G35 HV Divider Manual

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Contents

1 Introduction

The described HV divider serves to measure the high voltage applied to the electron cooler of CRYRING. It is designed to measure high voltages up to 35 kV. This document contains operation instructions and specifications of the components installed. As some of the drawings and datasheets come from suppliers, **the document is for internal use only at GSI and EMU**.

Safety instructions:

- **Divider structure has to be grounded before use! For this purpose a threaded rod is attached to the tap flange located below the stainless steel tank base (see fig. 1).**

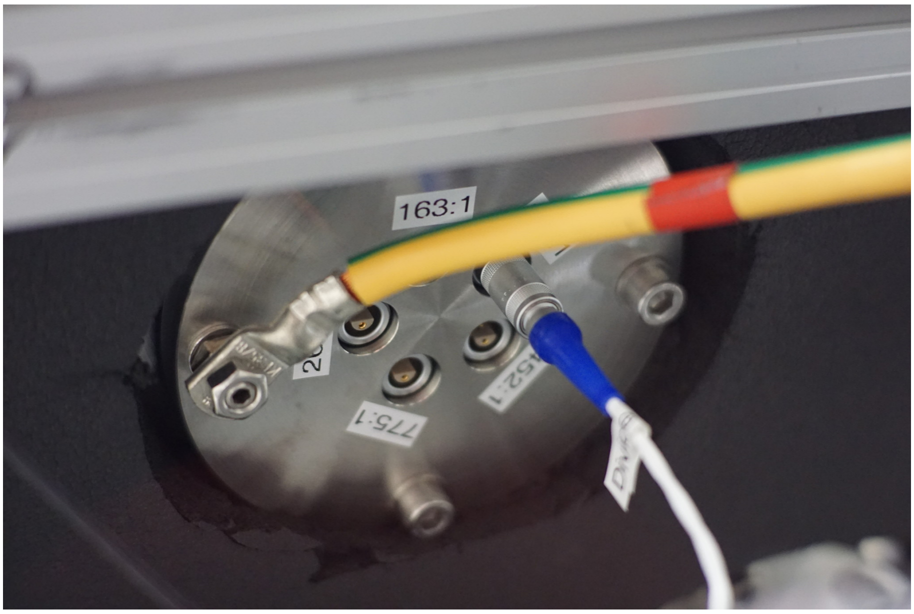


Figure 1: Tap flange with grounding cable and output cable attached.

- **Heinzinger HV connector of RG11 coaxial cable from electron cooler HV supply has to be securely connected to input socket (see fig. 2).**

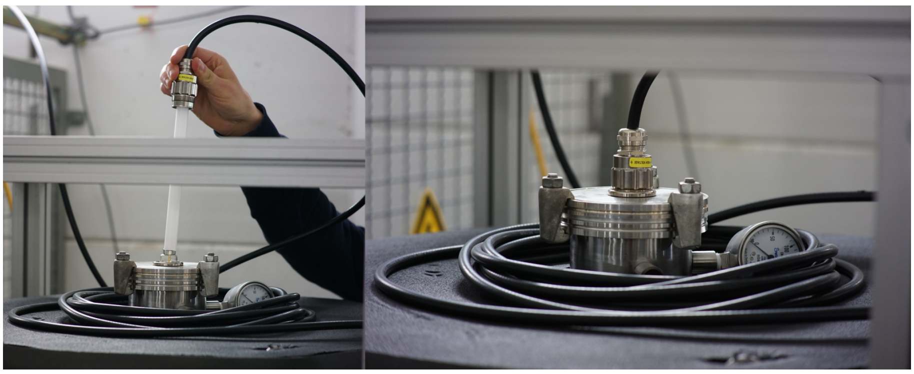


Figure 2: Left: Input connector and input socket. Right: Secure connection of input HV cable.

2 Setup

In the following subsections the mechanical and electrical setup of the divider is described. Subsequently the setup of the HV divider control parts as well as the control software are explained. Data sheets of the used components can be found in appendix C.

2.1 Electrical setup

Figure 3 shows the connection scheme of the G35 divider. The primary HV divider chain consists of 65 Vishay precision resistors (R_i) in serial connection on the high voltage side. In order to provide multiple scale factors to be able to cover different HV ranges the low voltage part of the divider is equipped with 16 additional precision resistors in a combination of parallel and serial connections ($R_{LV,i}$). In addition, a secondary divider chain consisting of ohmic and capacitive components is installed in parallel to the primary divider chain. This protects the sensitive precision resistors in case of HV transients. The overall resistance of the G35 is about 55 MΩ (primary chain: 119,6 MΩ). The available voltage taps from 100:1 up to 3500:1 provide the possibility to measure a wide span of voltages up to 35 kV using a precision DVM in the most precise 10 V range. [2]

Remark:

- **The quoted scale factors apply only if the measurement device has an input resistance of at least 10 GΩ. Otherwise the scale factor might be significantly different. Furthermore all calibrations given in this manual only apply to the G35 used in combination with the Keysight 3458A DVM.**

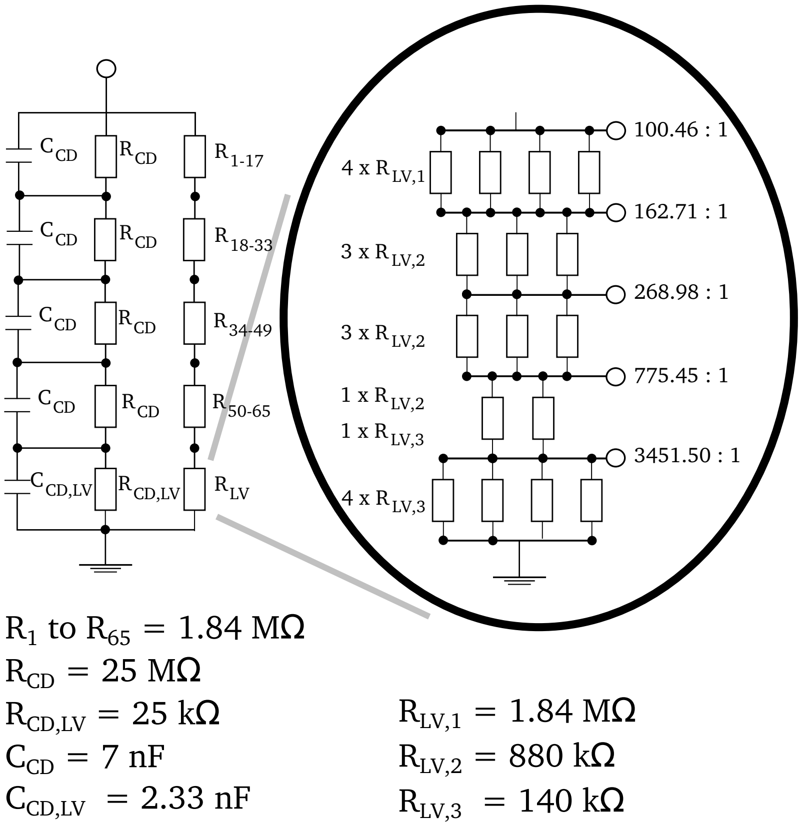


Figure 3: Electrical setup of the G35 HV divider. Figure taken from [2]

2.2 Mechanical setup

Figure 4 shows the mechanical setup of the G35 divider. All divider components are mounted on a movable KANYA frame. Due to the temperature dependence of the precision resistors, the environmental thermal conditions have to be precisely controlled. Therefore the primary and secondary divider chains are surrounded by a closed stainless-steel vessel. The divider features a slow control and climate control system located in the periphery below the vessel, which regulates the inner vessel temperature (see section 2.3). The nominal operating temperature of the G35 divider is 15 °C. All quoted calibration data in the main document refer to that temperature. Should the environmental conditions prevent stable operation at 15 °C, an additional calibration has been performed at 20 °C (see appendix A) For a technical drawing showing the outer dimensions of the G35 divider please refer to appendix B.

Remark:

- **Calibrations have been conducted at 15 °C. Temperature stabilization has to run at all times! Implementation of an outage warning into the CRYRING slow control is advised.**

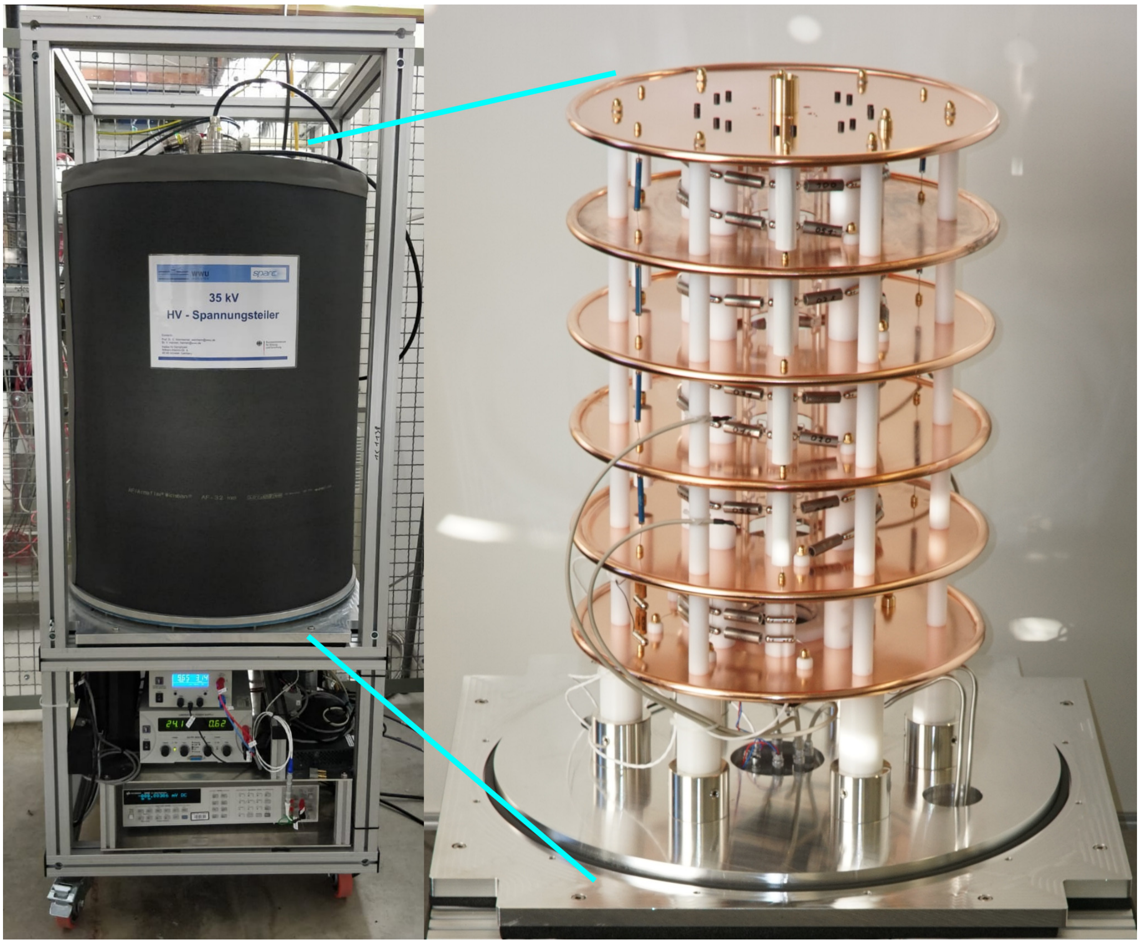


Figure 4: Mechanical setup of the G35 divider. Left: Complete divider system including periphery for the control of the steel vessels inner environmental conditions and voltage measurement. Right: Vessel inside including the precision divider chain.

2.3 Slow control setup

Figure 5 shows the slow control setup schematic of the G35 divider. The different components will be explained in the following paragraphs.

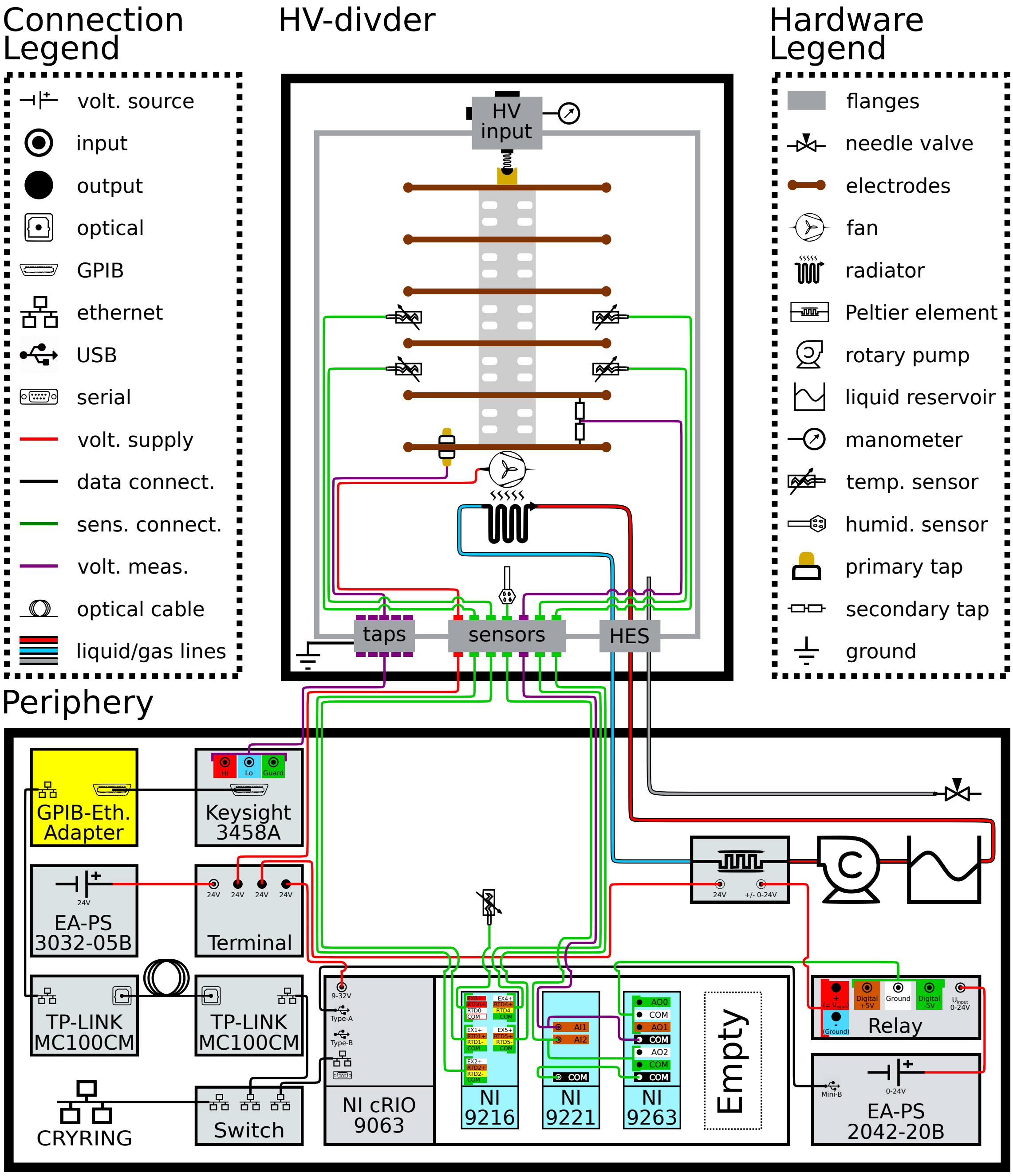


Figure 5: Slow control/HES (**H**eat **E**xchanger **S**ystem) setup of the G35 divider. To be able to see the detailed cable mantle color code for the cRIO modules please refer to the electronic version of this document. For a better overview all 230 V connections are omitted in this schematic.

Temperature regulation To maximize the dividers precision a constant temperature of 15 °C inside the steel vessel is critical. The regulation is realized via a LabVIEW 2014 based PID-control running on a NI cRIO 9063 real-time controller. The cooling/heating is conducted through a dedicated **H**eat **E**xchanger **S**ystem (HES). To measure the temperature inside the steel vessel, the divider features four PT100 sensors in divider plane 2 and 3 as depicted in fig. 5. All temperature sensors and read out via the NI 9216 RTD analog input module. The average of the four temperature readings serves as the temperature the PID-control regulates. To heat/cool the divider the PID-control sets the input voltage of a Peltier element based liquid to air thermoelectric assembly. Switching between heating and cooling is realized by a relay that switches the polarity of the supply voltage from the EA power supply (see paragraph Power supply). The relay itself is controlled by the Labview control software that determines the polarity by applying a 5 V control voltage from the NI 9263 analog output module to the relay. The thermoelectric assembly is integrated in a fluid circuit and heats/cools the liquid (a mix of 80% water and 20% Glysantin®) according to the set temperature of the control software. The liquid is pumped into the HV-divider via the HES flange by a rotary pump located in the periphery of the divider. Heat exchange in the divider occurs at a radiator/fan installation below a tunnel tube. The fan blows the heated/cooled air from the radiator into the tunnel tube. From the tunnel tube the air gets distributed to each resistor of the precision chain in order to homogeneously heat/cool all precision resistors. Additionally a water reservoir is installed in the fluid circuit to account for loss of fluid over time. The achieved regulation precision is approximately $\pm$0.1 K.

