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EOD Switching Unit

MS-F 10

10-to-1 High Voltage Multiplexer

User_Manual_1_01.doc
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User Manual

Rev. 1.01

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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 = 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.
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 4 case vents should continuously be cleared (fan inlet at rear side, air outlet at rear and top side), in order to prevent overheating. If mounted in a rack, please allow 2cm clearance at the top cover with respect to the next device above. 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. A temperature over 45°C indicates inadequate air ventilation.
Operate carefully with respect to risk of electrical shock	This device can provide voltages in the kV-rangeat its output lines, which is harmful in case of direct touch with the human body. Care must be taken to avoid unintentional touching of any output line to the human body or 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.
No outdoor operation	Outdoor operation of the device is not admissible.

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1. Purpose and Overview of the Device

Purpose of the EOD switch MS-F 10 is to select one of 10 voltages, which are applied to the rear side of this instrument and route this signal to the output. Voltage values up to +/-2kV (max.) may be applied for the purpose of connecting e.g. a EOD (electro optical deflector) device for laser beam steering, or another device representing a capacitive load.
Unlike standard voltage sources or stand-alone high voltage switches, the switching time is despite of the high voltages and high channel count relatively fast (<1µs) and allows for precise and swift switching (e.g. for beam steering). The subsequent figure shows a block diagram and thus the internal structure.

