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HS-500

Low Noise High Voltage Switch

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Jan 2024

Data Sheet & User Manual

Model Number HS-500 Rev. 1.46

Typical Applications:

- **beam line electrodes / ion optics**
- **ion traps**
- **piezo elements**

Features:

- **fast low noise switches (SPDT style)**
- **max. 500V switching voltage with TTL/CMOS level control**
- **35ns intrinsic rise/fall time**

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1. Safety Hints

Operate carefully with respect to risk of electrical shock	This device can provide high voltages at its output lines, which are harmful in case of direct touch with the human body or other external circuitry. Care must be taken to avoid unintentional touching of any output line, or contact to any devices which might be endangered by high voltages.
Read all 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 rear side off.
This equipment must be connected to an 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.
Change cabling only when device is off	Changing the cabling, when voltages are present at the outputs can lead to formation of harmful sparks.
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 and direct water contact.
Beware of external magnetic fields	External magnetic fields can impair, damage or even destroy this device. A maximum external field strength of no more than B = 5mT is admissible. Having placed the device at any time into an external magnetic of bigger B = 5mT (regardless if power was turned on or off) can lead to severe overheating of the device and severely increased hazard of fire. Beware of proximity to superconducting magnets.
Service is to be performed by qualified service persons only	All servicing on this equipment must be carried out by factory-qualified service personnel only.
Do not block chassis ventilation openings	Slots and openings in the chassis are provided for ventilation purposes to prevent overheating of the equipment and must not be restricted. All case vents should continuously be cleared in order to prevent overheating.
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 reduce the hazard of overheating.
No outdoor operation	Outdoor operation of the device is not admissible.

2. General Information and Overview

2.1 Purpose and Description of the Device

Purpose of the HS series devices is the fast switching of piezo elements, electrodes, electrostatic lenses or beam deflectors, etc. Unlike DC *power* switches, the outputs expect capacitive loads and only small permanent (continuous) currents. The outputs are optimized for high stability, precision and excel in providing very low noise. The HS series switches are housed in standard 19-inch rack-mount cases. They are available in single-channel or dual-channels versions. In the dual channel version two completely identical switched are housed inside the same housing. These two switches are completely independent.

fig 2.1: front view of a HS-200/HS-500 device (DUAL version)

2.2 Functional Principle and Block Diagram

The following scheme displays a block diagram of the internal structure and illustrates the functional principle. The control input (BNC socket on front plate) defines the position of the internal high voltage switch, which connects either input A or input B to the output. A digital signal (TTL/CMOS level 0V/5V) may be applied to this control input at a rate between 0Hz (static operation) to 2kHz (long term recommended not to exceed 1kHz). A three-position manual switch on the front side allows to override the digital control signal. The high voltage switching elements inside the device are implemented as SiC-FET-transistors, allowing fast switching transitions in the order of 100ns and less.

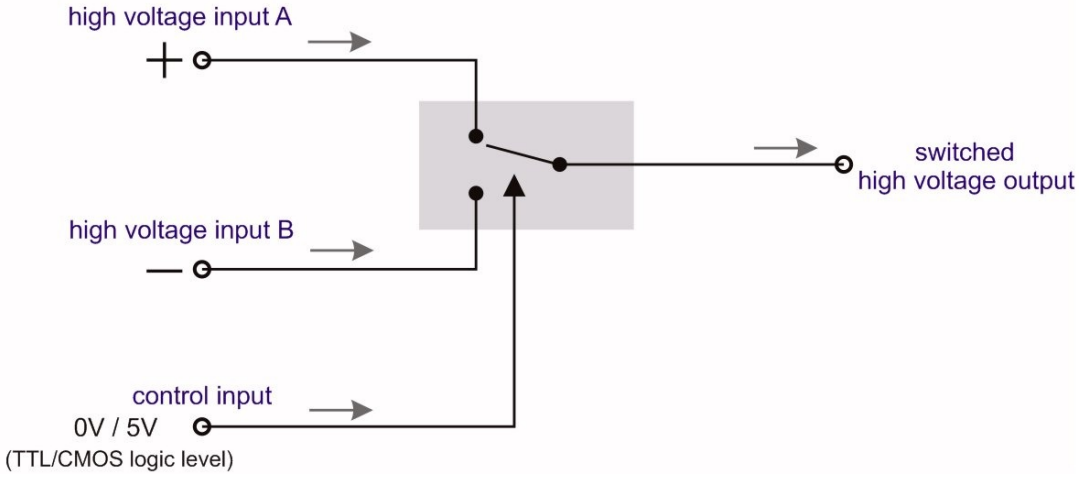

fig 2.2: Block diagram of a HS-200/HS-500 device. In case of the DUAL version, the depicted scheme exists twice, i.e. there are two independent switches.