Remarks:

- **Every month the liquid level has to be checked and liquid has to be refilled if necessary (see section 5.4).**
- **When initializing the divider control after it has been off for more than 1 hour, let the system settle for at least 1 hour to guarantee optimal thermal conditions. When voltage changes larger than 500 V occur, a settling time of approximately 10 minutes is advised.**

Humidity monitoring In order to maintain the dielectric strength of the divider, the humidity inside the tank is being monitored by a dedicated humidity sensor. Values distinctively exceeding 30 % humidity should raise an alarm in the CRYRING slow control framework (not implemented yet). The sensor is located inside the tank directly on top of the sensor flange. The supply voltage for this sensor is provided by the NI 9263 module attached to the cRIO system. Readout is conducted via the NI 9221 voltage input module.

Voltage measurements Two individual voltage measurements are being conducted by both divider chains. For the precision voltage measurements the voltage signal is transferred from one of five voltage taps to the measurement device (Keysight 3458A) via the tap flange. Detailed instructions for the preparation of the precision measurements are given in section 3. For diagnostic purposes an imprecise measurement of the voltage is constantly conducted via the secondary voltage tap. The secondary scale factor is fixed to approximately 4001:1 and the signal is transferred through the central sensor flange. The readout is conducted by the NI 9221 module and can be checked live in the HTML version of the control software (see paragraph control software).

Data transfer The data transfer to the CRYRING slow control is conducted via an Ethernet switch located in the periphery of the divider. Two data streams are fed into the switch. The first data stream consists of the measured voltages from the Keysight 3458A DVM. Since the multimeter only features a GPIB interface, a GPIB-Ethernet controller is attached to the GPIB port located at the rear of the DVM. Additionally, to galvanically decouple the DVM from other technical devices, two Ethernet-optical converters are connected to the GPIB adapter at the DVM. The second data stream consists of the cRIO data including temperature regulation, humidity and secondary voltage tap data (refer to the next paragraph).

Control software The G35 control software runs autonomically on the cRIO real-time controller. However to verify functionality and status of the HV divider it is also possible to monitor the software via a browser. To access the control software interface an internet explorer with the Microsoft Silverlight browser plug-in has to be available from inside the GSI network. The access itself is obtained by connecting to the following address:

- **http://140.181.141.116:8000/G35startup.html**
  (Check if the IP or the port are still correct if this address is not reachable.)

The interface is shown in figure 6. Several control parameters as well as sensor readouts are displayed via this interface. If required, the set temperature of the divider can be changed by assuming control over the software. First the control has to be requested by clicking the right mouse button and selecting the corresponding option. Then the user can change the desired parameters. Subsequently the control has to be released again by clicking the right mouse button and choosing the corresponding option.

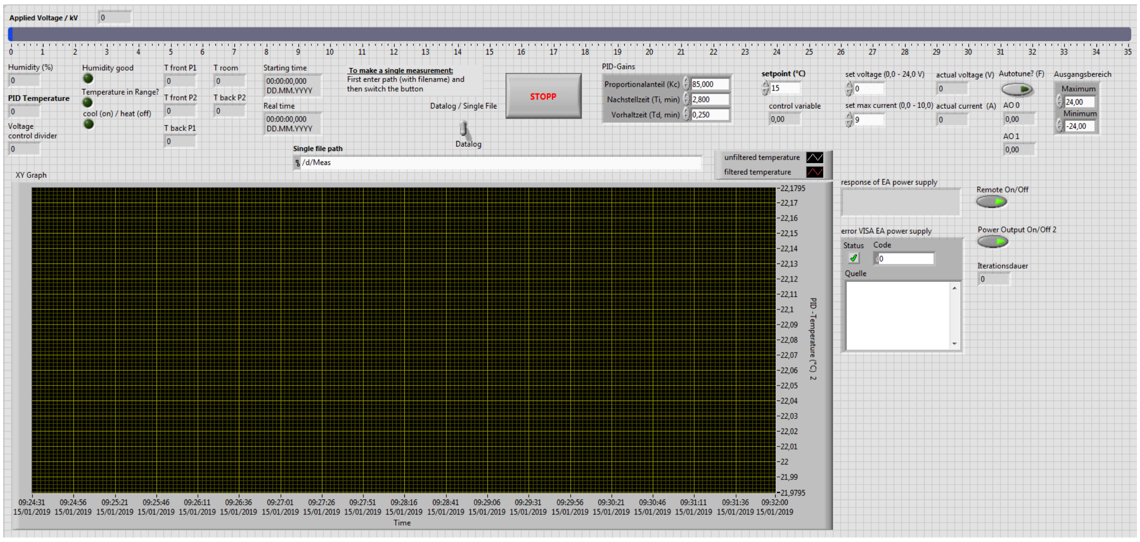


Figure 6: Slow control interface of the G35 divider. Temperatures, temperature setpoint, humidity, divider input voltage etc. are shown. If needed, control parameters such as the set temperature of the divider can be changed via this interface.

Data storage The sensor data taken by the cRIO controller is stored on the cRIO system. It can be accessed from the GSI network via **F**ile **T**ransfer **P**rotocol (FTP):

- **ftp://140.181.141.116/d/meas**
  (The subfolders and filenames are assigned according to month/date when the data was taken.)

Power supply The 230 V supply voltage connections for nine devices in the periphery are realized by two multi sockets located at two sides of the KANYA frame. A constant 24 V supply voltage for the fan inside the divider tank, the liquid-to-air thermoelectric assembly fan and the cRIO system is provided by an EA-PS 3032-05B power supply and distributed via a terminal. The dynamic 0-24 V regulated via the PID-control for the Peltier element of the thermoelectric assembly is provided by an EA-PS 2042-20B power supply.

3 Measurement preparations

In this section the general measurement preparations are presented. This includes the measurement wiring, calibration procedures as well as the Keysight 3458A configuration. Detailed step-by-step operating instructions are given in section 5. For a detailed description of the Keysight 3458A please refer to the Keysight 3458A User's Guide [1].

3.1 Calibrations

3.1.1 Keysight 3458A calibration

For the reproducibility of measurements in the ppm and sub-ppm range, it is important that changes of the DVMs reference voltage source and deviations caused by temperature fluctuations of the ambiance are compensated. Especially thermoelectric voltages of the measurement lines and aging of the DVMs inner components adversely affect the stability. Therefore two different corrections have to be conducted. First of all the offset of the DVM has to be determined, subsequently a correction factor (named Gain, in accordance with the Keysight 3458A User's Guide) is calculated by measuring the scaling of the maximum voltage in the measurement range to be calibrated. The resulting values for the offset and the Gain have to be applied to all measured values. To maximize measurement precision this calibration should be conducted before and after each precision measurement or at least once a day during a measurement campaign: [4]

1. Use the **ACAL 0** function of the DVM.
2. Conduct an offset calibration measurement. For this purpose short circuit the Hi and Lo input of the DVM. Measure the offset for 10 minutes and subtract the average offset U_{offset} from all following measurements.
3. Conduct a gain calibration measurement. For this purpose, connect a 10 V reference source to the DVM. Take care to use the correct polarity. E.g. if a negative voltage is applied to the G35 divider in the planned measurement, the gain calibration has to be conducted with a negative voltage also. The gain is then determined by:
$$\text{Gain} = \frac{U_{\text{gain}} - U_{\text{offset}}}{U_{\text{ref.}}} \tag{1}$$
where U_{gain} is the measured voltage and $U_{\text{ref.}}$ the 10 V reference source voltage.

Remark:

- **Should no reference source be available for the DVM calibration, at least perform step 1 (ACAL 0)! This sets the DVM in a state comparable to the last time ACAL 0 was performed and the previous "gain" factor can be used within an uncertainty of 4 ppm/year.**

3.1.2 G35 divider calibration

A major key to the precision of high voltage dividers are regular calibrations. In this section two different calibration methods are presented which should be performed at regular intervals. Furthermore the latest calibration results of the divider will be shown.

Absolute high voltage calibration Since HV dividers usually show a voltage dependent scale factor, a calibration of the scale factors has to be performed with voltages up to 35 kV. The University of Münster developed a suitable calibration method that has already been performed with the G35 divider (see subsection 4). This calibration should only be conducted by the HV-group of the Münster University because a dedicated calibration setup (figure 7) has to transported to GSI to be able to conduct the measurements. For further information please refer to the publication of the method under [3].

Remark:

- **It is advised to perform this calibration once a year. Alternatively perform this calibration before high precision experiments at CRYRING@ESR as this guarantees maximum precision of the HV divider. To conduct this calibration measurement please coordinate with the HV group from Münster.**

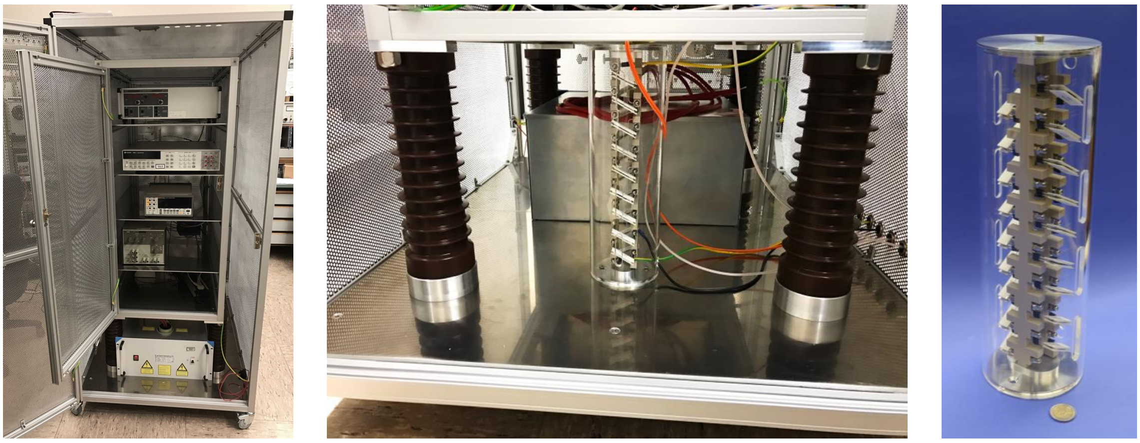


Figure 7: Mobile absolute calibration setup.

1 kV calibration A second method to calibrate the HV divider is a fully traceable method with the downside of being limited to 1 kV. The method utilizes a Fluke 752a reference divider which scales down voltages up to 1 kV. To calibrate a HV divider a known input voltage is applied to the unit under test and the output voltage is measured. To determine the input voltage the voltage is applied in parallel to the reference divider with a known scale factor $M_{\mathrm{ref.}}$ and measured with a precision DVM. Since the commercially available reference dividers are limited to 100:1 scale factors and 1 kV input voltage this technique can only be applied to the 100:1 scale factor of the G35 divider. The setup for this measurement is shown in figure 8. The M_{100} scale factor is determined by equation 2: [3]

$$M_{100} = \frac{U_{\mathrm{in}}}{U_{\mathrm{out}}} = \frac{U_2 \cdot M_{\mathrm{ref.}}}{U_1} \tag{2}$$

In order to calibrate scale factors $M_{\mathrm{i}} > 100:1$ a step-up technique with the same equipment is applied. The prerequisite to be able to use this method is that the M_{100} scale factor has already been determined by the method presented in figure 8. As shown in figure 9 the higher scale factors M_{i} are calibrated by applying U_{HV} not to the regular divider input, but to the M_{100} output connection. In this arrangement the subscale factor M_{i}' is determined by measuring the voltage drop over the low voltage resistors R_{LV} at a calibration voltage $U_{\mathrm{HV}} = U_{\mathrm{i,max}}/M_{100}$, where $U_{\mathrm{i,max}}$ is the maximum voltage that can be applied to the corresponding voltage tap (see table 1). Thus the voltage drop over the low voltage resistors R_{LV} is comparable to the voltage drop over these resistors if the maxi-

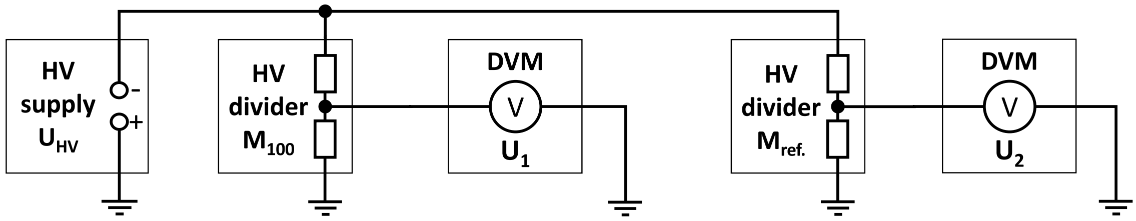


Figure 8: Setup of M_{100} scale factor calibration measurement. The input voltage U_{in} is determined by multiplication of the measured output voltage U_2 with the known scale factor $M_{\mathrm{ref.}}$ of a reference divider. Figure taken from [3].

mum input high voltage of $U_{\mathrm{i,max}}$ is applied to the complete divider chain. To determine the scale factor M_{i} equation 3 has to be applied: [3]

$$M_{\mathrm{i}} = \underbrace{\frac{U_{\mathrm{in}}}{U_{\mathrm{out}}}}_{M_{\mathrm{i}}'} \cdot M_{100} = \frac{U_2 \cdot M_{\mathrm{ref.}}}{U_1} \cdot M_{100} \tag{3}$$

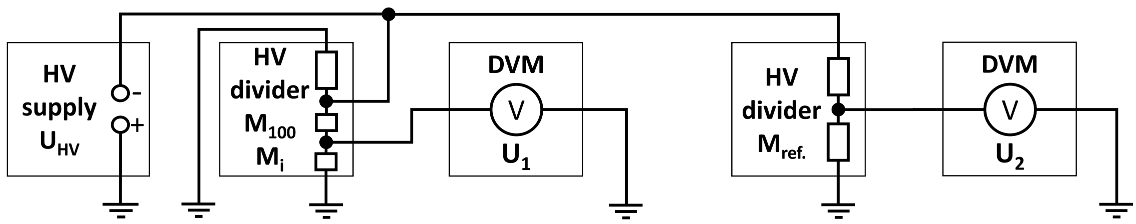


Figure 9: Connection scheme for the calibration of a HV divider with the two scale factors M_{100} and $M_{\mathrm{i}} > M_{100}$. Here the voltage created by a HV supply is not connected to the input of the unit under test, but to the scale factor M_{100} output connection. The scaled voltage U_1 is measured with a precision DVM at M_{i}'. A reference HV divider with scale factor $M_{\mathrm{ref.}}$ and a second DVM (U_2) are used to determine the input voltage. Figure and caption taken from [3].

Remark:

- **It is advised to perform this calibration every three month to guarantee the integrity of the G35 divider. Additionally this calibration is advised to be conducted before a measurement campaign and if the absolute calibration method cannot be conducted instead.**

3.2 Measurement wiring

Before taking measurements one out of five different scale factors, depending on the desired voltage to be measured has to be chosen. In table 1 the available scale factors with the corresponding voltage ranges are given. To use a specific scale factor the Lemo plug of the measurement cable has to plugged to the correct output of the tap flange (see figure 1). The Keysight 3458A has to be connected according to figure 5. To minimize ground loops keep the Guard switch of the Keysight 3458A in the Open (out) position. Furthermore the input high voltage cable has to be connected to the divider according to figure 2.

Table 1: Scale factors with voltage ranges for 15 °C divider temperature and -1 kV applied.

scale factors at 15°C / 1kV	voltage ranges
100.46470(3) : 1	100 V – 1205 V
162.71444(16) : 1	1206 V – 1952 V
268.98943(19) : 1	1953 V – 3227 V
775.48495(38) : 1	3228 V – 9305 V
3451.6866(23) : 1	9305 V – 35000 V

3.3 Keysight 3458A control

The Keysight 3458A is controlled via VISA commands. This is currently realized in the local implementation of the TRITON[1] software at CRYRING. To obtain the last measured value execute a VISA READ command. Configuration commands are send via a VISA WRITE command. For standard DC measurements with maximum precision the following configuration commands should be used:

NPLC 150 Number of power line cycles (NPLC) to set integration time of the DVM. The integration time t of the DVM is determined by the NPLC and the line frequency f_{line} (in this case 50 Hz) via $t = \mathrm{NPLC}/f_{\mathrm{line}}$. A measurement with 150 NPLC thus takes 3 s. If AZERO ON command is also used, the time to take one measurement approximately doubles to 6 s (see paragraph AZERO ON).

AZERO ON The autozero function ensures that any offset errors internal to the multimeter are nulled from subsequent DC or ohms measurements. With AZERO ON, the multimeter internally disconnects the input signal and makes a zero reading following every measurement. It then algebraically subtracts the zero reading from the preceding measurement. This approximately doubles the time required per reading.

NDIG 8 Designates the number of digits to be displayed by the multimeter.

DCV 10 For maximum precision the DVM should be operated in 10 V range (max. input 12 V). Please choose voltage tap of the G35 accordingly (also see table 1).

