

HS-200

Low Noise High Voltage Switch

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Data Sheet & User Manual

Rev. 1.31

Models HS-200 SINGLE/DUAL, BIPOLAR

Features:

- fast low noise switches (SPDT style)
- max. 200V switching voltage with TTL/CMOS level control
- 40ns intrinsic rise/fall time
- floating Outputs

Typical Applications:

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

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1. Safety Hints

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 $B = 5\text{mT}$ is admissible. Having placed the device at any time into an external magnetic of bigger $B = 5\text{mT}$ (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 must continuously be cleared, in order to prevent overheating.
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.
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.
Use correct mains voltage	Only use the mains voltage written on the rear side of the device, observe country-specific voltages.
No outdoor operation	Outdoor operation of the device is not admissible.



Danger: high voltages are present at the rear side of the device. Always proceed with appropriate measures of caution and safety.

2. General Information and Overview

2.1 Purpose and Description of the Device

Purpose of the HS series devices is the fast switching of electrodes, electrostatic lenses, beam deflectors or ion traps. Unlike DC *power* switches, the outputs expect capacitive loads. The outputs are optimized for high stability and 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 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. 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 MOSFET-transistors, allowing fast switching transitions in the order of 40ns and less.

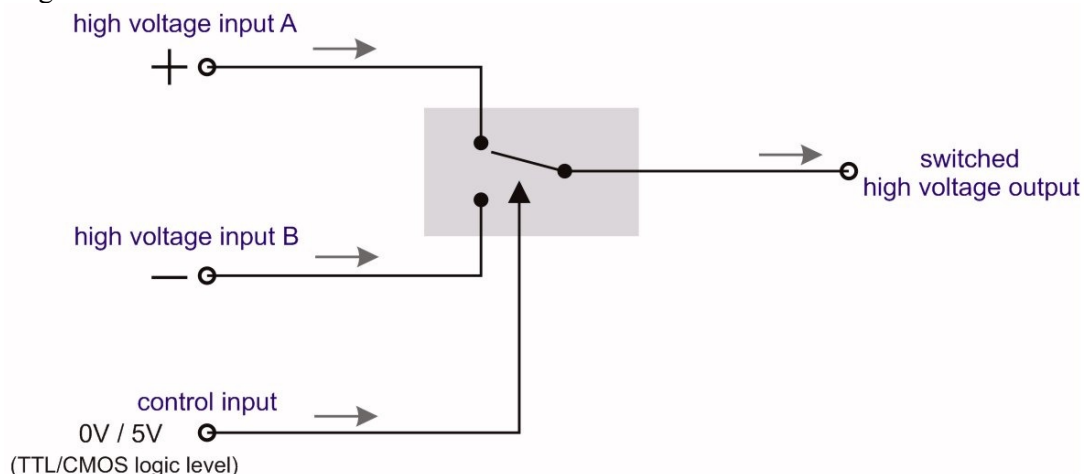


fig 2.2: Block diagram of a HS-200 device. Inside the DUAL version, this scheme exists twice, i.e. there are two independent switches.

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 in standard version the applied input 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. For normal operation the voltage *difference* (A-B) should not exceed +200V.

However, both input voltages may float up to +/-500V versus the case ground, which is an important feature in many applications.

Bipolar Version

In the case that the order of input voltages (input A more positive than input B) can not be permanently maintained, a bipolar version is also available. This version features internally two partial switches in each signal branch, being able to serve positive as well as negative electrical currents.

