stahl-electronics

HF-DRB series

RF Generator for Ion Traps

and Quadrupole Structures

HF-DRB_PaulDrives_Manual1_26.doc
November 2023

Datasheet

Rev. 1.26

Models

HF-DRB 170-10/400, HF-DRB 350-2/100, HF-DRB 300-10/400
HF-DRB 125-10/2000, HF-DRB 800-2/40

Main Features:

- Sine Generator and RF drive amplifier for Ion Traps
- amplitudes up to 1600Vpp (differentially), model dependent
- frequency 10kHz to approx. 2MHz, model dependent
- non-resonant design
- precision voltage stabilisation (device option)
- integrated precision oscillator

Purpose and Description of the Device

The purpose of the RF drive HF-DRB series is to supply AC voltages to Paul Ion Traps and other Quadrupole-type electrode setups for ion storage and manipulation. Unlike standard RF (radio- frequency) power amplifiers, the device is capable to handle capacitive loads, which are related to vacuum setups for ion trapping and storage and transportation.
The two outputs provide signals, which differ by 180° in phase, thus effectively doubling the voltage seen by a trapped particle. The HF-DRB device is designed to deliver voltages of several hundred volts AC on each output at frequencies between 10kHz up to 2 MHz (model dependent) into a 20pF to 75pF load (ion trap electrodes); admissible load depends on version.
This generator is housed in a standard 19-inch rack-mount case and features a remote control section, by which the user can control the device via a standard USB connection.

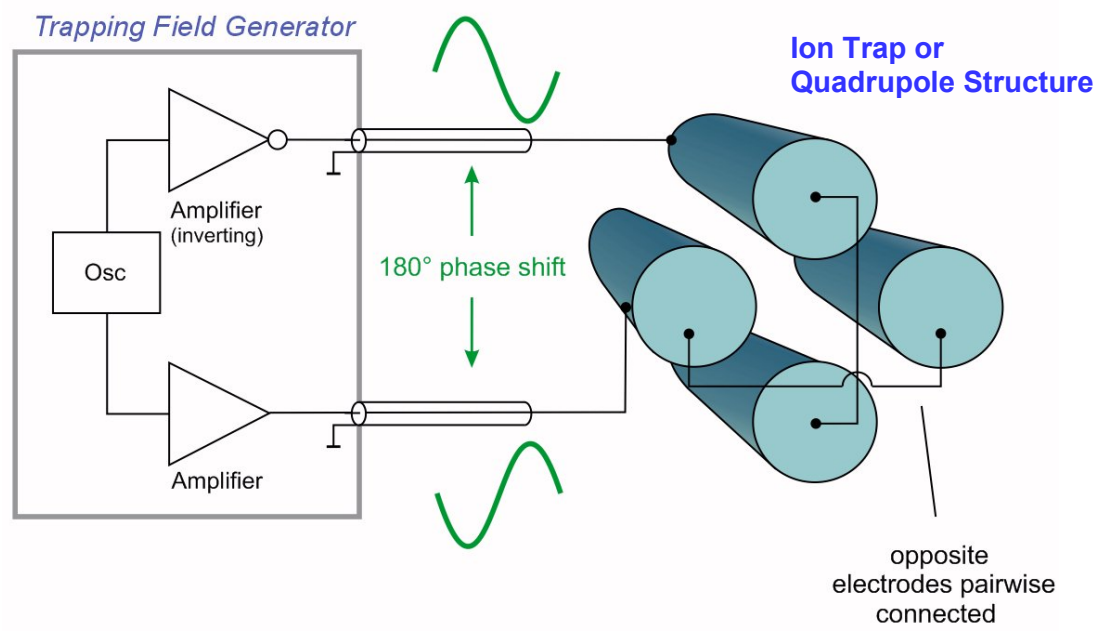

Fig. 1: Typical RF drive application: supply of Paul Traps or RF Ion Guides. The twin output doubles the effective voltage due to the 180° phase shift.