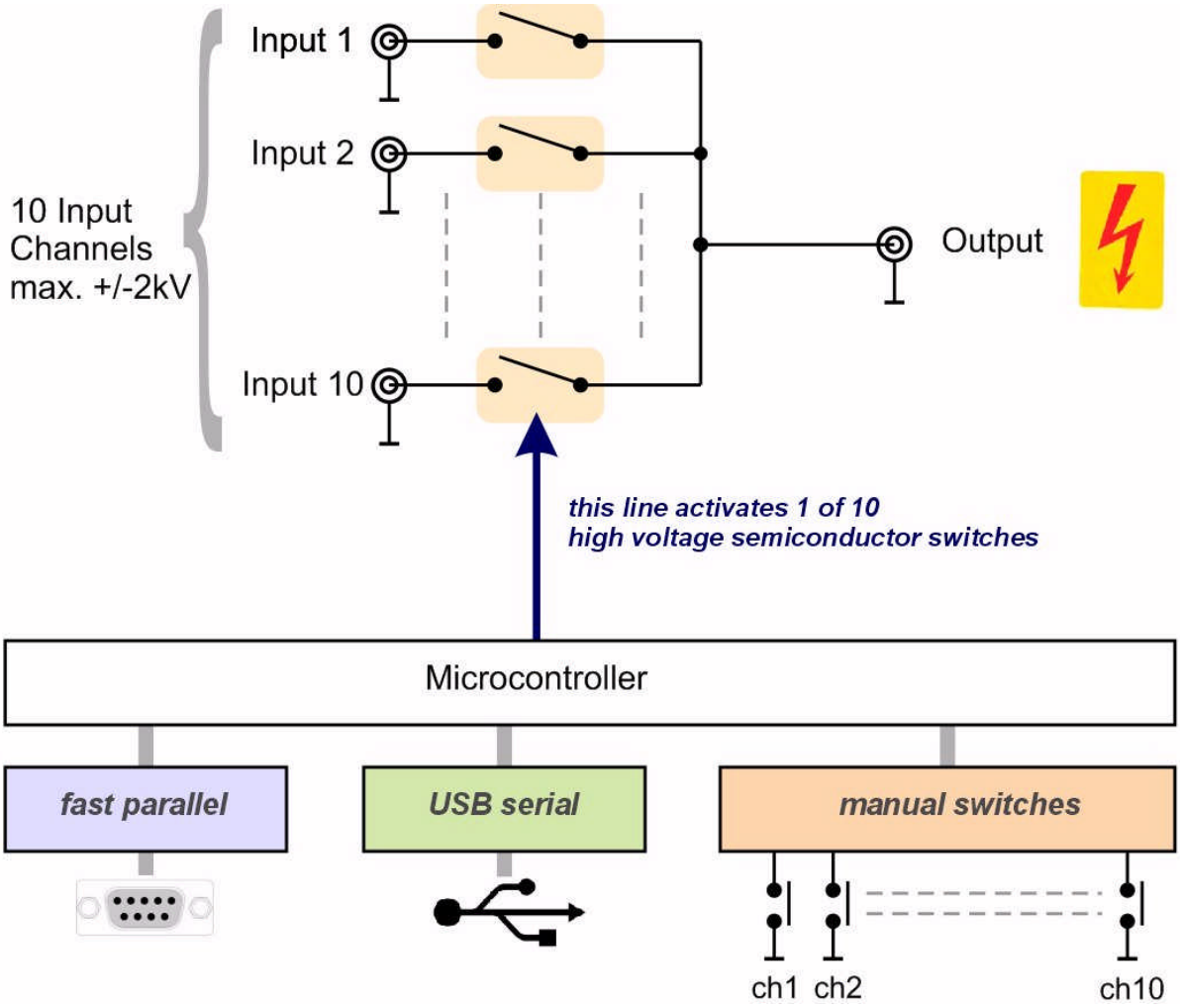

Fig. 1
Block diagram of the internal structure, illustrating the functional principle. Depending on the operation mode, the control interface receives commands via the USB connection, through a parallel port or upon manually pressing buttons on the front plate. The addressed semiconductor switch selects 1 of 10 inputs and connects the latter to the output.

In favour for versatility, the device features 3 modes to select a certain (one of ten) input channel:

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- ***Manual Mode***
  using switches on the front side for manually selecting an input

- ***Parallel Mode (Sub-D)***
  using a proprietary parallel connection on the front side for fast input channel selection

- ***USB Mode***
  using a standard USB connection and 'Virtual COMPort' settings to send device commands by means of self-written code (VisualBasic, LabVIEW™, Pascal, etc.)

To operate the device, one of these 3 modes needs to be selected manually on the front plate. The Signal Source Switch rotates through these modes by repeated pressing on it. Fastest operation is achieved in the Parallel Mode (approx 50µs response time), followed by USB commands (typ. 4ms response time) and manual switching (100ms).

The 10 high voltage input lines (10 SHV connectors are located at the rear side) are routed by 10 semiconductor switching elements to the output (SHV socket) in a bipolar way, i.e. electrical currents can flow in both directions out/in at the output as soon as a switch is activated. Voltages within -2kV to +2kV are admissible at each input, however, routine operation should not exceed -1.75kV to +1.75kV for longer times. A brake-bofore make delay circuit (approx. 1µs dead time) ensures that, at no time, 2 switches are 'on' in parallel, to avoid an unintentional short cut between the input lines (so-called shoot-through).

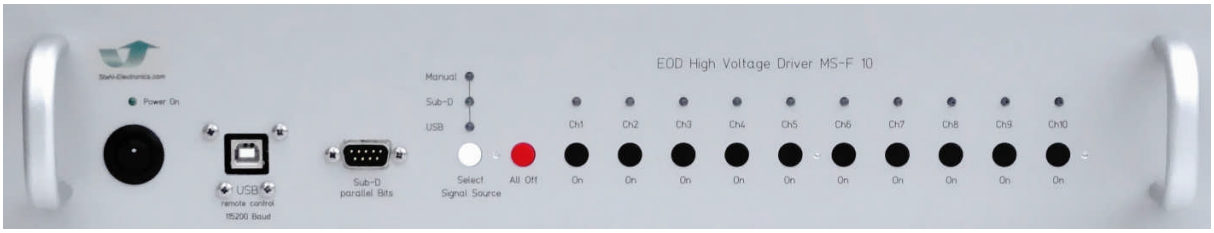

fig. 2: front side view with mains switch (use rear side switch if the device is not in use for a longer time), USB socket (galvanically isolated), 9pole-SubD socket, mode switch, 'all-off' switch and 10 switches to activate a high voltage switch in manual mode.

