2-Channel Amplifier & Cryogenic Biasing Module
A3-5b, A3-7b, A7 / RTA50

- Datasheet -

V. 2.5

Features:

- **Analog Room Temperature Interface for Cryogenic Amplifiers**
- **Creates and Monitors Required Supply Lines**
- **Microcontroller-Assisted Analysis of Possible Malfunctions**
- **Dual-Channel or Differential-to-Single Ended Signal Conversion**

Overview

The **A3, A7 and RTA50** amplifier and room temperature controller units consist of three main blocks, which are useful to operate and monitor cryogenic preamplifiers. The supply section feeds a cryogenic device with stable supply voltage. Another section provides low noise post-amplification of the signals coming from the cryogenic stage. The third section allows monitoring the biasing conditions (DC values) and gives assistance in analysing possible malfunctions and cabling problems in the inaccessible cryogenic region.
The device is housed inside a shielded aluminium case, which needs to be powered up by an external +/-5V supply.

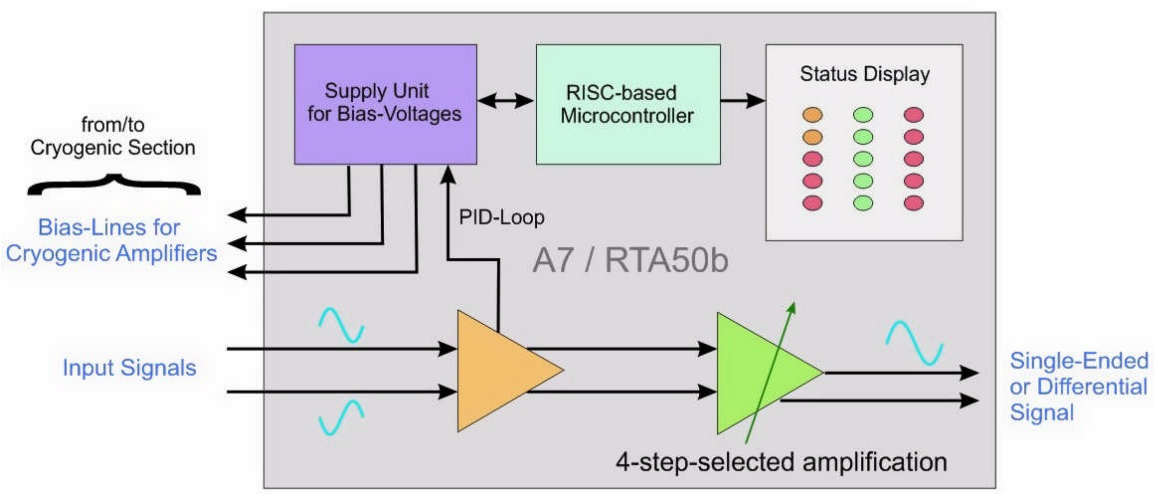

Figure 1: Block diagram (2-channel version shown)

Figure 2 a, b, c: Sloped view, front and rear view

Amplifier section

This section consists mainly of two parts: a 2-channel FET low noise preamplifier with adjustable gain and a 50Ω-Output buffer stage. Additionally a dual/differential switch allows for operating the device in two modes:

Dual-Channel Mode:
In this mode the two channels are independent from each other, except that their amplification factor is coupled and matched on a 1-2% -level. A typical application is the amplification of low level shot noise signals to be further processed by a cross-correlator.

Differential Mode:
In this mode the voltage difference is created and fed to output A. Therefore a differential to single-ended conversion is performed, which may be used e.g. in FT-ICR experiments. Again, the gain of the two individual channels is adjustable and matched on a 1-2% level.

The selectable amplification steps depend on the device version (see table below). Furthermore they may be easily altered by the user on demand (see figure 5).

	#1	#2	#3	#4
A7	10	20	50	100
A7-2	20	40	100	200
DUAL A3-5b A3-5 single	60	125	250	500
DUAL A3-7b	20	50	100	200
RTA 50 B	10	20	50	150

Table 1: Amplification steps, default values. Numbers mentioned are in V/V, observed at high impedance output termination. Divide these values by a factor of two if the output is loaded with 50 Ω (e.g. for a Spectrum Analyzer).

The amplification is changed in discrete steps using the button on the top display (see figure 4), each push sets the amplification higher, pressing longer (> 0.5sec.) resets it to the minimum value. The two inputs feature low noise properties (≤ 2nV/√Hz), are AC coupled and have a high (10MOhm), 75 Ohm or 50 Ohm input impedance in case the device is delivered in conjunction with a cryogenic preamplifier. The output has 50 Ohm output impedance and about $2V_{pp}$ maximum voltage span (1MHz). The overall bandwidth is typ. 40kHz to 70MHz, regardless of the amplification settings. Bandwidth may be customized upon request.