[1] Refer to A. Buß (a_buss09@uni-muenster.de) or K. Mohr (K.Mohr@gsi.de)

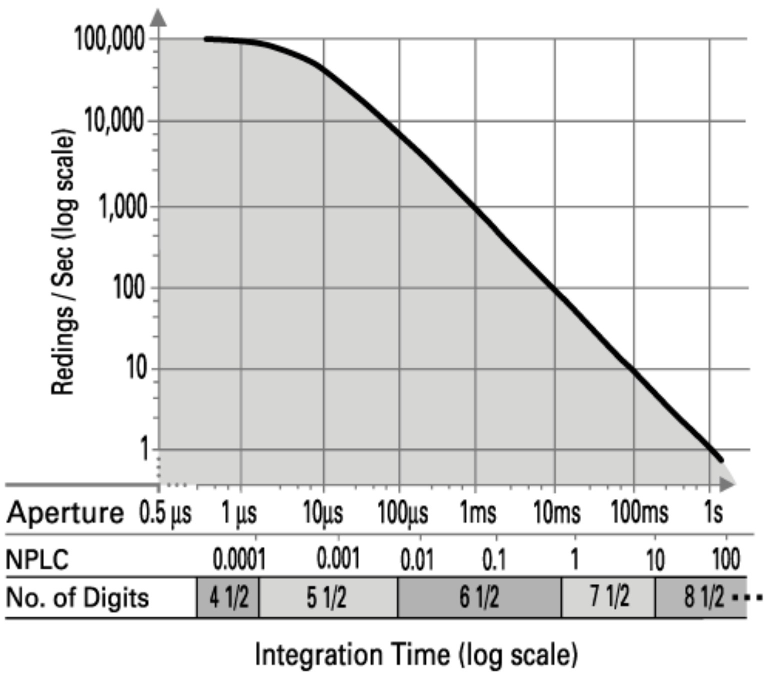


Figure 10: Impact of Keysight 3458A integration time on measurement precision and reading rate. The graph shows reading rates for AZERO OFF and a line frequency of 60 Hz. This graph was taken from the Keysight 3458A data sheet.

TARM HOLD Triggering is disabled. This command can be used when the DVM is initialized. At this point no measurements are initiated.

TARM SGL Triggers a single measurement then becomes HOLD (DVM awaits new trigger command). After the nominal integration time the measured value can be obtained by using a VISA READ command.

Remark:

- **For fast measurements as needed for dielectronic recombination measurements the DVM has to operated in the high speed mode. This mode is established via the command PRESET FAST. For operation details in this mode refer to the Keysight 3458A User's Guide [1].**

4 Calibration results

In this section the latest calibration results of the G35 are presented as well as the description of how to proceed with future calibration results. For a complete overview of the calibration results please refer to appendix A.

Calibration calculation The voltage dependency of the G35 divider is determined with the absolute calibration (see paragraph absolute calibration in subsection 3.1.2) by measuring the voltage dependency of the M_{100} scale factor which includes the whole high voltage precision chain. The M_{100} scale factor therefore is used to determine all higher scale factors. To calculate each scale factor for a divider temperature of 15 °C, the factors of table 2 have to be applied to equation 4 and equation 5.

Voltage dependent scale factor determination:

$$M_s = \underbrace{\frac{1}{a + b \cdot U_{in}[\text{kV}] + c \cdot (U_{in}[\text{kV}])^2 + d \cdot (U_{in}[\text{kV}])^3}}_{M_{100}} \cdot M_{s\_\text{factor}} \tag{4}$$

Uncertainty determination:

$$\begin{aligned} u_{M_s} &= J(x) \cdot V_x \cdot J^T(x) \\ u_{M_s} &: \text{uncertainty of scale factor } M_s \\ J(x) &: \text{Jacobian matrix } J_i(x) = \frac{\partial M_s}{\partial x_i}(x) \\ V_x &: \text{covariance matrix} \end{aligned} \tag{5}$$

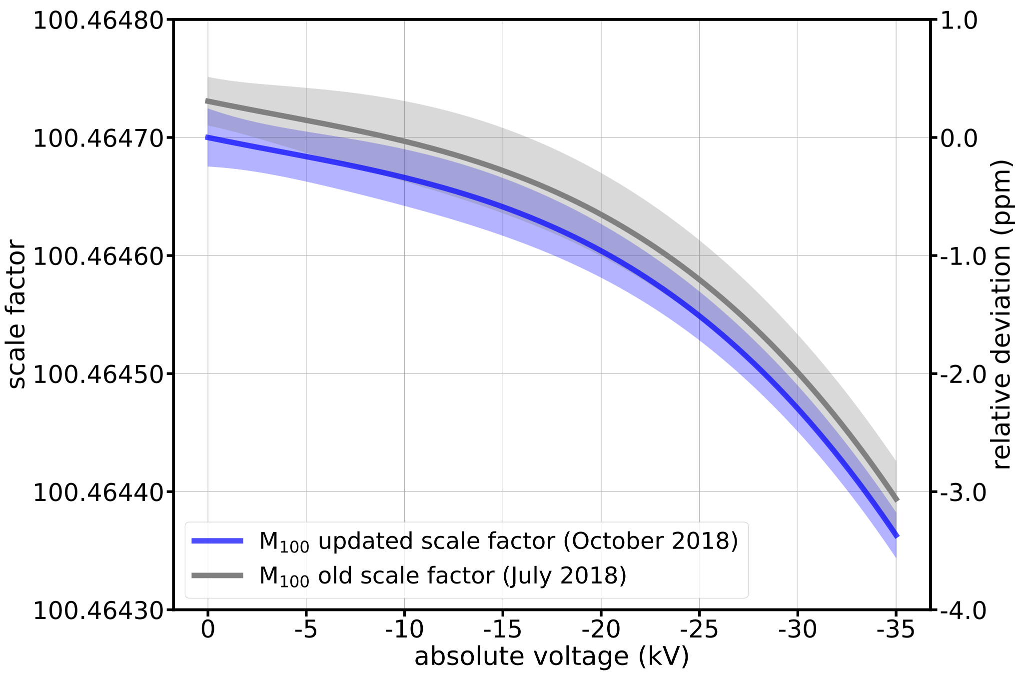


Figure 11: Result of updated M_{100} scale factor calibration. The voltage dependency was measured in July 2018 (gray) and was updated with the 1 kV calibration measurement conducted in October 2018 (blue).

Calibration updates Since the absolute calibration method is a complex measurement that has to be conducted by the HV-group of the University of Münster, the latest absolute calibration measurement was conducted in July 2018. The results of these measurements are presented in table 2 and figure 11. If no new absolute calibration can be conducted it is possible to update the last measurement results by conducting the 1 kV calibration. It can be assumed that the voltage dependency of the G35 divider stays constant within a year and therefore only the voltage independent total resistance has to be calibrated. The factor "a" in equation 4 is the inverse of the M_{100} scale factor when no load is applied. As can be seen in figure 11 the scale factor at 1 kV input voltage is the same as for 0 kV within the uncertainties. Therefore the inverse of the measured M_{100} scale factor can be used to update the value of factor "a" which is also presented in the results table (measured on 10th of October, 2018).

Table 2: Factor values and covariances to determine the G35 scale factors for a divider temperature of 15 °C and negative polarity. To calculate the voltage dependent scale factors the values in this table are applied to equation 4. The uncertainties are determined by applying the covariances according to equation 5.

factor	value	uncertainty
a^*	$9.95374461 \cdot 10^{-3}$	$2.42 \cdot 10^{-9}$
~~a_{old}~~	~~$9.95374155 \cdot 10^{-3}$~~	~~$2.02 \cdot 10^{-9}$~~
b	$3.42 \cdot 10^{-10}$	$4.70 \cdot 10^{-10}$
c	$-7.6 \cdot 10^{-12}$	$2.45 \cdot 10^{-11}$
d	$7.20 \cdot 10^{-13}$	$3.61 \cdot 10^{-13}$
M_{100_factor}	1	———
M_{163_factor}	1.6196176	$1.5 \cdot 10^{-6}$
M_{269_factor}	2.6774509	$1.6 \cdot 10^{-6}$
M_{775_factor}	7.7189804	$2.7 \cdot 10^{-6}$
M_{3452_factor}	34.357179	$2.0 \cdot 10^{-5}$
$\mathrm{Cov}(a,b)$	$-5.96 \cdot 10^{-19}$	———
$\mathrm{Cov}(a,c)$	$2.54 \cdot 10^{-20}$	———
$\mathrm{Cov}(a,d)$	$-3.33 \cdot 10^{-22}$	———
$\mathrm{Cov}(b,c)$	$-1.12 \cdot 10^{-20}$	———
$\mathrm{Cov}(b,d)$	$1.57 \cdot 10^{-22}$	———
$\mathrm{Cov}(c,d)$	$-8.72 \cdot 10^{-24}$	———

*Measured with 1 kV calibration at GSI on 10th of October, 2018.

5 Operating instructions

This chapter contains the step by step operating instruction for the commissioning of the G35 divider. The included step by step descriptions are largely taken and partly literally translated from the appendix of [4]. For a schematic overview of the components for each operating instruction please refer to figure 5.

5.1 Filling the G35 divider tank with nitrogen gas N_2

Remark:

- **Please note that currently there is a leak at a feedthrough of the tap flange. Therefore the nitrogen overpressure cannot be held!**

Preparations, materials:

- Nitrogen 5.0 gas bottle with 10 l volume.
- Pressure regulator with suitable gas tube for the 6 mm tube fitting of the manual valve below the divider tank mounted on the HES flange.

Execution:

1. Disconnect HV divider from voltage source and ground the divider.
2. Switch off the EA-PS 2042-20B power supply to stop the temperature regulation.
3. Leave the EA-PS 3032-05B power supply switched on to keep the fan inside the divider running during the whole procedure.
4. Connect gas bottle, pressure regulator and gas tube. Then rinse/dry the tube with gas from the bottle.
5. Connect gas tube to the manual valve at the HES flange.
6. Open manual valve at the HES flange and seal plug at the HV input flange (located on top of the divider).
7. Open outlet of gas bottle and rinse the HV divider with nitrogen gas.
8. Close input on HV input flange with the seal plug.
9. Fill the divider with nitrogen gas until the low pressure manometer attached to the HV input flange shows an overpressure of approximately 70 mbar.
10. Close the manual valve at the HES flange.
11. Close outlet of gas bottle then disconnect the gas tube.
12. Switch on the EA-PS 2042-20B power supply and press reset button of the NI cRIO 9063 controller to restart temperature regulation.
13. Wait one hour to be certain that all resistors reach the setpoint temperature before the divider is ready for operation.

5.2 Commissioning of the G35 divider

Before switching on HV divider controls and applying voltage to the divider the following initial state should be established:

Preparations:

- Power plug of both multiple sockets below the divider unplugged.
- Power switch of both multiple sockets below the divider switched off.
- Liquid level of liquid reservoir at upper mark.
- Cap of liquid reservoir closed.
- No loose cables visible.
- Power switches of EA-PS 2042-20B and EA-PS 3032-05B power supplies switched off.
- Power switch of Keysight 3458A switched off.
- Manual valve at HES flange closed.
- Seal plug at the HV input flange closed.
- No high voltage plug connected to the HV feedthrough at the HV input flange.

From this state the HV divider can be commissioned with the following steps:

Commissioning of the HV divider:

1. Check if ground cable is connected to the tap flange.
2. Measure if HV divider is connected to lab ground.
3. Clean high voltage plug of the high voltage cable with alcohol and let it dry.
4. If needed also clean the high voltage jack at the HV input flange with alcohol and let it dry.
5. Connect the high voltage plug to the high voltage jack.
6. Connect power plugs of both multiple sockets below the divider to line voltage.
7. Switch on both multiple sockets.
8. Rotary pump of heat-exchanger system starts.
9. Switch on both, the EA-PS 2042-20B and EA-PS 3032-05B power supplies. Then check that EA-PS 3032-05B is set to 24 V supply voltage.
    - Fans inside the divider and at the thermoelectric assembly outside the divider start running.
    - NI cRIO 9063 controller boots and conducts self-test.
    - Slow control software of the divider activates.
    - Green power light of NI cRIO 9063 controller is active.
    - Check if the temperature setpoint is set correctly (usually 15 °C) and if the slow control functions correctly. To do that please connect to the control software via an Internet Explorer browser with Microsoft Silverlight plugin from within

the GSI network. The address is:
http://140.181.141.116:8000/G35startup.html

10. Connect voltage tap to the Keysight 3458A DVM.

11. Switch on the Keysight 3458A DVM.

After these steps have been successfully conducted the temperature regulation needs approximately one hour to reach the setpoint. If the divider has been transported before commissioning please conduct a manual high voltage test by slowly increasing the input voltage in order to detect any possible transport damage. Before using the divider, it has to be stabilized to the set temperature for at least 1 hour for optimal thermal conditions. Furthermore it is advised to let the Keysight 3458A DVM warm up for at least 2 hours before conducting high precision measurements.
The divider is now operational, but should always be maintained according to section 5.4.

5.3 Deactivation of the G35 divider

Before deactivation of the HV divider controls following initial state should be established:

Preparations:

- HV divider disconnected from voltage source and the divider grounded. Please wait 5 minutes after disconnecting the divider from the voltage source in order to avoid possible undesired discharges.
- High voltage plug disconnected from the high voltage jack at the HV input flange and dummy cap mounted on the high voltage feedthrough.
- Voltage tap disconnected from the Keysight 3458A DVM.

Through the following steps the HV divider is deactivated:

Deactivation:

1. Switched off both power switches of the EA-PS 2042-20B and EA-PS 3032-05B power supplies.
2. Switch off both multiple sockets in the periphery of the divider.
3. Disconnect power plugs of both multiple sockets.
4. If divider is to be moved, disconnect the ground cable from the tap flange.

5.4 Maintenance of the G35 divider

The G35 divider has to be maintained on a regular basis to guarantee optimal functionality. Mainly mechanically stressed components as well as the heat-exchanger system have to be maintained. The following components have to be checked:

Maintenance:

- Check all pipes and connections of the heat-exchanger system for loss of liquid.
- Check liquid level of the liquid reservoir and if necessary refill it with a mixture of 80% water and 20% Glysantin®.
- A small amount of liquid loss due to evaporation is common, should greater losses occur without finding the source on the outside of the divider, the interior of the divider has to be checked for leaks.
  Please refer to the HV group of the University of Münster if a leak inside the divider has to be checked/repaired.
- Check all electrical connections of the heat-exchanger system.
- Check current limit of the EA-PS 2042-20B power supply (10 A; can be set via the control software described in the G35 HV divider manual).
- Check current limit of the EA-PS 3032-05B power supply (0.8 A; can be set via the front panel of the device). The device should be set to a constant voltage of 24 V.
- Check operating parameters (see section 5.5).

5.5 Monitoring of the operating parameters

The operating parameters have to be checked on a daily basis to guarantee optimal functionality of the divider. The following steps have to be conducted:

Monitoring steps:

- Rotary pump of the heat-exchanger system is running.
- Power supply EA-PS 3032-05B is switched on and shows a voltage of 24 V.
- Power supply EA-PS 2042-20B is switched on and shows a voltage $\leq$ 30 V (current $\leq$ 10 A).
- Green power light of NI cRIO 9063 controller is active.
- Check functionality of temperature regulation:
  - Connect to the control software via an Internet Explorer browser with Microsoft Silverlight plugin from within the GSI network via the address: http://140.181.141.116:8000/G35startup.html

Remarks:

- **Should the temperature regulation be stuck, please restart the system by switching power supply EA-PS 2042-20B off and on again and subsequently pressing the reset button of NI cRIO 9063 controller.**
- **Should the pump be stuck mechanically please switch off the pump, drain off liquid until the pump can pump air and switch on the pump for a short time. Then refill liquid according to section 5.4 and restart the pump.**

5.6 DVM calibration guide

Please conduct this calibration before and after every precision measurement or at least once a day during a measurement campaign.

Preparations, materials:

- 8.5 digit precision digital voltmeter (in this case Keysight 3458A) in warmed up state (at least 3 hours).
- DC voltage reference, e.g. Fluke 732A or comparable in calibrated state ($U_{\mathrm{ref.}}$ has to be known on a sub-ppm level).
- Shielded two wire PTFE cable with copper-tellurium banana plugs. Such a cable was provided with the G35 divider though it has a Lemo FFA.1S.302.CYBC42Z connector on one end. Therefore an adapter Lemo to banana is also included in the G35 equipment.
- Measuring program for data acquisition, e.g. as implemented in the TRITON software[2] at CRYRING.

Measurement wiring (needed from execution bullet point 2 onwards):

- Short circuit guard and ground at both devices.
- Connect the shielding of the measuring cable to the guard/ground of both devices.
- Set the guard switch of the Keysight 3458A DVM to the Open (out) position to minimize possible ground loops.
- Connect positive and negative pole of the measuring wire to the 10 V Hi and Lo outputs of the 10 V reference.
- If a gain measurement for positive voltages is to be conducted, connect positive and negative pole of the measuring wire to the Hi and Lo inputs of the DVM with the same polarity. If a gain measurement for negative voltages is to be conducted, connect positive and negative pole of the measuring wire to the Hi and Lo inputs of the DVM with inverse polarity. For the offset measurement, the same wiring is to be used, only that positive and negative pole at the 10 V-reference have to be disconnected from the reference and be short-circuited.