Device Nomenclature and Parameter Range

Examples: (1) HF-DRB 170 - 10/400

- 10/400: lower / upper limit of frequency range in kHz
- 170: nominal peak-peak output voltage each output

corresponding to: 2x 170Vpp each output, f = 10 to 400kHz

(2) HF-DRB 350-2/100
corresponding to: 2x 350Vpp each output, f = 2 to 100kHz

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Functional Principle and Block Diagram

The following picture (fig. 2a) displays a block diagram of the internal structure, illustrating the functional principle. A digital oscillator provides a sine wave of freely adjustable and precise frequency. An inverter circuit creates the inverted signal, or in other words a 180° shift. These two signals are fed into power amplifiers (one for each channel) and the resulting signals are presented at the output (typ. a few hundret volts of voltage).
The device features an offset DC input, by which the output voltages can be shifted. Voltages being applied to these input lines are added to the AC signal (RF) of the outputs (this feature is not shown in fig. 2a/b).
The USB section allows for remote control of essential functions of the device via a standard USB connection. Please refer to control elements on front plate in next chapter and command syntax for remote control in the appendix.

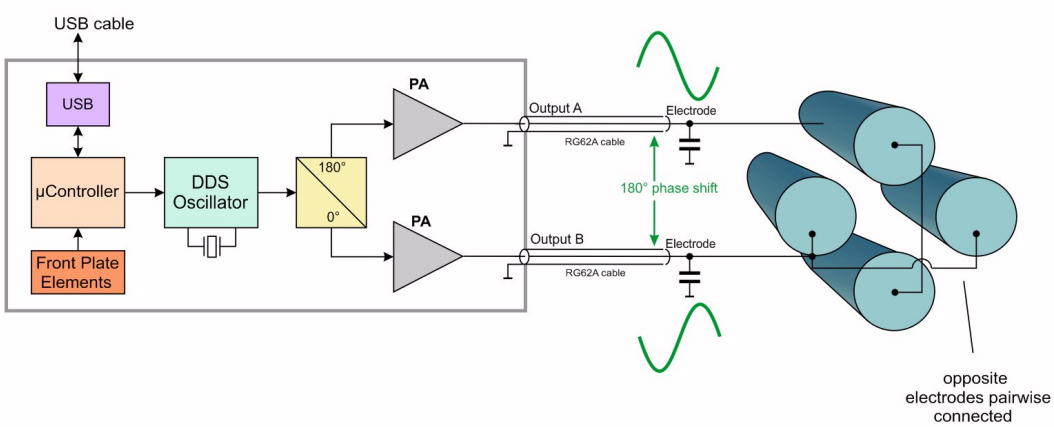

Fig. 2a: Block diagram of the internal structure, illustrating the functional principle.

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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, check temperature	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. 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 55°C indicates inadequate air ventilation. Check temperature (front display or via PC/USB readout) on regular base to avoid device damage and fire hazard.
Operate carefully with respect to risk of electrical shock	This device can produce high voltages at its output lines, which is harmful in case of direct touch with the human body. This voltage may be even exceeded, in case that an additional external voltage is applied to the "floating GND" input, the device is shut off before disabling the outputs, or an internal failure occurs. 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.

Operation and Control elements

Mains Supply Switch | LCD Display | Phase Output | Activate/ Deactivate Switch | Control Keys | Excitation Input

The front plate contains the main control elements of the device:

Mains Supply Switch

The device is powered up after activating the rear-side mains supply switch and switching the power button on the front plate into the "on" position. A Power-on-LED (green) indicates proper operation of the internal circuitry. A warning beeper will temporarily sound, which is used for ventilation fan-speed monitoring. If the warning beeper permanently sounds, the device must not be put into operation. In general, if the device is not in use for a longer time, it is recommended to deactivate the rear side mains switch to cut the device completely off from mains supply. This is mainly for safety reasons.

Phase Output

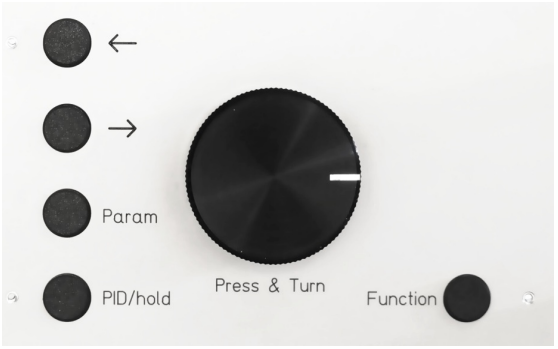
The HF-DR devices feature an internal precision oscillator, which provides a logic level (i.e. 0V / 5V) output to monitor the oscillators phase. This output is helpful e.g. in case of an ion extraction out of the trap and exact timing with small jitter (<1ns) is required. External triggers or pulse generators may be connected to this output therefor.

