

**Τ.Ε.Ι. ΣΤΕΡΕΑΣ ΕΛΛΑΔΑΣ
ΤΜΗΜΑ ΗΛΕΚΤΡΟΝΙΚΩΝ ΜΗΧΑΝΙΚΩΝ ΤΕ**

ΕΡΓΑΣΤΗΡΙΟ

«ΗΛΕΚΤΡΟΝΙΚΕΣ ΔΙΑΤΑΞΕΙΣ ΦΑΣΜΑΤΟΣΚΟΠΙΑΣ»

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ΔΗΛΕΚΤΡΙΚΗΣ ΦΑΣΜΑΤΟΣΚΟΠΙΑΣ ΥΨΗΛΩΝ
ΤΑΣΕΩΝ ΠΟΛΩΣΗΣ”*

Α.ΚΑΝΑΠΙΤΣΑΣ
Καθηγητής

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Στην παρούσα εργαστηριακή άσκηση θα μελετηθεί ο τρόπος εγκατάστασης, η υλοποίηση της κατάλληλης συνδεσμολογίας και η λειτουργία της διάταξης Διηλεκτρικής Φασματοσκοπίας *Novocontrol Alpha Broadband High Voltage Booster*.

Παρατίθενται παρακάτω οδηγίες και τεχνικά χαρακτηριστικά απο το εγχειρίδιο χρήσης της διάταξης.

Broadband High Voltage Booster HVB 300 for Alpha-A High Resolution Dielectric / Impedance Analyzer

User's Manual

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Novocontrol Technologies
GmbH & Co. KG
Obererbacher Strasse 9
D-56414 Hundsangen
Germany

Phone: ++(0) 64 35 - 96 23-0
FAX: ++(0) 64 35 - 96 23-33
Email: novo@novocontrol.de
WWW: <http://www.novocontrol.de>

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1. Safety Precautions

The following safety precautions should be read carefully before using this product.

Before connecting the line power cord to the **HVB 300** :

- Carefully read the **HVB 300** manual. Contact Novocontrol in case of anything unclear. Operation without having read the manual or by not qualified operators is prohibited.
- Connect the **HVB 300** additional permanent **Protective Earth PE Contact** to a protective earth contact of your line power net.
This connection provides a second protective earth wire in addition to the standard protective earth wire of the line power cord. Refer to "Rear Panel, Protective Earth" for details.

Before switching any instruments on :

- Make sure that the line power voltage indicated on the **HVB 300** rear matches the actual voltage of your power line.
Caution : Operating the HVB 300 at incorrect line voltage may result in permanent device damage, possibly voiding warranty.
- Make sure that the line power cord is connected only to a power line with protective earth contact. The grounding of any parts of the **HVB 300** must not be broken.
The **HVB 300** power cord contains a separate ground wire for only use with grounded power line outlets. When proper connections are made, the instrument chassis is connected to the power ground line by the power cord ground wire.

Warning: Failure of this connection may result in personal injury or death due to electric shock.

- The **Sample HV1 and Sample HV4 SHV sockets** of the high voltage interface, the **sample cell connection cables**, the two **sample cell SHV sockets 1 and 4**, inner parts of the **sample cell like e.g. electrode wires and electrodes** may be at **high voltage up to +-150 Vp**.

Warning: Touching this voltage may result in personal injury or death due to electric shock.

- If you intend to control the **Alpha-A** analyzer in combination with the **HVB 300** by own GPIB programs, refer to the "Operating the **Alpha-A** with **HVB 300** by GPIB commands" chapter for additional safety considerations.
- Set up all cable connections as described in the "Setting up the System for Measurement" chapter.

- Do not exceed the maximum voltage or current limits specified in the "Instrument Description" chapter for any connectors and sockets.
Caution: Exceeding the specified limits may result in permanent device failure.
- There are no parts inside the **HVB 300** which require maintenance or adjustments. Therefore the instrument should not be opened. In any case remove the power cord and any test cables before opening the case or removing any parts from the case.
Warning : Opening the case or removing parts may expose conductors at high lethal voltages if the HVB 300 is connected to the power supply. Even if the instrument is disconnected from line power, internal capacitors may still be charged at high voltage up to 500 Vpp.
- To clean the instrument, use a damp cloth or mild, water based cleaner. Clean the exterior of the instrument only. Do not apply cleaner directly to the instrument or allow liquids to enter or spill the instrument.

After having switched on the **HVB 300** and the **Alpha-A** mainframe:

Before operating the system always make sure that the device code

ALPHA + HVB 300

is displayed at the Alpha mainframe after power on or reset.

Warning: If other device codes as "ALPHA + HVB 300" are displayed, switch off the HVB 300 and Alpha-A mainframe and check the system set-up. System operation in this state is not allowed and may result in unexpected high voltages at the 300Vpp Out terminal.

2. Inspection

The **HVB 300** was tested and mechanically inspected before shipment. After unpacking, inspect all items for obvious physical damage. Report any damage to Novocontrol Technologies immediately. Save the original packing in order to prove damage that may have occurred during transit.

The Broadband **HVB 300** for the **Alpha-A** analyzer includes the following items :

- **HVB 300** mainframe
- High voltage test sample 100 pF
- High voltage test sample RC network
- Load short calibration standard
- Line power cable
- 2 high voltage cables 1 m with SHV (safe high voltage) connectors
- 3 BNC cable 25 cm
- **HVB 300** user's manual

3. Introduction

The **HVB 300** is a device for extending the voltage range of the Novocontrol Technologies **Alpha-A** High Resolution Dielectric-Impedance Gain Phase Analyzer.

The **Alpha-A** can be operated in combination with the **HVB 300** or with other test interfaces. See "System Connections" or the Alpha-A user manual for more.

With the **HVB 300** connected, the system can create up to ± 150 Vp ac and / or dc bias voltage at the sample. The ac frequency range is from 3 μ Hz .. 1 HMz. The maximum current is about 70 mA. The output impedance is 200 Ω .

The system can measure both samples with high impedance up to 10^{15} Ω and low impedance down to 0.1 Ω . For samples with impedance < 2 k Ω , the output voltage will decrease due to the 200 Ω output impedance. Refer to "Breakdown, High Frequency and Load Considerations" for details.

The **Alpha-A** in combination with the **HVB 300** can be operated either by the Novocontrol WinDETA software or by internal Alpha GPIB commands. For details refer to the WinDETA manual, the Alpha manual and "Operating the **Alpha-A** with **HVB 300** by GPIB commands".

4. Instrument Description

4.1. Front Panel

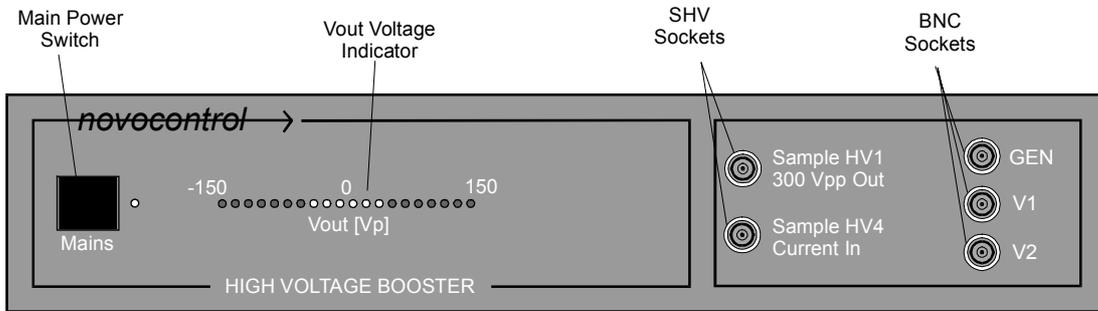


Fig. 4.1.1 : HVB 300 front panel.