Execution:

1. Perform the **ACAL 0** self calibration of the Keysight 3458A DVM as follows (DVM input is disconnected):
   - Press **Local** button on DVM front panel.
   - Press **Auto Cal** button on DVM front panel.
   - Press **0** button on DVM front panel.
   - Confirm with **Enter** button on DVM front panel.
   - Wait approx. 10 minutes until self calibration is finished and DVM shows measured voltages on front panel.

[2] Refer to A. Buß (a_buss09@uni-muenster.de) or K. Mohr (K.Mohr@gsi.de)

2. Wire the setup according to the previous instructions and wait at least a minute for thermal equilibrium of the connectors.

3. Setup the Keysight 3458A DVM using the following settings:

   - **AZERO ON, NDIG 8, DCV 10, TARM HOLD**

4. Conduct a 10 minute "gain" measurement.

5. Average all recorded values obtaining U_{gain}.

6. Wire setup for the offset measurement according to the instructions.

7. Conduct a 10 minute offset measurement obtaining U_{offset}.

8. Average all recorded values.

Analysis:

After conducting both measurements, the "gain" factor can be determined using the following equation:

$$\mathrm{Gain} = \frac{U_{\mathrm{gain}} - U_{\mathrm{offset}}}{U_{\mathrm{ref.}}} \tag{6}$$

After evaluation of the "gain" factor, all following measured values have to be corrected as follows:

$$U_{\mathrm{meas.}}^{\mathrm{corr.}} = \frac{U_{\mathrm{meas.}} - U_{\mathrm{offset}}}{\mathrm{Gain}} \tag{7}$$

where $U_{\mathrm{meas.}}$ us the measured value recorded by the DVM and $U_{\mathrm{meas.}}^{\mathrm{corr.}}$ is the offset and gain corrected value. **Remarks:**

- **Should no reference source be available for the DVM calibration, at least perform ACAL 0 self calibration. This sets the DVM in a state comparable to the last time ACAL 0 was performed and the previous "gain" factor can be used within an uncertainty of 4 ppm/year.**

- **The "gain" factor as well as the offset are highly temperature dependent. Should the ambient temperature change by more than ± 1 K or should the DVM be switched off after a calibration, this calibration measurement has to be conducted again.**

- **Uncertainties of measured values are determined by uncertainty propagation of the individual contributions.**

- **To determine the uncertainties for each measurement device please refer to the calibration certificate of the 10 V reference and the Keysight 3458A data sheet. Since the uncertainties given by these sources are conservative, the uncertainties can also be determined precisely by conducting dedicated characterization measurements, should higher precision be desired. Please refer to the HV-group of the Münster University in this case.**

5.7 1 kV calibration guide

This section contains the step-by-step instructions for the 1 kV calibration. This calibration method should be conducted on a regular basis to check the integrity of the G35 divider as it can be performed with much less effort than the absolute calibration on high voltage. Furthermore the calibrated scale factors can be used to update the voltage dependent calibration from the absolute calibration as described in the HV divider manual under section 3.1.2. The 1 kV calibration itself is divided in two steps. Firstly the M_{100}^{G35} scale factor is calibrated. To calibrate the higher scale factors, a step-up technique is used in a second set of measurements, where subscale factors M_{i}' are measured as also described in section 3.1.2.

Preparations, materials:

- Two 8.5 digit precision DVMs, e.g. of the class as the Keysight 3458A which is a component of the G35 divider. Both DVMs have to be calibrated beforehand (see section 5.6).
- DC voltage reference, e.g. Fluke 732A or comparable in calibrated state ($U_{\mathrm{10V}}^{\mathrm{ref}}$ has to be known on a sub-ppm level).
- A reference divider with 10:1 and 100:1 scale factors in calibrated state, e.g. a Fluke 752A or comparable ($M_{10/100}^{\mathrm{ref.}}$ has to be known on a sub-ppm level). Please note that the calibration has to be conducted under the same ambient conditions it is to be used in the following measurements.
- A ppm-stable DCV voltage source, e.g. FuG MCP 1250M.
  Remarks:
  - **Never use a voltage source that provides voltages substantially greater than 1 kV since the PTFE wires and the banana plugs are not voltage-proof in these regions.**
  - **Should the source be less stable, the synchronicity between both used DVMs becomes a crucial factor and the calibration might yield false results if synchronicity cannot be guaranteed.**
- Active devices such as DVMs and voltage sources should have a warm-up time of at least 2 hours (simply leave them switched on).
- G35 divider set to temperature at which it is to be calibrated (usually 15 or 20 °C). The divider has to be stabilized to the set temperature for at least 1 hour for optimal thermal conditions.
- Two shielded two wire PTFE cables (Lemo 2xAWG24-19 PTFE AG) with copper-tellurium banana plugs and Lemo FFA.1S.302.CYBC42Z connectors. Both cables are included in the G35 equipment.
- One shielded two wire PTFE cable (Lemo 2xAWG24-19 PTFE AG) with copper-tellurium banana plugs on both ends. This cable is currently not included in the G35 equipment but have the Lemo connectors on both ends. For the suggested measurement setup an adaptation to banana plug is needed on one end of each cable. One Lemo-Banana adapter is currently included in the G35 equipment.
  Remark:
  - **The connector types to be used for this cable depend on the outputs/input sockets of the reference divider and the second DVM that are used**

for the calibration. This guide assumes the device configuration as suggested above.

- One SHV cable with SHV plug on one end and banana plug on the other end.
  Remarks:
  - **Do not use the suggested cable for voltages substantially greater than 1 kV since this is not a standard cable.**
  - **The connector types to be used for this cable depend on the outputs/input sockets of the voltage source and the reference divider that are used for the calibration. This guide assumes the device configuration as suggested above.**
- One RG11 coaxial cable with Heinzinger HV plug on one end and banana plug on the other end. This cable is included in the G35 equipment.
  Remarks:
  - **Do not use the suggested cable for voltages substantially greater than 1 kV since this is not a standard cable.**
  - **The banana plug to be used for this cable depends on the input sockets of the reference divider that is used for the calibration. This guide assumes the device configuration as suggested above.**
- Measuring program for data acquisition, e.g. as implemented in the TRITON software[3] at CRYRING.

5.7.1 M_{100} calibration

Execution:

1. Conduct DVM calibration for both multimeters according to section 5.6. For all of the following measurements use DVM configuration as proposed for the DVM calibration.
2. Connect the components of the setup according to figure 12 left.
3. Measure if all ground connections are established correctly (e.g. with handheld multimeter).
4. Conduct a 10 minute offset measurement with this setup. To do so short circuit the Hi and Lo inputs of the reference divider. Please note that this offset can be different to the offset of the DVM calibration due to the different wiring. It is advised to use this offset to correct the measured values in the following measurement. The offset from the DVM calibration is only to be used to determine the “gain” factor.
5. Remove short circuit between Hi and Lo inputs of the reference divider.
6. Set current limit of the voltage source according to expected maximum current depending on the total resistance of the G35 divider and the reference divider in use.
7. Switch on voltage source and slowly ramp up voltage to 1 kV.
8. Wait 10 minutes before taking a measurement as the G35 divider warms up.

[3] Refer to A. Buß (a_buss09@uni-muenster.de) or K. Mohr (K.Mohr@gsi.de)

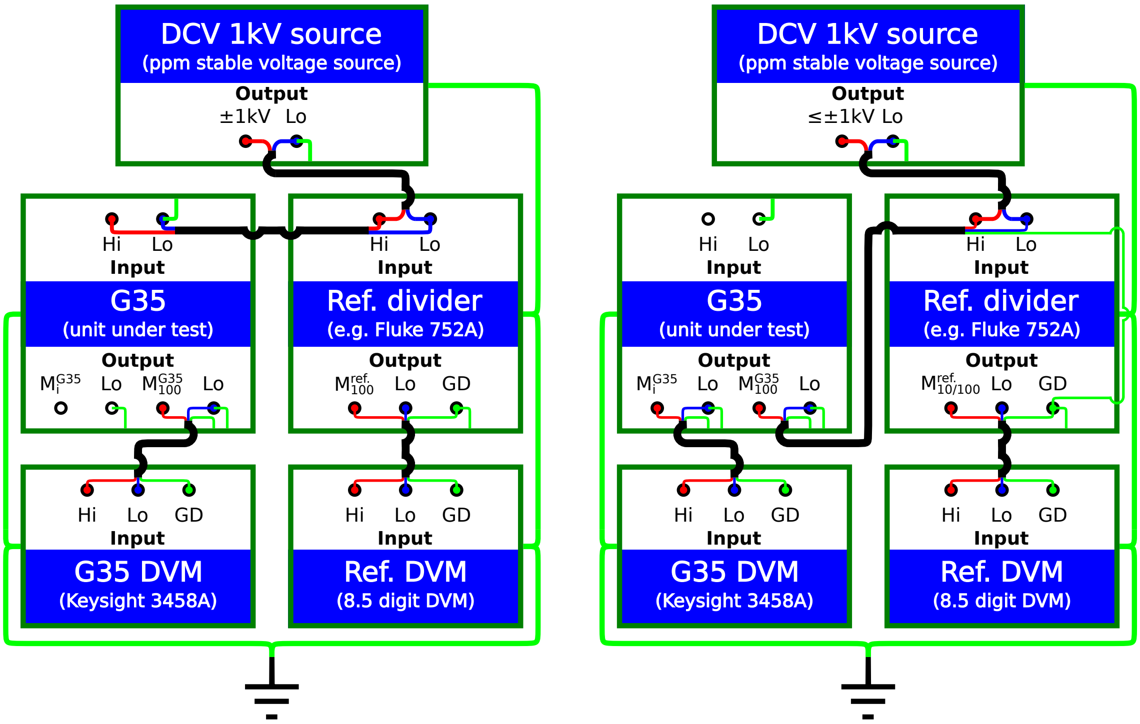


Figure 12: Connection schemes for 1 kV calibration of the G35 divider. The ground connections (light green) that are strictly within the device borders (dark green) and not part of a cable (black wires) are internally connected. The black cables and the green ground connections outside of the device borders have to be connected by the user. Left: M_{100}^{G35} calibration. Right: M_i^{G35} calibration via determination of subscale factors M_i'.

9. Conduct a 20 minute measurement and average all measured values for analysis.

Analysis:

The M_{100}^{G35} is determined by the following equation:

$$M_{100}^{G35} = \frac{U_{in}}{U_{out}^{G35}} = \frac{\frac{U_{meas.}^{ref.} - U_{offset}^{ref.}}{Gain_{ref.}} \cdot M_{100}^{ref.}}{\frac{U_{meas.}^{G35} - U_{offset}^{G35}}{Gain_{G35}}} \tag{8}$$

where:

M_{100}^{G35} : M_{100} Scale factor of G35 divider
U_{in} : Input voltage to both dividers
U_{out}^{G35} : Gain/offset corrected output voltage of G35
$U_{meas.}^{ref.}$: Output voltage of ref. divider measured with ref. DVM
$U_{offset}^{ref.}$: Offset of reference divider DVM
$\mathrm{Gain}_{ref.}$: Gain factor of reference divider DVM
$M_{100}^{ref.}$: M_{100} scale factor of reference divider
$U_{meas.}^{G35}$: Output voltage of G35 divider measured with Keysight 3458A
U_{offset}^{G35} : Offset of Keysight 3458A
Gain_{G35} : Gain factor of Keysight 3458A

Remarks:

- **Uncertainties of measured values are determined by uncertainty propagation of the uncertainties of the individual contributions.**
- **To determine the uncertainties for each measurement device please refer to the calibration certificate of the 10 V reference and the manuals of both DVMs and of the reference divider. Since the uncertainties given by these sources are conservative, the uncertainties can also be determined precisely by conducting dedicated characterization measurements, should higher precision be desired. Please refer to the HV-group of the Münster University in this case.**

5.7.2 $\mathrm{M_i}$ calibration

Execution:

1. Since this measurement is only meaningful in combination with the M_{100}^{G35} calibration, please perform all previous steps that were introduced in this section.
2. Connect the components of the setup according to figure 12 right. In this calibration the input voltage is not applied to the HV input of the G35 divider but to the M_{100}^{G35} voltage tap in order to measure the subscale factors M_{i}'.
3. Measure if all ground connections are established correctly (e.g. with handheld multimeter).
4. Conduct a 10 minute offset measurement with this setup. To do so short circuit the Hi and Lo inputs of the reference divider. Please note that this offset can be different to the offset of the DVM calibration due to the different wiring. It is advised to use this offset to correct the measured values in the following measurement. The offset from the DVM calibration is only to be used to determine the “gain” factor.
5. Remove short circuit between Hi and Lo inputs of the reference divider.
6. Set current limit of the voltage source according to expected maximum current depending on the total resistance of the G35 divider and the reference divider in use.

   The following steps have to be repeated for all scale factors $\mathbf{M_i^{G35} > M_{100}^{G35}}$:
7. Connect the voltage tap to be calibrated to the Keysight 3458A DVM of the G35.
8. Switch on voltage source and slowly ramp up voltage to desired value depending on the current scale factor to be calibrated (see table 3). The input voltage are chosen in such a way that the tap resistors are loaded as if an input voltage of 35 kV was applied to the HV input of the G35.
9. Wait 10 minutes before taking a measurement as the G35 divider warms up.
10. Conduct a 20 minute measurement and average all measured values for analysis.

Table 3: Input voltages U_{in} and reference scale factors $M^{\mathrm{ref}}_{10/100}$ to be used for the respective scale factor $M^{\mathrm{G35}}_{\mathrm{i}}$ to be calibrated.

scale factor $M^{\mathrm{G35}}_{\mathrm{i}}$	input voltage U_{in} (V)	reference scale factor $M^{\mathrm{ref}}_{10/100}$
M_{163}	19	10
M_{269}	32	10
M_{775}	93	10
M_{3452}	340	100

Analysis:

The scale factor to be calibrated $M^{\mathrm{G35}}_{\mathrm{i}}$ is determined by the following equation:

$$M^{\mathrm{G35}}_{\mathrm{i}} = \frac{U_{\mathrm{in}}}{U^{\mathrm{G35}}_{\mathrm{out}}} \cdot M^{\mathrm{G35}}_{100} = \frac{\frac{U^{\mathrm{ref}}_{\mathrm{meas.}} - U^{\mathrm{ref}}_{\mathrm{offset}}}{\mathrm{Gain}_{\mathrm{ref}}} \cdot M^{\mathrm{ref}}_{10/100}}{\frac{U^{\mathrm{G35}}_{\mathrm{meas.}} - U^{\mathrm{G35}}_{\mathrm{offset}}}{\mathrm{Gain}_{\mathrm{G35}}}} \cdot M^{\mathrm{G35}}_{100} \tag{9}$$

where:

M^{G35}_{i} : Scale factors of G35 divider $> M_{100}$
U_{in} : Input voltage to both dividers
M^{G35}_{100} : M_{100} Scale factor of G35 divider
$U^{\mathrm{G35}}_{\mathrm{out}}$: Gain/offset corrected output voltage of G35
$U^{\mathrm{ref.}}_{\mathrm{meas.}}$: Output voltage of ref. divider measured with ref. DVM
$U^{\mathrm{ref.}}_{\mathrm{offset}}$: Offset of reference divider DVM
$\mathrm{Gain}_{\mathrm{ref.}}$: Gain factor of reference divider DVM
$M^{\mathrm{ref}}_{10/100}$: M_{100} scale factor of reference divider
$U^{\mathrm{G35}}_{\mathrm{meas.}}$: Output voltage of G35 divider measured with Keysight 3458A
$U^{\mathrm{G35}}_{\mathrm{offset}}$: Offset of Keysight 3458A
$\mathrm{Gain}_{\mathrm{G35}}$: Gain factor of Keysight 3458A

Remarks:

- **Uncertainties of measured values are determined by uncertainty propagation of the uncertainties of the individual contributions.**
- **To determine the uncertainties for each measurement device please refer to the calibration certificate of the 10 V reference and the manuals of both DVMs and of the reference divider. Since the uncertainties given by these sources are conservative, the uncertainties can also be determined precisely by conducting dedicated characterization measurements, should higher precision be desired. Please refer to the HV-group of the Münster University in this case.**

References

[1] Keysight Technologies. Keysight 3458A User's Guide. URL https://literature.cdn.keysight.com/litweb/pdf/03458-90014.pdf.

[2] O. Rest, V. Hannen, D. Winzen, and C. Weinheimer. Absolute calibration of a ppm-precise HV divider for the electron cooler of the ion storage ring CRYRING@ESR. Lecture Notes in Electrical Engineering, to be published.

[3] O. Rest, D. Winzen, S. Bauer, R. Berendes, J. Meisner, T. Thümmler, S. Wüstling, and C. Weinheimer. A novel ppm-precise absolute calibration method for precision high-voltage dividers. Metrologia, to be published. URL: https://arxiv.org/abs/1903.01261.

[4] T Thümmler. Präzisionsueberwachung und Kalibration der Hochspannung für das KATRIN-Experiment. PhD thesis, University of Münster, 2007. URL: https://miami.uni-muenster.de/Record/0e96c5e3-6f06-489e-a73f-5859fbe9cae7.

