HF-D series

RF drive amplifiers for Ion Traps

HFD_Drives_Manual_2_1.doc
28 - April - 2013

Datasheet

Rev. 2.1

Models HF-D 200, HF-D 425, HF-D 600

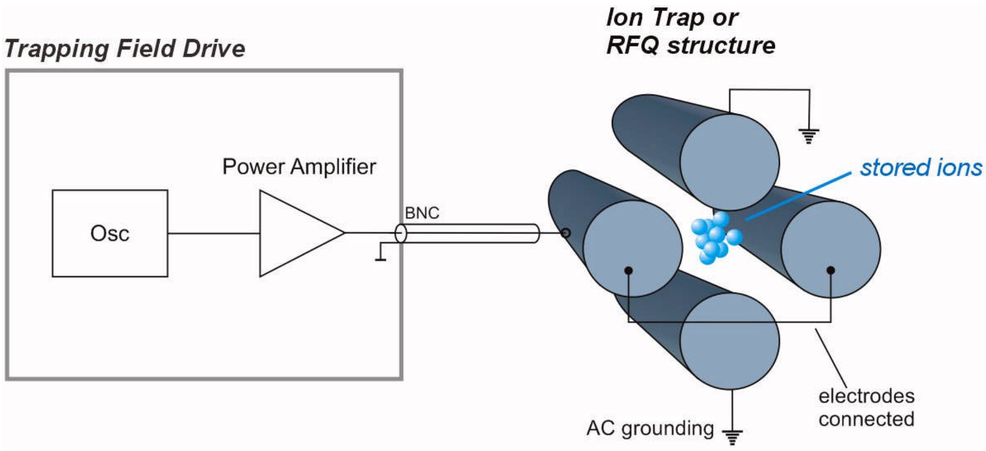
Main Features:

- RF drive amplifier for ion traps
- up to $600V_{pp}$ into 100pF load
- f = 360kHz to 1.5MHz, model dependent
- non resonant broadband design
- precision voltage stabilisation (device option)

www.stahl-electronics.com

Purpose and Description of the Device

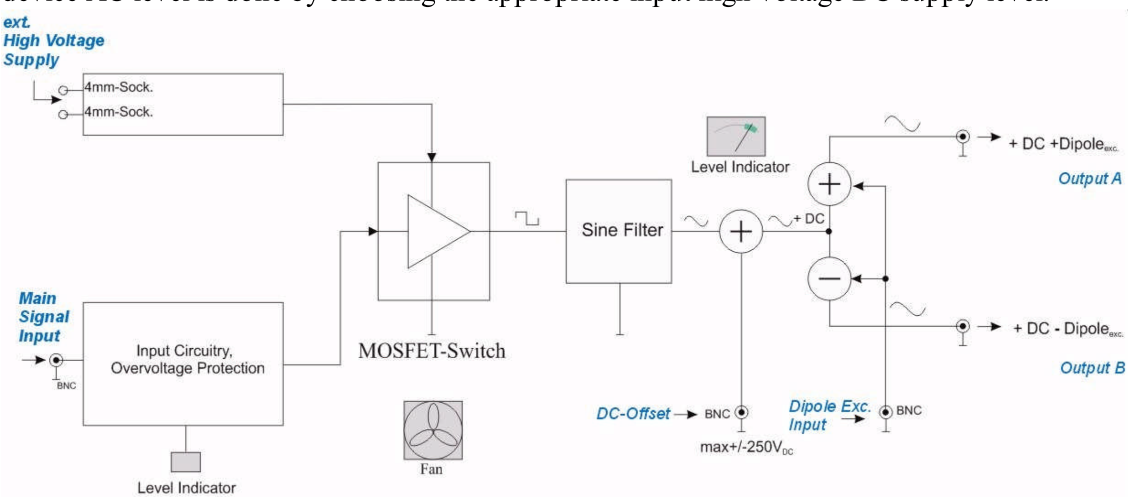
Purpose of the RF drives HF-D 200, HF-D 425 and HF-D 600 is the supply of AC voltages to Paul Ion Traps and other Quadrupole-type electrode setups for ion storage and manipulation. Unlike standard RF (radio- frequency) power amplifiers, the device is capable to handle capacitive loads, which are related to vacuum setups for ion trapping and storage. The devices feature a fast-turn-on/off capability to capture ions in flight. Other common RF drives usually require a certain amount of time to build up the nominal output voltage since they are based on a resonant voltage transformation. In contrast the RF drive HF-D series consists of broadband devices which allow for instant turn-on and fast turn-off of the AC output voltage. The HF-D 200A version is designed to deliver up to 200V_{pp} AC voltage of 600kHz to 1.5MHz frequency into a 100pF load on each output, the HF-D 425 is designed to deliver up to 425V_{pp} AC voltage of 459kHz to 900kHz frequency into a 75pF load on each output and the HF-D 600 is designed to deliver up to 600V_{pp} AC voltage of 300kHz to 600kHz frequency into a 75pF load on each output. The devices are housed in a standard 19-inch rack-mount case.