Unlike high voltage pulse-generators, the internal switch circuitry is implemented as fast *static* switch, which means that the applied control input level defines the (static) switch position as illustrated in the

scheme above. The output is connected to the selected input by a (transistor based) resistor. The non-selected input is isolated from the output by a high isolation resistance.
Note that the applied supply voltages at inputs A and B must obey a certain order: voltage at input A always needs to be more positive than voltage at input B. In general, both input voltages may float up to +/-500V versus the case ground. However, for normal operation the voltage *difference* (A-B) should not exceed 500V.

Application example:
Generation of 10µs-duration positive 500Volt-pulse

The subsequent oscilloscope screen shot shows a typical application example. A control pulse of logic levels (high = 5V, low = 0V) is applied to the control input. High voltage inputs A and B were provided with an external voltage of +250V and -250V respectively. At the edges of the control signal the switch is triggered, and switches from -250V to +250V and after 10µs back. Trace 2 shows the control signal, being used to trigger the switch (trace 2: 5V/div.). A rectangular pulse results with steep slopes and constant-voltage static levels.

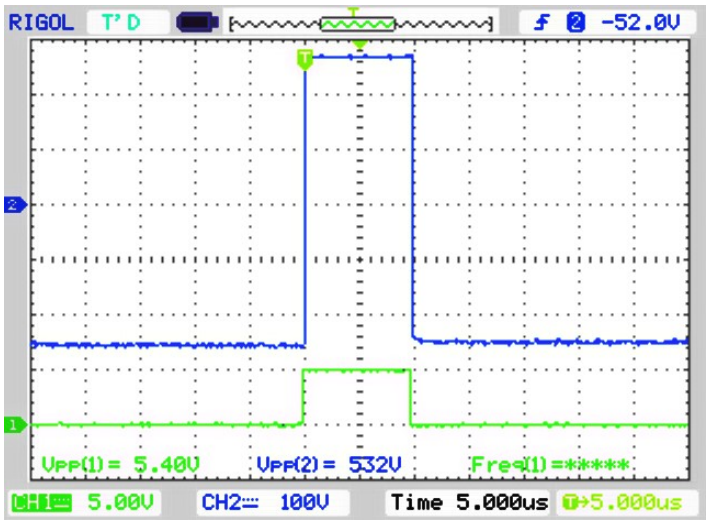

fig 2.3: Oscilloscope screen shot of a positive 500V step pulse, Δt = 10µs duration.
The lower trace (trace 2) shows the digital control signal, trace 1 (upper trace) the output signal.

2.3. Device Variety

The following devices are currently members of the HS series device family:

HS-200	single or dual version	Output voltages of maximum 200V span[1)]
HS-500	single or dual version	Output voltages of maximum 500V span[1)]
HS-1000	single or dual version	Output voltages of max. 1000V span[1)]
HS-2000	single version	Output voltages of max. 2000V span[1)]

The devices with outputs up to 500V (vs. GND) are provided by default with BNC outputs at their rear side, the other variants with higher voltages have SHV connectors. Voltages are referenced to case ground.

Note [1)]: span is the maximum voltage difference between positive and negative inputs A and B.

3. Installation

3.1. Mechanical and Electrical Installation

Positioning: Provide sufficient air cooling of the device and locate in normal horizontal position to allow for defined air convection. Rack mounting into a standard 19" rack is as well possible as resting the device on a table. If mounted in a rack, please make sure that all case vents are permanently cleared in order to prevent overheating.

fig. 3.1: Keep air vents always cleared to ensure sufficient ventilation

Beware of external magnetic fields:
Strong external magnetic fields can impair, damage or even destroy this device (e.g. proximity to a superconducting magnet). A maximum external field strength of no more than B = 5mT is admissible. Not observing this important condition can lead to severe overheating of the device and increases the hazard of fire.

Connecting to mains power:
Connect the device to the mains power supply (either 220 to 240V ac or 100 to 115V ac, depending on version) 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 2A current. The mains power input is **not** wide-range rated, either 100…120V or, 220…240V need to be connected.