The front panel contains the following elements.

The **Main Power Switch** applies line power to the **HVB 300**.

Caution: Before switching on make sure

- that the line voltage indicated at the HVB 300 rear line power connector matches your actual line voltage;
- that all cable connections are properly established as described in "System Connections".

The **HVB 300 power cord** contains a separate ground wire for only use with grounded outlets. When proper connections are made, the instrument chassis is connected to the power ground line by the power cord ground wire.

Warning: Failure of this connection may result in personal injury or death due to electric shock.

The **Vout Voltage Indicator** displays the peak voltage applied to the **300 Vpp Out** socket by a LED bar graph.

- The **GEN** socket has to be connected to the **Alpha-A** analyzer **GEN** socket.

GEN is internally connected to the internal voltage amplifier input. 1.92 V input voltage at **GEN** will result in approx. 150 V output voltage at **300 Vpp Out**.

- The **V1** socket has to be connected to the **V1** socket of the **Alpha-A** mainframe.

V1 supplies a fraction of the **300 Vpp Out** voltage created by an internal voltage divider. The maximum voltage at this pin is 4.5 Vp ac or / and dc.

This output is short protected to system ground. Do not apply any external voltages or currents.

- The **V2** socket has to be connected to the **V2** socket of the **Alpha-A** mainframe.

V2 provides the voltage output of the **HVB 300** internal current to voltage converter.

This output is short protected to system ground. Do not apply any external voltages or currents.

- The **300 Vpp Out** SHV socket has to be connected to signal source input of the Novocontrol **BDS 1200HV** high voltage sample cell or to any other sample impedance under test as the voltage source.

300 Vpp Out is internally connected via a 200 Ω resistor and a voltage activation switch to the internal high voltage amplifier output. The maximum output voltage is about ± 150 V ac and / or dc. The current is limited to about 70 mA. The output impedance is 200 Ω . This output is short protected to system ground. Do not apply any external voltages or currents.

Caution: Connecting the **300 Vpp Out** to any of the **GEN**, **V1** or **V2** sockets may result in permanent damage of the instrument.

- The **Current In** SHV socket has to be connected to the current output of the Novocontrol **BDS 1200HV** high voltage sample cell or to any other sample impedance under test as the current sense.

Current In is internally connected via an activation switch to the **HVB 300** internal current amplifier.

The maximum current is about ± 70 mA ac and / or dc.

If **Current In** is internally connected, it will be at low impedance and with this at nearly zero potential.

If **Current In** is internally disconnected, it will be at high impedance (open). In this case, **Current In** may be at the same potential as the **300 Vpp Out** socket if connected via a sample or sample cell.

The **Current In** socket input is protected against short circuits to the **300 Vpp Out** socket.

Warning: Touching the voltage at the **300 Vpp Out** or **Current In** sockets may result in personal injury or death due to electric shock.

Note: The cable connection between the **300 Vpp Out** and **Current In** socket must have low capacity. Use only the original 1 m SHV cable supplied by Novocontrol.

4.2. Rear Panel

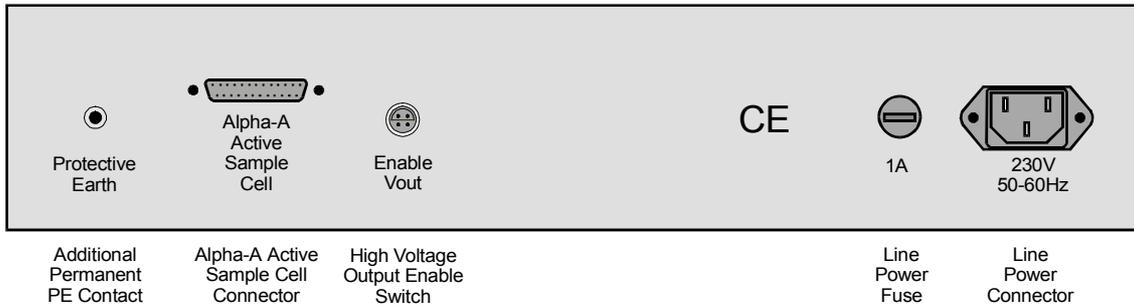


Fig. 4.2.1 : **HVB 300** rear panel.

The rear panel contains the following elements :

Additional permanent **Protective Earth** contact.

This is a second protective earth connector (PE). The standard (first) PE connection is done by the PE wire of the line power cord. As the **HVB 300** internally builds up voltages up to 500 Vpp, for safety reasons a second PE connection should be established which grounds the instrument in case of failure of the standard power cord PE wire. For this purpose the additional **Protective Earth Contact** should be connected by a separate ground wire permanently to the protective earth potential of the building line power net. An example is shown below.

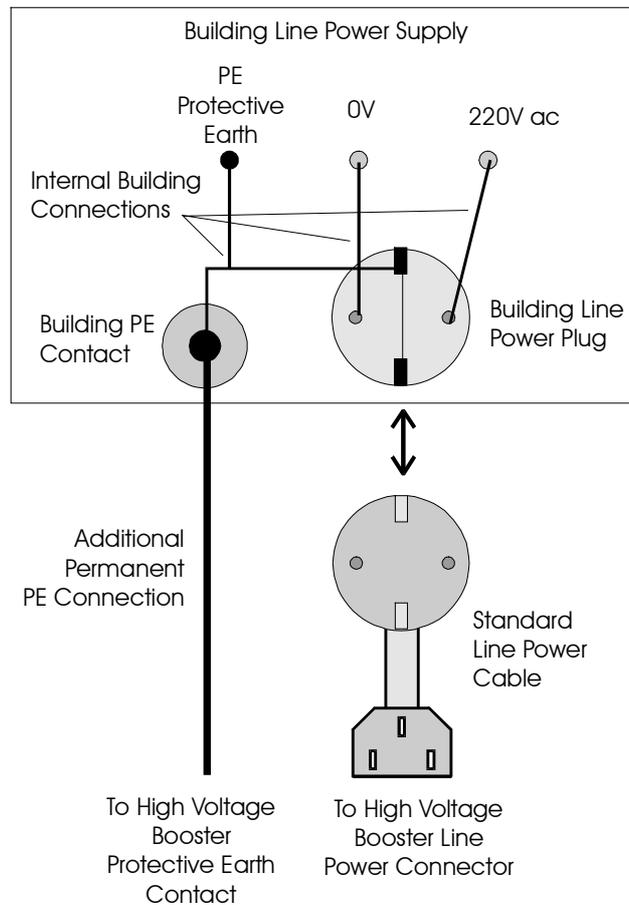


Fig. 4.2.2 : Connection scheme of the **HVB 300** line power cable and the additional permanent **Protective Earth Contact** to the building line power net.

Alpha-A Active Sample Cell Connector. Connects the **HVB 300** to the corresponding socket of the **Alpha-A** mainframe. Use only the 25 pin Sub-D cable supplied by Novocontrol. The cable provides a one to one connection for each of the 25 pins.

Warning: This connector provides operating power and control voltages for the **HVB 300**. Do not connect any other devices to this terminal. Connecting other devices (like serial or parallel ports) may result in damage of devices.

Enable Vout. Triggers an internal **Enable Vout Switch** which connects the **HVB 300** internal high voltage amplifier output to the front panel **300 Vpp Out** socket. If **Enable Vout** is left open, the **300 Vpp Out** socket is internally disconnected from the high voltage amplifier.

In order to connect the output, pins 1 and 2 of the **Enable Vout** socket must be connected by an external cable. The figure below shows the **HVB 300** internal schematics of the **Enable Vout Switch** and the **Enable Vout** socket. Refer to "Principles of Operation" for additional details.