RF drive typical application: supply of Paul Traps or RF Ion Guides.
Note that an oscillator is not included in the HF-D series devices.

2.2 Functional Principle and Block Diagram

The following picture displays a block diagram of the internal structure, illustrating the functional principle. The voltage at the main signal input controls a fast electronic switch, which switches between the high and low level of the external supply voltage, creating a rectangular shaped high voltage signal. The rate at which this switching happens is defined by the frequency at the signal input (for instance 600kHz). A subsequent sine wave filter removes the higher harmonics, thus creating a sine-shaped high voltage waveform. The DC level of the externally supplied DC voltage at rear input defines the devices output AC level, since both voltages are in linear relation. This also means that output regulation of the device AC level is done by choosing the appropriate input high voltage DC supply level.



www.stahl-electronics.com phone: +49 6242-504882, fax: +49 6242 504884

Operation and Control elements
Elements on the front plate

Mains Supply Input Enable Range Selector Output Voltmeter Dipole Excitation Input
Switch Fan/Temperature Warning

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 deactivate the rear side mains switch to cut the device completely off from mains supply. This is mainly for safety reasons.

Input

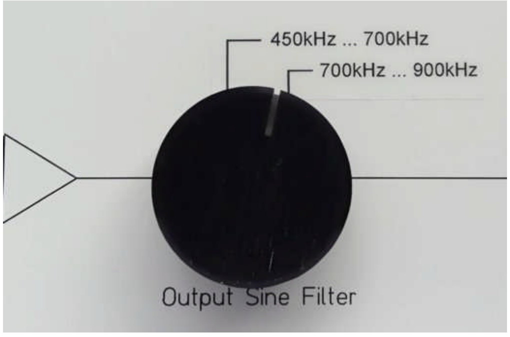
The input signal (sine wave) is fed into the BNC input at the front side (75Ω input impedance nominally). An AC voltage level of nominally 5Vpp should be applied. The LED indicator above the BNC socket lightens up green, if a sufficiently large signal level is applied, red otherwise (i.e. input AC voltage too small). The waveform of the applied signal should be "sine" to allow for proper operation and meeting of the specifications. This input may be fed by a common function generator or radio frequency (RF) signal source. Please make sure that the device is not permanently operated with input voltage being too low (LED indicator red). Note that the output voltage is **not** supposed to be controlled by the amplitude value of this input, but by variation of the DC supply on rear side. The latter supply voltage is in good approximation proportional to the output AC voltage.
Once the device is installed and cabled in a given setup, it is recommended to choose the input voltage level to be approx. 15% higher than the transition threshold (red-to-green) of the level indictor LED. A second LED indicator above the one mentioned before lightens up green if the external DC supply voltage exceeds approximately 150V to 180V, showing the presence of DC voltage at the rear side.