Cabling of voltage outputs:
Always provide appropriate and safe cabling when connecting the device to other devices or vacuum/experimental setups. Cabling is preferred using high voltage cable with proper shielding. BNC or SHV connector cables are a suitable choice in order to ensure proper shielding against external noise pickup and in order to provide protective ground for safety reasons. 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 1).

Please note that wiring may only be done when the device is turned off. Connecting a powered-up output to external circuitry can easily cause sparks and electrical discharges. The resulting overvoltages can severely and permanently damage the device itself and also external circuitry.

4. Operation and Control Elements

4.1 Elements on the front plate

mains supply switch | Switch 1 BNC ext. / manual | Switch 2 BNC ext. / manual

fig. 4.1: front plate elements

The front plate contains the control elements of the device. It is powered up after turning on the rear-side mains supply switch and also the power button on the front plate. The Power-on-LED (green) indicates proper operation of the internal circuitry.

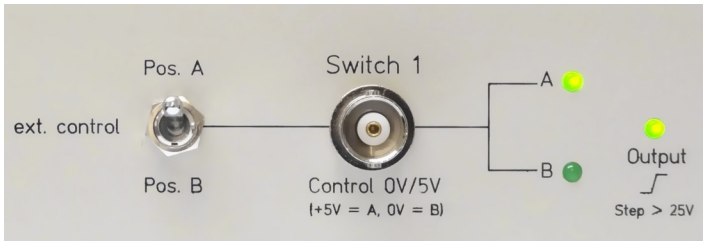

fig. 4.2: manual switch, BNC input and LED indicators, showing the switch position and indicating operation (voltage step detector) .

Each channel features a three-position manual switch (fig. 4.2). In upper position the output (rear side) is connected to the high voltage input A, whereas moved into lower position it connects the output to input B. In center position, the control voltage applied to the BNC input, defines the switch state. A high level connects the output with A, low level to B. Standard 5V / 0V signal may be applied to this control input. In practical cases a PC controlled Delay-Gate generator or function generator is often connected here. Switching rates up to 2kHz are supported (see specifications table). The LED indicators on the right hand side show the switch status, indicating which input (A or B) is connected to the output. HS series switch devices after production date dec. 2017 feature also a slope/step detector, with an LED lighting up upon occurence of positive or negative output steps lager approx. 25V, thus indicating correct functionality.

4.2 Elements on the rear side

fig. 4.3: rear side elements (a dual channel version is shown)

The rear side of the device contains the ventilation elements, 230V supply connector, power on/off switch (with fuses) and the high voltage inputs and outputs.

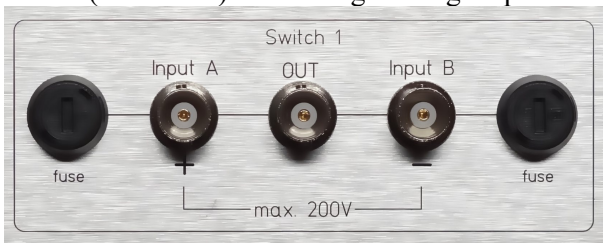

fig. 4.4: BNC sockets for at inputs and output

Fig. 4.4 shows the BNC sockets for the two DC high voltage supply voltages A, and B and the switch output OUT. Please note that the voltage on input A needs to be more positive compared to the voltage on input B. This is indicated by the plus and minus sign “+” and “-“. In general, both input voltages

may reside in the range between -500V and +500V versus GND, but their difference should not exceed 500V. The fuse sockets shown in fig. 4.4 contain safety fuses for the two high voltage inputs. In case extensive currents flow, they may blow. Nominal rating is 63mA, medium fast blow.
The inputs A and B can be connected to an appropriate high voltage supply, e.g. to a device of *stahl-electronics* HV-series. The output is supposed to be connected to capacitive load like switched electrode, piezo element or ion trap. Note that excessive capacitive loads impair the switching speed performance. Nominal loads from 0pF to 300pF can be connected (max. 1.5nF), see next section for resulting waveforms at different loads.

4.3 Output Characteristics

Dynamic Response

As soon as the internal switch connects either input A or B to the output, the latter assumes the voltage on the respective input. There is a time constant related to each voltage transition, essentially given by the internal switch resistance (approx. 140 Ω), the internal output current limit (approx. 1A) and the capacitive load on the output, including all cables to an experimental setup. In case of BNC cable type one may count about 100pF each meter cable length, therefore extensively long cables should be avoided. The following oscilloscope screen shots show voltage step transitions observed at the output with small (17pF) and larger capacitive loads (250pF) for further illustration.