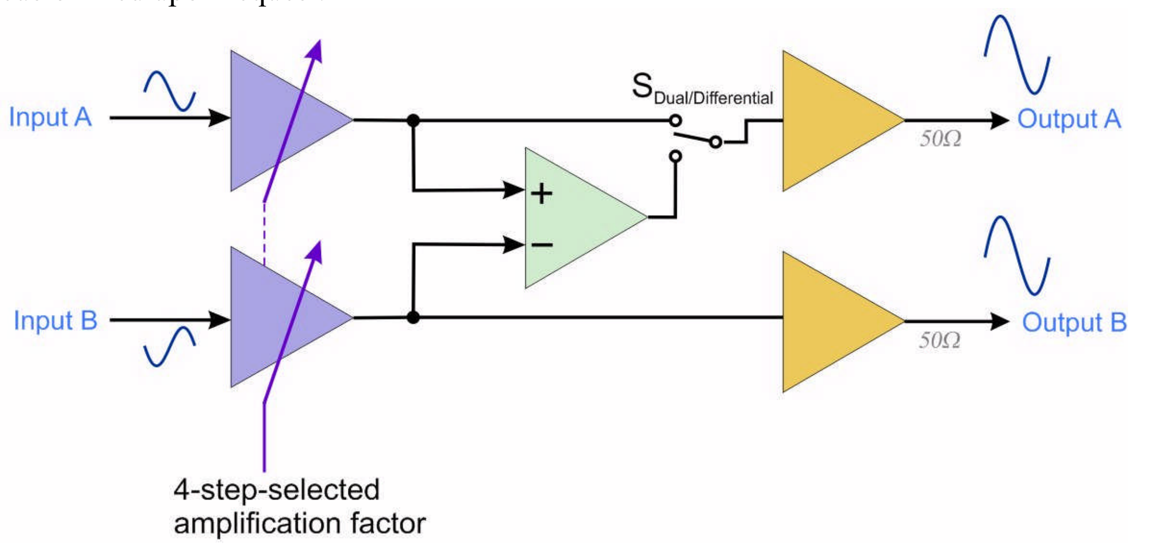

Figure 3: Schematic diagram of the analog amplifier circuitry. The mode switch $S_{Dual/Differential}$ allows for choosing between dual-channel or differential operation.

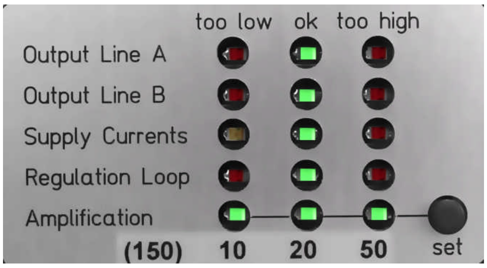

Figure 4: Picture of LED Display on top side. The display shows status information about a coonected cryo amplifier and indicates the set amplification factor. The lower row shows the chosen amplification with 3 LED; in case all 3 are lightened up, the maximum amplification is set (e.g. 150 V/V).

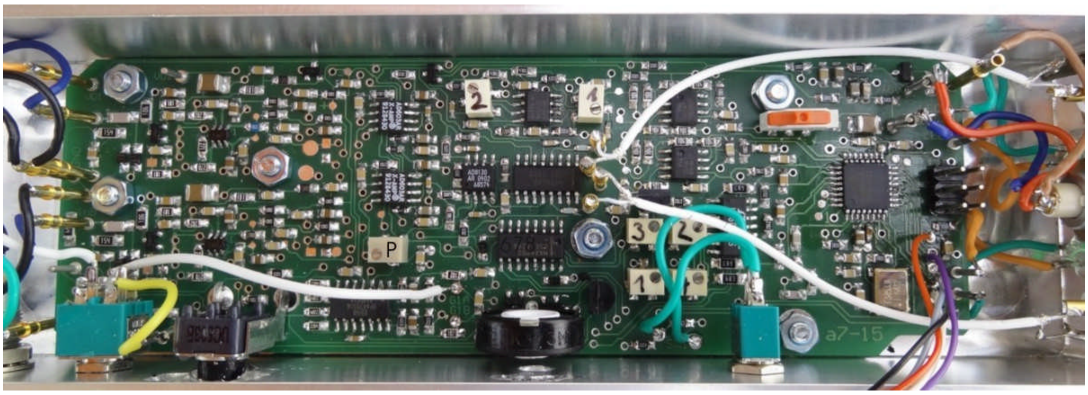

Figure 5: View into the device; the 4 different amplification steps can be altered by changing the position of the 4 variable resistors, denominated as 1, 2, 3, and 4 at the lower part.

As mentioned before, the amplification values stated in table 1 may be changed from the factory presets. To do so, carefully unscrew and open the device lid in order to get access to the 4 variable resistors denominated 1, 2, 3 and 4 as shown in figure 5, lower part. Carefully change their settings to their desired value while monitoring the overall amplification using a signal generator to supply an AC input signal (e.g. at 1MHz, 1mV) and observing the output with an oscilloscope or spectrum analyzer.