Enable

The "Enable" section of the device allows to turn the output power completely on or off. This section consists of a manual switch, a disable BNC input and status indicator. The output power of the device is either enabled or disabled (LED indicator shows green or red light). The user may select this state by choosing the desired switch position manually (putting it up or down), or by applying an external signal of logic level to the corresponding BNC input. When the manual switch lever is centered, a logic "LOW" level (0 Volts) disables, a logic level "HIGH" (+5 Volts) enables the RF outputs. The reaction time upon a change of this level is about 1 to 2 signal periods.

www.stahl-electronics.com phone: +49 6242-504882, fax: +49 6242 504884

Range Selector



For proper operation of the internal sine wave filter, the frequency range selector knob must be placed in the appropriate position, depending on the input frequency chosen. Avoid running the device permanently in the wrong position, since this may load the internal device circuitry after some time due to excessive heat production.

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 red warning LEDs. In case they lighten up, the output is intentionally disabled for safety reasons and a warning beeper will sound.

Output Voltmeter

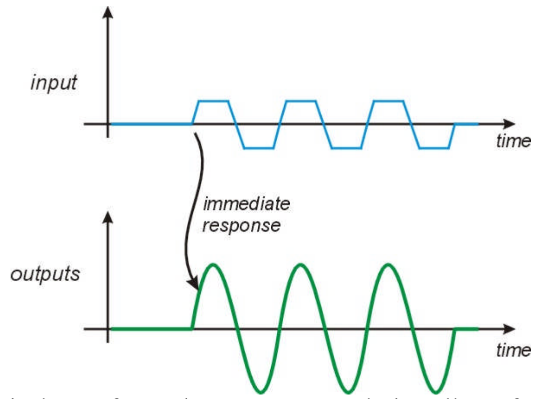
The Output Voltmeter shows the output AC voltage in terms of Volts-peak-peak. It averages over the two outputs A and B (rear side of device). Note, that one always has to ensure by choosing an appropriate DC supply level at the rear side, that the output level does not constantly exceed its nominal value of 200Vpp, 425Vpp or 600Vpp respectively. **Note that otherwise the device may overheat and get damaged**. Therefore always carefully watch this indicator when changing the external DC supply voltage or changing other conditions of devices attached (e.g. cabling).

Excitation Input and Test Output

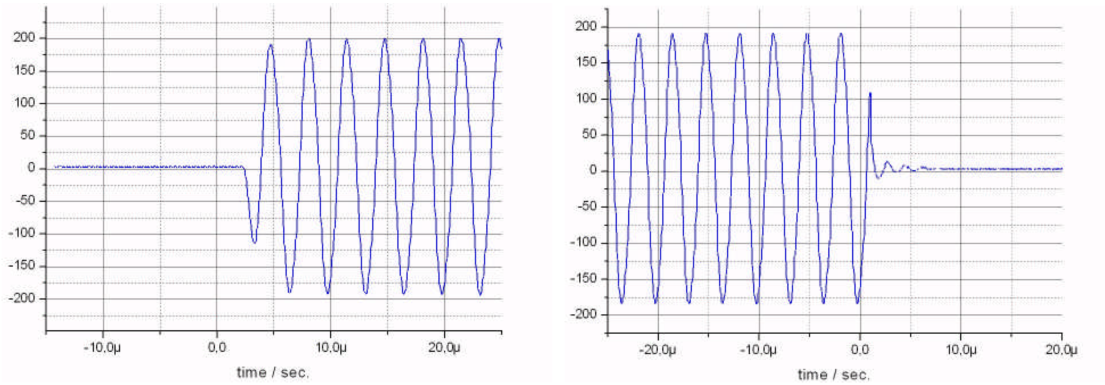
At the **BNC test output** socket (placed on rear or front side), one can check the general functionality of the device. 1/100 of the output amplitude, being averaged over the two outputs A and B is provided here. This applies for AC components as well as the (optional) DC-Offset.
The **excitation input** allows for adding a voltage difference between the two outputs A and B. This voltage is linearly superposed to the RF field. A voltage up to 20Vpp may be applied here. Please observe the frequency response (figures below) i.e. the transfer function has a certain frequency-dependency.
The “unbalanced” LED indicator above the excitation socket lightens up if a large AC voltage difference (greater roughly 15Vpp) between the outputs A and B is detected. It therefore lightens up in case of an intentionally applied excitation signal, or if there is a malfunction, e.g. an unbalanced capacitive or resistive load on the outputs A or B. This indicator may serve as coarse, but nevertheless important, check for correctly attached cables and circuitry on the outputs. However, a thorough cabling check is recommended before applying any signals to the outputs.