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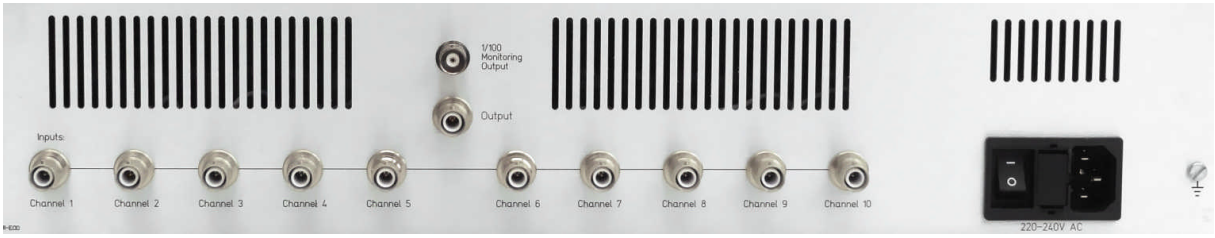

fig. 3: rear side view with mains switch, 10 SHV input sockets, 1 output socket and a 1/100 attenuated output for monitoring purposes; please always use a 2m BNC cable to connect the monitoring output to an oscilloscope (no further termination required).

2. Switching and Output Characterstics

Waveform Timing

One of ten inputs is routed to the output on command at a certain time, creating a step-shaped waveform. The subsequent figures depict typical output waveforms (step-up voltage and and step-down voltage) at the switching instant. These graphs were taken with 125pF of 'dummy'-load at the output to simulate short cabling and capacitive load of a EOD modulator.

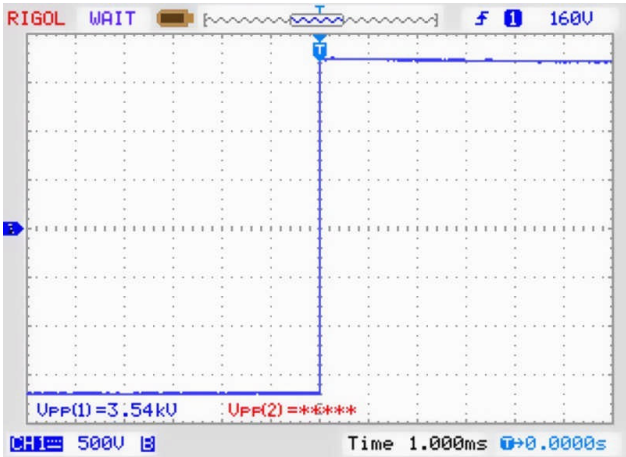

Fig. 4: Positive step of 3.5kV step size, measured with oscilloscope at the rear side monitoring output, 1ms/div grid size

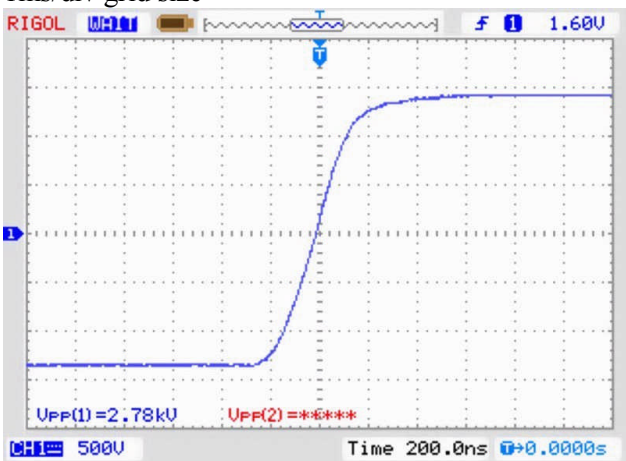

Fig. 5: timing detail with 200ns / div grid spacing, positive step of 2.8kV step size,