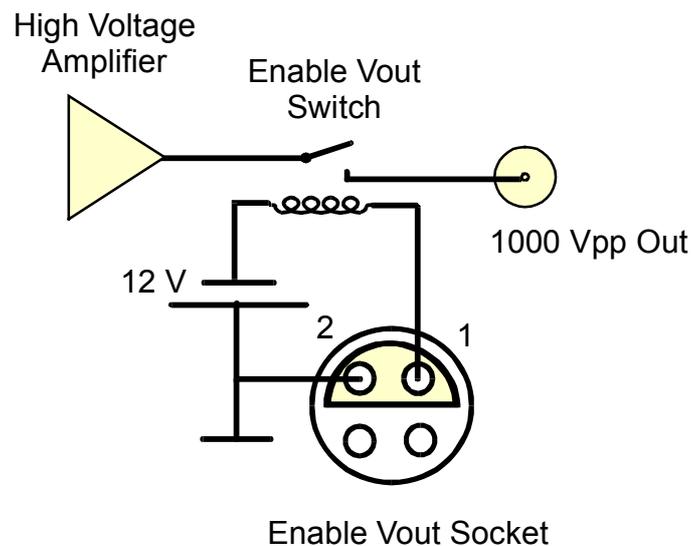


Fig. 4.2.3. **HVB 300** internal **Vout Enable** system. In order to enable output voltage, connect pins 1 and 2 by an external wire.

If the Novocontrol **High Voltage Sample Cell** is used, connect the **HVB 300 Enable Vout** socket by the cable supplied with the sample cell to the sample cell **Enable Vout** socket. In this case the **1000 Vpp Out** socket will be only connected to the internal high voltage amplifier if the sample cell **Enable Vout Switch** is pressed. For details, refer to "**High Voltage Sample Cell**".

Line Power Connector. Follow the procedure below to connect the **HVB 300** to the line power.

1. Make sure that the line voltage indicated below the **HVB 300 line power connector** matches your actual line voltage. There is no option for changing the line voltage. If the line voltage does not match your actual line voltage, contact Novocontrol for replacement by another instrument.

Caution : Operating the HVB 300 at incorrect line voltage may result in permanent device damage, possibly voiding warranty.

2. Do not switch the instrument on before connected to the line power. Do not switch the instrument on before all other connections described in "Setting up the System for Measurement" are established.

3. Connect the female end of the power supply cord to the **HVB 300 Line Power Connector**.

4. Connect the other end of the power cord to a grounded AC power line plug.

The power cord contains a separate ground wire for only use with grounded outlets. When proper connections are made, the instrument chassis is connected to the power ground line by the power cord ground wire.

Warning : Failure of this connection may result in personal injury or death due to electric shock.

Line Power Fuse. The fuse protects the **HVB 300** power cord. Generally, the fuse should not break except for internal malfunction. Therefore in case of break, it is strongly recommended to contact Novocontrol for support. If the fuse has to be replaced, proceed as follows.

1. Switch the instrument off. Disconnect the power cord first from the line power and than from the **HVB 300 Line Power Connector**.
2. Replace the fuse by the following type :
 - 1A, slow blow for line voltage 220V-240V

5. Novocontrol High Voltage Sample Cell BDS 1200HV

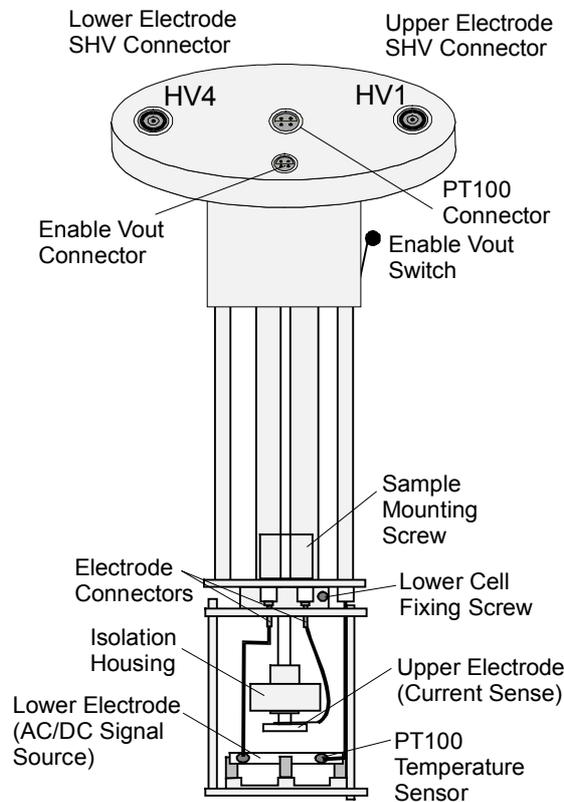


Fig. 5.1: High Voltage Sample Cell

The **High Voltage Sample Cell** contains the following elements :

Lower Electrode SHV Connector

The inner contact of this Save High Voltage connector is connected to the lower sample electrode. The outer contact is connected to the cell case. This socket should be connected by a SHV BNC cable to the signal source. For the **HVB 300** this is the **300 Vpp Out** socket.

Upper Electrode SHV Connector

The inner contact of this Save High Voltage connector is connected to the upper sample electrode. The outer contact is connected to the cell case. This socket should be connected by a SHV BNC cable to the current sense of the impedance measurement instrument. For the **HVB 300** this is the **Current In** socket.

Enable Vout Connector and Enable Vout Switch

They are internally in the cell connected are as shown below.

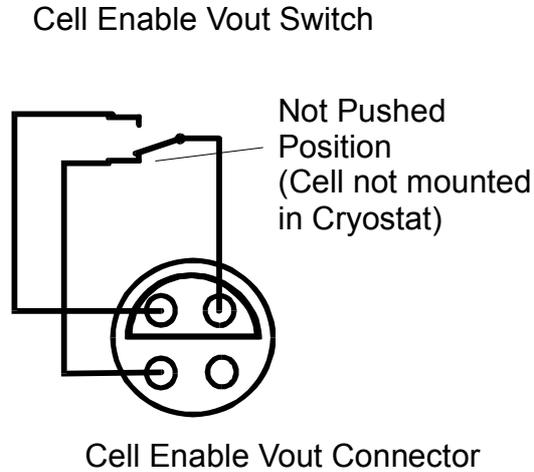


Fig. 5.2: Cell Internal Enable Vout Switch and Connector scheme.

The purpose of the **Enable Vout Switch** is to disable the high voltage signal source output if the cell is not immersed in a surrounding cryostat or shielding unit. In this case the switch is in the not pushed position. If the cell is immersed in the cryostat, the switch changes to the pushed position.

For the **HVB 300** the sample cell **Enable Vout** socket should be connected to the **HVB 300 Enable Vout** socket. In this case, the **HVB 300** will only apply voltage to the **300 Vpp Out** socket if the **Enable Vout Switch** is pushed (cell immersed into cryostat).

PT100 Connector

This 4 wire connector can be used for sensing the sample temperature. This is done with a PT100 temperature sensor mounted in the **Lower Electrode** plate. The PT100 is connected as shown below.

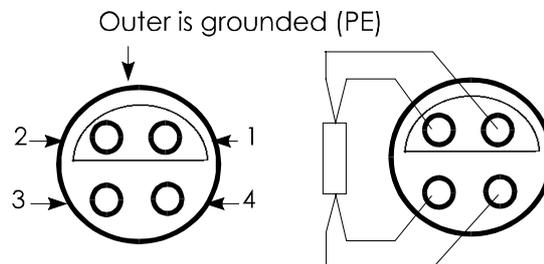


Fig. 5.3: PT100 temperature connector of the high voltage sample cell.