Activate/Deactivate Switch

This input allows for activating and deactivating the output amplitude of the device. It may be operated
- manually with the switch on the front plate plate
- remotely via USB connnection or
- using the logic level being applied to the BNC input socket (left open: activated)

A low level at the BNC input socket here deactivates the RF power, high level activates it.
For safety reasons the manual switch position, being switched to 'off' overrides other settings.

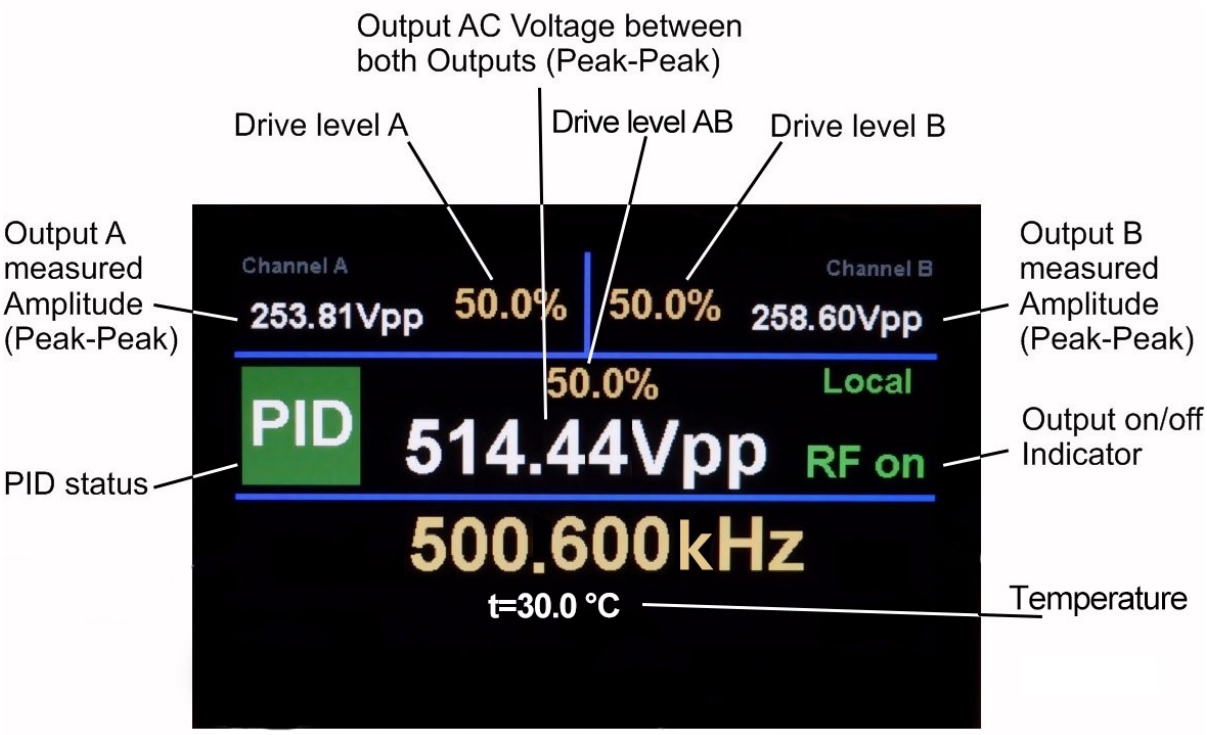
Control Keys



The device is manually operated by the control keys and the selection wheel. Pressing the button 'Param' selects the parameter to be changed. This button 'rotates' through the following parameters:

- Frequency
- Signal Drive level (average over both outputs)
- Signal Drive level, output A only
- Signal Drive level, output B only

…and then back to Frequency.
Once the parameter is selected, use the arrows → and ← to choose the digit to be changed and rotate the wheel to change the parameter value. Pressing the wheel has the same effect as selecting the next right digit.
'Function' is reserved for special functions and also toggles the device from 'manual' to 'remote mode'. In the latter the device is controlled via the USB bus interface by a PC, and manual entries are locked out. For 'PID/Hold' function see below.