100V step

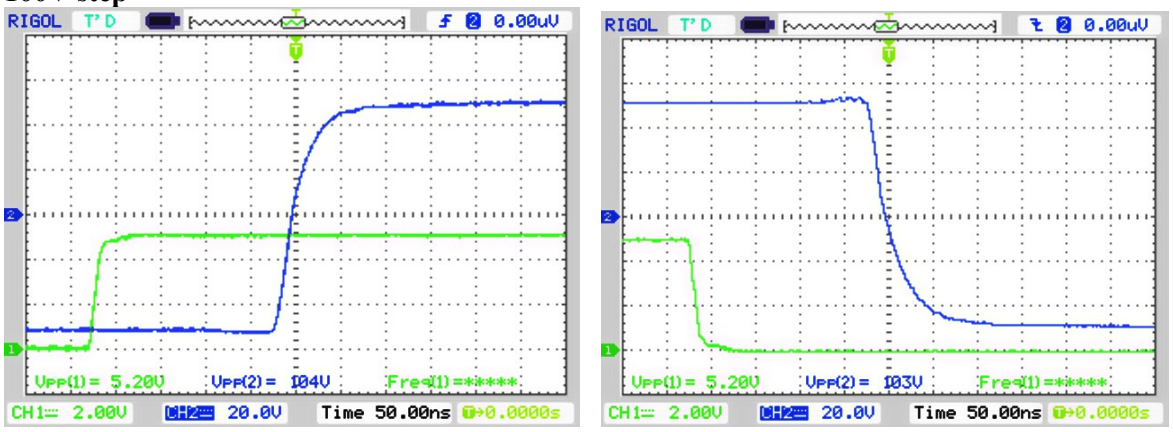

fig. 4.5 positive and negative voltage step of 100V with small capacitive load (C = 17pF) at the output, transient rise time (10% to 90% of voltage step size) is in the order of 40ns in each case. The green trace shows the input trigger signal.

200V step

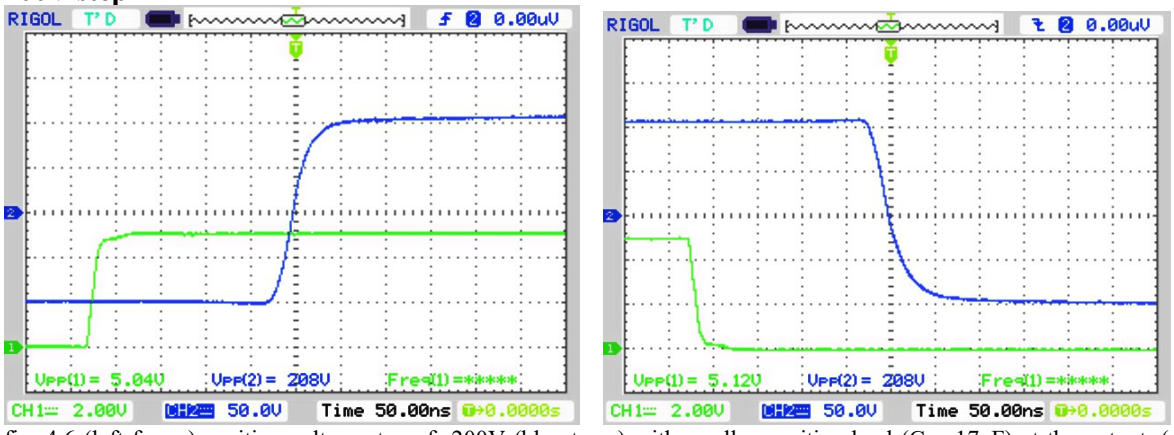

fig. 4.6 (left frame) positive voltage step of 200V (blue trace) with small capacitive load (C = 17pF) at the output; (right frame) negative step of 200V with small capacitive load (C=17pF); transient rise time (10% to 90% of voltage step size) is in the order of 45ns in each case. The green trace shows the input trigger signal.

