Set voltage	3.4ms	
Query (voltage and current)	4.2ms	(note: voltages and currents are calculated and updated inside the device only twice per sec.)
Query voltage	6.5ms	(note: this command forces immediate voltage reading)
Query current	6.5ms	(note: this command forces immediate current reading)
Check lock	2.7ms	
String to LCD-display	4.5ms	(16 characters sent)

Note that customization up to **1 MBaud** is also feasible as option, however, USB-related latency times in the order of 1ms mostly set a limit in this case. Typically at 1 MBaud the

cycle time is about 1.5ms for the 'Set Voltage' command, restricted by the USB communication to the PC.

Please note that the 'string to LCD display' command requires furthermore about 4.6ms more to indicate the string sent on the screen, after the device has already responded. It is therefore not recommended to use this command if maximum speed (about 300 commands per second at 115200Baud) is relevant.
In order to avoid jamming of the data flow it is also recommended to wait for each command to be answered by an response (full cycle time, as indicated above) and not sending data *before* the response of the previous command has been completed.
Note that if the protocol mode of the front display of the device is used, a screen contents may need up to 500ms to be updated. In case of frequently sent commands this can result in some commands to be 'swallowed' and not displayed correctly.

DECLARATION OF CONFORMITY

Manufacturer's Name: **Dr. Stefan Stahl**
- Electronics for Science and Research -

Manufacturer's Address: **Kellerweg 23**
67582 Mettenheim
Germany.

Declares, that the product

Product Name: **BS and BSA series voltage supply**
Model Number: **BS 1-4, BS 1-8, BS 1-10, BS 1-16 and derivatives**

Product Options: **This declaration covers all options of the above product(s)**

Conforms with the following European Directives:

The product herewith complies with the requirements of the:

1. Low Voltage Directive 73/73EEC;

2. EMC Directive 89/336/EEC (including 93/68/EEC) and carries the CE Marking accordingly

Date of Issue _____

1. January 2018 **General Director**

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