LCD Display

The LCD Display shows the main functions and parameters of the device, like chosen drive level, selected frequency, PID status. The display reduces light intensity after 60 minutes to prolongate its lifetime. For general operation of the device see below (picture above shows display of the Dual-Channel resonant version).

Excitation Input

If this option is installed, the excitation input allows for adding a small voltage difference to one of the RF outputs. This serves for creating an additional (e.g. quadrupole) component for ion excitation. This voltage is linearly superposed to the RF field. A voltage up to 10Vpp (20Vpp for short durations) may be applied here. It will be transferred to one of the output with an attenuntion of approx. 1/500 in the frequency range between 2kHz and 1MHz. The LED indicator above the BNC input sockets lightens up at voltages larger approx. 7Vpp.

External Power Supply

For biasing reasons an external power source is required for some HF-DRB models. This source should provide a stable DC voltage of approx. 1.35 times the specified peak-peak voltage each channel. E.g. a HF-DRB 125-10/2000 device (delivering 125Vpp each output line) requires $170V_{DC}$ of external bias voltage. Normally the manufacturer provides such external stabilized power sources. This external source should have a safety current limit (300mA) and safety output power limit (50W). The external power supply needs to be connected to the HF-DRB device using 4mm (banana type) **safety connectors**. The HF-DRB indicated on the front display whether, or not, the external power supply is connected and delivers biasing voltage. In case the biasing voltage is too low or too high, a safety warning appears on the display. Beware of applying too high bias voltages over longer periods (minutes, hours), since overheating of the device may damage the device.

Basic Device Operation

To operate the device, first complete wiring to the Ion Trap (or Quadrupole Structure), make sure there are no shortcuts. Connect setup to the device high voltage outputs (rear side) using appropriate cabling (coaxial cables), which can sustain the voltages and protect from unintentional touching. Note that during turning the device on/off, temporary voltage transients of +/-500V may occur at the outputs. The attached setup should be able to tolerate these transients
Note also that some HF-DRB devices require an external additional power source (see chapter above) to operate.
In order to start operation, turn the device on and put the 'Activate/Deactivate Switch' to the 'enable' position. The display should show 'RF on' now. Increase the drive level (by pressing the 'Param' button, turning the selection wheel and using the → / ← buttons) to a low value, say 25%. The amplitude indicators should start to show some amplitude value (e.g. 70Vpp). Press the 'Param' button to select the frequency settings (cursor blinking).
In case a short cut to GND or very heavy load is detected at one the outputs, one will observe a too low amplitude, being indicated on the front display. Otherwise, the device is now ready for operation. Note that essentially the output voltage scales almost linearly with the set drive level, 0% drive level corresponds to (almost) zero amplitude, 100% drive level corresponds to the max. amplitude.
Please observe that the drive level only coarsly defines the output voltage, thereor adjust the desired output voltage by adaptation of the drive level. This adaptation can also be executed in a half-automated way, see chapter 'PID loop' below.
The parasitic capacitances, which are connected to the output lines should not be excessively high, to allow the device to achieve the desired high output voltage level. E.g. for device variants reaching as high as 2 MHz, a maximum load being not higher as 25pF each channel are recommended. Higher loads will not damage the device but the outputs may not entirely reach the desired high level of output AC voltage.

Use of Offset

The device provides Offset inputs at the rear side (two input, each for outputs A and B), DC voltages applied here are forwarded through each a 1 to 2 MΩ-resistor to the respective output. A decoupling capacitor at each input of approx. 15nF to GND is used to buffer the DC offset voltages. Note that the internal high voltage AC amplifiers are coupled to the outputs through 20nF coupling capacitors.
Note that in case the offset inputs are *not* being used, one should short cut these inputs to GND, through short cut plugs or 50 Ohm terminations. Otherwise, they may charge up to an undefined DC level.

PID loop

The device features a regulation loop, which is activated by pressing the corresponding PID/Hold button (press again to turn off again). In the instance of pressing this button, the current amplitude reading (A-B) of the differential amplitude between both outputs is measured and internally stored. Subsequently the drive levels of both channels are always adjusted such that this differential amplitude value is kept constant. The increased stability of this value is advantageous for maintaining more stable conditions at the setup being connected. The subsequent graphs show a typical stability.