500V step

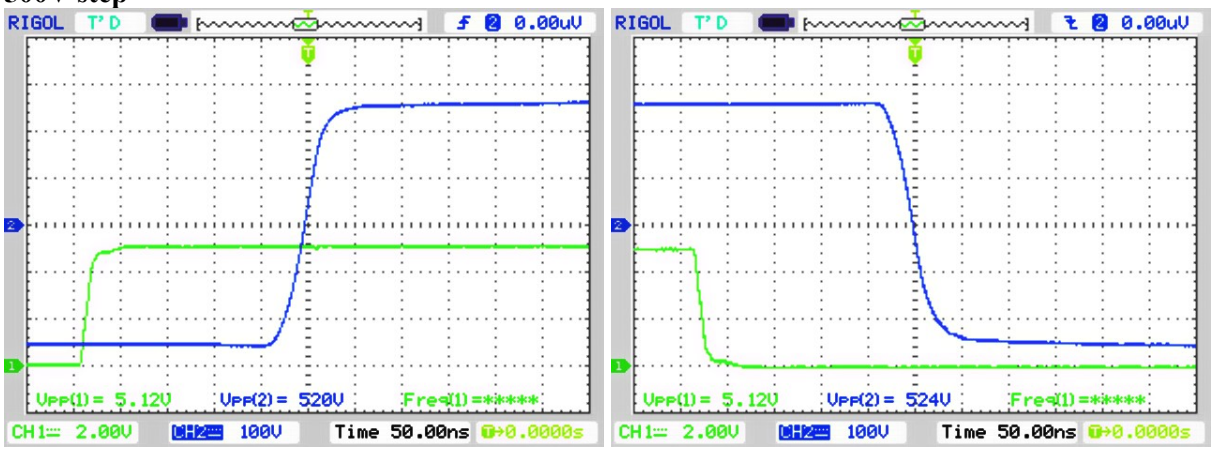

fig. 4.7 (left frame) positive voltage step of 500V (blue trace) with small capacitive load (C = 17pF) at the output; (right frame) negative step of 500V with small capacitive load (C=17pF); transient rise time (10% to 90% of voltage step size) is in the order of 50ns in each case. The green trace shows the input trigger signal.

500V step with large load

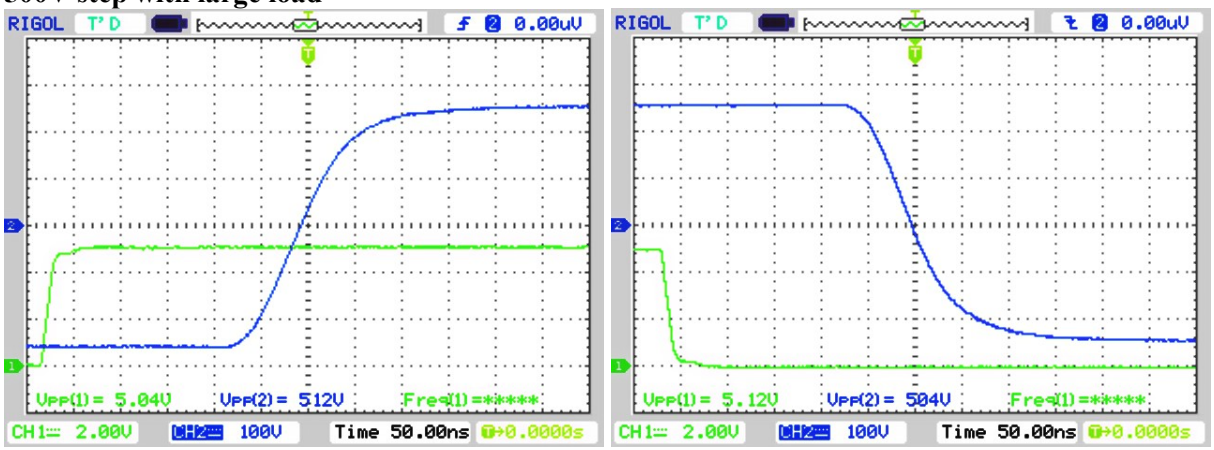

fig. 4.8 (left frame) positive voltage step of 500V (blue trace) with capacitive load of 250pF at output; (right frame) negative step of 500V with same load; transient rise time (10% to 90% of voltage step size) is in the order of 110ns in each case. The green trace shows the input trigger signal. The slower rise/fall times are mainly caused by the internal safety current limit of approx. 1.1 Ampere

Noise and Ripple

In contrast to other devices, based on switched circuit / power switching technology, the HS series devices feature a very low noise level. This makes them specially suited for ion traps, ion sources and low energy beam line applications. Each output exhibits a very low broadband noise (DC to 20MHz) of smaller than 120µV_{rms} and a low ripple level (50Hz) smaller 50µV_{rms}. In general, the outputs are completely free of parasitic switching spikes in the RF region, unlike traditional high-voltage switching devices, which were formerly used for beam lines or ion traps.