Output Characteristics
Stability and Fast Turn-On/Off Feature

The outputs A an B provide a sinusoidal waveform with identical amplitude and phase. Phase jitter and amplitude jitter are in the order of < +/-1°, and about 2x 10^{-3} relative to the output amplitude, respectively. Note that instability of the externally supplied DC high voltage will add fluctuations to this intrinsic amplitude instability.



Theoretical waveform: the non-resonant design allows for immediate response (turn-on / turn-off) of the high frequency output



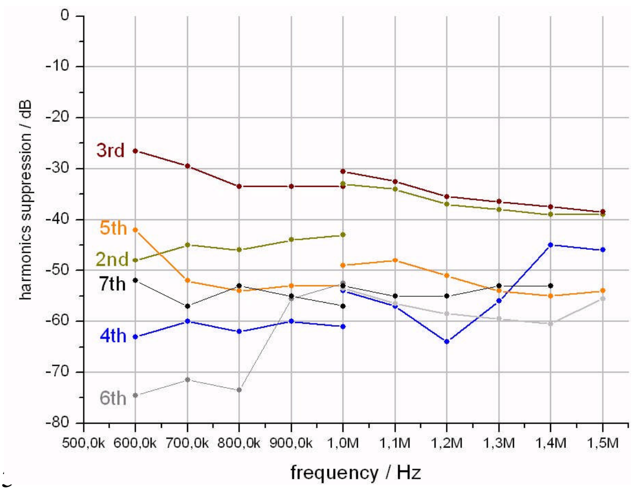
Experimentally measured waveforms during turn-on / turn-of events; f = 350kHz, U_{out} = 380Vpp.

The HF-D amplifiers feature immediate turn-on characteristics as shown above, due to their inherent broadband design. The remaining waveform tails during turn-on/off events typically last for about one signal period. The transient waveforms shown in the figure above were obtained using the "external enable" input on the front plate.

Please note that the output amplitude at high amplitudes >150Vpp may show significant drift in time due to internal heating effects with a typical time constant of 30 minutes. This drift (decreasing amplitude) may be in the order of several percent after starting the device operation, unless an external correction loop is implemented (see below).

Output Harmonics

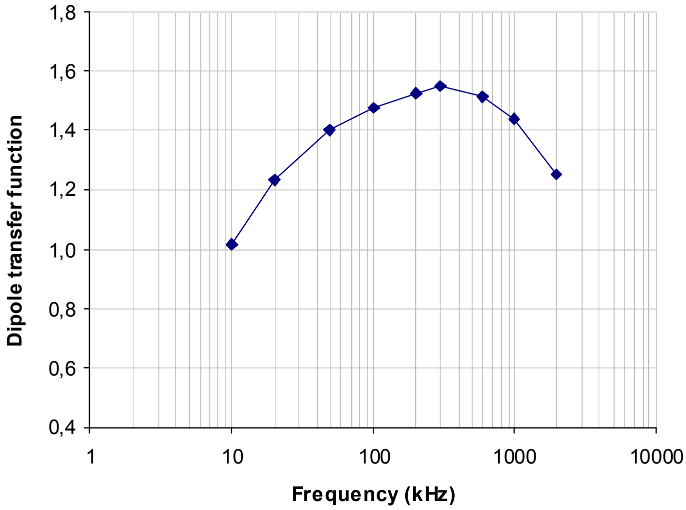
The output waveform is essentially a sine wave with some remains of higher harmonics. The subsequent graph depicts a typical harmonics content in dB with respect to the main (fundamental) frequency, which are a left-over from the sine-forming process.



Dipole Excitation

The Dipole excitation input on the front plate can be used to create a voltage *difference* between the two outputs A and B. This voltage, being in the order of a few volts, may be used to excite motion or energy of trapped ions. Observe, that the internal circuitry features a certain transfer function, which is shown in the subsequent figure. For instance applying a voltage of 10Vpp at 300kHz will create a voltage difference of 15Vpp at the outputs. Maximum output voltage difference is approximately 20Vpp. Beyond that value the circuitry will get into saturation.