As long as the regulation loop is capable of maintaining the same differential amplitude value, the indicator will be green on the display, red otherwise. Grey color means that the PID loop is not activated.

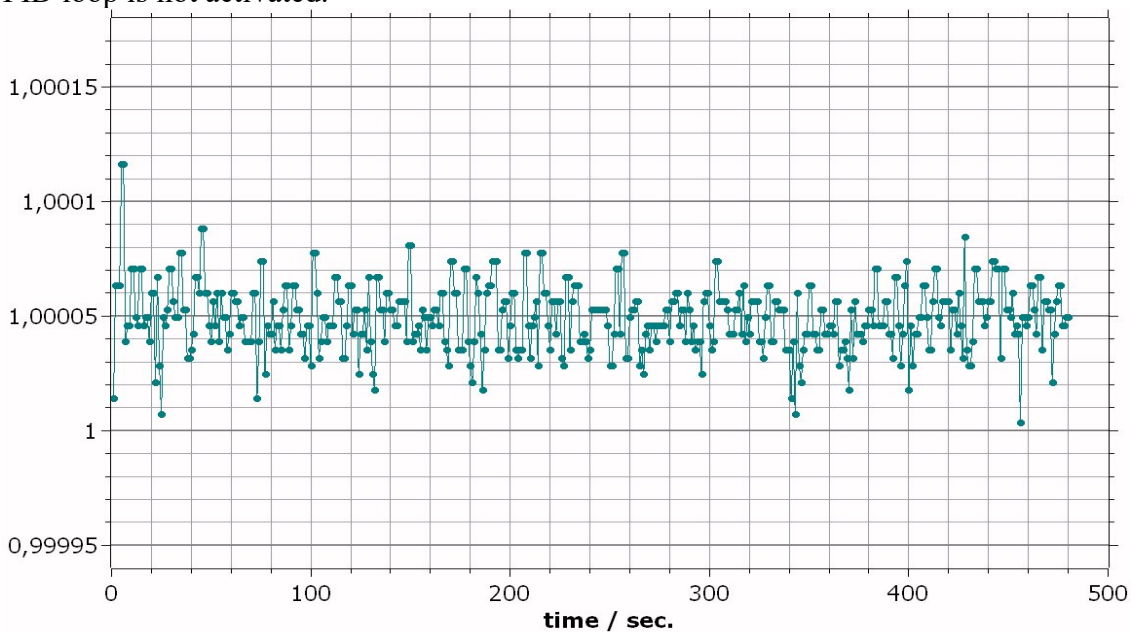


fig. 4a: Typical stability of output amplitude at medium load (AC voltage difference between both outputs at 400Vpp) with PID being activated. Within a 8 minute interval the instability (relative amplitude deviation) is only on a level of 25ppm rms, i.e. in the 10^{-5} range.

Fan/Temperature Warning

In case there is a problem with the ventilation fans or signs of overheating inside the device, the latter is indicated by a display reading. Eventually the output is intentionally disabled for safety reasons. In this case, turn the device immediately off and check for (obvious) reasons. In case of unclear situation please contact manufacturer.
The device is equipped with several temperature sensors; the device will automatically shut down the outputs if temperature surpasses a certain level (higher than 71 degrees Celsius); the display will show the message: "Temperature too High!"

Remote Operation

The device can be remotely controlled using the USB connection at the rear side. By pressing the ‘function’ button the modes are switched between local and remote. Please refer to appendix for command syntax. In ‘remote mode’ manual pressing of the control keys on the front plate is disabled.