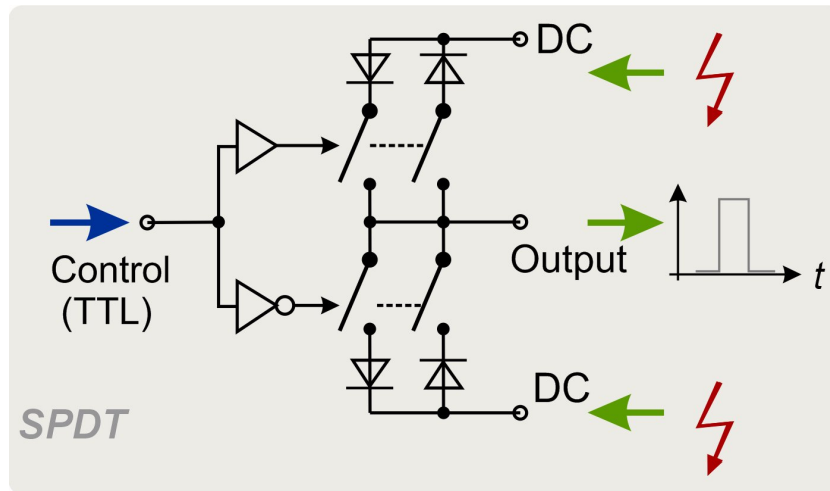


fig 2.3: The bipolar version features two partial switches in each signal branch, thus can handle all voltage polarities.

There are two disadvantages in this version, which are due to the altered internal circuitry: first, the signal switching speed is slower (see also specification table), secondly the additional diodes shown in 2.3 have the effect that the output voltage suffers from a drop of approximately 0.7V, thus the bipolar device may be regarded as less precise as the non-bipolar version.

**Application example:
Generation of 10µs-duration positive 200V-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 200V and 0V respectively. At the edges of the control signal the switch is triggered, and switches from 0V to 200V (trace 1: 50V/div.) and after 10µs back to 0 Volt. 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.

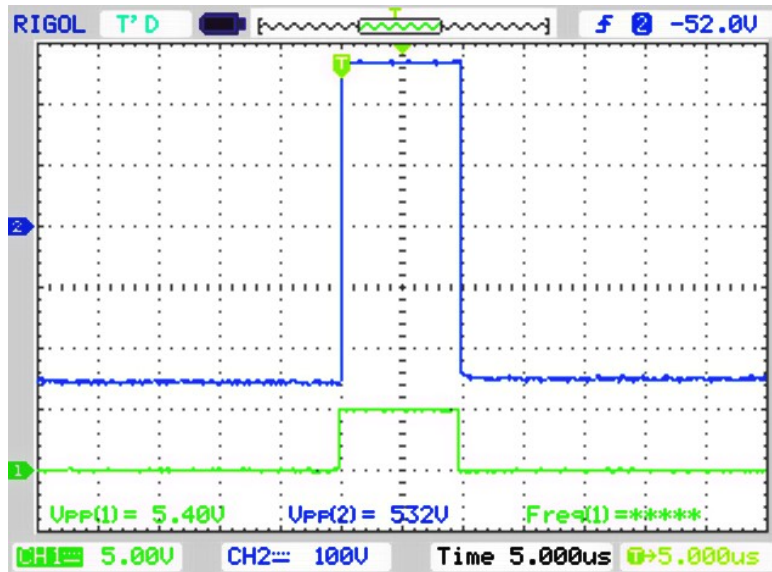


fig 2.4: Oscilloscope screen shot of a positive 200V pulse, $\Delta t = 10\mu s$ duration. The lower trace (trace 2) shows the digital control signal, trace 1 (upper trace) the output signal.

2.3. Device Variety

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

HS-200	single or dual version standard or bipolar version	Output voltages of maximum 200V span ¹⁾
HS-500	single or dual version standard or bipolar 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 (SPDT)	Output voltages of max. 1000V 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 $B = 5\text{mT}$ 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 (220 to 240V ac) 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.

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

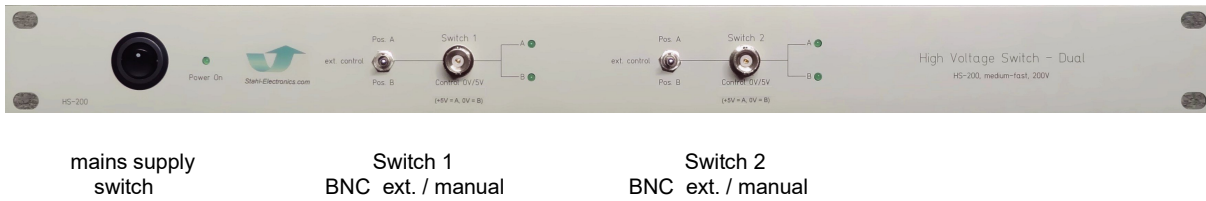


fig. 4.1: front plate elements

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.