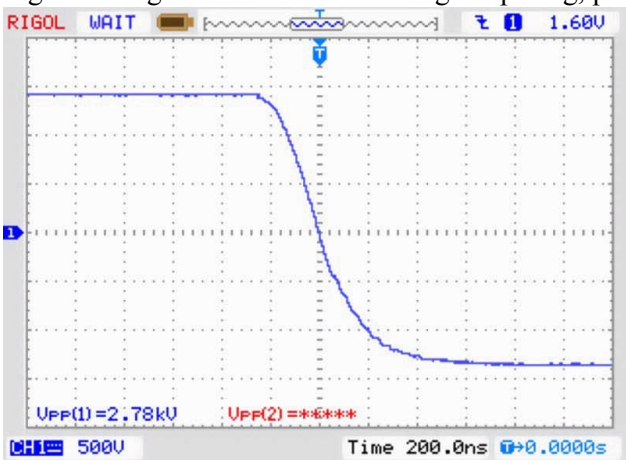

Fig. 6: Negative step of 2.8kV step size, timing detail with 200ns / div grid spacing

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As one can see in the graphs depicted above, typically a transition time (10% value to 90% value) of 200ns is observed at small loads, which may rise to approx. 800ns depending on the capactive load at the output. A known issue regarding output waveform is described in the appendix.

Voltage drop

A voltage drop of typically 2 to 4 volts needs to be taken into account, serially inside each switch from input to output. This feature is due to the inherent properties of the switching elements. Although being small in comparison with typical switching voltages in the kV range, this may need to be taken into account at precision applications.

On/off resistances

An 'ideal switch' would have zero resistance when turned on and infinite resistance when deactivated. The semiconductor switches inside MS-F 10 have typically an 'on' resistance of approx. 220 Ohm and a 'off'-(isolation-) resistance of larger 10GOhm. Note that these values are dfficult to measure with a standard multimeter (DMM), due to the fixed internal voltage drop (see above).

Brake-before-make delay

A brake-before-make delay circuit (approx. 1µs dead time) ensures that, at no time, 2 switches are activated at the same time, thus otherwise creating a short cut between the input lines (so-called shoot-through). This also means that during switching, for a short time (1µs) the output is left open (floating). Usually this has no adverse effect, but may be taken into account in case the device is loaded with significant DC currents (unlike a EOD operation).

3. Switching Speed Limitations.

Although the typical switching time (transition time as depicted in figures 2 and 3) is typically less than 1µs, one should keep in mind that the device takes about 50µs, to react upon a change on the parallel bus (9pole Sub-D). Additionally, since each switching process deposites some amount of energy into the selected swithing element, one should observe the following limitation to avoid overheating: The maximum average frequency (abundancy) of switching instances for a certain switch (all ten are equal) must not exceed 2kHz.

4. High-Voltage Input circuitry

The high voltage inputs are rated at 2kV maximum voltage vs. GND and are internally buffered with 18nF capacitors (to GND) at each input to provide sufficient short term stability with respect to possible output current pulses. 300MOhm resistors in parallel to the input buffer capacitors ensure discharging for safety reasons on a time scale of approx. 20 seconds.
Note that the external voltage supplies, which are required to provide voltages to the 10 inputs, must sustain a certain electrical current. The latter arises from charging/discharging capacitive elements, and is given by the switching step size ΔU at the output, average

switching frequency f_{sw} and effective switching capacitance C_{eff}. As a rule of thumb this required current is approx.

$$I_{required} = 0.5 \cdot f_{sw} \cdot \Delta U \cdot C_{eff}$$

Where C_{eff} consists of two parts, the capacitive load being attached to the output (no resistive load is assumed) plus the internal capacitive load of approx. 340pF.
E.g. at 125pF external load, thus C_{eff} = 465pF, 2kHz = f_{sw} and ΔU= 4kV step size, a supply current of 1.86mA is required at each input being involved to provide voltage for the mentioned voltage steps.