Upper Electrode

The sample should be mounted between the **Upper** and **Lower Electrode**. For details of sample preparation and mounting refer to the "Sample Preparation and Measurement Accuracy" chapter of the Alpha-A analyzer manual. The **Upper Electrode** senses the sample current, the **Lower Electrode** applies the voltage to the sample.

Lower Electrode

Applies the signal generator output voltage to the sample material.

The sample cell lower part containing the sample capacitor can be separated as shown below. This eases handling during the sample preparation and allows cell usage with various lower samples cells.

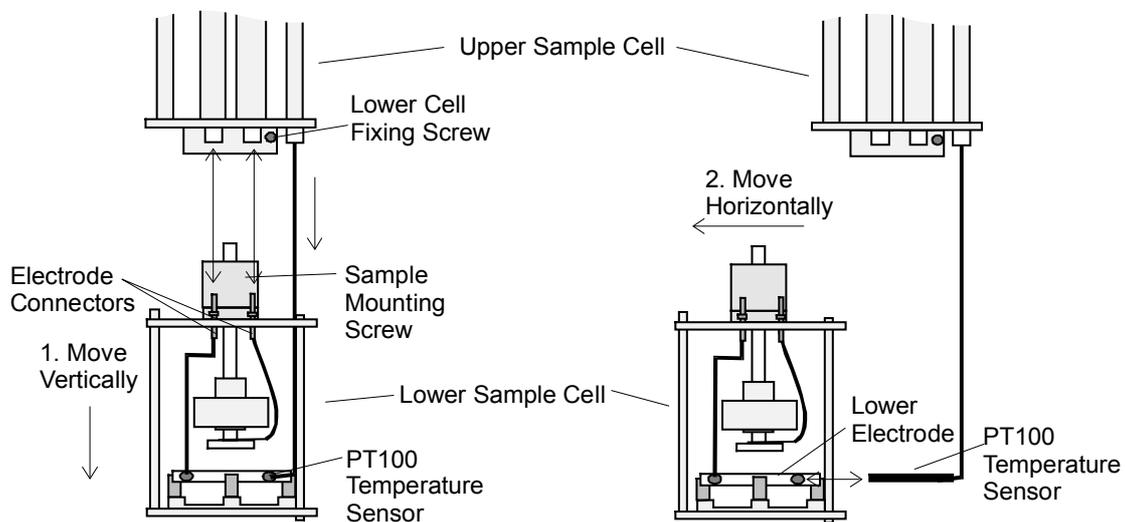


Fig. 5.4: Procedure of separating the lower sample cell from the upper cell.

In order to separate the **Lower Sample Cell** from the **Upper Sample Cell** :

- Loosen the **Lower Cell Fixing Screw**.
- In a first step, slowly move the lower sample cell vertically to the upper sample cell as shown in fig. 5.4. While moving stepwise, pull the both **Electrode Connectors** out of the connection lines. The **PT100 Sensor** remains in the lower electrode at this time and shifts itself out of the upper sample cell. The PT100 can be shifted vertically by about 5 cm with respect to the upper sample cell, but can not be disconnected from the upper sample cell.
Caution: Do not pull to strong. Otherwise the PT100 connections maybe damaged.
- In a second step move the lower sample cell horizontally in order pull the PT100 sensor out of the **Lower Electrode**.

Important : If the lower sample cell has to be re-mounted after separation, connect the upper electrode to the thicker line of the upper sample cell and the lower electrode to the thinner line. The connections must not be exchanged.

In order to measure a sample, it must be built into the sample capacitor. For this purpose, the sample should not directly be placed between the electrodes of the sample cell. Instead, it should be placed between two disposable electrodes as shown in fig. 5.6. Disposable electrodes are available from Novocontrol in various diameters.

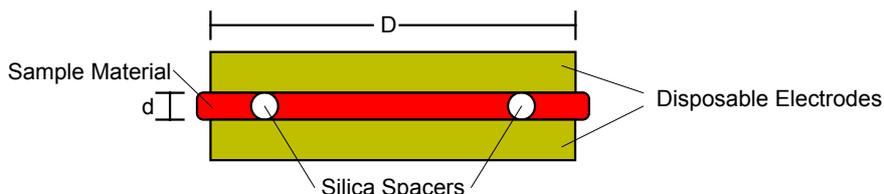


Fig. 5.6: Sample capacitor prepared with two round disposable plate electrodes.

The two electrodes with the sample between can be seen as a separate sample capacitor which can be placed between the active sample cell electrodes as shown in fig. 5.7. This procedure simplifies the sample preparation, protects the electrodes from contamination and allows to remove the sample easily.

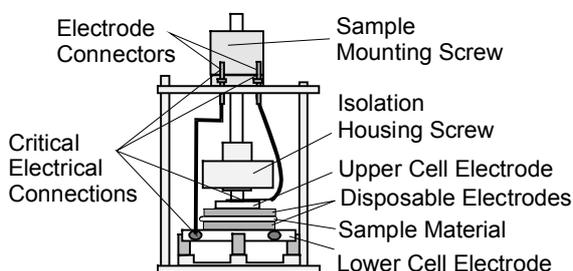


Fig. 5.7: Lower sample cell part with sample mounted between disposable electrodes.

Important

- Use the **Sample Mounting Screw** in order to fix the **Disposable Electrodes** by the **Upper Cell Electrode**.
- Do not use the **Insulation Housing Screw** in order to fix the sample. This may result in improper contact and damage of the upper electrode isolation.
- Before starting a measurement check the **Critical Electrical Connections** for proper contact.
- Tighten to the **Upper Cell Electrode** by rotating it clockwise against the **Isolation Housing Screw** until a fix connection is established.

- Tighten the screw of the **Lower Cell Electrode** connection wire with screw driver until a fix connection is established.
- Check the two **Electrode Connectors** for proper contact with the upper sample cell connection lines.
- From time to time, all four **Critical Electrical Connections** contacts should be cleaned and polished in order to remove insulating oxide layers. This applies especially if the cell was exposed to high temperatures before.

For this purpose :

- Remove the **Upper Cell Electrode** by rotating it anti clockwise against the **Isolation Housing Screw**,
- Remove the **Lower Cell Electrode** connection wire by unscrewing it from the **Lower Cell Electrode**,
- Pull the two electrode connectors out of the upper sample cell connections lines.

For additional sample preparation hints, refer to "Sample Preparation" in the Alpha analyzer manual.

6. Setting up the System for Measurement

6.1. System Requirements

You must have the following components in order to operate the **HVB 300** in combination with an **Alpha-A** analyzer.

- A Novocontrol **HVB 300**.
- An Novocontrol Technologies **Alpha-A** High Resolution Dielectric Analyzer.
- For dielectric material measurements a suitable sample cell is required. The Novocontrol **High Voltage Sample Cell** is recommended.

The system has to be operated under control of a separate host computer by the GPIB IEEE 488 bus and an additional software package. You can either use standard software from Novocontrol or own written software.

If you intend to control the **Alpha-A** in combination with the **HVB 300** by own software, refer to the "Operating the **Alpha-A** with **HVB 300** by GPIB commands" chapter. The following components are required.

- A standard software development tool like e.g. a Basic interpreter or C compiler.

- A host computer with an GPIB IEEE 488 interface port. The computer and the IEEE 488 interface must match to the software development tool.

The Novocontrol **WinDETA / WinIMP** software supports dielectric and impedance measurements with optional support of temperature control. You must have the following components in order to operate the **Alpha-A** in combination with the **HVB 300** by WinDETA or WinIMP.

- The WinDETA or WinIMP software package from Novocontrol.
- Either a Novocontrol GPIB card or a National Instruments GPIB card which matches your MS-Windows system for remote control of the Alpha analyzer.
- An IBM compatible PC with a 486 or higher processor with at least 16 MB memory and MS-Windows95, 98 or NT operating system. A PC with a Pentium processor is recommended.
- If temperature control for the sample cell (**Alpha-A + HVB 300** in combination with a Novocontrol **High Voltage Sample Cell**) is required : The Novocontrol **WinDETA software**, a Novocontrol temperature control system based on the **QUATRO**, **Novocool**, or **Novotherm** controller or another temperature control system based on an **Eurotherm 818 or 2400** series temperature controllers.