Static Switch Behavior

In case of low-frequency or static operation, the ‘on’-state serial resistance of input A or B to OUT amounts to approx 140 Ohms, and increases to larger 100 MOhm in the ‘off’ state.

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5. Maintenance

The HS series high voltage switches are designed for years of reliable operation. Under normal operating conditions, they should not require electrical maintenance, except routine cleaning of dust. If any question should arise, please contact the manufacturer.

Routine cleaning

All ventilation openings 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 and external voltage sources are powered off. The front panel may be cleaned periodically with a clean cloth and mild 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.

Fire hazard

Please note, that excessive accumulation of dust inside the case of the device can lead to overheating. This, together with possible discharges increases the risk of fire, caused by electrical sparks. Routinely cleaning the device from dust minimizes this risk. It is therefore recommended to send the device to the manufacturer routinely in 5-year intervals for internal cleaning from dust, or to have it cleaned by an accordingly qualified electronical workshop. Environmental conditions containing oil mists (e.g. in proximity to a vacuum pump or mechanical machines) place a severe danger, since inflammable substances may enter the device through the ventilation holes. If in doubt, cleaning by an accordingly qualified electronical workshop or the manufacturer is strongly recommended.
An increased hazard of fire can also occur if the device has been (permanently or temporarily) located in proximity to a strong (e.g. superconducting) magnet. A maximum external field of no more than B = 5mT is admissible and must not be exceeded at any time.

6. Specifications

	typ.	max.	Conditions and remarks
Control Input			
required drive level	0V and 5V	-2V to +6V vs. GND	TTL/ HC-MOS compatible
threshold	2.4V		
input impedance vs. GND	2kΩ // 6pF		
drive rate / switching rate		2kHz	device will inhibit control signals with considerably higher rates
Output Switch			
static resistance from A or B to OUT "on"-state	140Ω	200Ω	I_{OUT} < 200mA
isolation resistance from A or B to OUT	>100MΩ		voltage differences from A or B to OUT smaller or equal 500V
leakage currents from A or B to OUT	40nA*	200nA*	voltage differences from A or B to OUT smaller or equal 500V
intrinsic switch capacitance on OUT terminal	80pF		
Noise		120µV_{rms}	f = DC to 20MHz
admissible DC current		80mA	continuous current
admissible pulsed current		1.7A	Δt < 1.5ms, repetition rate <= 2 Hz
internal current limit, shortly at switching instant	1A	1.7A	Δt < 700µs

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Transfer characteristics			
delay from control input to output response	240ns		200V to 500V output step size (positive or negative going)
delay jitter	0.4ns rms		T = 25°C +/-1°C
max. pulse duration		infinite	
min. pulse duration	6.6µs		
Output rise or fall time, 10% to 90% step size	35ns		capacitive load of 17pF (probehead)
	70ns		capacitive load of 250pF
Input Voltage Rating			
Input A or B vs. GND		+/-500V	both polarities may be applied vs. GND
Voltage difference from A to B		500V	input A always needs to be on more positive potential with respect to B
Fuse rating	63mA fast		fuse replaceable on rear side
Environmental Conditions			
Magnetic Field		max. 5 mT	Attention: keep safe distance from superconducting NMR-style magnets
Storage Temperature		-55 C° to +85 C°	
Operating Humidity & Temperature	noncondensing relative humidity up to 80% between temperatures of +10°C and +28°C. Outdoor operation of the device is not admissible.		
Power Supply	AC input voltage 230V_{AC} at 50Hz/60Hz or alternatively 110V_{AC}. The power entry module is EMI/RFI-filtered. Fuse: medium fast blow 100mA (110V) or 200mA (230V), 2ea Note: Supply voltage needs to be defined at time or ordering. Power supply input is not wide-range rated (either 230V or 110V).		
Power Consumption	3.2W	5.1W	
Case Dimensions	19.00” wide x 10” deep x 1 height unit. Front-panel mounting holes are dimensioned for M6 rack configurations weight approximately 2.1kg		

Note *): Inputs A and B feature approx. 1 GΩ resistors to ground for protection against parasitic charge up. Currents through these protection resistors add to the numbers mentioned above.

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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:	**HS series high voltage switch**
Model Number:	**HS-200, HS-500**
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

Mettenheim, 25. Jan. 2017, Dr. Stefan Stahl, CEO

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