5. Output cable length and load

The length of the output cable, leading to a EOD or other capacitive load should be preferably short for two reasons:

1. in order to minimize parasitic load and thus improving switching speed and
2. to avoid cable reflections ('pulse-ringing')

The cable length should preferably not exceed 1.5m (corresponding to 150pF in case of RG58 type cable) and the capactive load (EOD load) be no larger than 50pF.
Resistive loads are not considered but are of minor importance as long as the corresponding resistance is larger than approx. 10MOhm.

6 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 allow 2cm clearance at the top cover with respect to the next device above. All ventilation slits must permanently be cleared in order to prevent overheating.

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.

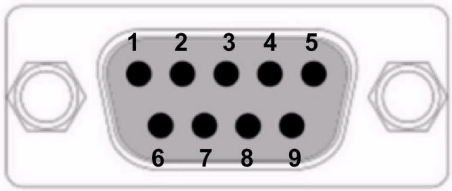
Connecting to mains power:
Connect the device to the mains power supply by using an appropriate power cord, being properly wired and providing a grounded outlet. The power cord must be suited with respect to possible load currents and be rated to 5A current. **Please observe country depending mains voltage ratings.**

Cabling of voltage output:
Always provide appropriate and safe cabling when connecting the device to other devices or vacuum/experimental setups. Cabling is prefered using high voltage cable with proper shielding. 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 and any external supply is turned off. Connecting a powered 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.

7. Parallel Port Input

For fast switch selection of the device, the proprietary parallel port (9pole Sub-D) on the front side can be used. It is implemented as a male 9-pole Sub-D socket with the subsequently depicted pinout (0V / 5V-Logic):



Pin 1	Bit 0
Pin 2	Bit 1
Pin 3	Bit 2
Pin 4	Bit 3
Pin 5	GND
Pin 6	Strobe
Pin 7 - 9	unused

Bit-Combination and corresponding selected Switch:

0 0 0 0	all switches off
0 0 0 1	switch 1 on
0 0 1 0	switch 2 on
--- and so on---	
1 0 1 0	switch 10 on

After the desired bit combination is applied, one should wait min. 0.5µs (= t_s) and then apply a rising edge at the strobe line, indicating that the bit values are valid. After this rising edge on strobe the data should be present at least 30µs longer (= t_h) and the minimum 'high' time for the strobe signal is also 30µs. A full cycle must not be shorter than 65µs, i.e. 15kHz max. update rate.