Appendix A Calibration history

A.1 Absolute calibration results

The voltage dependency has been determined for each scale factor with the absolute calibration method described in section 3.1.2 for divider temperatures of 15 °C and 20 °C. The resulting plots have been created by applying the data of tables 2 and 4 to equations 4 and 5.

Table 4: Factor values and covariances to determine the G35 scale factors for a divider temperature of 20 °C and negative polarity. To calculate the voltage dependent scale factors the values in this table are applied to equation 4. The uncertainties are determined by applying the covariances according to equation 5. In contrast to the 15 °C measurements, the values have not been updated since July 2018.

factor	value	uncertainty
a	$9.95377088 \cdot 10^{-3}$	$2.56 \cdot 10^{-9}$
b	$6.74 \cdot 10^{-10}$	$5.02 \cdot 10^{-10}$
c	$1.5 \cdot 10^{-12}$	$2.54 \cdot 10^{-11}$
d	$7.11 \cdot 10^{-13}$	$3.71 \cdot 10^{-13}$
M_{100_factor}	1	———
M_{163_factor}	1.6196137	$1.5 \cdot 10^{-6}$
M_{269_factor}	2.6774450	$1.6 \cdot 10^{-6}$
M_{775_factor}	7.7189633	$2.7 \cdot 10^{-6}$
M_{3452_factor}	34.357172	$2.0 \cdot 10^{-5}$
$\mathrm{Cov}(a, b)$	$-8.71 \cdot 10^{-19}$	———
$\mathrm{Cov}(a, c)$	$3.60 \cdot 10^{-20}$	———
$\mathrm{Cov}(a, d)$	$-4.64 \cdot 10^{-22}$	———
$\mathrm{Cov}(b, c)$	$-1.24 \cdot 10^{-20}$	———
$\mathrm{Cov}(b, d)$	$1.72 \cdot 10^{-22}$	———
$\mathrm{Cov}(c, d)$	$-9.29 \cdot 10^{-24}$	———

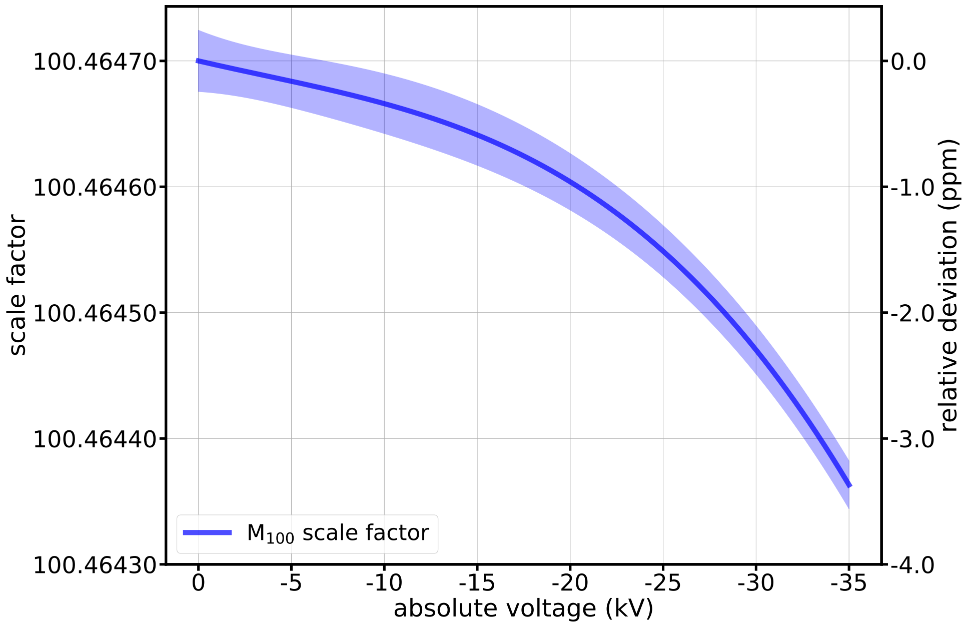


Figure 13: M_{100} absolute calibration for 15 °C divider temperature as of October 2018.

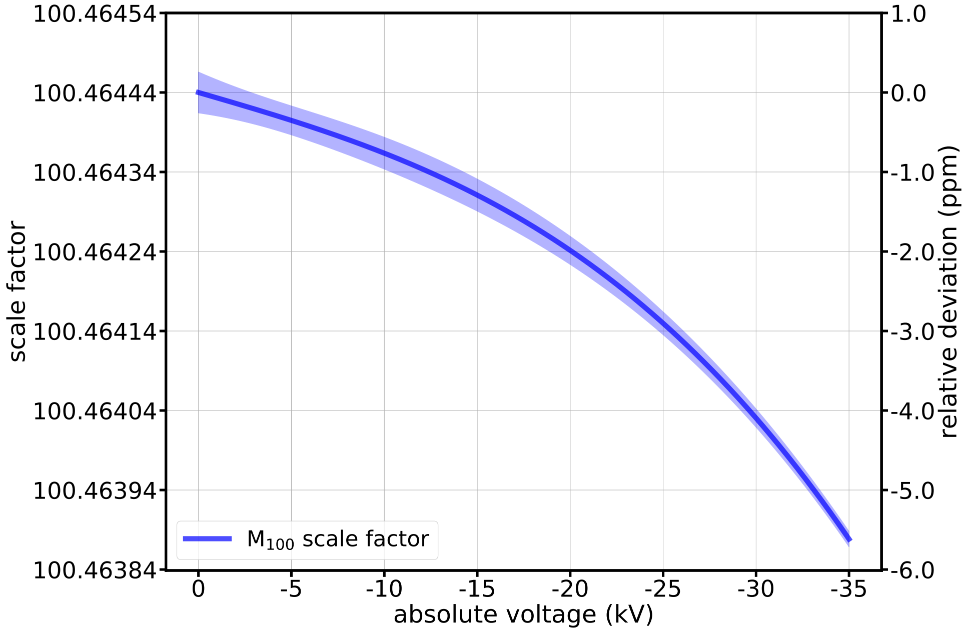


Figure 14: M_{100} absolute calibration for 20 °C divider temperature as of July 2018.

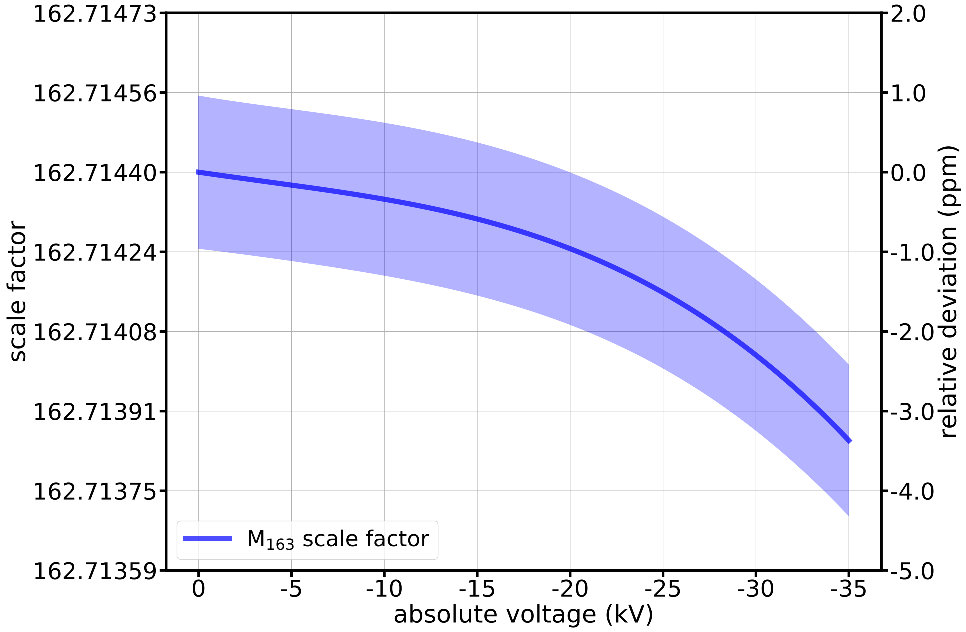


Figure 15: M_{163} absolute calibration for 15 °C divider temperature as of October 2018.

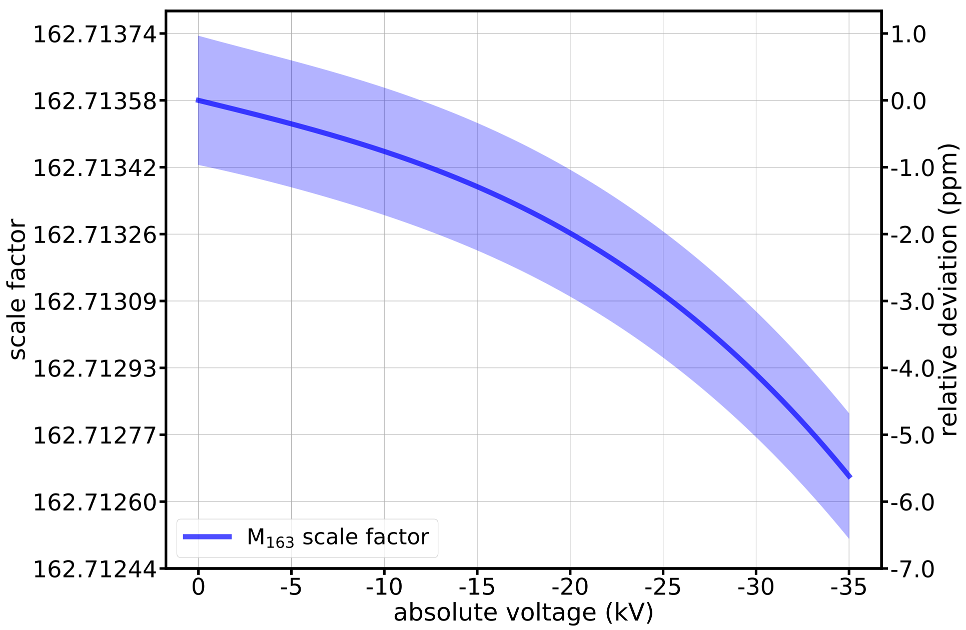


Figure 16: M_{163} absolute calibration for 20 °C divider temperature as of July 2018.

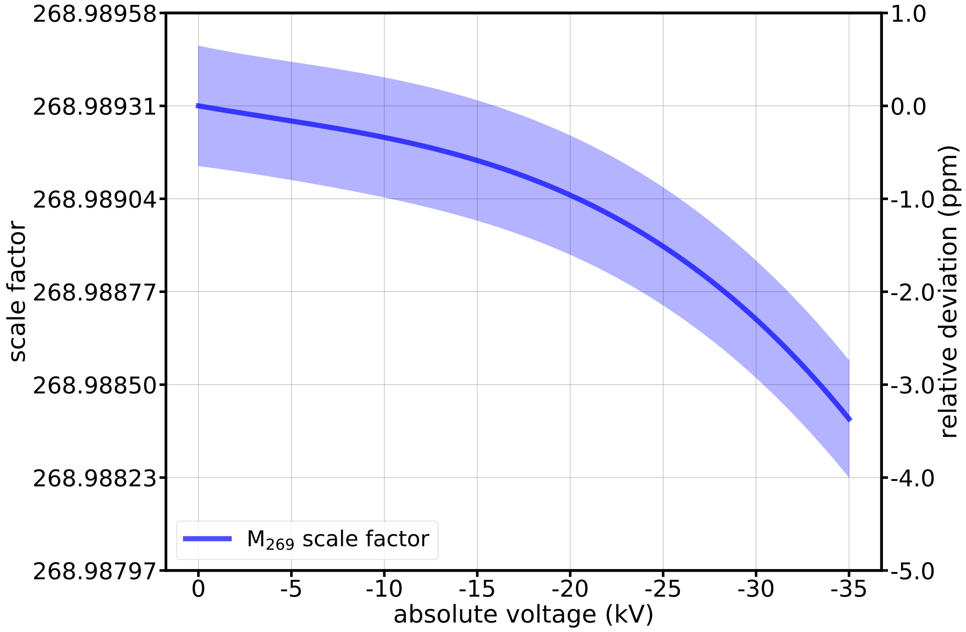


Figure 17: M_{269} absolute calibration for 15 °C divider temperature as of October 2018.

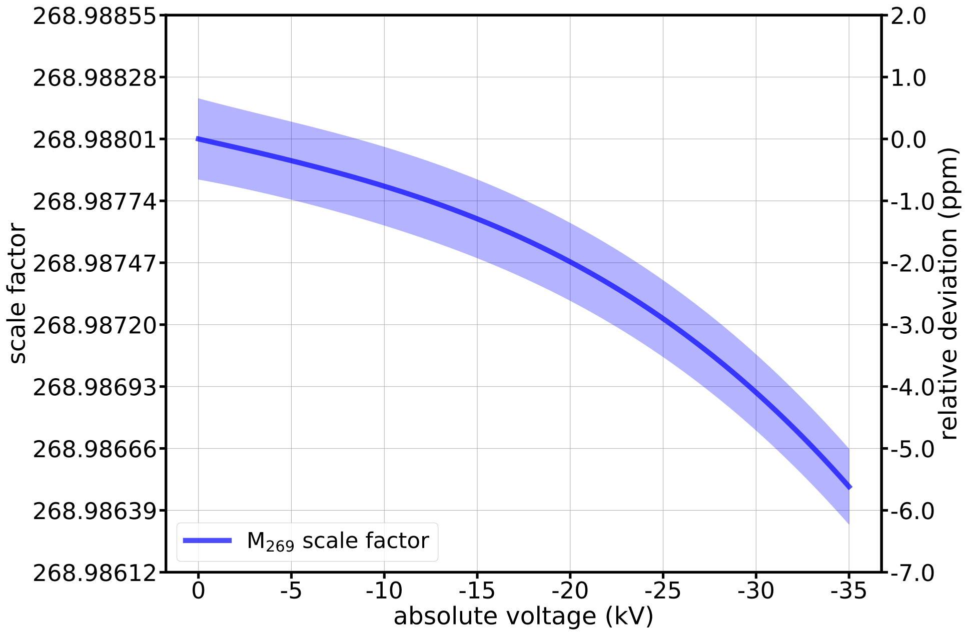


Figure 18: M_{269} absolute calibration for 20 °C divider temperature as of July 2018.

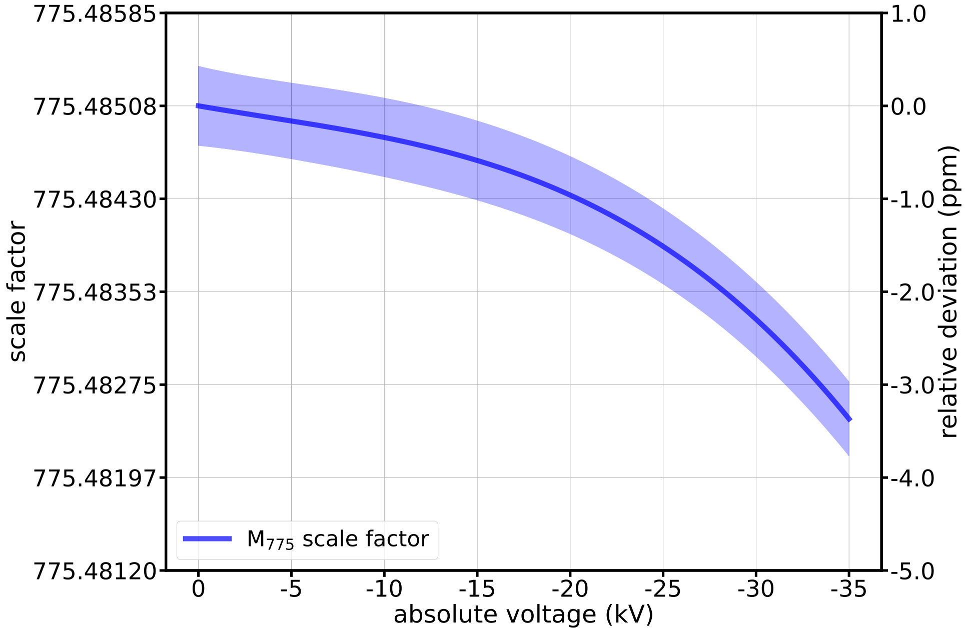


Figure 19: M_{775} absolute calibration for 15 °C divider temperature as of October 2018.