6.2. System Connections for High Voltage Measurements

In order to set up the **Alpha-A** analyzer in combination with the **HVB 300** for a dielectric material or impedance measurement, the following connections have to be done.

Caution : Before setting up any connections :

- **Switch off the HVB 300 and all devices connected to it.**
- **Switch off the Alpha-A analyzer and all devices connected to it.**
- **Set up all connections as described in the "Rear Panel" chapter.**
- **Respect the voltage and current limitations described in the "Front Panel" chapter.**

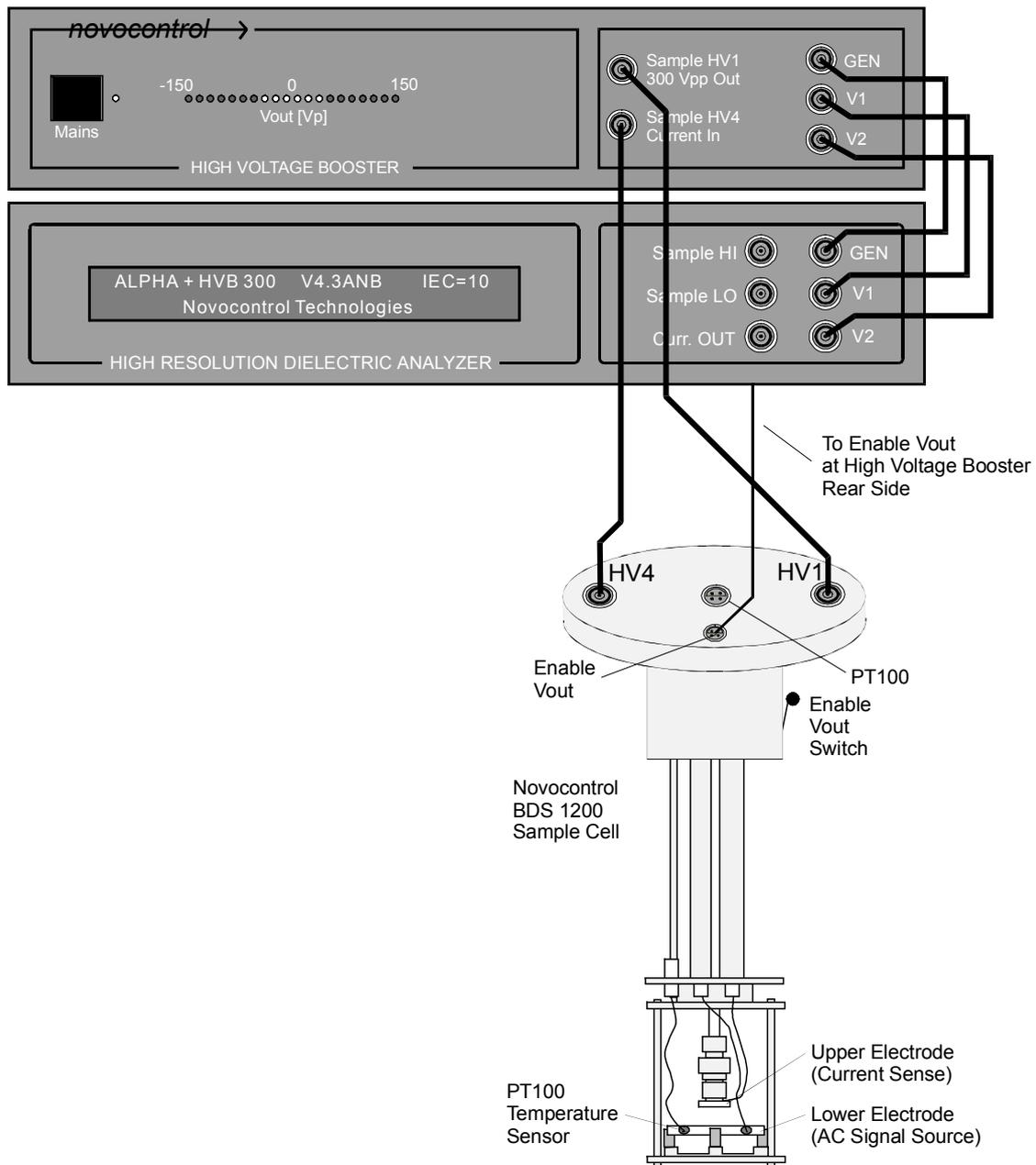


Fig. 6.2.1 : Connections of combination **Alpha-A** and **HVB 300** to the Novocontrol **High Voltage Sample Cell**. Instead of the dielectric sample cell, any impedance of interest maybe connected between the **300 Vpp Out** and **Current In** terminals. In addition, the connections described in the "Rear Panel" chapter are required.

Note : If the Novocontrol **High Voltage Sample Cell** is used, make sure that the **HVB 300 Current In** input is connected to the **upper sample cell electrode** (sample cell terminal **HV4**). This electrode is better isolated than the lower one. Do not touch the electrodes while the instrument is measuring. For proper operation, the sample cell has to be shielded. This is

generally done by placing it into a grounded metal cryostat or a metal shielding tube. Both are available by Novocontrol.

Warning: The **300 Vpp Out** and **Current In** sockets may be at high voltage up to ± 150 Vp ac and / or dc. In addition high voltage may be at the **sample cell electrodes**, **electrode connection wires** and the **lines inside the sample cell**. **Touching any of those conductors may result in personal injury or death due to electric shock.**

The system may now be switched on. It is recommended to first switch the **HVB 300** on and then the **Alpha-A** mainframe. The **Alpha-A** mainframe should after about 10 seconds show in its display the following boot message.

```
ALPHA + HVB 300 V4.3ANB IEC=10  
Novocontrol Technologies
```

which indicates that the **HVB 300** was properly detected by the mainframe.

Before operating the system always make sure that the device code

ALPHA + HVB 300

is displayed after power on or reset.

Warning: If other device codes as "ALPHA + HVB 300" are displayed, switch off the system and check the set-up. System operation in this state is not allowed and may result in unexpected high voltages at the 300 Vpp Out terminal.

7. Principle of Operation

The principal setup of the high voltage system is shown below.