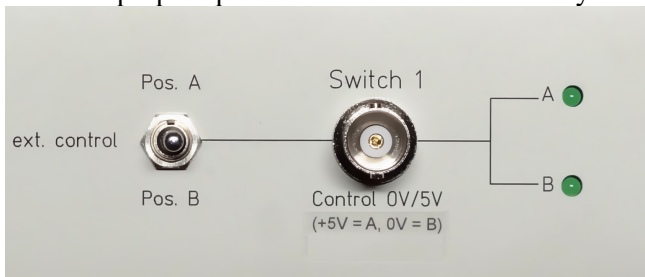


fig. 4.2: manual switch, BNC input and LED indicators.

Each channel features a three-position manual switch (fig. 4.2). Lifted upwards, the output (rear side) is connected to the high voltage input A, moved into lower position it connects the output to input B. In the center position of this switch the control voltage, being applied to the BNC input, defines the high voltage switch position. A high level connects the output with A, low level to B. Common 5V / 0V signal may be applied to this BNC control input. In practical cases a PC controlled Delay-Gate generator or function generator is often connected to this BNC input. Switching rates up to 2kHz are supported. The LED indicators on the right side show the switch status, indicating which input (A or B) is connected to the output.

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, 115V/230V supply connector, power on/off switch (with fuses) and the high voltage inputs and outputs.

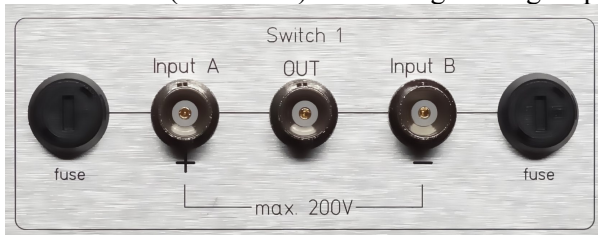


fig. 4.4: BNC sockets for at inputs and output

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 -200V and +200V versus GND, but their difference should not exceed 200V.

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, fast blow.

The inputs A and B can be connected to an appropriate high voltage supply, e.g. a device from the *stahl-electronics* HV-series. The output is supposed to be connected to a switched electrode element or ion trap. Please note that the capacitive load on this output may impair the switching speed performance. Nominal loads from 0pF to 300pF may be connected. See also next section for waveforms.

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 connected BNC cable, 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 (applies for standard version, not for the bipolar version, see also specifications table).