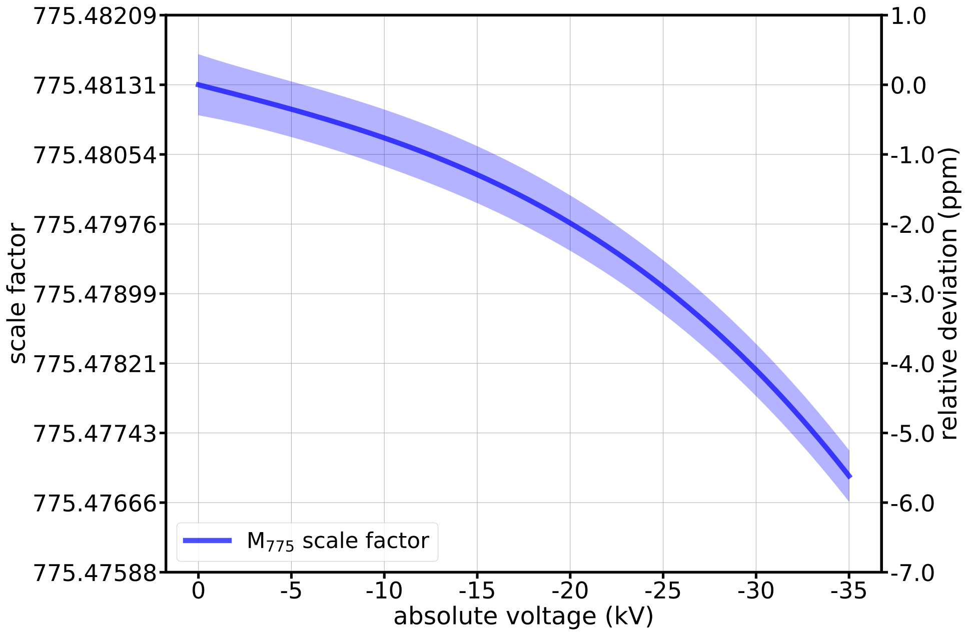


Figure 20: M_{775} absolute calibration for 20 °C divider temperature as of July 2018.

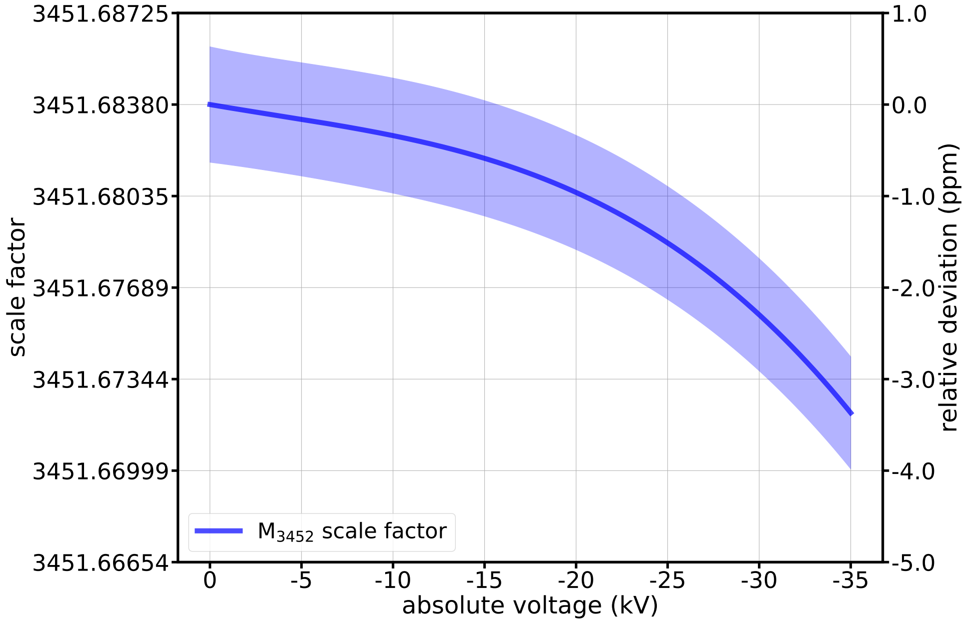


Figure 21: M_{3452} absolute calibration for 15 °C divider temperature as of October 2018.

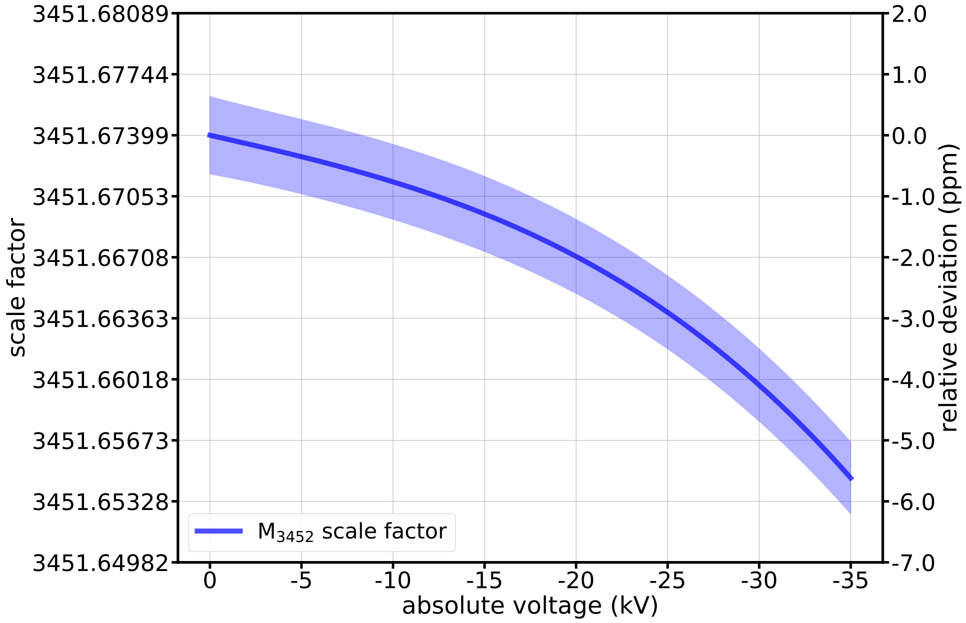


Figure 22: M_{3452} absolute calibration for 20 °C divider temperature as of July 2018.

A.2 1 kV calibration history

To check the stability of the G35 scale factor, a calibration history with the 1 kV calibration method (see section 3.1.2) has been recorded. As advised in the manual this history should be updated on a regular basis. The 1 kV calibration histories for each scale factor and 15 °C / 20 °C divider temperature can be found in the following figures.

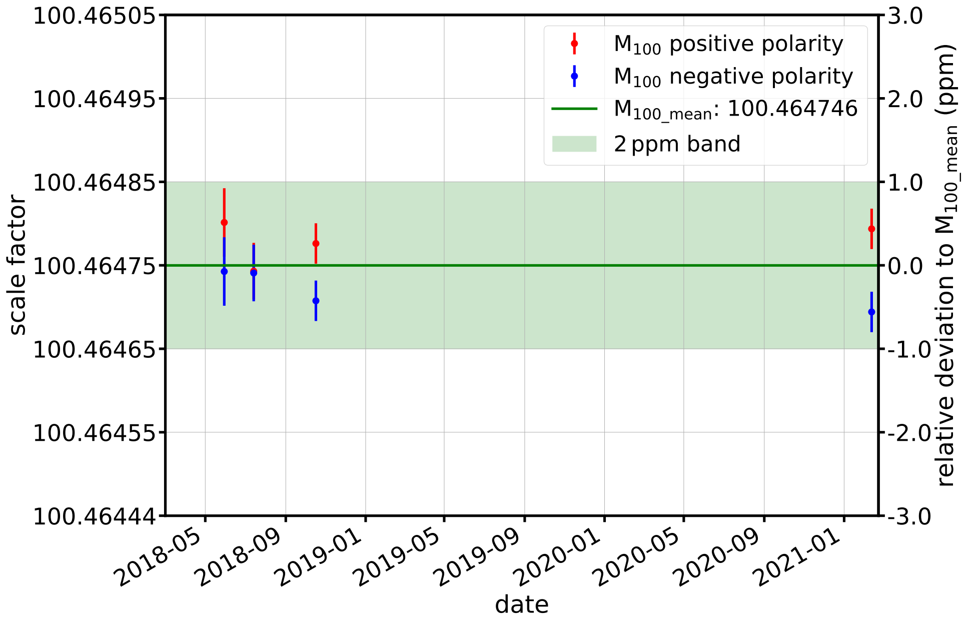


Figure 23: M_{100} 1 kV calibration history for 15 °C divider temperature.

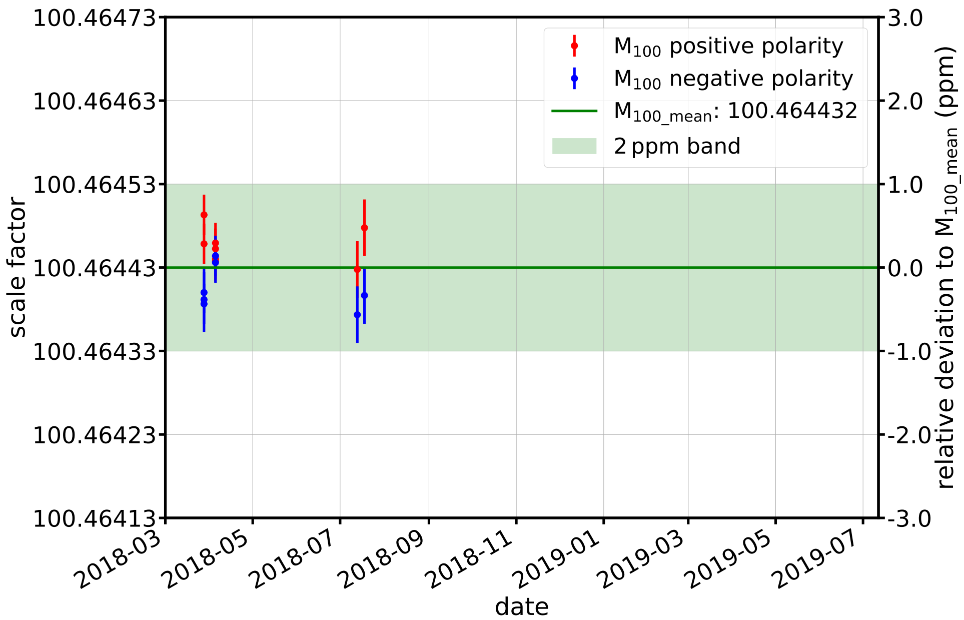


Figure 24: M_{100} 1 kV calibration history for 20 °C divider temperature.

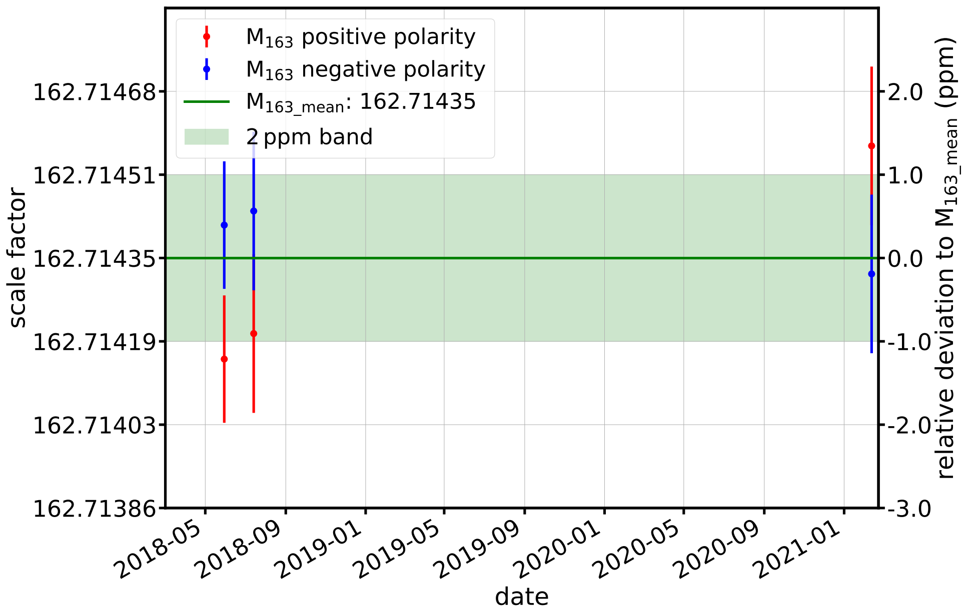


Figure 25: M_{163} 1 kV calibration history for 15 °C divider temperature.

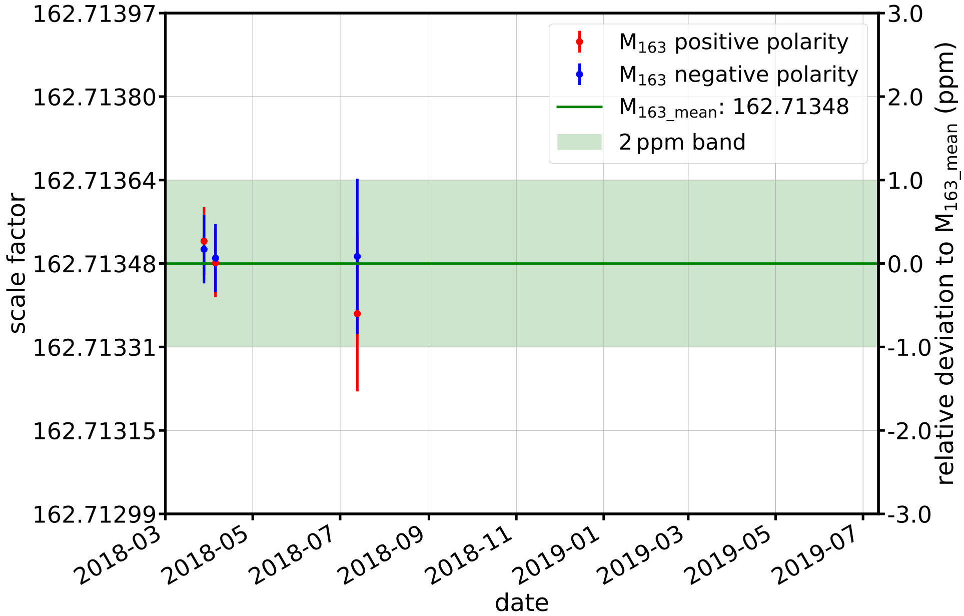


Figure 26: M_{163} 1 kV calibration history for 20 °C divider temperature.

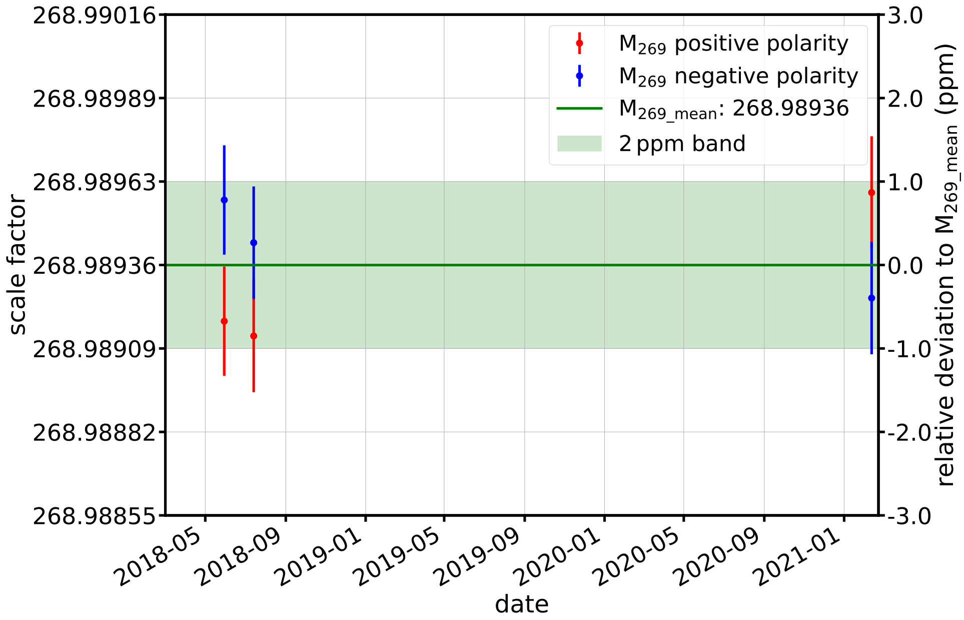


Figure 27: M_{269} 1 kV calibration history for 15 °C divider temperature.

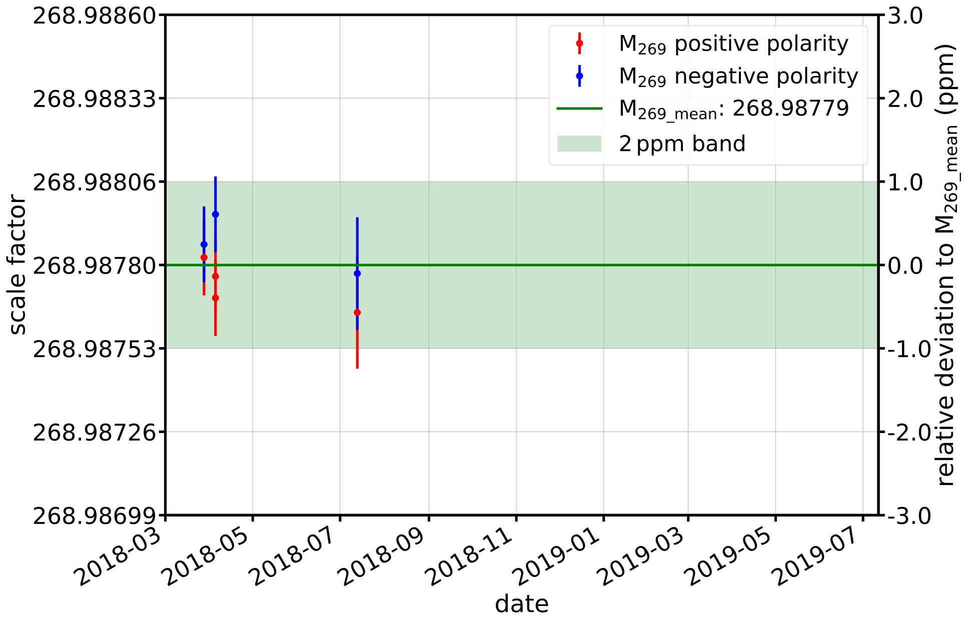


Figure 28: M_{269} 1 kV calibration history for 20 °C divider temperature.