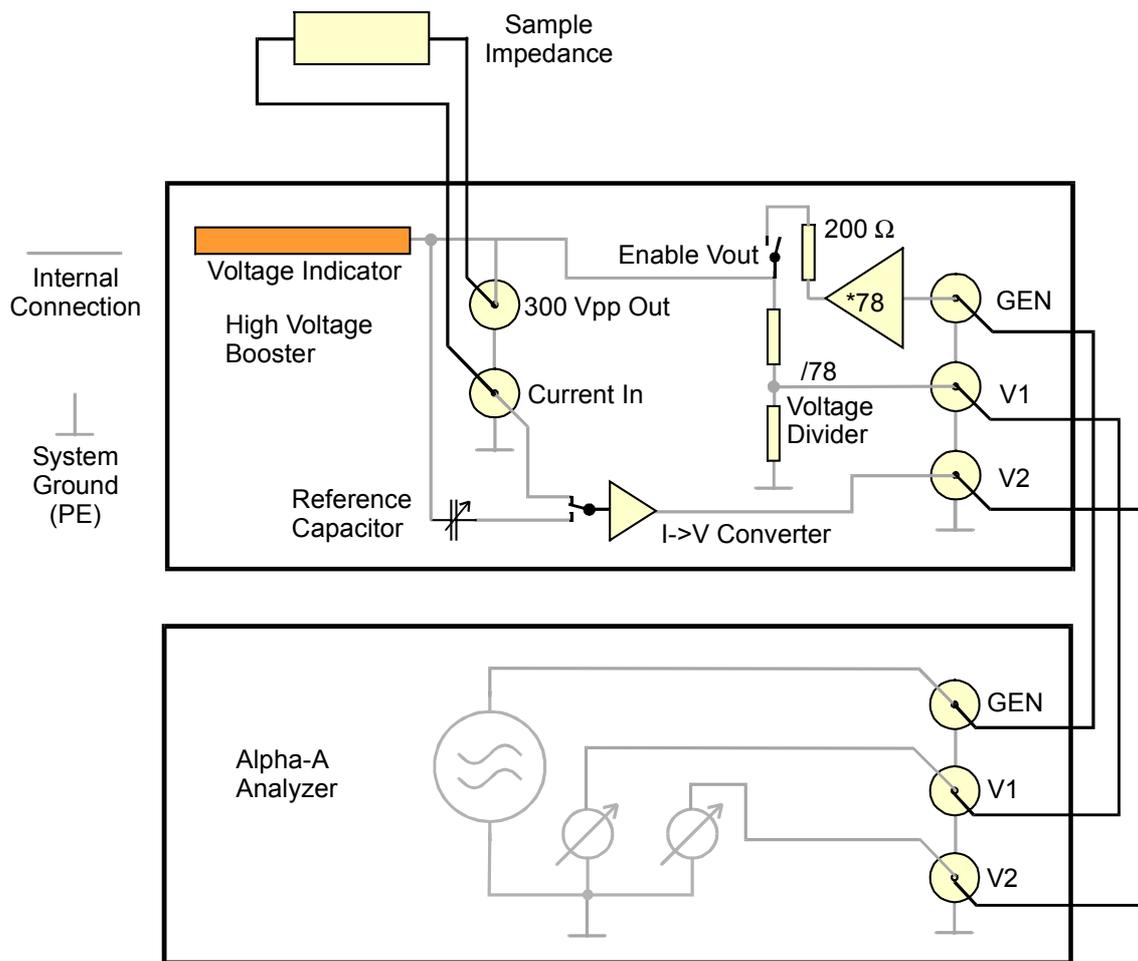


Fig. 7.1 : Principle schematic of the **Alpha-A** analyzer in combination with the **HVB 300**.

The internal **Alpha-A** ac generator (at **GEN**) creates an ac voltage in the range 0 V .. 1.92 Vp. The signal maybe superimposed by an additional dc bias from -1.92 V .. 1.92 V. Both signals are limited by software, so that the total voltage at the **GEN** socket does not exceed +/-1.92 Vp.

The **GEN** signal is externally connected via the **HVB 300 GEN** socket to the high voltage amplifier and increased by a factor ~78. The maximum output voltage which may contain both ac and dc contributions is +/-150 Vp. The amplifier current is limited to +/-70 mA. The output impedance is adjusted to 200 Ω by an output resistor. This signal is applied via the internal **Enable Vout Safety Switch** to the **300 Vpp Out** socket.

The **Enable Vout Safety Switch** is normally open and in this state the output voltage is disabled. In operating mode, the **Enable Vout Safety Switch** has to be closed by applying an external connection to the **Enable Vout Connector** at the **HVB 300** rear. Refer to "Rear Panel" and "High Voltage Sample Cell" for details.

The output voltage peak amplitude at the **300 Vpp Out** socket is displayed by the **Voltage Indicator**.

The **300 Vpp Out** signal is further applied to the **Voltage Divider**, reduced by a factor ~ 78 and applied via the two **V1** sockets to the Alpha input voltage Channel 1.

The **300 Vpp Out** signal is applied in addition either to the the internal variable **Reference Capacitor** or the **Sample Impedance**.

The sample current is sensed by the **Current In** socket.

The reference capacitor or the sample can be connected by two internal switches to the HVB 300 current input. The current input has low impedance and therefore is nearly at ground potential. The sample or reference current is converted by the **I -> V Converter** into a voltage which is measured by the analyzer voltage Channel 2.

Refer to the Alpha manual for further details on voltage measurement, sine wave correlation technique, current to voltage conversion, impedance measurement and reference technique.

8. Using DC-Bias

In the high voltage mode with **HVB 300** connected, the system allows to add an additional dc bias voltage U_b to the ac signal of the high voltage amplifier. It is applied to the sample as shown below.

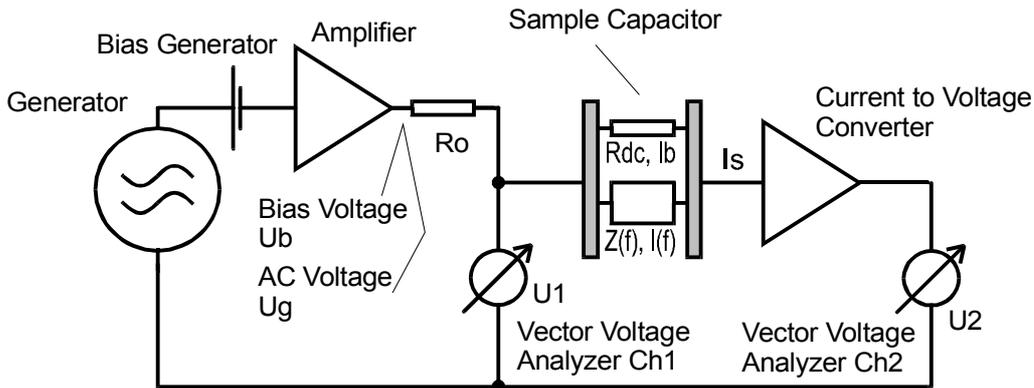


Fig. 8.1 : Electrical set-up in the high voltage system with an additional bias voltage applied to the sample capacitor.

The samples current I_s is the sum of the of the bias current I_b caused by the sample dc resistance R_{dc} and the ac current $I(f)$ caused by the sample impedance $Z(f)$ at the actual frequency of the generator. If the amplifier output resistance R_o is neglected

$$I_s = I_b + I(f) = \frac{U_b}{R_{dc}} + \frac{U_g}{Z(f)}$$

In the high voltage system (**Alpha-A + HVB 300**), all signals are always dc coupled and no restrictions for the ratio R_{dc} to $Z(f)$ or for R_{dc} apply. Nevertheless, the following problems may arise.

- If the sample current exceeds about +70 mA, it will be limited by the high voltage amplifier to this value. If R_{dc} is sufficiently low, the current limit will be completely driven by the bias current I_b . In this case no additional current will be left for the ac signal and the ac signal may drop to very small values probably causing noise in the measured data.
E.g. for a dc bias of 100V and a sample resistance of 1 k Ω , the voltage at the sample will be limited due to the current limit to 1 k Ω * 70 mA = 70 V dc without a significant ac contribution.
This situation can be avoided by decreasing the total voltage applied to the sample ($U_b + U_g$) until no current limitation applies anymore.
- If a high dc bias voltage U_b and a small ac voltage U_g is selected, and in addition R_{dc} is comparable to $Z(f)$, the bias current I_b will be high against the ac current $I(f)$. As the current channel is dc coupled, $I(f)$ will only give a small portion to the totally measured current I_s and the accuracy may decrease.

- For R_{dc} low or comparable to the amplifier output resistance $R_o = 200 \Omega$, the dc bias voltage at the sample U_{bs} will decrease with respect to the select bias voltage U_b according to

$$U_{bs} = U_b \frac{R_{dc}}{R_{dc} + R_o}$$

- For sufficiently low R_{dc} , considerable power may be applied to the sample which may result in self heating. The power created by the dc bias voltage in the sample is

$$P_s = \frac{U_{bs}^2}{R_{dc}}$$

E. g. for $U_{bs} = 140 \text{ V}$ and $R_{dc} = 2 \text{ k}\Omega$, $P_s = 9.8 \text{ W}$. The ac impedance $Z(f)$ may contribute additional heating power.