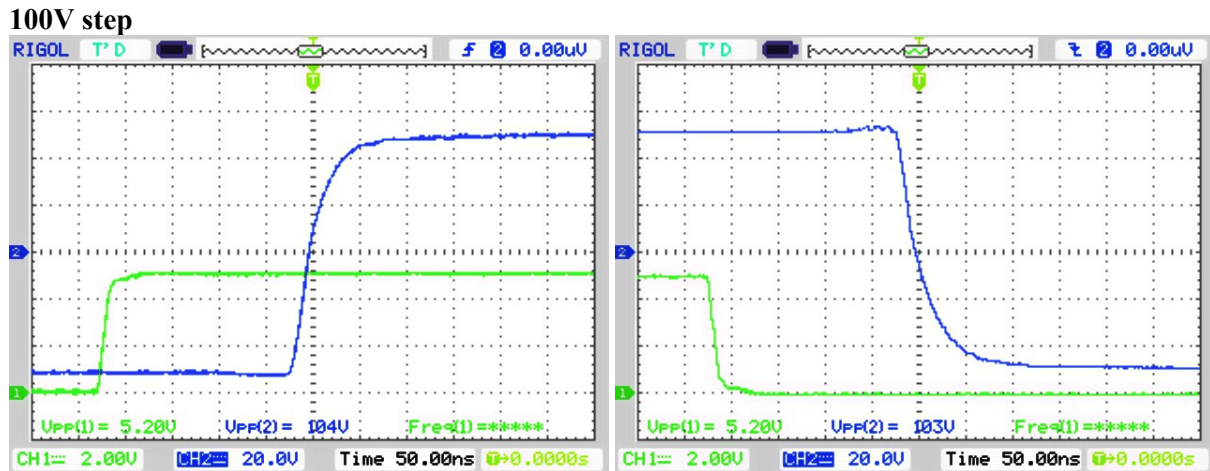


fig. 4.5 (left frame) positive voltage step of 100V (blue trace) with small capacitive load ($C = 17\text{pF}$) at the output; (right frame) negative step of 100V with small capacitive load ($C=17\text{pF}$); transient rise time (10% to 90% of voltage step size) is in the order of 45ns in each case. The green trace shows the input trigger signal.

200V step

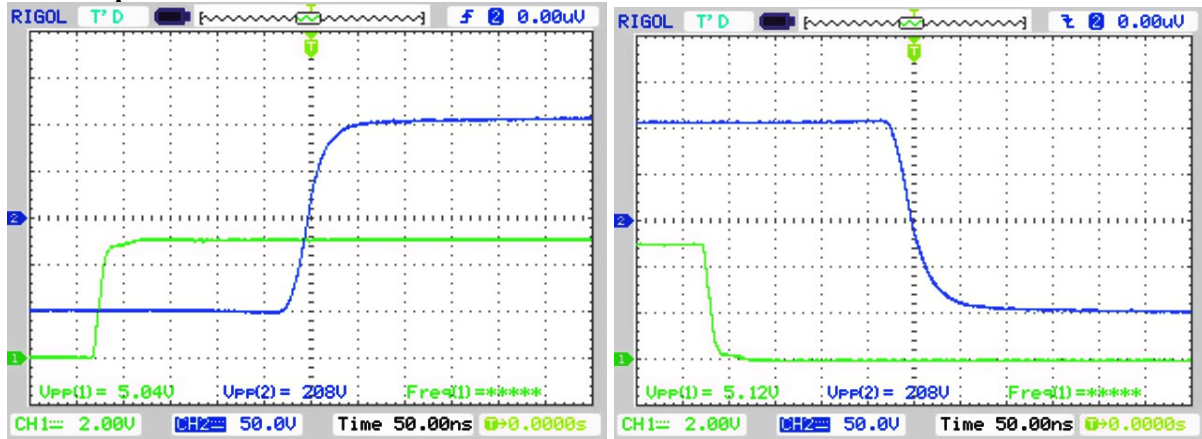


fig. 4.6 (left frame) positive voltage step of 200V (blue trace) with small capacitive load ($C = 17\text{pF}$) at the output; (right frame) negative step of 200V with small capacitive load ($C=17\text{pF}$); transient rise time (10% to 90% of voltage step size) is in the order of 45ns in each case.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