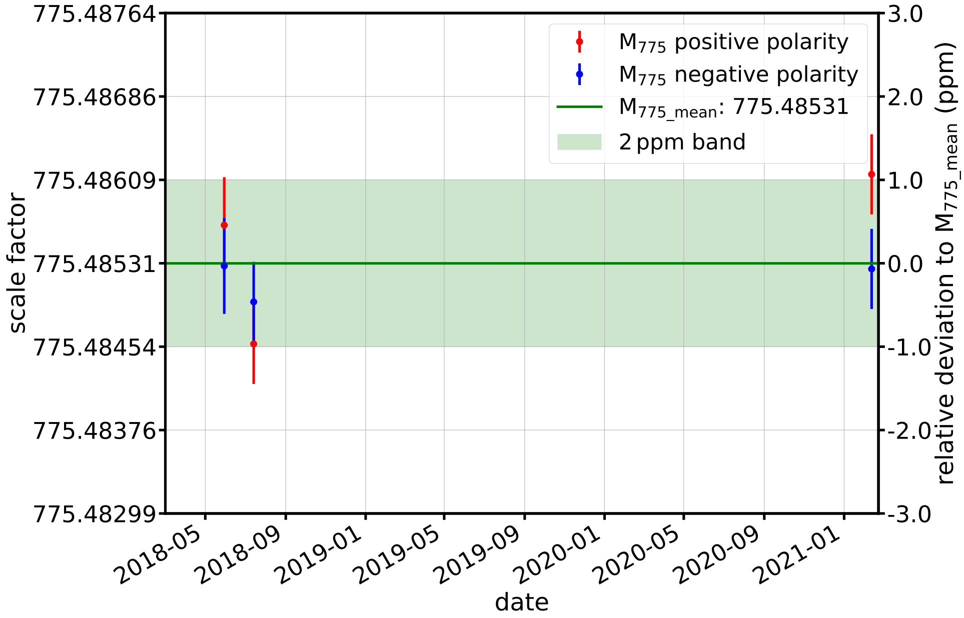


Figure 29: M_{775} 1 kV calibration history for 15 °C divider temperature.

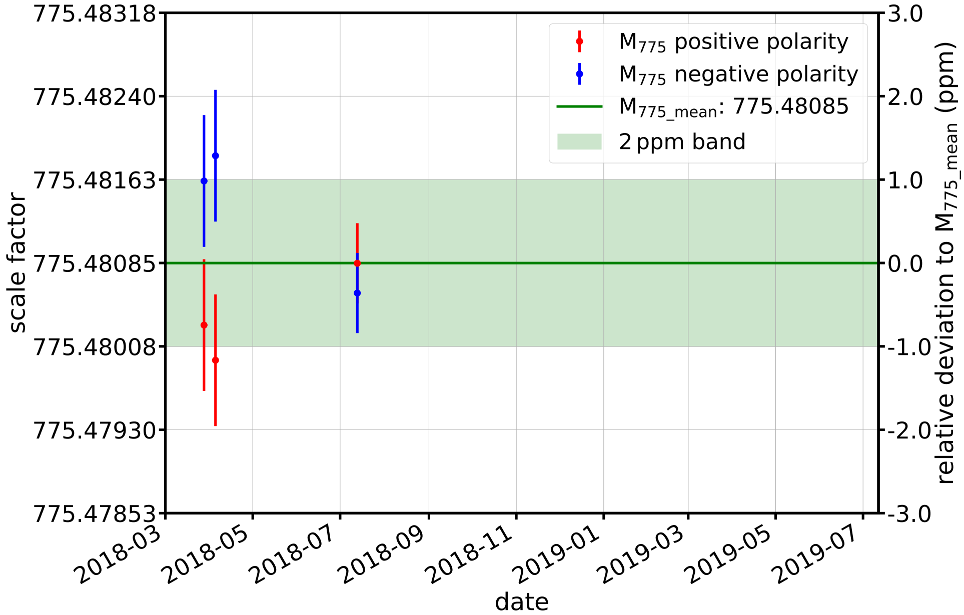


Figure 30: M_{775} 1 kV calibration history for 20 °C divider temperature.

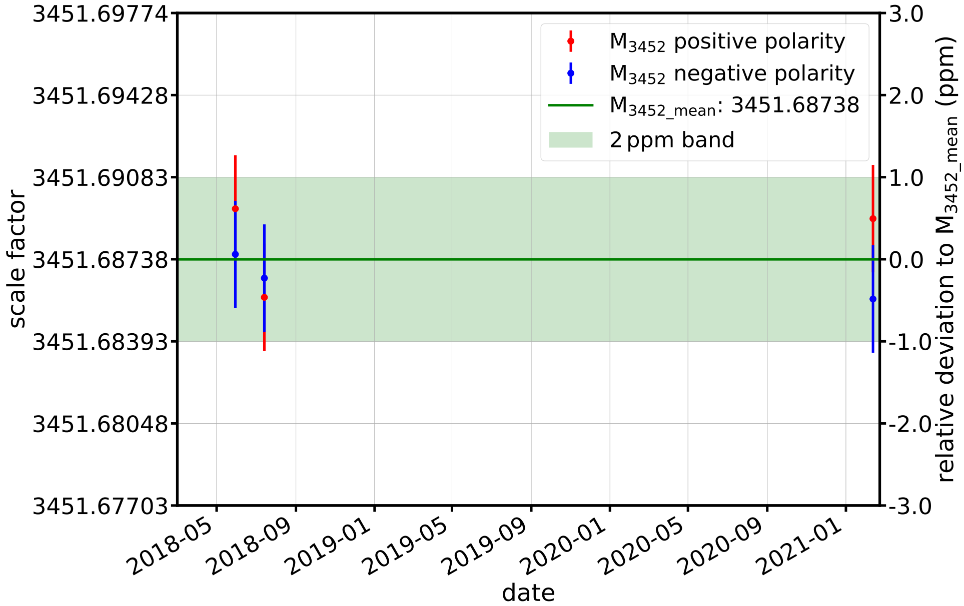


Figure 31: M_{3452} 1 kV calibration history for 15 °C divider temperature.

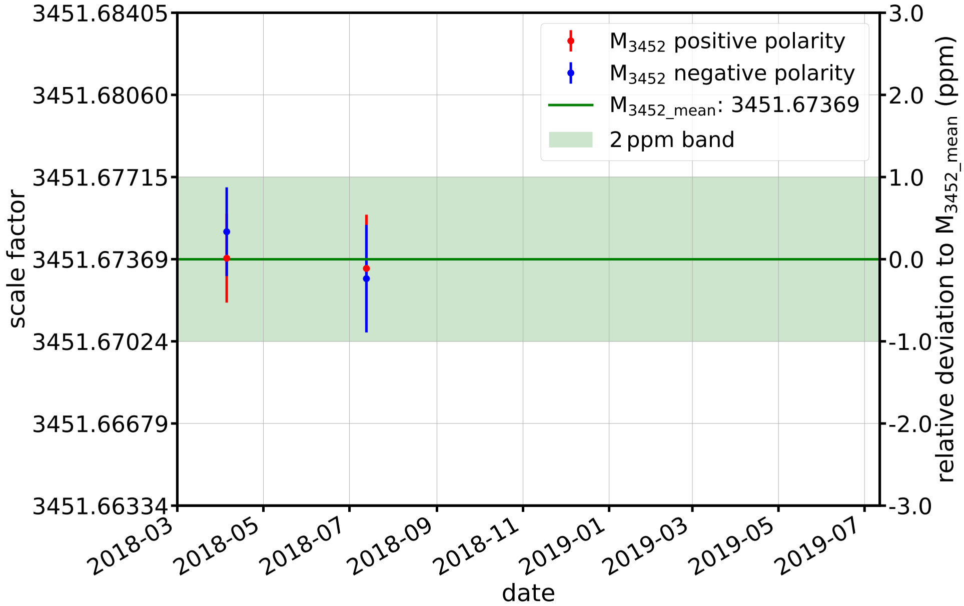
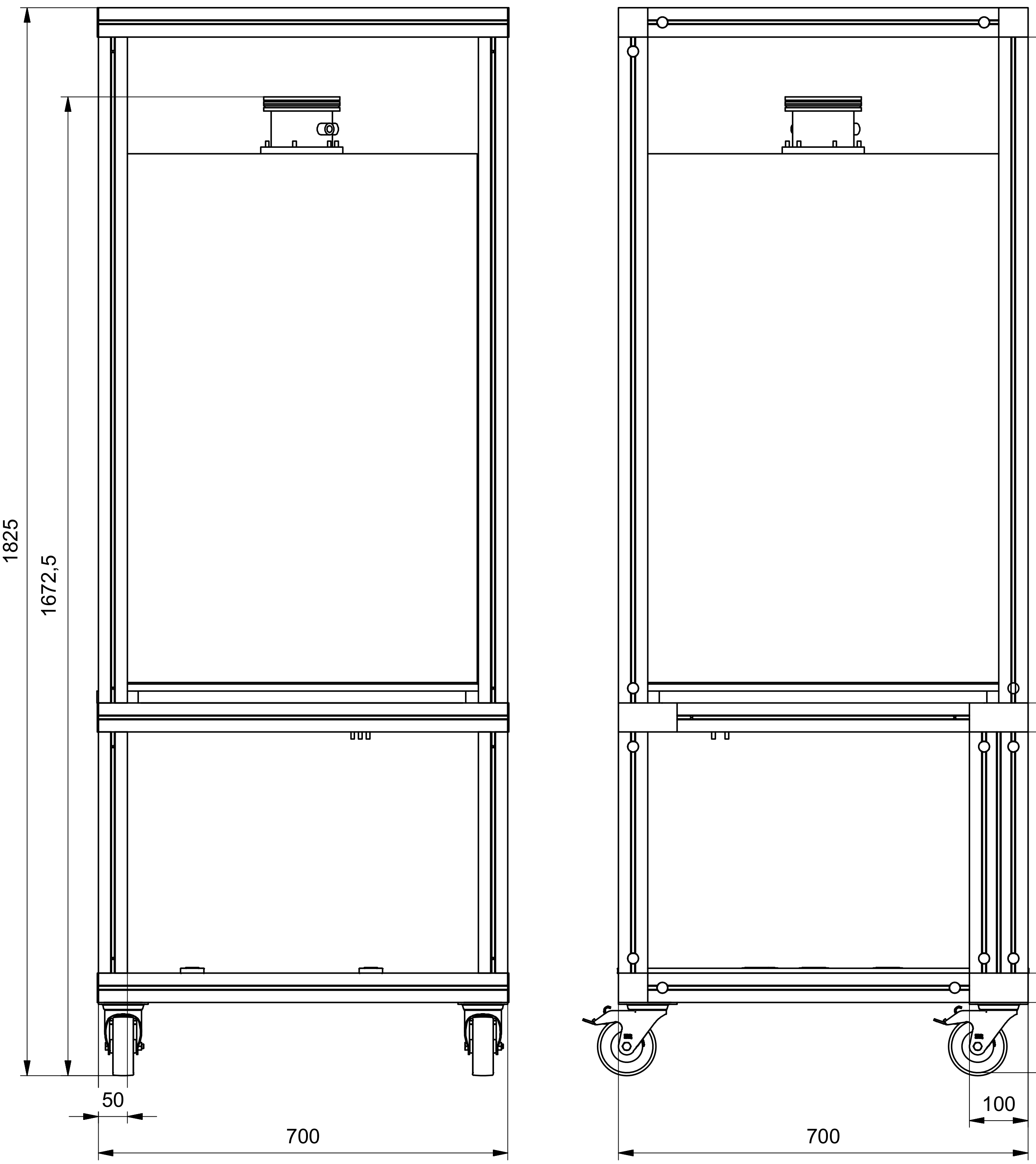


Figure 32: M_{3452} 1 kV calibration history for 20 °C divider temperature.

Appendix B Divider outer dimensions (technical drawing)



Westfälische Wilhelms-Universität Münster

Maßstab : 1 : 10	Werkstoff :	
BG: 1	Pos. Nr. : 1	Anzahl : 1

	Datum	Name
Gezeichnet	18.04.2019	Daniel Winzen
Kontrolliert		
Norm		
Revisionsnr.	V62	

Status	Änderungen	Datum	Name

Institut für Kernphysik
Wilhelm-Klemm-Str. 9
48149 Münster

Teilerdimensionen

1

A4

Appendix C Spec sheets

EA-PS 2000 B SINGLE 100W - 320W
LABORNETZGERÄTE / LABORATORY POWER SUPPLIES

EA-PS 2084-05 B

- **Mikrocontrollergesteuert**
- **Geeignet für**
  - **Schul- und Ausbildungsbetrieb**
  - **Industrie- und Systemanwendungen**
  - **Werkstatt und Entwicklung**
  - **Laboratorien und Prüfinstitute**
- **Ausgangsleistungen: 100W, 160W oder 320W**
- **Ausgangsspannungen: 0...42V und 0...84V**
- **Ausgangsströme: bis zu 0...20A**
- **Übertemperaturschutz (OT)**
- **Vierstellige Anzeige für Spannung und Strom**
- **Konvektions- oder Lüfterkühlung**
- **Gehäuse oben und unten geschlossen**
- **Sicherheitsausgangsbuchsen**
- **Sicherheit EN 60950**

- **Microprocessor controlled**
- **Designed for**
  - **Schools,university and laboratories**
  - **Industry and system applications**
  - **Workshop and development**
  - **Laboratories and test institutes**
- **Output power ratings: 100W, 160W or 320W**
- **Output voltages: 0...42V and 0...84V**
- **Output currents: up to 0...20A**
- **Overtemperature protection (OT)**
- **Four-digit display for voltage and current**
- **Convection or fan cooling**
- **Chassis top and bottom closed**
- **Safety output sockets**
- **Safety EN60950**

Allgemeines

Die Labornetzgeräte der Serie EA-PS 2000 B sind in drei Leistungsklassen mit 100W, 160W oder 320W verfügbar. Der kompakte Aufbau, das praktisches Gehäusedesign und ein günstiges Preis-Leistungsverhältnis zeichnen diese Serie aus.
Die Geräte sind oben und unten geschlossen und haben keine außenliegenden Kühlkörper. Deshalb eignen sie sich besonders gut für die Verwendung im Schul- und Ausbildungsbereich.
Die Sicherheitsausgangsbuchsen befinden sich auf der Frontseite des Gerätes. Spannung und Strom können kontinuierlich von Null bis zum Nennwert eingestellt werden.

General

The laboratory power supplies of the EA-PS 2000 B series are available in three power ratings of 100W, 160W or 320W. The series demonstrates compact design, practical housing and excellent value. The units are closed at top and bottom and have no external heatsinks. Thus they are especially suitable for use in schools and training establishments.
The safety output sockets are located on the front face of the unit. Voltage and current can be adjusted from zero to the required value. The units can be connected in parallel or in series. A flexible power management ensures reliable operation at full load.

Schutzfunktionen

Neben einem Überspannungsschutz (OVP), der angeschlossene Verbraucher vor zu hoher Spannung schützen soll, gibt es nun auch einen Überstromschutz. Dieser schaltet den Ausgang bei Erreichen einer von 0...110% Nennstrom einstellbaren Schwelle ab und schützt die Last bei einem Defekt vor Überstrom und somit Zerstörung.

Protective features

Besides standard features like overvoltage protection (OVP), which is intended to protect sensitive user applications against unwanted voltage peaks or high voltage, the series now features an overcurrent protection with an adjustable threshold of 0...110% nominal current. It will protect a malfunctioning application from overcurrent by immediate output shutdown.

Datum / Date: 12.03.12

EA-PS 2000 B SINGLE 100W - 320W
LABORNETZGERÄTE / LABORATORY POWER SUPPLIES

PC-Schnittstelle
Über eine serienmäßig eingebaute USB-Schnittstelle und eine separat erhältliche Windows-Software kann das Gerät überwacht und ferngesteuert werden. Pro Gerät ist optional eine kostenpflichtige Lizenz zu erwerben, um es in der Software für Bedienung freizuschalten. Der Anschluß erfolgt per USB-Kabel, das mit der Software in einem Kit kommt.

Flexible Leistungsbegrenzung
Die Sollwerte von Strom und Spannung justieren sich gegenseitig, um die max. Leistung nach P = U * I nicht zu überschreiten. Das erlaubt, entweder mit einer hohen Ausgangsspannung oder einem hohen Ausgangsstrom zu arbeiten.