Supply section

The supply section provides supply voltages to power up a connected cryogenic amplifier. There is a positive supply voltage, denominated as D1 (and optionally a second one D2), additionally one or two negative regulated voltages (G or G1A and G1B), and a user-adjusted auxiliary low-current biasing voltage (G2). They are stable and fairly noise-free, helping to achieve a good signal-to-noise ratio S/N of the processed cryogenic signals. **At time of shipment the voltages are factory-preset to directly connect to a HFC-50 or NexGen3 amplifier.**

The positive voltage range (D1, D2) ranges from zero up to approx. +4.6V. The two variable resistors at the rear part, denominated 1 and 2 (see figure 5) change the positive cryo amplifier supply voltages D1 and D2 respectively. Turning the adjust screw counter-clockwise increases the voltage (D1, D2).
The biasing voltage G is normally used as transistor gate-drive and ranges from -4.8V to approx. -1V. Since gate-drive values are usually below zero, it is called “negative bias”. This output line furthermore incorporates a “PID”-Servo Loop as an important feature.

This regulation loop can be locked to the cryogenic amplifiers output in order to stabilize the biasing conditions. This is helpful, if the cryogenic system is operated at different temperatures, or if the temperature of the cryogenic amplifier changes with time, due to any reason (changes in vacuum conditions, loosening of thermal links, etc.). This automatic loop liberates the user from frequent manual adjustments, making the use of cryogenic stages easier and more reliable. In combination with a cryogenic amplifier like the NexGen3-Series amplifiers (V.09 or V.2014) or the HFC-50 / HFC-60, little or no adjustments are required, after the voltages have been adjusted once.

The additional auxiliary voltage G2 is user-adjusted on the front side of the device (see also figure 8), its range is approx. -1.1 V to +3 V. This voltage output may be used to fine-adjust calibration voltages like the C1/C2 voltages at the HFC 50 cryogenic amplifier. The G2 may also be kept open and unused otherwise.

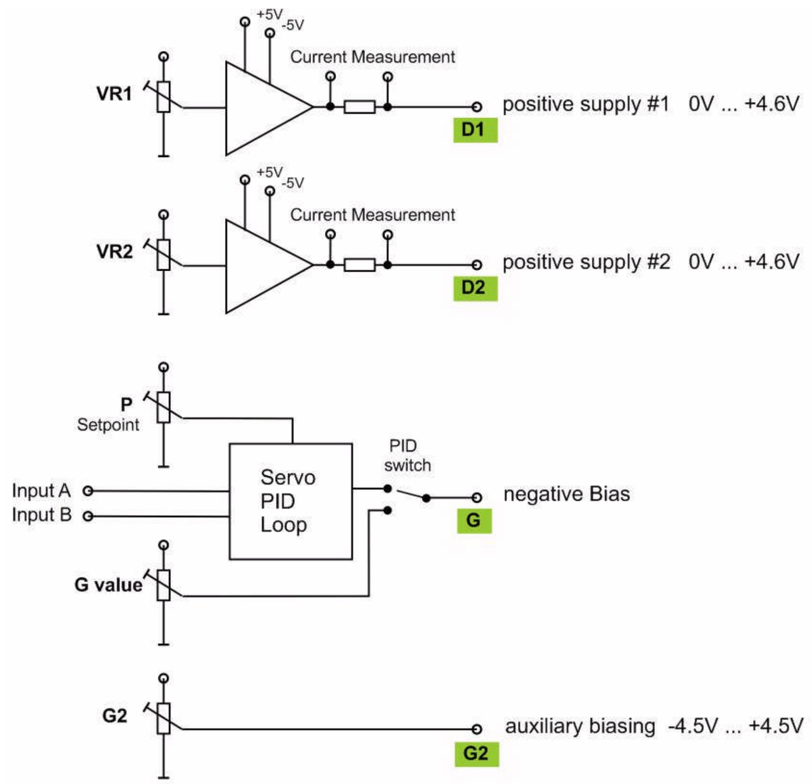

Figure 6: Simplified diagram showing the circuitry to generate 4 biasing voltages.

By default and depending on the mating cryogenic amplifier device, the factory settings for HFC-50 amplifiers are about D1 = +3V to 4.0V, DC-output setpoint (PID) at 0.69V to 1.9V, for a NexGen3 amplifier (dual channel) D1 = +4.4V, DC-output setpoint (PID) 1.9V and NexGen3 single channel D1 = +3.3V, setpoint (PID) 1.1V.
The position of the PID switch decides, if a manual setting of G is used or the servo PID loop should take over the task of providing a negative bias G. In this case the loop will establish a fixed DC-voltage on the outputs of the connected cryogenic amplifier, which means keeping the cryogenic amplifier at constant biasing conditions, featuring low noise and constant amplification. If desired, the nominal output voltage, to which the Servo Loop refers, can be influenced by changing the variable resistor marked P after opening the lid of the device (see figure 5). The 2mm-socket output at the side of the device (see figure 8) allows for monitoring the setpoint value while being manually changed. Note that the latter voltage is displayed inverted (multiplied by ‘-1’) on this socket.