200V step with larger load

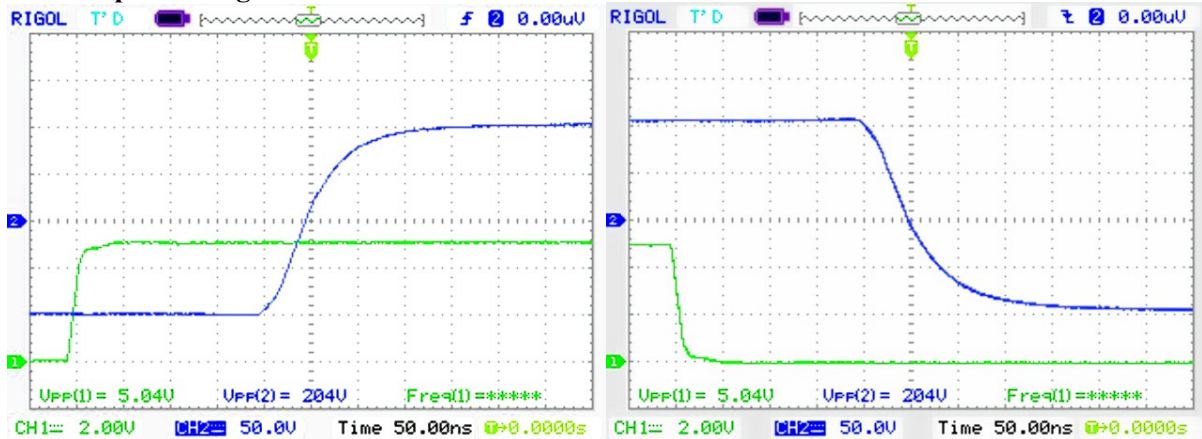


fig. 4.7 (left frame) positive voltage step of 200V (blue trace) with capacitive load of 250pF the output; (right frame) negative step of 200V with same load; transient rise time (10% to 90% of voltage step size) is in the order of 80ns in each case. The green trace shows the input trigger signal. The slower rise/fall times are mainly caused by the internal safety current limit of approx. 1.1 Amperes

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 $350\mu\text{V}_{\text{rms}}$ and a low ripple level (50Hz) smaller $50\mu\text{V}_{\text{rms}}$. In general the outputs are completely free of parasitic switching spikes in the RF region.

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.

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 is 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 4-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 4-year intervals for internal cleaning from dust, or to have it cleaned by an accordingly qualified electronics workshop. Also, ambient conditions containing oil mists (e.g. in proximity to a vacuum pump or mechanical machines) place a severe danger, since inflammable substances could enter the device through the ventilation holes. If in doubt, cleaning by an accordingly qualified electrical workshop or the manufacturer is strongly recommended.

An increased hazard of fire may 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 $B = 5\text{mT}$ is admissible and must **never** be exceeded.

6. Specifications

Control Input			
	typ.	max.	Conditions and remarks
required drive level	0V and 5V	-2V to +6V vs. GND	
threshold	2.4V		
input impedance	2k Ω // 6pF		
drive rate / switching rate		2kHz	
Output Switch, static			
static resistance from A or B to OUT "on"-state	130 Ω	180 Ω	$I_{\text{OUT}} < 200\text{mA}$
isolation resistance from A or B to OUT	>10M Ω		voltage differences from A or B to OUT smaller or equal 200V
leakage currents from A or B to OUT	50nA*)	200nA*)	voltage differences from A or B to OUT smaller or equal 200V
Parameter	typ.	max.	Conditions and remarks
intrinsic switch capacitance on OUT terminal	40pF		approx. 85pF for bipolar version
Noise		350 μV_{rms}	
admissible DC current (continuous)		60mA	