Specifications

Amplifier and Output		
Output voltage	each line max 200Vpp (peak-peak) to 800Vpp @ approx. 35pF load after cable, model depending	
Frequency	model depending; typ. 10 kHz to 2MHz , model depending	
Output Power	typ. 10W, < 26W	
Output connector type	SHV or Amphenol multipin connectors (customizable)	
DC Offset (option)	max. +/-200V DC (optionally +/-500V) (applied to rear side offset BNC input, connected through 1 to 2 MΩ to the corresponding output channel)	
Capacitive load capability each output	≤ 55pF recommended, load to be connected to output leads	
Auxiliary Excitation (Option) **Input** (front plate)	0 to 20Vpp, 50Ω transfer function: approx. 1/500 of amplitude is superposed to RF amplitude	
Front Plate Display Readings		
Voltage Accuracy: (voltages > 25% of full scale)	typical	maximum error
Scale error each channel	2.5%	4.5%
Offset error each channel	4V	7V
Voltage Difference (floating coil option FL)		
Scale error	3%	4.5%
Offset error	2V	
Phase Accuracy (voltage larger 100Vpp)	typical	
Error, equal connected capacitive loads	2°	8°
Frequency	20ppm	35ppm
Environmental Conditions		
Magnetic Field	max. 5mT admissible	
Storage Temperature	-55 °C to +85 °C	
Operating Humidity & Temperature	noncondensing relative humidity up to 95% temperatures between +0°C to +30°C.	
Power Supply		
AC Supply Rating	AC input voltage 230V_{AC} +/-5%, at 50Hz or 60Hz, or 100 to 120V, (model depending) typ. 62W consumption at max. amplitude. The power entry module is EMI/RFI-filtered. Fuse: medium fast blow 2A (230V), 3.5A (100V to 120V)	
Case dimensions	19.00” wide x 10” to 20” deep, model dependend. Front-panel mounting holes are configured for M6 rack configurations	
Weight	approximately 7.5 kg	
External Power Source	An external power source (50W rating) is required for several models, see chapters above, fuse (rear side) 500mA, medium-fast	

Note 1): Capacitive loads must be minimized for achieving highest amplitudes. Note that dissipative effects of loads can significantly reduce maximum amplitudes; this is specially true for high output frequencies above 400kHz.

Software installation

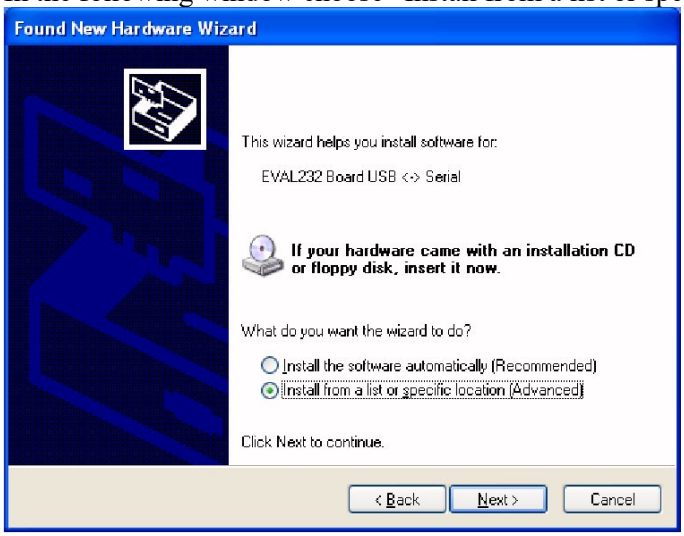
USB-Driver

The device uses the USB bus for connecting to a control PC. After proper cabling of the USB connection (see section before) Windows should automatically identify the connected device. Depending on the Windows version, please allow up to **two minutes** to automatically identify the connected device and to install drivers. In case this fails, 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/USB stick also 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.

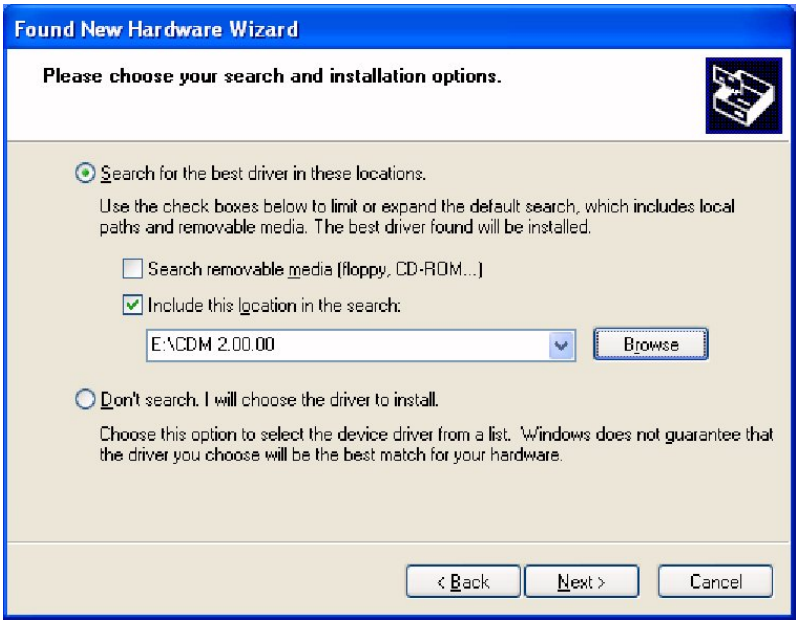
In case of Windows XP systems, USB drivers may not be installed automatically and of the "Found New Hardware Wizard" may open up,

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.