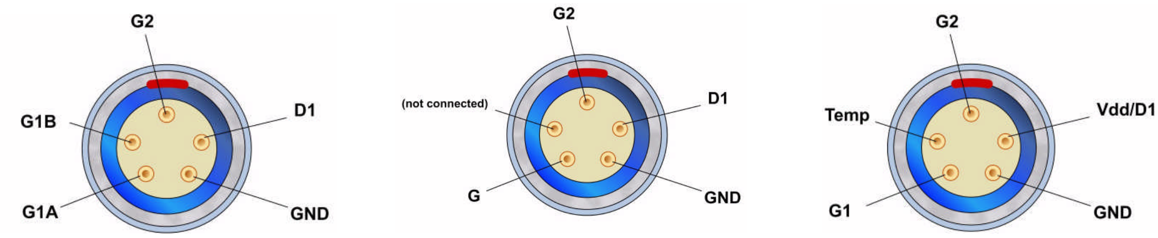

Figure 7:
Pin locations at the biasing connector, view from outside. The socket is Lemo Type 0B, 5pole. Left side: Configuration for HCF 50/60 amplifier, center: for NexGen$_3$ V.2014 amplifiers, dual channel (G2 is not required), right NexGen$_3$ single channel. Terminal 'Temp' provides 5µA of constant current for a temperature check diode. For cable colour assignment see next page.

Figure 8: Elements on the side of the device.
From left to right: Biasing socket (see figure above), PID switch (up-position: PID active, down- position: G manually adjusted), G value adjust knob (for manual G adjustment), PID setpoint monitoring output plug; G2 (also sometimes denominated as C1 or C2) variable resistor, to be changed by screwdriver (only one turn), Mode-switch (dual/differential).

The Servo PID Loop essentially acts like depicted in the subsequent diagram. Assuming an inverting cryogenic amplifier (simplified as field effect transistor FET), the Servo Loop can be understood as a slowly reacting circuit, which tries to hold the DC output level of an attached cryogenic amplifier constant. Essentially the two DC levels of the input lines are observed, filtered and compared to their nominal value (e.g. about 1.6V in case of a HFC-series amplifier). Deviations are fed into an integrator circuit, which generates a correction signal on the G output towards the cryogenic amplifier. This loop reacts on deviations from the setpoint with a signal-integrator rate of approx. 0.01V/sec per millivolt of deviation. Please note that for NexGen3 devices after production date 09/2014 the PID loop may not be able to lock, if the cryogenic amplifier is operated at room temperature (since the required voltage G would be too negative). After cooling the cryogenic amplifier down, e.g. a few degrees below zero °C, it will work again.

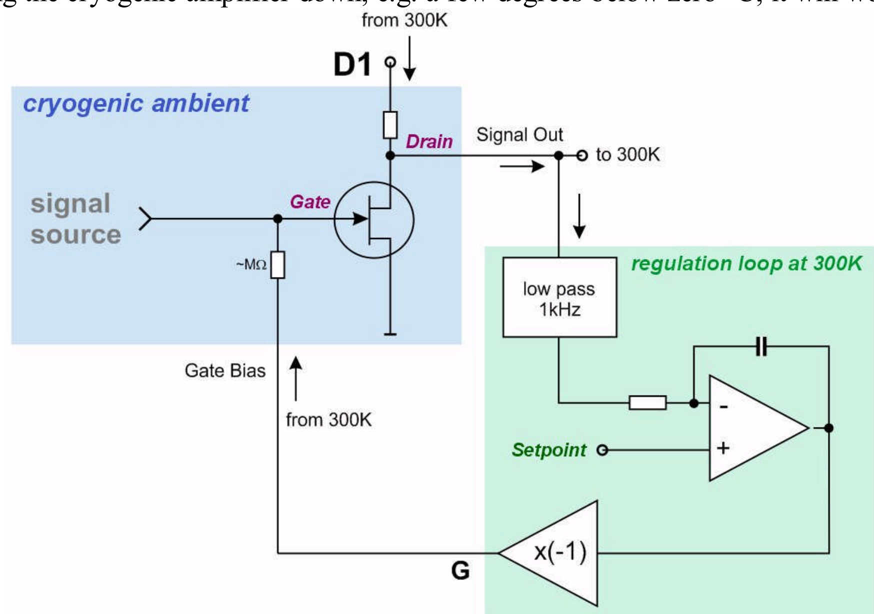

Figure 9:
Simplified diagram of the Servo PID Loop, which can be understood as a slowly reacting circuit, which tries to hold the DC output level of an attached cryogenic amplifier constant.

Wire-Assignment of supplied bias cable:

The bias cable being supplied by the manufacturer, which connects to the biasing socket (see figure 7 and 8) features assignment to the following lines:

for HFC-50 / 60 devices:

(version A3-5b)

Blue or green	GND
Red or pink	D1 (V_{DD})
Black or grey	G
Yellow Spare	
White	G2

(version A3-7b)

White	GND
Grey	D1 (V_{DD})
Green	G
Yellow	G2

for NexGen$_3$ V.2014 devices, dual channel:

Blue or green	GND
Red or pink	D1 (V_{DD})
Black or grey	G1A
Yellow G1B	
White	G2

for NexGen$_3$ V.2014 devices, single channel:

Blue or green	GND
Red or pink	D1 (V_{DD})
Black or grey	G1(A)
Yellow	Temp
White	G2

The lines (copper strand) may be soft-soldered to vacuum feedthroughs, eventually using DC filters to prevent noise entering the cryogenic setup.