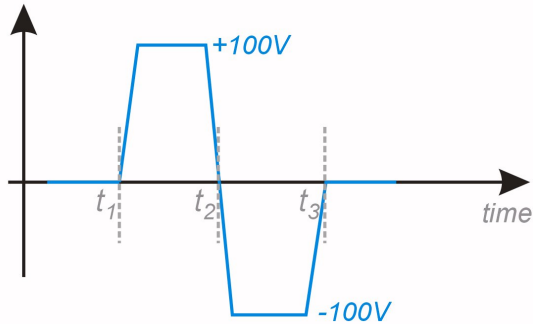
internal current limit, shortly at switching instant	1.1A	1.7A	
Timing characteristics			
a) standard version			
delay from control input change to output reaction	240ns	290ns	200V output step size (positive or negative going)
delay jitter	0.6ns rms		T = 25°C +/-1°C
max. pulse duration		infinite	
min. pulse duration	6.6µs		Shorter upon request
Output rise or fall time, 10% to 90% step size	40ns or 20ns **)		capacitive load of 17pF (probehead)
	80ns or 42ns **)	100ns	capacitive load of 250pF
b) bipolar version			
delay from control input change to output reaction	240ns	300ns	200V output step size
delay jitter	0.4ns rms		
max. pulse duration		infinite	
min. pulse duration	6.6µs		
Output rise or fall time, 10% to 90% step size	80ns		capacitive load of 17pF (probehead)
	155ns	175ns	capacitive load of 250pF
Output rise or fall time, 20% to 80% step size	50ns		capacitive load of 17pF (probehead)
	93ns	105ns	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		200V	input A always needs to be on more positive level with respect to B in standard version, whereas polarity does not matter in bipolar version
Fuse rating	63mA fast		fuse replaceable on rear side
Environmental Conditions			
Magnetic Field		max. 5 mT	
Storage Temperature	-55 C° to +85 C°		
Operating Humidity & Temperature	noncondensing relative humidity up to 80% between temperatures of +10°C and +30°C.		
Power Supply	AC input voltage 230V _{AC} at 50Hz/60Hz or alternatively 120V _{AC} , +/-8% tolerance. The power entry module is EMI/RFI-filtered. Fuse: medium fast blow 100mA (230V) or 200mA (120V)		
Power Consumption	typ. 3.5W	max. 5W	
Case dimensions	19.00" wide x 10" deep x 1 height unit. Front-panel mounting holes are configured 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.

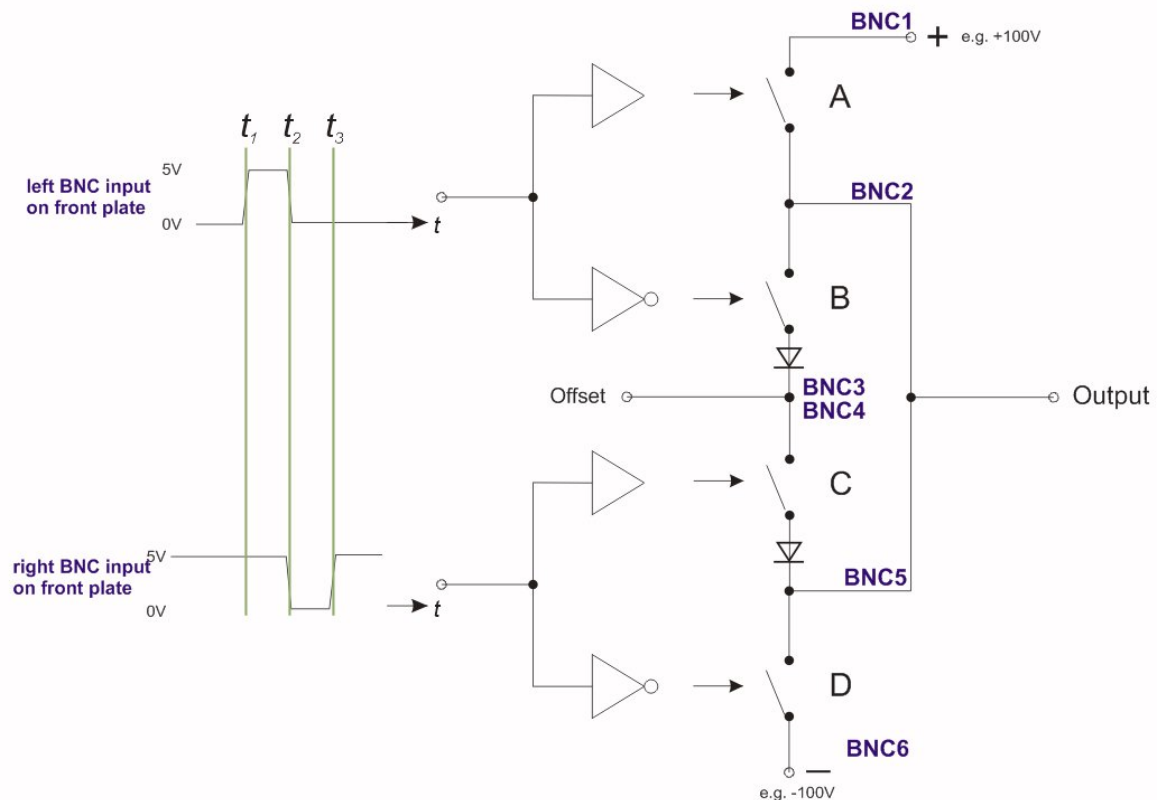
Note **): Improved version, applies for special devices with production date later Jan 1, 2020

Addendum: Creation of bipolar double pulses

For special purposes, this device can be ordered with slight alterations. For creating a double pulse like depicted below, protecting diodes can be inserted by the manufacturer and timing can be optimized.