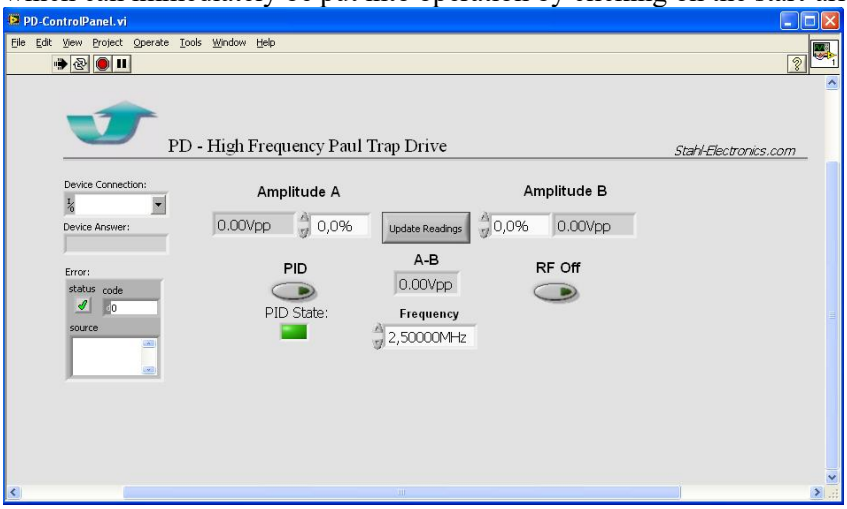


Click "**OK**" and "**Finish**" to complete the first driver installation.

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 for use and indicate this by showing "HV Series: Device Ready" (or similar) in the lower right screen corner of your PC for a couple of seconds.
Windows usually recommends to restart Windows now, but for immediate use of the HV-Series devices 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.

LabVIEW™ control program

Assuming that LabVIEW™ in Version 18 or higher is available on the target PC, copy the path containing the LabVIEW™ source code VI's from the installation CD to a place of your choice on a local drive. By double-clicking on the corresponding file the control panel for the device will open, which can immediately be put into operation by clicking on the start-arrow in the upper left corner.



The device parameters may be entered in the corresponding numeric fields, after choosing the established COM-connection to the device and serial number ('PD' + last three digits).

Devices with option ‘FL’ feature only one drive level setting.
Note that the provided LabVIEW control program is intended to give an example, how to operate the device. Seft-written progams may use the command syntax described below and use common programming languages, like Matlab, C, Delphi or Python.

Remark:
One known problematic point with National Instruments drivers is the fact that they tend to collide sometimes with other drivers, especially for Tektronix oscilloscopes. If in doubt the other drivers should be temporarily removed and installed again.

Appendix

User-Defined Remote-Control and List of Commands

Introduction

The device can be controlled using the provided LabVIEW™ cource code blocks, or by self-written program code. Standard program compilers/interpreters like C++, Python or Pascal/Delphi dialects may be used for this purpose and also simple command-line terminal programs (e.g. HyperTerminal™) will do. The physical line connection to the device (USB-connection 1.0 protocol, but also 2.0 compatible) needs to be established beforehand, like described in section 3.2.1. USB-drivers for Windows™ versions, Mac OS and Linux are provided. Please check eventually the USB-manufacturers homepage (www.ftdichip.com) for latest updates.

Note that the physical communication acts like a so-called RS232 device, communicating with standard settings (115200 Baud, 8N1 protocol, no handshake). In self-written code the 115200 Baud rate parameter needs to be set accordingly. In Windows™ operating systems the device appears on a ‘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 by the user inside the Windows™ system control panel.