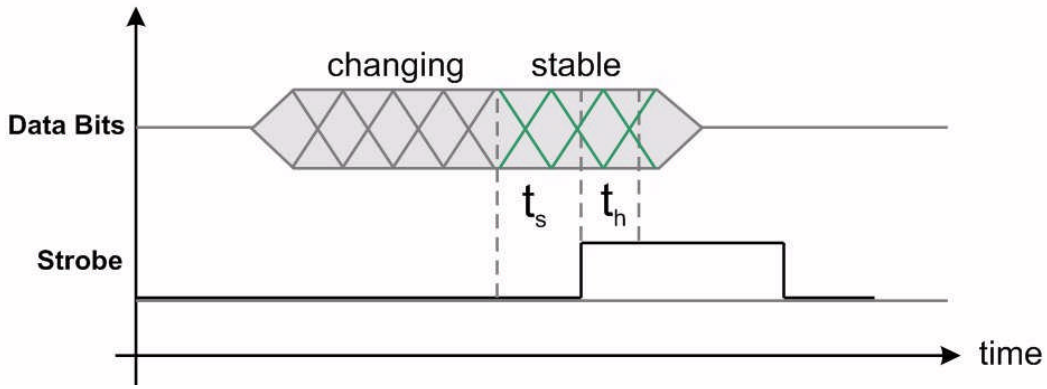


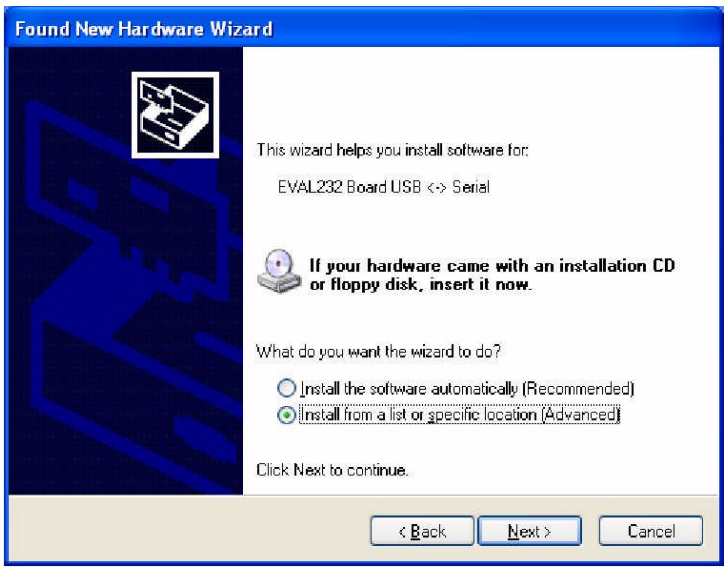
fig. 7: timing diagram of parallel port.

8. USB connection:

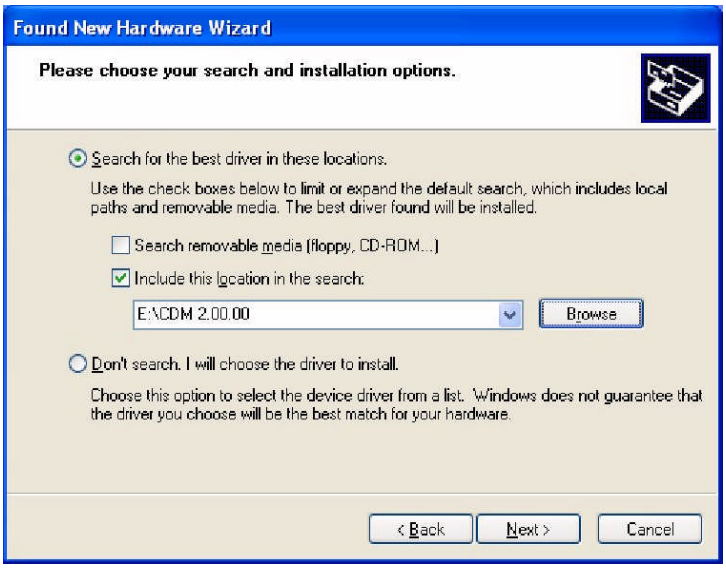
Use a standard type-A-B connection cable (USB 2.0 standard) to connect the device to the control computer. After connecting to a PC the "Found New Hardware Wizard" should open regardless if the device is already switched on or not, since the corresponding receiver inside the device is powered by the USB bus itself and therefore autonomous. 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, which is the manufacturer of the USB bus interface circuitry.
Latest drivers, also for different other operating systems can be downloaded from http://www.ftdichip.com/FTDrivers.htm.
Execute the following steps under Windows XP after automatic start of the "Found New Hardware Wizard":
The following screen opens up,

in which you 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**"



And afterwards you choose "**Search for the best driver in these locations**" and "**Include this location in the search**". Browse now to the 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 driver comes 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. Windows usually recommends to restart Windows now, but for immediate one can skip this point. Nevertheless the PC should be restarted at a later point and latest before installing any other piece of hardware or software.

For comand syntax to control the device via USB connection please see appendix.

9. Maintenance

The device is designed for years of reliable operation. Under normal operating conditions, it 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 is powered off. Do not use compressed air to clear the vents. 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 2-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 2-year intervals for internal cleaning from dust, or to have it cleaned by an accordingly qualified electronical workshop. Also air conditions containing oil mists (e.g. 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 electronical 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 = 5mT is admissible and must never be exceeded at any time, regardless whether the device is turned on or off.