To create such a waveform structure, all 4 partial switched, available in the dual configuration of the HS-200 are required. As shown below, they needed to be connected together in a certain way and controlled by an external 2-channel pulse generator.



The timing sequence acts in the following way. *Before* the pulse sequence starts ($t < t_1$), partial switched B and C are active and forward the offset voltage to the output. BNC connectors BNC 2 and BNC 5 need to be connected by the user for this purpose (this is the output), as well as BNC 3 and BNC 4 (offset input).

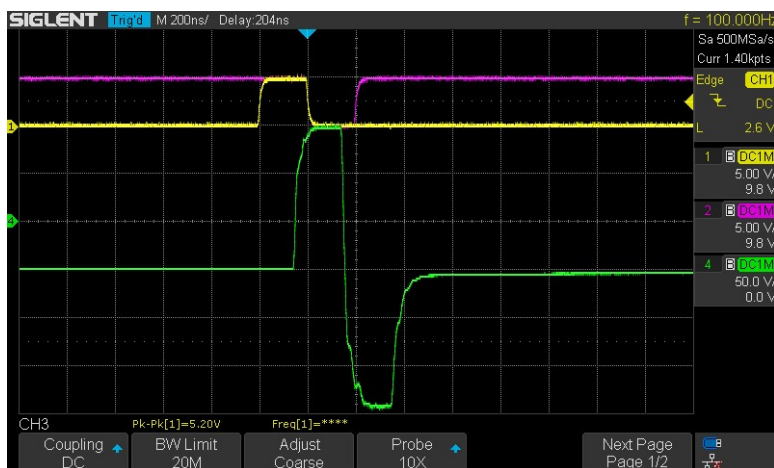
At time $t = t_1$ a zero-to-5V transition on the left control input activates internal switch A, thus the positive voltage on BNC 1 will be forwarded to the output. This creates the positive output pulse.

At time $t = t_2$ the left control input should return to zero and the right control input, which was at +5V before, should become zero as well. In this instance switch D become active and forwards the negative voltage on BNC 6 to the output. This creates the negative output pulse. Finally, after $t = t_3$, partial switches A and D will be inactive again (0V to 5V transition on right BNC control input) and the original situation is restored, thus the offset voltage is being forwarded to the output.

Note, that for proper timing the positive pulse on the left control input, and as well the low-pulse on the right control input should reside in the range 100ns to about 20 μ s. In contrast to the standard HS 200 version a purely static operation of the switches is no supported in favor of faster timing.

Note also, that this hierarchy of voltages must be kept: positive supply (BNC 1) more positive than offset supply (BNC 3 and 4) and more positive than negative supply (BNC 6). This is important, since with wrong polarity (i.e. hierarchy not maintained) parasitic cross conduction through the internal switches may lead to large electrical currents, which could either damage the switches or the external power supply being used. In case accidentally wrong voltages were applied, the protection fuses (rear side of the device, BNC 1, 3, 4, 6) may blow. For safety reasons it is recommend to use current-limited external voltage supplies. Their current limit sound be set to about 1milliAmpere.

Example screenshot:



Yellow trace: left control input

Pink trace: right control input

Green trace: Output

Supply voltages: +100V on BNC 1, -50V on BNC 3 and 4, -200V on BNC 6,

Output load on BNC 2/3: 200pF

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-200 dual, HS-200 dual bipolar

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, 26. Jan. 2017, Dr. Stefan Stahl, CEO