Monitoring section

This section consists mainly of a microcontroller and an attached LED (light emitting diode) status display. The microcontroller makes use of instrumentation amplifiers inside the supply unit and observes the biasing currents and voltages once a cryogenic amplifier is connected. Additionally the cryo-amplifier *outputs* (being connected to the inputs A and B) are checked with respect to their DC level. This information is processed and the results are displayed on a LED-display, by which an overview of the cryogenic amplifier's status is obtained. Eventual problems in the cryogenic region are therefore easier to locate.

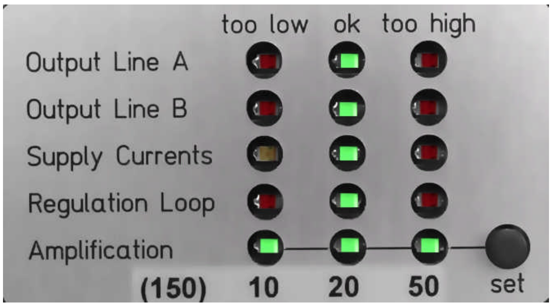

Figure 10.
LEDs indicate the status of biasing lines, assisting to find problems in the non-accessible cryogenic region. The bottom row represents the set amplification factor, and the amplification selection switch. In case of a single channel version, 'channel B' does not exist.

The threshold levels, upon which the LEDs change their status, are set by default (software programming) to the following values:

Version for HFC-50 / 60 series cryogenic amplifiers

	too low	ok	too high	remark
Output Line A (monitoring DC level)	< 0.4V	0.4V … 1.9V	>1.9V	*)
Output Line B (monitoring DC level)	< 0.4V	0.4V … 1.9V	>1.9V	*)
Supply Currents	< 2.8mA	2.8mA … 6.3mA	>6.3 mA	monitors supply current D1 *)
Regulation Loop (monitoring voltage G)	< -4.9V	-4.9V … -1.0V	> -1.0V	factory setting for HFC-50 / HFC-60

Table 2a: DC threshold levels, defining the range in which individual LEDs will lighten up.
Note*) : explicit range may vary depending on parameters of mating cryogenic device.

Version for NexGen3 series KC05 du V.2014 cryogenic amplifiers *(e.g. FT-ICR amplifiers)*
(remark for single channel version: only channel ‘A’ exists)

	too low	ok	too high	remark
Output Line A (monitoring DC level)	< 1.5V	1.5V … 2.4V	>2.4V	*)
Output Line B (monitoring DC level)	< 1.5V	1.5V … 2.4V	>2.4V	*)
Supply Currents	< 2.9mA	2.9mA … 6.1mA	>6.1 mA	monitors supply current D1 *)
Regulation Loop (monitoring voltage G)	< -4.9V	-4.9V … -1.0V	> -1.0V	factory setting for NexGen3, V.2014

Table 2a: DC threshold levels, defining the range in which individual LEDs will lighten up.
Note*) : customized ranges are available on request, for NexGen3 single channel amplifier DC-level: ‘ok’ for 0.9 to 1,8V, current ‘ok’ for 0.75 to 3.9mA, regulation loop ‘ok ‘ for -0.7 to -3V.

In case no malfunction is detected (all LEDs on “green”), another LED on the rear side (“Function”) lightens up, indicating correct operation without obvious errors.

Trouble Shooting

In case not all LEDs show green light, there could be the following reasons.
DC level on Output line A or B <u>too low</u>:
- there could be a short from a cryogenic output line to GND or
- bad connection internally inside the line (coax or twisted pair recommended)
- temperature of the cryogenic amplifier not low enough

DC level on Output line A or B too high:
- may be caused by a short to the positive supply line or wrong biasing on the G line.
- A missing GND connection (300K-to-cryogenic) could also be the reason.

Supply current too low:
- bad connection of the positive supply line
- biasing G too negative
- missing GND connection (300K to cryogenic)

Supply current too high:
- short cut from positive supply line to GND or short cut from an output to GND
  → disconnect cryogenic amplifier latest after 5 minutes immediately to prevent damage
- biasing G too positive (e.g. during manual operation, PID disabled)
- biasing line G not connected at all or shorted to GND

Regulation Loop
This indicator should be observed while the Servo PID Loop is engaged, otherwise (PID switch at “G (man.)”) may be ignored.

too high:
- missing GND connection (300K to cryogenic)

too low:
- temperature of cryo amplifier too high (300K or slightly above)
- PID setpoint is set too high
- bad connection or broken line from the cryo amplifier output to the device input

If one of these error conditions occurs, check carefully all connections, eventually also the nominal resistances of the supply lines to the cryogenic amplifier according to the cryogenic amplifier data sheet / manual. Note that in case the cryogenic amplifier is operated at room temperature, the regulation loop may not lock due to occurrence of leakage currents. This problem will disappear as soon as the amplifier is cooled down substatially below 0°C.