Dipole excitation transfer function, i.e. ratio of output voltage-difference to excitation input voltage, a sine wave is assumed.



Precision Output Amplitude Regulation

In case the corresponding option is installed, the device features a BNC output at the rear side (marked in left picture) , at which a DC-voltage, being proportional to the AC output amplitude is presented. The corresponding scaling factor is approximately $1V_{DC}$ per $200V_{AC}$ on the AC outputs. By using this DC output voltage, an external correction loop may adapt and continuously modify the supply high voltage to keep the magnitude of AC output signal constant. This eliminates temporal and temperature-related drifts of the AC amplitudes. Typically a stability on a 0.25%-level is reached that way. E.g. dedicated ***stahl-electronics*** HVD-series supplies support this functionality. Please refer to their data sheets or manuals for more details.

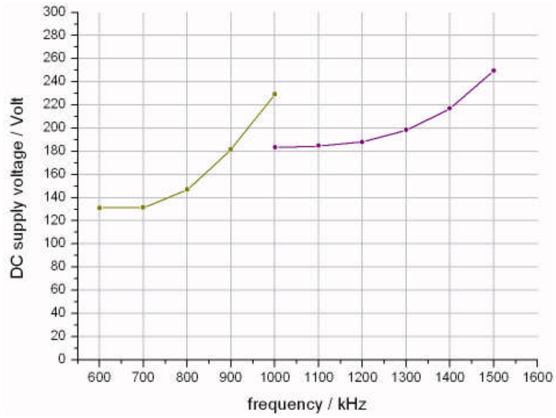
www.stahl-electronics.com phone: +49 6242-504882, fax: +49 6242 504884

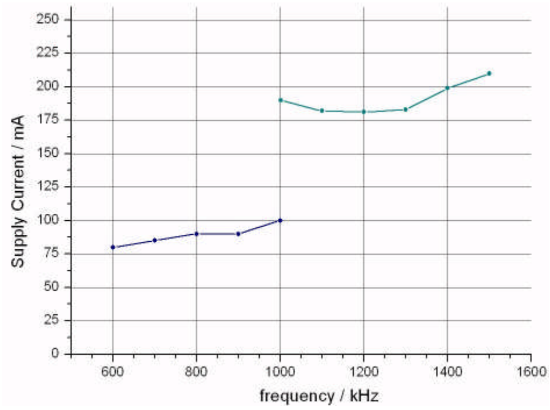
Specifications

Input Specification		
Input voltage level	nom. 5Vpp (Volts-peak-peak), 4.5Vpp to 8Vpp applicable without damage, nom. 75 Ω input, ac coupled recommended signal level: 15% higher then LED indicator green-red transition	
Output Specifications		
Output voltage HF-D 200A HF-D 425 HF-D 600	 0 to 200Vpp (Volts-peak-peak) = 70.7V_{rms} 0 to 425Vpp (Volts-peak-peak) = 150.3V_{rms} 0 to 600Vpp (Volts-peak-peak) = 212.1V_{rms}	
Frequency range HF-D 200A HF-D 425 HF-D 600	 600kHz to 1.5MHz 450kHz to 900kHz 360kHz to 630kHz	
Output connector type (unless customized)	BNC	
DC Offset	max. +/-300V DC (applied to rear side BNC offset input)	
Capacitive load capability	max. 100pF, ≤ 75pF recommended	
1/100 Test Output	typical	maximum
Delay with respect to outputs A and B	35ns	
Scaling Error	3 %	8%
Dipole Excitation **Input** (front plate)	0 to 10Vpp, 50Ω	< 12Vpp
Output (rear side)	see figure 4.6 (sine wave assumed)	20Vpp @ ≤100pF load
Front Plate Digital Voltmeter Reading (Volts-peak-peak)		
Accuracy:	typical	maximum
Scale error	0.5%	2%
Offset error	2V	3V
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 +10°C to +30°C.	
Power Supply		
AC Supply Rating	AC input voltage 230V_{AC} at 50Hz or 60Hz. The power entry module is EMI/RFI-filtered. Fuse: medium fast blow 2x 0.8A typ. 12W consumption	
External DC Supply	typ. 200V to 600V DC, see figure 6.1, 6.2, 6.3	