Decommissioning

Decommissioning of the device is recommended after latest 80’000 hours of operation. Please contact manufacturer for appropriate waste disposal and observe applicable legal regulations.

10. Specifications

Device Function	Fast High-Voltage Multiplexer, selects one of ten (or: none) inputs and connects to output
Input Voltage Range	0 to +/-2kV vs. GND (short term, 20s) 0 to +/-1.75kV permanently
Input and Output Connectors	SHV
Swiching time (Output voltage rise or fall time, 10% to 90%)	200ns to 1µs (see text)
Input-Output on-Resistance	typ. 220 Ohm
Input-Output off-Resistance	typ. > 10GOhm
Input-GND-Resistance	typ. 300MOhm
Intrinsic (internal) output capacitance	280pF to 670pF, depending on applied voltages, typ. 340pF
Monitoring Control Output	1/100 voltage of device output, BNC socket
Device control modes	- Manual - USB - Parallel Port
USB- Communication	
Remote Connection Hardware	USB 2.0 compatible connection to PCs with galvanic isolation 115200 Baud (virtual COM port, data format is 8N1)
USB Isolation Rating	max. +/-350V vs. case GND, or 1000V optional
Command Language	Clear ASCII code, commands see Appendix
Driver Support	USB drivers are required and available for various operating systems. Free driver routines are available.
Environmental Conditions	
Magnetic Field	max. 5 mT admissible
Storage Temperature	-55 C° to +85 C°
Operating Humidity & Temperature	noncondensing relative humidity < 95%, at temperatures of +10°C and +35°C.
Power Supply and Case Dimensions	
AC Supply Rating	AC input voltage $230V_{AC}$ at 50Hz or alternatively $115V_{AC}$ at 60Hz The power entry module is EMI/RFI-filtered. Fuse: slow blow 2.0A
Power Consumption	typ. 10W
Dimensions	19.00” wide x 10” deep. Front-panel mount holes are configured for 19” racks
Weight	approximately 3.0kg, configuration dependent

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Appendix

Fig 8: connect the device to a PC through standrad A-B USB-cable

User-Defined Remote-Control and List of Commands

In order to access the device by self-written program code, the commands for remote-control are described below.

Commands are sent in clear ASCII text strings in order to communicate between a control device, like a standard PC and the HV Series voltage sources. The commands are sent through a standard USB-connection (1.0 protocol, but also 2.0 compatible). In case LabVIEW™ (Version 8.0 or higher) is used, the open source-text SubVI's (provided by the manufacturer) can be freely altered if required.

Establishing USB connection and sending commands:

Before sending any command, the USB connection to the device has to be established. This is basically done by connecting the device by a suitable cable (standard USB A- and B-plug) and installing an appropriate USB driver. Drivers for Windows (2000, ME, XP, Vista, Win7), Mac OS and Linux are provided by the manufacturer. You might also consult the USB-circuitry manufacturers homepage (www.ftdichip.com) for latest updates. The readily available "virtual COM port" (VCP) drivers allow simple access on the USB connection in the fashion of "classical" serial port (RS232) communication. This means, once the connection is opened, the user can send clear-text ASCII-strings over USB line to the connected device. The default baud rate is pre-set at 115200 bits per second, i.e. one voltage setting command takes about 3millisec (see also below). The data format is 8N1 (i.e. 8 data bits, no parity bit, 1 stop bit) and no flow control.

The following table lists the available commands, their functions and text strings which are returned from the sevice as answer. For simplicity several abbreviations are used: "xx" stands for the device serial number. This serial number can be found on the rear side of the device. Generally all commands must be terminated with an 'Return' (13 in ASCII code). After establishing the USB link and turning the device on, an "IDN identifier request" can be sent in order to retrieve the serial number, which will be used to address the device. Please see also examples and more details after the table.