Specifications

Parameter	typical Value	Remarks/Conditions
Freq. Range @ 300K for ±3dB deviation .	40 kHz....70 MHz 80 kHz....70 MHz	high impedance input version 75Ω or 50Ω input version. NMR version: range starts at approx. 500kHz
Gain Voltage gain (factory preset) gain mismatch between A and B	x 20 ± 5% x 50 ± 5% x 100 ± 5% x 200 ± 5% 1.5 %	expressed as V/V at high impedance load; divide by 2 in case of 50 Ohm load. See table 1 for further details. f = 100kHz…20MHz
Input Noise *single channel mode* voltage noise density *differential channel mode* voltage noise density	1.7nV / √Hz 2.5nV / √Hz	A = x100… x200, f = 1MHz
Input Impedance at either input DC input capacitance vs. GND AC	150 kΩ 18pF 150kΩ or 75 Ω or 50Ω	options

Maximum AC Output Voltage	1.5V_{pp}	f = 1MHz; exceeding this level results in higher harmonics bigger 40dBc compared to fundamental signal
Output Power	max. 15mW	50Ω load
Output Impedance signal output biasing output G2 biasing output G1 positive supply output D1 positive supply output D2	 50Ω 1kΩ 1kΩ 25Ω 25Ω	 @ f = 1 … 20MHz D1/2 = 0… 4.2V Supply currents of $V_{DD1/2}$ are limited to roughly 40mA (sourcing)
Temperature Check (Option) output current	5 µA +/-10%	positive current to supply silicon diode inside cryogenic amplifier; voltage is forwarded to BNC output
Operating Voltage (required external supply)	+5.9V and -5V (+/-5% each)	$I_{supply, +5V}$ = 63mA typ $I_{supply, -5V}$ = 42mA typ
Operating Temperature	T = 0°C… +30°C	
Magnetic Properties	Device consists mostly of non-magnetic materials. small amounts of ferromagnetic substances < 1gr. possible	For use with FT-ICR cells, it is recommended to locate the device min. 15cm away from the center of the ion trap/FT-ICR cell structure in order to avoid magnetic disturbance
Geometrical Size/Weight	207 x 50 x 28 mm³, 300gr.	
Mains Adaptor for A3-7 / A7 / A3-5(b) / RTA50	Input 230V_{AC} +/-10% Output +/-5V_{DC}, max. 200mA Power typ. 3W, max. 4.9W or Input 115V_{AC} +/-10% Output +/-5V_{DC}, max. 200mA Power typ. 4.5W Weight approx. 950gr.	**Attention: the external B-field into which the mains adaptor is placed must not exceed B = 10mT to prevent damage or fire hazard.**

Maximum Ratings

Note: Stress above these ratings may cause permanent damage or degradation of device performance. Exposure to absolute maximum conditions for extended periods may also degrade device parameters or reliability.

Quantity	Limits		Remarks
	min.	max.	
pos. Supply Voltage V_{DD}	-0.3V	+5.5V	**Avoid connecting the voltage supply lines with wrong polarity.**
neg. Supply Voltage V_{SS}	+0.3V	-5.5V	
difference between positive and negative Supply Voltage		12V	
Input Voltage absolute value (AC+DC) AC		 150 V_{pk} vs. GND 5V_{pp}, f = 0 … 5MHz	 derating inversely proportional with frequency above 5MHz
Admissible Input Current (see remarks)		50 mA_{eff} 1A_{pk}	permanent current through protection circuitry maximum peak current for less than 10ms, at max. 1 Hz repetition rate
Output Voltage			under normal conditions no voltage source must be applied to the outputs
Storage Temperature	-40°C	125°C	
Storage Humidity		65% @ 40°C	
External magnetic field		150mT	

Table 3: Absolute Maximum Ratings

Required External Supply

The device needs an external low noise +/-5V supply to be powered up, which can be purchased from the manufacturer on request. The external voltages have to be applied to the 3-pin Lemo-connector socket (type 0B) at the output side of the aluminium case. Figure 12 illustrates the pin locations. Please observe that positive and negative supply lines never must be exchanged or permanent damage might occur. It is recommended to use the power supply being provided by the manufacturer, at which an appropriate cable is already installed.

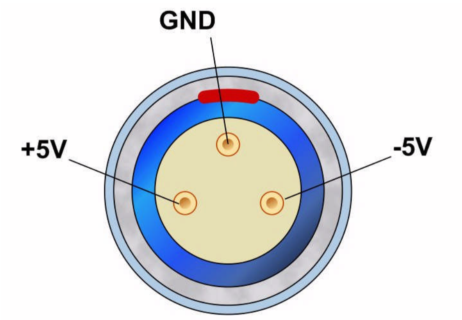

Figure 11:
Supply socket "type 0B" for external +/-5V supply. The picture shows the socket seen from outside the box.