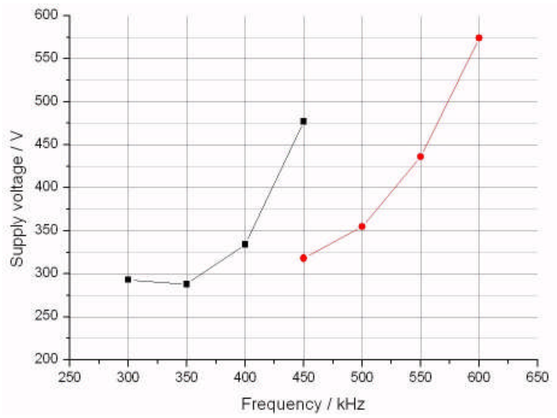
www.stahl-electronics.com phone: +49 6242-504882, fax: +49 6242 504884

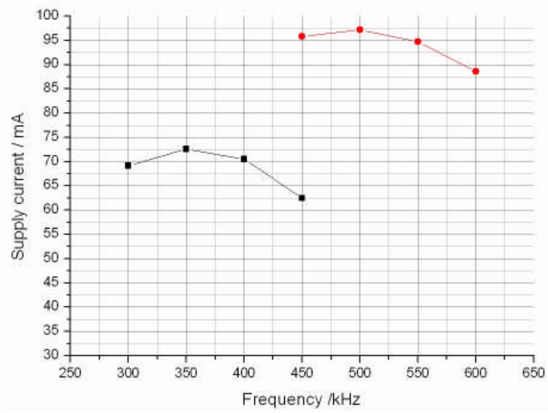
specifications continued	
Case dimensions	19.00” wide x 10” deep. Front-panel mounting holes are configured for M6 rack configurations
Weight	approximately 5.6 kg



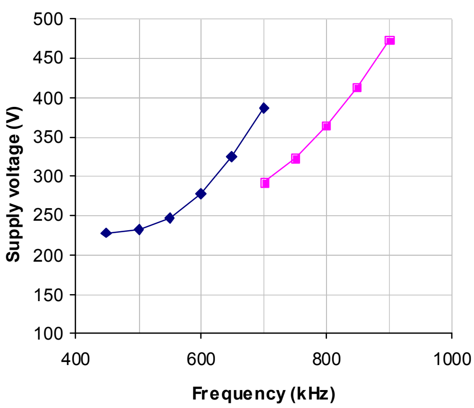


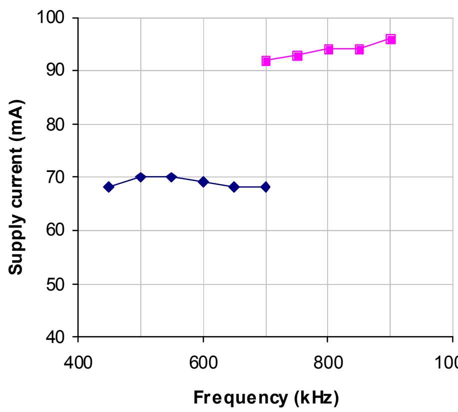
Device version HF-D 200A: required externally supplied DC voltage and current consumption to obtain 200Vpp output amplitude with 100pF load capacitance each output. Both graphs are split in a lower and upper frequency band, according to the position of the range selector knob.





Device version HF-D 600: required externally supplied DC voltage and current consumption to obtain 600Vpp output amplitude with 100pF load capacitance each output. Both graphs are split in a lower and upper frequency band, according to the position of the range selector knob.





Device version HF-D 425: required externally supplied DC voltage and current consumption to obtain 425Vpp output amplitude with 70pF load capacitance each output. Both graphs are split in a lower and upper frequency band, according to the position of the range selector knob.

www.stahl-electronics.com phone: +49 6242-504882, fax: +49 6242 504884

www.stahl-electronics.com phone: +49 6242-504882, fax: +49 6242 504884