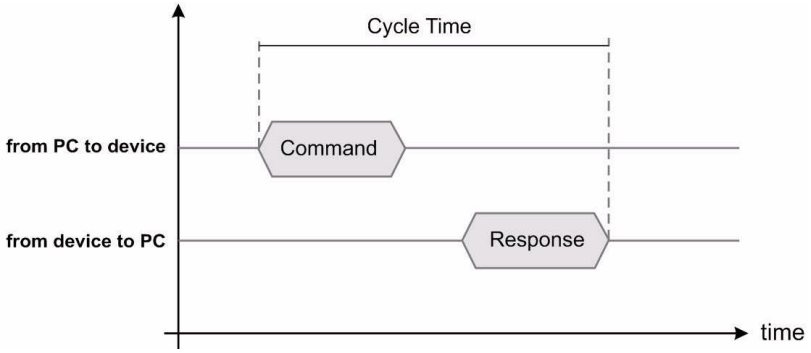
Command Function	**ASCII Strings** sent to device or received + CR ('carriage-return') at string ends	**Observations and comments**
Identify device	sent IDN received EODxx	The device replies with its serial number (xx)
Activate channel	sent EODxx CHYY received CHYY	Activates channel YY (YY = 01 up to 10), 00 switches all channels off. xx is the device serial number (starting from 01 to max. 99)
Deactivate all channels	sent EODxx OFF received Output disabled	Deactivates all channels

Possible Error Messages:

-"Device in Local Mode"
-"Channel out of range"
-"Syntax Error"

Communication Speed USB-Connection

The device is shipped with a USB-transmission speed of 115200 Baud as default value, or with a customized transmission speed as an option. In the latter case this customized speed is noted on the rear side of the device. The 'cycle time' for commands (as illustrated in the sketch below, time period from start of any command sent to device until end of its answer) is about 3ms to 4ms and scales up/down if a slower/faster speed is selected.



In order to avoid jamming of the data flow it is recommended to wait for each command being answered (full cycle time, as indicated above) and not sending data *before* response has been completed.

Known Device Issues

The output waveform may vary from the ideal rectangular shape in the following case:
Step size larger than 2.2kV (both directions up or down, independend of abolute voltage value), and at the same no switching event on the particular channel within the last 800ms. In this case the output waveform can significantly deviate from its ideal behaviour, like depicted below.

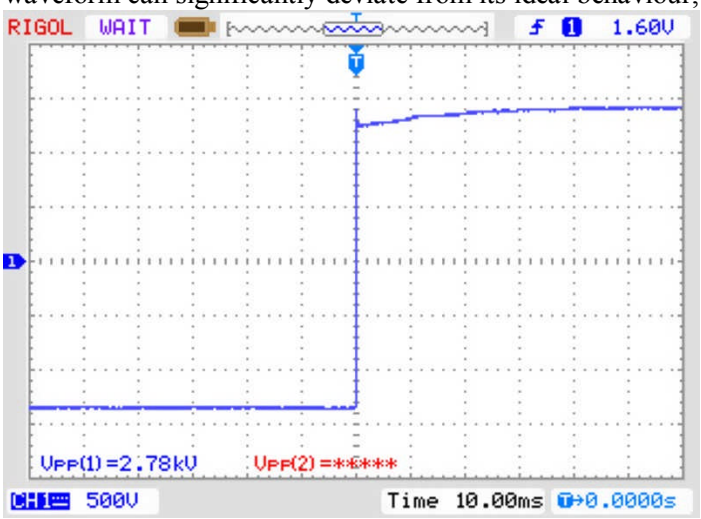


Fig 9: At certain conditions the output waveform deviates from the ideal behaviour, a 30ms long tail of approx. 6% of total step size appears

This effect is primarily due to temporary charge trapping inside the semiconductor switch. It vanishes at lower step sizes, more frequent value changes or if the respective switch is not changed for more than approx. 10sec.

User Manual Version Revision History:

1	Preliminary version	01/2016
1.01	Corrections in specifications and addition of command syntax	12/2016

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