Typical Characteristics

Frequency Response

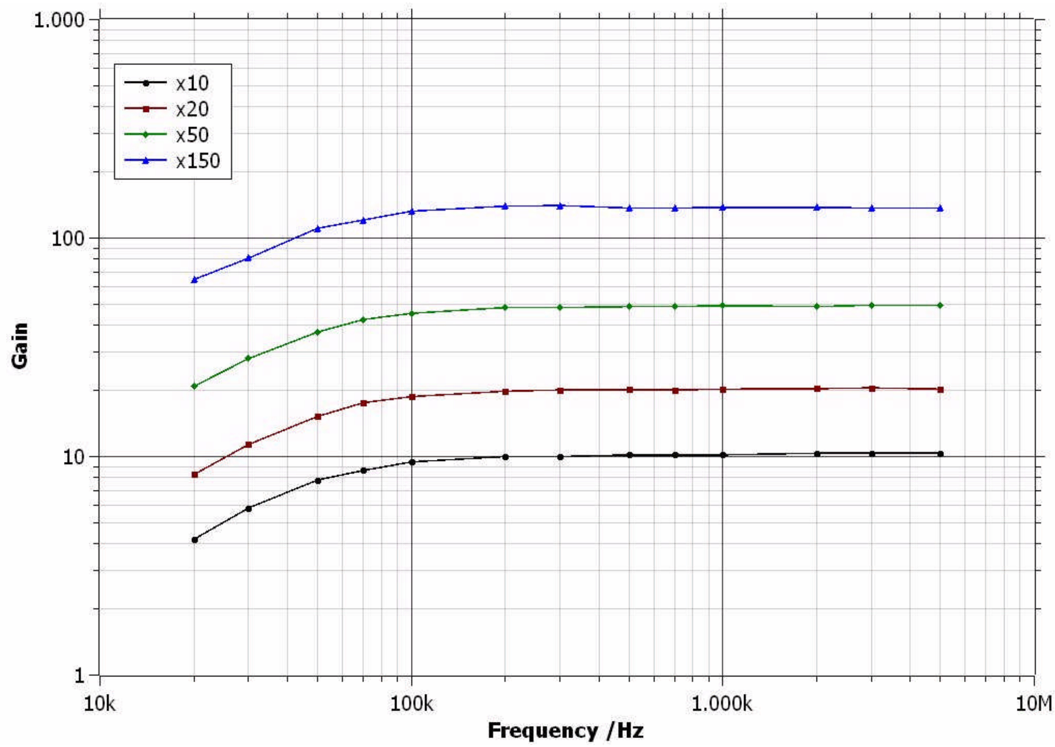

Figure 12: Frequency response (amplification in V/V) for 4 possible amplification factors, selected by the selection switch (device versions see table 1). Numbers apply for single-channel operation as well as for differential channel mode. This graph represents the low frequency portion of the frequency response function. Output loaded with high-Z impedance, input also high impedance version.
Note that for NMR version range starts at approx. 500kHz

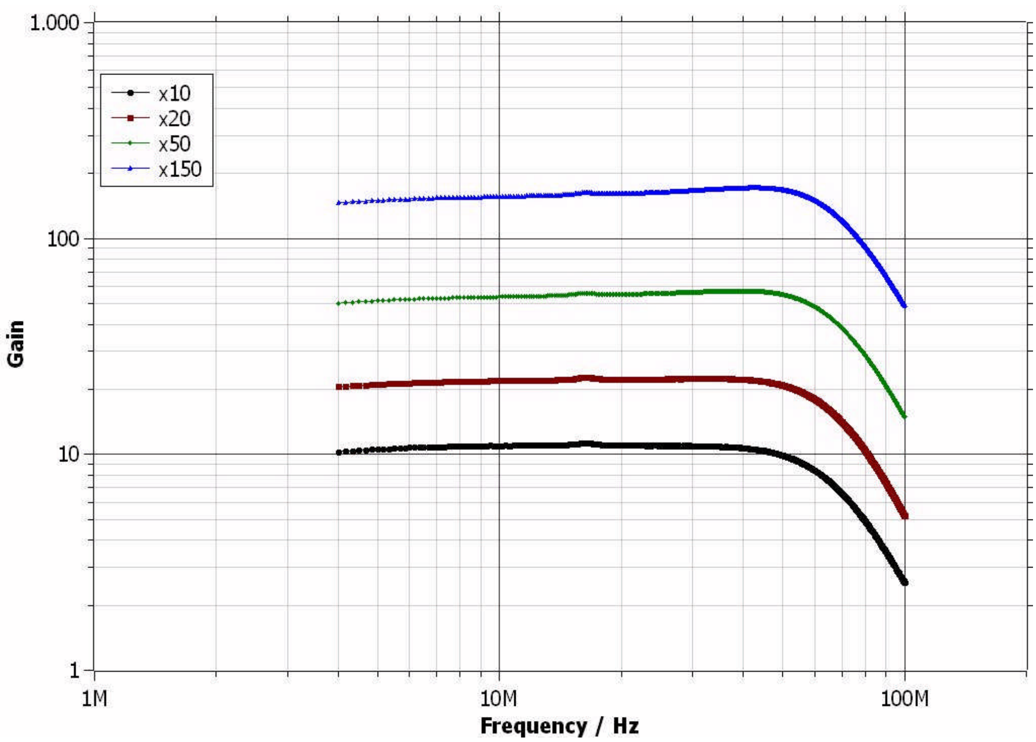

Figure 13: Frequency response (amplification in V/V) for 4 possible amplification factors, selected by the selection switch (device versions see table 1). Numbers apply for single-channel operation as well as for differential channel mode.
This graph represents the high frequency portion of the frequency response function. Output loaded with high-Z impedance.