Note: Both the ac voltage and dc-bias voltage applied to the sample are measured by the **Alpha** analyzer and can be displayed or saved by WinDETA software as the dependent variable "Measured AC Voltage" and "Measured Bias Voltage". Refer to the WinDETA manual "Dependent Variables" for details. In own GPIB programs, the Alpha commands **ZEXTRE?** and **ZDCA?** may be used, respectively.

9. Breakdown, High Frequency and Load Considerations

Both for high frequency performance and for breakdown currents, the capacity of the connection cables in the path from the amplifier **300 Vpp Out** socket to the sample is important. During operation, the cable capacity is charged by the high voltage amplifier like the sample itself.

If in this situation a short or breakdown in the sample occurs, the energy stored in the cable capacity will be applied via the shorted sample to the system current input. As the breakdown usually happens within a very short time, a short but strong current peak of several amperes will be applied to the system current input. The current magnitude of the peak is not limited by the 200Ω output impedance of the high voltage amplifier, but mainly depends on the total value of all line capacities from the high voltage amplifier output to the sample.

The system with the original 1m **High Voltage Connection Cables** and the **High Voltage Sample Cell** is designed to withstand short circuit and breakdown currents without damage or degrading performance. Anyhow, significantly higher current peaks may damage the input current amplifier.

Therefore, only the original high voltage cables delivered with the system should be used. If own cables are used, make sure the external cable total cable capacity in the high voltage path from the 300 Vpp Out socket to the sample does not exceed 150 pF.

The maximum voltage available at the sample depends on the sample impedance Z_s and the cable capacity. The cable impedance

$$Z_c = -\frac{j}{2\pi f C_c}$$

(f Frequency and Cc cable capacity) in parallel with Zs creates a load on the **HVB 300** output resistance Ro which decrease the ac voltage Usample at the sample by a factor

$$\frac{U_{sample}}{U_g} = \left| \frac{Zl}{Zl + Ro} \right|$$

with respect to the high voltage amplifier output voltage Ug. Zl is the total load impedance made up by a parallel circuit of Zs and the cable impedance Zc.

In addition, for higher voltages, the current limit of about 70 mA of the high voltage amplifier may be reached. This will limit the voltage Ug of the high voltage amplifier (before the output resistor Ro) to

$$U_{g\max} = 70mA |Zl + Ro|$$

Example : At f = 1 MHz, a sample capacity of 100 pF and a cable capacity = 100 pF, Zl = -j 796 Ω ($j = \sqrt{-1}$). This will limit the maximum available amplifier voltage to about 55 Vp corresponding to 39 Vrms. The voltage at the sample will be further reduced by Ro by a factor

$$\frac{U_{sample}}{U_g} = \frac{796}{\sqrt{796^2 + 200^2}} = 0,96$$

At frequencies > 160 kHz, the available **HVB 300** output voltage is further limited by internal amplifier slew rate to 300 Vpp at 160 kHz and 60 Vpp at 1 MHz with a linear decrease in between.

Note : Both the ac voltage and the dc bias voltage applied to the sample are measured by the **Alpha-A** analyzer and can be displayed or saved by WinDETA software as the dependent variable "Measured AC Voltage" and "Measured Bias Voltage". Refer to the WinDETA manual "Dependent Variables" for details. In own GPIB programs, the Alpha commands **ZEXTRE?** and **ZDCA?** may be used, respectively.

10. Calibrations

The following kinds of calibration should be done for the **Alpha-A** in combination with the **HVB 300**.

1. Internal Alpha All Calibration of the amplification and phase shifts of the HVB 300 impedance converter measurement ranges.

-Disconnect the cables from the **300 Vpp Vout** and **Current In** terminals before starting the calibration.

-Make sure that the **HVB 300** internal **Enable Vout** switch is closed. For details refer to "**Rear Panel, Enable Vout**". If you are using the **High Voltage Sample Cell**, place the cell into a cryostat or shielding unit in order close the **Enable Vout** switch.

In order to start the calibration with WinDETA:

-Make sure that in the WinDETA "Analyzers" menu, "**Alpha + High Volt Amp. +- 150Vp**" is selected as the actual impedance system.

-Select "**Calibrate BDC or Alpha All**" from the WinDETA menu item "**Analyzers, Options** (Alpha + High Voltage Amp. +-150Vp).

In order to start the calibration by own GPIB programs:

-Use the GPIB commands ***RST, ZRUNCAL=ALL_INIT** and **ZRUNCAL=ALL**.

This calibration should be done in intervals of approximately 4 weeks in order to compensate for long term drift effects.

As low frequencies are involved, the calibration will run for about 25 minutes.

2. Internal Reference Calibration.

This is a subset of the Alpha All Calibration and includes only calibrations of the ranges used in combination with reference capacitor measurements.

This calibration should be done from time to time. Highest precision will be reached, if the calibration is done immediately before a measurement.

-Disconnect the cables from the **150 Vpp Vout** and **Current In** terminals before starting the calibration.

-Make sure that the **HVB 300** internal **Enable Vout** switch is closed. For details refer to "**Rear Panel, Enable Vout**". If you are using the **High Voltage Sample Cell**, place the cell into a cryostat or shielding unit in order close the **Enable Vout** switch.

In order to start the calibration with WinDETA:

-Make sure that in the WinDETA "Analyzers" menu, "**Alpha + High Volt. Amp. +-150Vp**" is selected as the actual impedance system.

-Select "**Calibrate BDC or ALPHA Reference**" from the WinDETA menu item "**Analyzers, Options** (Alpha + High Voltage Amp. +-150Vp)".

In order to start the calibration by own GPIB programs:

-Use the commands ***RST**, **ZRUNCAL=REF_INIT** and **ZRUNCAL=REF**.

3. External Interface Low Impedance Load Short Calibration

Calibrates the **HVB 300** current to voltage converter ranges for sample impedance $< 1 \text{ k}\Omega$. In addition the properties of the sample connection lines and the sample cell are included. This calibration is only used for low impedance samples with impedance $< 1 \text{ k}\Omega$.

It should be done in intervals of approximately 4 weeks in order to compensate for long term drift effects.

The calibration requires an external $100 \text{ }\Omega$ resistor and a short calibration standard supplied with the **HVB 300**.

Important:

- The load short calibration measures low impedance below $0.1 \text{ }\Omega$. It is therefore required, that the contact resistance of the used cables and electrodes are reproducible within $0.1 \text{ }\Omega$ with respect to a later measurement.
It is recommended to check the calibration, by re measuring the $100 \text{ }\Omega$ standard and the short standard after the calibration and check the measured result.
- After the calibration was done make sure that it is activated by the "**Use Low Impedance Load Short Calibration**" switch of the WinDETA dialog "Analyzers, Options Alpha, Configuration". Otherwise, the calibration data will be saved but not applied during measurements.
- Before performing a Load Short Calibration, an **All Calibration** is recommended.
- Make sure that the **HVB 300** internal **Enable Vout** switch is closed. For details refer to "**Rear Panel, Enable Vout**". If you are using the **High Voltage Sample Cell**, place the cell into a cryostat or shielding unit in order close the **Enable Vout** switch.

The calibration is started by the Alpha GPIB command sequences ***RST**, **ZRUNCAL=SL_INIT**, **ZRUNCAL=SL_SHORT** and **ZRUNCAL=SL_100**

or

the WinDETA menu item "Analyzers, Options (Alpha Analyzer), "**Alpha Load Short Calibration**".