Command List

Inside this table the abbreviation “DDDDD” represents the name of the device including its serial number, e.g. “PD001” means a device with serial number “001”. All commands must be terminated with an CR (‘carriage-return’) symbol “↵” (13 in ASCII code). First, after establishing the USB link to the HV 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. 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 Frequency	sent DDDDD F XXXXXXXX	The frequency of the output signal is set. XXXXXXXX is a decimal number between

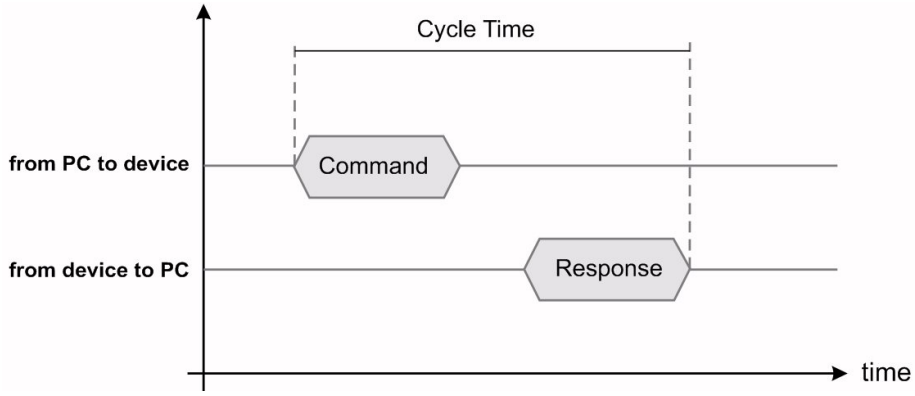
	received ACK (ASCII Acknowledge, 0x06)	00000000 and 10000000 which represents the the Frequency in Hz, leading zeros must not be omitted, Example:00500000 means 500kHz Note: Device must be in Remote Mode!
Set Amplitude	sent DDDDD X YYY.YYY received ACK (ASCII Acknowledge, 0x06)	The amplitude of Channel X(‘AB’ or 'A' or 'B') is set. YYY.YYY is a decimal number between 000.000 and 100.000 which represents the percentage of the maximum voltage of the internal DAC for the selected Channel. Device must be in Remote Mode!

Activate/ deactivate software PID loop	sent DDDDD PID OFF or DDDDD PID OFF received PID Started or PID Stopped	This command activates deactivate the PID loop to hold the output amplitude constant
RF ON/ OFF	sent DDDDD ENABLE or DDDDD DISABLE received RF Enabled or RF Disabled	ENABLE enables the RF output and DISABLE disables it. Caution: Switching from remote in local mode automatically enables the RF output, if not disabled by the front panel switch or BNC input. Device must be in Remote Mode.
Read Amplitude	sent DDDDD R X received X.XX or XX.XX or XXX.XX	Reads the amplitude of channel A, B or the differential amplitude (X = 'A','B' or 'D'). Caution: the return string has no fixed length. For example an amplitude of 86.29Vpp will return 4 digits and an amplitude of 239.04Vpp will return 5 digits. Device can be in any mode.
Read PID state	sent DDDDD R PID received PID OFF or PID OK or PID OUT OF RANGE	Reads the state of the PID loop. Device can be in any mode.
Read back Frequency	sent DDDDD F? received XXXXXXXX	Reads back the frequency in Hz with leading zeros (8 digits).
Read back set Amplitude	sent DDDDD X? received X.XXXX or XX.XXXX or	Reads back the currently set Amplitude of A or B (X=’A’ or X=’B’) in percent of the maximum Voltage of the internal DAC. Caution: the return string has no fixed length.

	XXX.XXXX	
Device in Local Mode	sent DDDDD L? received 0 or 1	Checks if device is in Local Mode. 0: Remote Control 1: Local Mode

Communication Speed

The device has a transmission speed of 115200 Baud (115200 Raw-Bits per second). Note that this speed grade corresponds to the 'Fast-Mode' regarding the HV- or BS-Series devices from Stahl-Electronics. However, the cycle time as illustrated below can be up to 25ms. In self-written program allow sufficient time to pass to avoid data collsision and ‘jamming’ of the serial connection.



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: **HF-Drive (Paul Traps)**
Model Number: **HF-DRB**

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 _____

21. Jan 2019 **General Director**

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