Noise Data

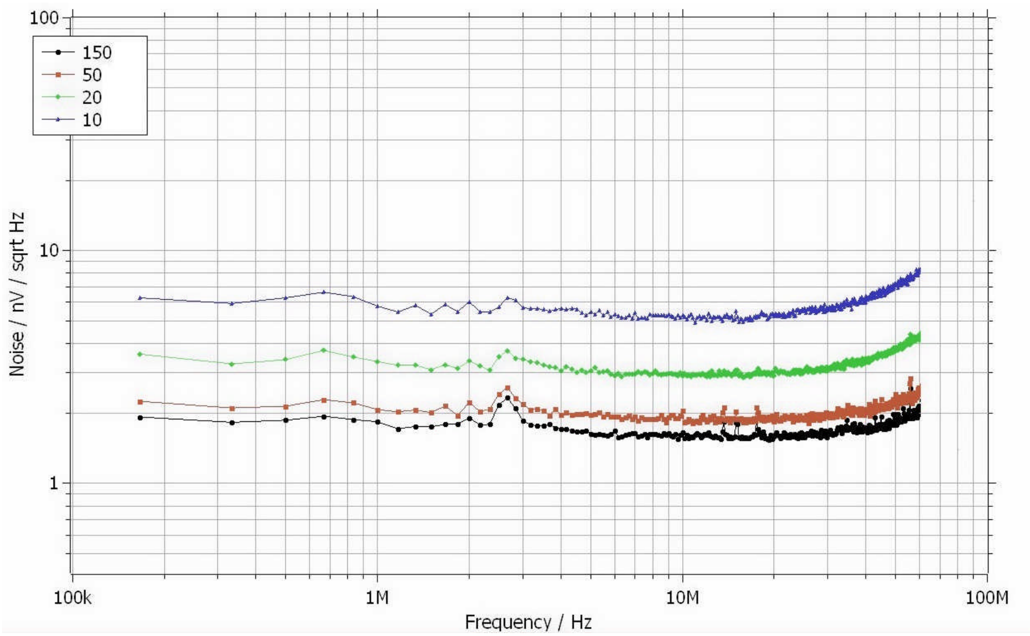

Figure 14: Input voltage noise density in dual channel mode at 4 different amplification factors.

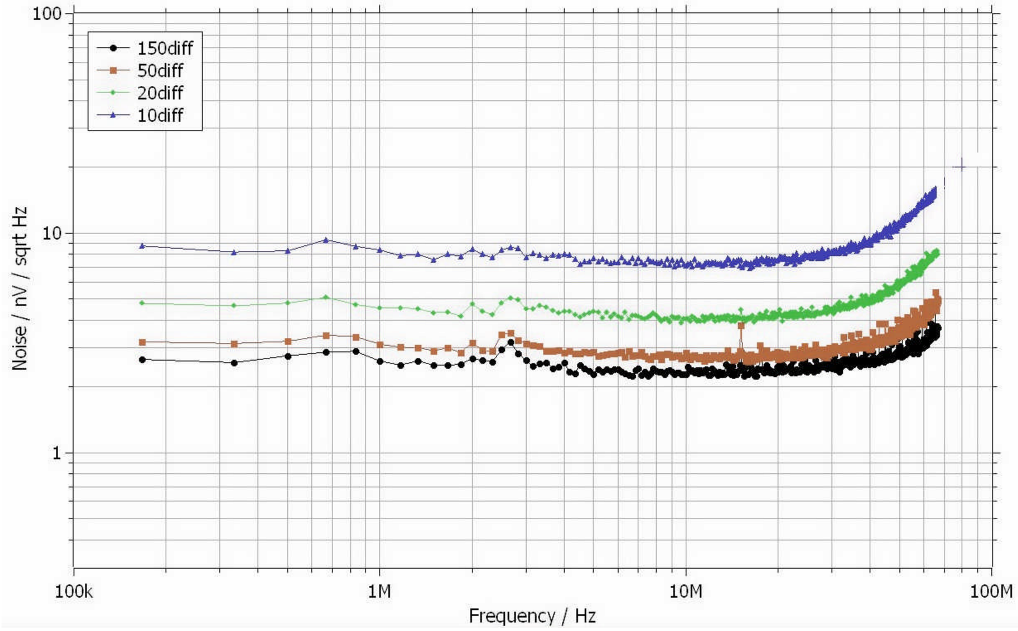

Figure 15: Input voltage noise density in differential mode at 4 different amplification factors.