After starting the calibration you will be asked by WinDETA or by the Alpha display for the GPIB command set to connect the short and load calibration standards to the HVB 300 as shown below.

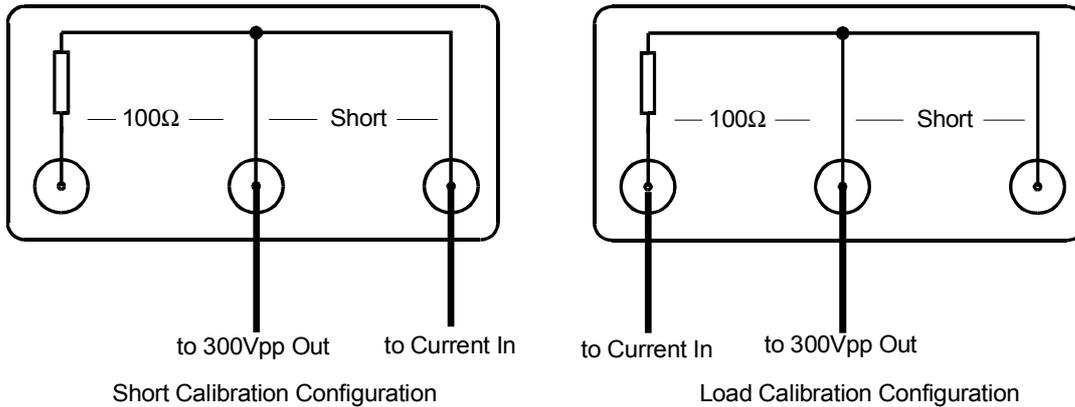


Fig. 9.1 : Short / Load calibration configurations for the HVB 300 interface.

4. Optional low capacity open calibration

With the **HVB 300** connected, this calibration has the same effect as the corresponding low capacity open calibration for the other Alpha-A lower voltage test interfaces. Refer to the Alpha manual for details. In order to do the calibration:

-Disconnect the cables from the **150 Vpp Vout** and **Current In** terminals before starting the calibration.

-Make sure that the **HVB 300** internal **Enable Vout** switch is closed. For details refer to "**Rear Panel, Enable Vout**". If you are using the **High Voltage Sample Cell**, place the cell into a cryostat or shielding unit in order close the **Enable Vout** switch.

If you are using WinDETA:

-Select in the "Analyzer" menu, "**Alpha + High Volt. Amp. +-150Vp**" for the actual impedance system.

-Select "**Alpha Low Capacity Open Calibration**" from the WinDETA menu item "**Analyzers, Options** (Alpha + High Voltage Amp. +-150Vp).

If you are using own GPIB programs:

-Proceed as described in the Alpha-A manual "Low Capacity Open Calibration" for the Alpha-A analyzer.

11. Operating the Alpha-A with HVB 300 by GPIB commands

Most of the commands are the same for operation of the Alpha-A analyzer with and without **HVB 300** connected. **Nevertheless, the following differences apply with the HVB 300 connected.**

-The MODE=VOLT command (gain phase mode) is not available and not allowed with the HVB 300 connected.

-The ACV=, DCE= and MST commands are only available after a system connections test with the ZRUNCAL=CONCHECK command has been done. Details are described below.

If the Alpha-A mainframe is connected to the **HVB 300** by the 25 pin Sub-D cable as described in the "Rear Panel" chapter, the Analyzer will automatically enter the **IMP_HV150** mode. For details refer to the **MODE=** command in the Alpha-A manual. As a result the Alpha will adjust its current and voltage ranges to the **HVB 300**.

The ranges of the **ACV=** and **DCV=** commands which set the ac and dc voltage will be extended and the **HVB 300** amplification ratio will be taken into account so that the commands can be used as usual.

E.g. **DCV=50** will set 50V dc bias voltage at the **300 Vpp Vout** socket. On the other hand, the voltage at the GEN socket which acts as the voltage source for the **HVB 300** will be about a factor 78 lower, which is the HVB 300 high voltage amplifier amplification.

A similar situation applies for the V1 terminal which is driven by the output of the **HVB 300** internal voltage divider and therefore by a factor 78 below the voltage at the **300 Vpp Vout** terminal. Anyhow, the Alpha will internally correct for this and display the voltage at the **300 Vpp Vout** terminal by internal multiplying the measured voltage at V1.

This concept will work as long as the external device setup and cabling as described in "System Connections for Measurements" is correctly realized.

On the other hand, problems may arise for an erroneous cabling setup different from the set-up described in the "System Connections for Measurements".

Warning : With connected HVB 300 this may result in set-ups which may be either dangerous for the operator as unexpected high voltages may be applied to unexpected system parts or may damage the instrumentation by applying high voltage to low voltage terminals.

In order to avoid such situations for the device combination **Alpha-A** and **HVB 300**, the Alpha mainframe enters a special **ZCON_TO_CHECK** state =1 after power on or ***RST** where any output voltage at the **GEN** and **300 Vpp Vout** terminals and the **ACV=, DCV=** and **MST** commands are disabled for safety reasons.

In order to switch the Alpha in the **ZCON_TO_CHECK = 0** state where the previous limitations do not apply, a system connections test for the actual selected mode is required. The system connections test should be started by the **ZRUNCAL=CONCHECK** command after the proper

system setup was established as described in the "System Connections for Measurements" chapters.

During the test a small voltage will be applied to the **GEN** socket which results in a not dangerous voltage at the **300 Vpp Vout** socket if connected. The Alpha checks then the **V1** and **V2** terminals for proper voltages in order to make sure a proper system and cabling setup. If so, the system connections test is passed and **ZCON_TO_CHECK** state will change to 0 and the **ACV=**, **DCV=** and **MST** commands will be available.

-The system connections test will be automatically applied at the beginning of any calibration started by the **ZRUNCAL=** command.

-The system connections test is only required with the **HVB 300** connected. The Alpha-A mainframe automatically detects the **HVB 300** if connected by the 25 pin Sub-D cable as described in the "Rear Panel" chapter.

12. Technical Data

Line voltage : 220 - 240 V ac, 50 - 60 Hz or
110 V ac, 50 - 60 Hz (see instrument rear)

Power consumption : 50 W

Environment

Operating temperature : 0° to 40°C
Storage temperature : -10° to 60°C
Specification limits : 20° to 30°C

Voltage Amplifier

Output impedance 200 Ω

Maximum output voltage 300 Vpp ac or dc
for $f > 160$ kHz linear decrease in ac amplitude to 60 Vpp at 1 MHz

Maximum output current about ± 70 mA, protected against permanent short to system ground

Frequency range DC to 1MHz.

Voltage amplification V_{out}/V_{in} About 78

Voltage divider

Voltage division V_{out}/V_1 About 78

Current to voltage converter

Frequency range

3 μ Hz .. 1 MHz

Current ranges (rms)

40 mA, 15 mA, 1.5 mA, 150 μ A, 15 μ A, 1.5 μ A,
150 nA, 15 nA, 1.5 nA, 150 pA, 15 pA, 1.5 pA

Current resolution (reproducibility)

± 5 fA $\pm 10^{-5}$ of current range

$\pm 30 \text{ fA/Hz} \cdot \text{frequency of measurement}$

Capacity range

$10^{-15} - 0.01 \text{ F}$

Resistance range

$0.1 - 2 \cdot 10^{15} \Omega$

Accuracy in $\tan(\delta)$ for capacitive samples:

$\pm 3 \cdot 10^{-5} \pm 10^{-3}$ of measured value

for frequency between 1 Hz .. 100 kHz and
sample capacity between 50 pF .. 2 nF

Reference capacitors

63 build in low loss precision reference capacitors from 25 pF .. 2 nF

13. Test Sample Results