Steuerungs- und Überwachungssoftware
Das auf einer optional erhältlichen Software-CD enthaltene Programm EasyPS2000 kann jeweils ein Gerät komplett fernsteuern bzw. überwachen. Alle Funktionen des Gerätes sind auf einer grafischen Oberfläche verfügbar. Durch mehrere Instanzen der Software können mehrere Geräte gleichzeitig angesteuert werden.
Die Software bietet folgendes:
- Ereignis-Log
- Freischaltungsdialog für Gerätelizenzen
- Automatisierte Fernsteuerung (Sequencing) via CSV
- Datenaufzeichnung (Logging) in CSV
- Windows-kompatibel
- Leicht zu bedienende Oberfläche
- Ein PS 2000B pro Instanz steuerbar

Optionen
- Gerätelizenz für EasyPS2000 Steuerungssoftware

PC interface
The unit can be monitored and remotely controlled by a Windows software and via an USB port which is equipped as standard. In order to unlock a device and to enable full functionality of the software, it is required to purchase a licence for every unit. Connection to the PC is done with the USB cable, which is included with the software kit.

Flexible power ranging
The set values of voltage and current adjust each other in order to maintain the max. output power according to P = U * I. This allows to work with either high output voltage or with high output current.

Control and monitoring software
The software EasyPS2000, which is contained on an optionally available software CD, allows complete remote control or monitoring of the device. All functions of the device are also available on the graphical user interface. Multiple instances of the software allow control of several units simultaneously.

The main features:
- Event log
- Unlocking dialogue for device licences
- Automated control by CSV tables (sequencing)
- Data logging to CSV
- Windows compatible
- Easy to use GUI
- One PS 2000 B per instance

Options
- Device licence for EasyPS2000 control software

Technische Daten	Technical Data	PS 2042-06B	PS 2042-10B	PS 2042-20B	PS 2084-03B	PS 2084-05B	PS 2084-10B
Eingangsspannung	**Input voltage**	90...264V	90...264V	90...264V	90...264V	90...264V	90...264V
-Frequenz	-Frequency	45...65Hz	45...65Hz	45...65Hz	45...65Hz	45...65Hz	45...65Hz
-Leistungsfaktor	-Power factor	>0,99	>0,99	>0,99	>0,99	>0,99	>0,99
Ausgangsspannung	**Output voltage**	0...42V	0...42V	0...42V	0...84V	0...84V	0...84V
-Stabilität bei 0-100% Last	-Stability at 0-100% load	<0,15%	<0,15%	<0,15%	<0,15%	<0,15%	<0,15%
-Stabilität bei ±10% ΔU_E	-Stability at ±10% ΔU_{IN}	<0,02%	<0,02%	<0,02%	<0,02%	<0,02%	<0,02%
-Restwelligkeit BWL 20MHz	-Ripple BWL 20MHz	<80mV$_{PP}$ 9mV$_{RMS}$	<80mV$_{PP}$ 9mV$_{RMS}$	<80mV$_{PP}$ 9mV$_{RMS}$	<60mV$_{PP}$ 10mV$_{RMS}$	<60mV$_{PP}$ 10mV$_{RMS}$	<60mV$_{PP}$ 10mV$_{RMS}$
-Ausregelung 10-100% Last	-Regulation 10-100% load	<1ms	<2ms	<2ms	<2ms	<1ms	<1ms
-OVP-Einstellung	-OVP adjustment	0...46,2V	0...46,2V	0...46,2V	0...92,4V	0...92,4V	0...92,4V
-Genauigkeit	-Accuracy	≤0,2%	≤0,2%	≤0,2%	≤0,2%	≤0,2%	≤0,2%
Ausgangsstrom	**Output current**	0...6A	0...10A	0...20A	0...3A	0...5A	0...10A
-Stabilität bei 0-100% ΔU_A	-Stability at 0-100% ΔU_{OUT}	<0,05%	<0,05%	<0,05%	<0,05%	<0,05%	<0,05%
-Stabilität bei ±10% ΔU_E	-Stability at ±10% ΔU_{IN}	<0,15%	<0,15%	<0,15%	<0,15%	<0,15%	<0,15%
-Restwelligkeit	-Ripple	<25mA$_{PP}$ 9mA$_{RMS}$	<40mA$_{PP}$ 15mA$_{RMS}$	<80mA$_{PP}$ 30mA$_{RMS}$	<6mA$_{PP}$ 2mA$_{RMS}$	<9mA$_{PP}$ 3mA$_{RMS}$	<18mA$_{PP}$ 6mA$_{RMS}$
-Genauigkeit	-Accuracy	≤0,2%	≤0,2%	≤0,2%	≤0,2%	≤0,2%	≤0,2%
Wirkungsgrad	**Efficiency**	85%	85%	85%	85%	85%	85%
Ausgangsleistung	**Output power**	100W	160W	320W	100W	160W	320W
Kühlung	**Cooling**	natürliche Konvektion / natural convection		Lüfter / Fan	natürliche Konvektion / natural convection		Lüfter / Fan
Schutzklasse	**Protection class**	1					
Betriebstemperatur	**Operation temperature**	0...50°C					
Lagertemperatur	**Storage temperature**	-20...70°C					
Abmessungen (BxHxT)	**Dimensions (WxHxD)**	174x82x240mm	174x82x240mm	174x82x320mm	174x82x240mm	174x82x240mm	174x82x320mm
Gewicht	**Weight**	1,9kg	2kg	2,3kg	1,9kg	2kg	2,3kg
Artikelnummer	**Article No.**	39200112	39200113	39200114	39200116	39200117	39200118

Irrtümer und Änderungen vorbehalten / Subject to modification without notice, errors and omissions excepted
Alle Wertangaben sind typische Werte / All values are typical values

Datum / Date: 12.03.12

Labornetzgeräte EA-PS 3000 B / Laboratory Power Supplies EA-PS 3000 B

EA-PS 3032-10 B

Die seit Jahren bewährte Netzgeräteserie zeigt sich nicht nur im neuen Design, sondern ist durch umfangreiche Erweiterungen aufgewertet worden. Dazu zählen u.a. die LED-Anzeigen mit Preset-Funktionen für Strom und OVP, ein umfangreiches Analoginterface und Zustandsanzeigen via LED's.
Die Serie wurde außerdem durch die Leistungsklasse der 640W-Geräte in getakteter Ausführung mit PFC erweitert.

Die Geräte sind oben und unten geschlossen und haben keine außenliegenden Kühlkörper und eignen sich sowohl besonders für die Verwendung im Schul- und Ausbildungsbereich als auch im Industriebereich.

Die Geräte werden in 3 Leistungsklassen angeboten: 160W und 320W in Längsreglertechnologie und 640W in getakteler Version.

Die Ausgangswerte (U+I) sowie die voreingestellten Werte (U, I und OVP) werden auf getrennten digitalen Instrumenten angezeigt.
Der Spannungsabfall auf den Lastleitungen kann durch die Fernfühlung (Sense) kompensiert werden. Die Anschlüsse hierzu befinden sich auf der Rückseite.

Auf der Front befindet sich eine Interfacebuchse mit analogen Ein- und Ausgängen zur externen Programmierung und Überwachung.
Hier kann auch die USB to Analog Schnittstelle EA-UTA12 zur externen Steuerung via Windows PC angeschlossen werden. (siehe Seite 33)

- **Digitale Anzeigen**
- **Grob- und Feineinstellung**
- **Ausgang. 0...16V, 0...32V, 0...65V, 0...150V**
- **Leistung: 160W, 320W, 640W**
- **Übertemperaturschutz OT**
- **Überspannungsschutz OVP**
- **Konstantstrom- (CC) und Konstantspannungsbetrieb (CV)**
- **Parallel- u. Serienschaltung**
- **Programmierung via USB (Seite 33)**
- **Steuerung, Überwachung über PC**

- **Digital Displays**
- **Adjustment coarse and fine**
- **Output 0...16V, 0...32V, 0...65V, 0...150V**
- **Power: 160W, 320W, 640W**
- **Over temperature protected (OT)**
- **Over Voltage Protection (OVP)**
- **Constant Current- (CC) and Constant Voltage (CV) Mode**
- **Parallel- and Series Connection**
- **Programming via USB (Page 33)**
- **Control and Monitoring via PC**

The since years established power supply series shows up in a new design with extensive extensions.
Among them are: LED-displays wit preset functions for current and OVP, an extensive analog interface and staus indications via LED's.
The series was also extended by the 640W units in switch-mode technology with power factor correction (PFC).

There are no ventilation slots in either the top or base of the equipment, also no external heatsinks. For improved safety all sockets are recessed. This attention to the safety and unit protection makes it ideal for schools and universities as well as test and development laboratories and industry.

These units are available in three power classes: 160W and 320W as linear regulators and 640W in switched mode technology.

The output values (V, I) and the preset values (V, I and OVP) are indicated on separate digital instruments.
The voltage drop on the load cable can be compensated by the remote sense. The connectors for the remote sense are on the rear side of the units.

On the front is an interface socket with analog in- and outputs for the external programming and monitoring.
On this socket also the universal USB to analog interface EA-UTA 12 can be connected for the external control via a windows PC. (see Page 33)

Labornetzgeräte EA-PS 3000 B / Laboratory Power Supplies EA-PS 3000 B

Technische Daten EA-	Technical Data EA-	PS 3016-10 B	PS 3016-20 B	PS 3016-40 B	PS 3032-05 B	PS 3032-10 B
Eing. Spannung	Input Voltage	115V / 230V AC	115V / 230V AC	88...264V AC	115V / 230V AC	115V / 230V AC
-Eingangsfrequenz	-Input frequency	50/60Hz	50/60Hz	50/60Hz	50/60Hz	50/60Hz
-Leistungsfaktorkorrektur	-Power factor correction	nein/no	nein/no	>0,99 (PFC)	nein/no	nein/no
Ausgangsspannung	Output Voltage	0...16V	0...16V	0...16V	0...32V	0...32V
-Feineinstellbereich	-Fine Adjustment Range	ca. 800mV	ca. 800mV	ca. 800mV	ca. 1,6V	ca. 1,6V
-Stabilität 0...100% Last	-Stability at 0-100% load	<8mV	<8mV	<10mV	<8mV	<8mV
-Stabilität ±10% U_E	-Stability at ±10% ÷ V_{IN}	<5m$V_{eff.}$	<5m$V_{eff.}$	<5m$V_{eff.}$	<5m$V_{eff.}$	<5m$V_{eff.}$
-Restwelligkeit	-Ripple	<1mV	<1mV	<10mV	<1mV	<1mV
-Überspannungsschutz	OVP Adjustment	ja/yes preselect	ja/yes preselect	ja/yes preselect	ja/yes preselect	ja/yes preselect
Ausgangsstrom	Output current	0...10A	0...20A	0...40A	0...5A	0...10A
-Feineinstellbereich	-Fine Adjustment Range	ca. 1A	ca. 2A	ca. 4A	ca. 500mA	ca. 1A
Betriebstemperatur	Operating Temperature	0...40°C	0...40°C	0...40°C	0...40°C	0...40°C
Abmessungen BxHxT(mm)	Dimensions WxHxD (mm)	240 x 120 x 300	240 x 120 x 300	240 x 120 x 300	240 x 120 x 300	240 x 120 x 300
Gewicht	Weight	6,5kg	10kg	5,5kg	6,5kg	10kg
Artikel Nr.	Article Nb.	35320170	35320173	35320176	35320171	35320174

Technische Daten EA-	Technical Data EA-	PS 3032-20 B	PS 3065-03 B	PS 3065-05 B	PS 3065-10 B	PS 3150-04 B
Eing. Spannung	Input Voltage	88...264V AC	115V / 230V AC	115V / 230V AC	88...264V AC	88...264V AC
-Eingangsfrequenz	-Input frequency	50/60Hz	50Hz	50Hz	50/60Hz	50/60Hz
-Leistungsfaktorkorrektur	-Power factor correction	>0,99 (PFC)	nein/no	nein/no	>0,99 (PFC)	>0,99 (PFC)
Ausgangsspannung	Output Voltage	0...32V	0...65V	0...65V	0...65V	0...150V
-Feineinstellbereich	-Fine Adjustment Range	ca. 1,6V	ca. 3,5V	ca. 3,5V	ca. 3,5V	ca. 15V
-Stabilität 0...100% Last	-Stability at 0-100% load	<20mV	<8mV	<8mV	<40mV	<60mV
-Stabilität ±10% U_E	-Stability at ±10% ÷ V_{IN}	<5m$V_{eff.}$	<5m$V_{eff.}$	<5m$V_{eff.}$	<5m$V_{eff.}$	<5m$V_{eff.}$
-Restwelligkeit	-Ripple	<15mV	<1mV	<1mV	<20mV	<100mV
-Überspannungsschutz	OVP Adjustment	ja/yes preselect	ja/yes preselect	ja/yes preselect	ja/yes preselect	ja/yes preselect
Ausgangsstrom	Output current	0...20A	0...2,5A	0...5A	0...10A	0...4A
-Feineinstellbereich	-Fine Adjustment Range	ca. 2A	ca. 250mA	ca. 500mA	ca. 1A	ca. 400mA
Betriebstemperatur	Operating Temperature	0...40°C	0...40°C	0...40°C	0...40°C	0...40°C
Abmessungen BxHxT(mm)	Dimensions WxHxD (mm)	240 x 120 x 300	240 x 120 x 300	240 x 120 x 300	240 x 120 x 300	240 x 120 x 300
Gewicht	Weight	5,5kg	6,5kg	10kg	5,5kg	5,5kg
Artikel Nr.	Article Nb.	35320177	35320172	35320175	35320178	35320179

EHEIM

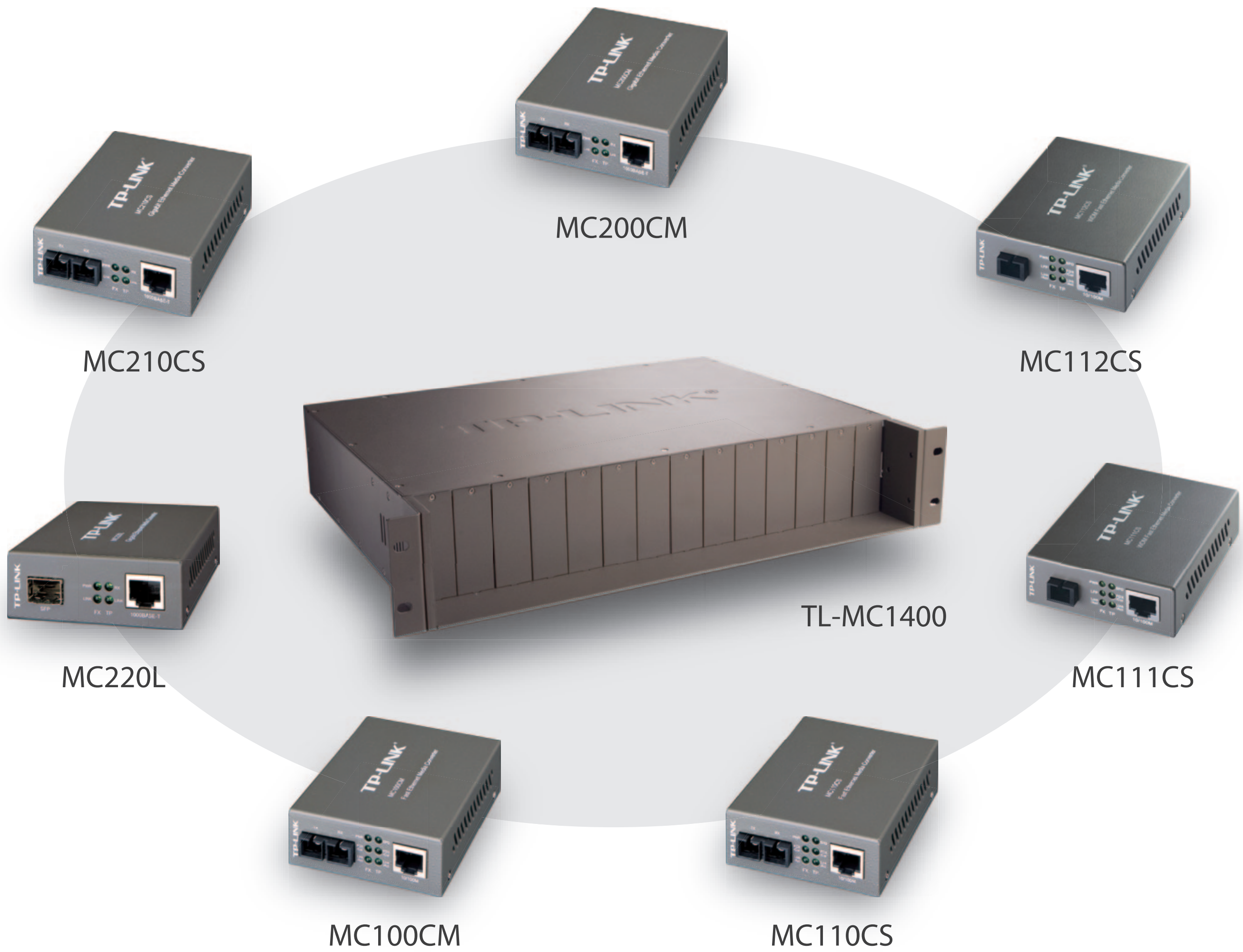
1250
3250

Gebrauchsanleitung	D
Instructions	GB / USA
Mode d'emploi	F
Gebruiksaanwijzing	NL
Bruksanvisning	S
Bruksanvisning	N
Käyttöohje	FIN
Brugsanvisning	DK
Istruzioni	I
Instrucciones	E
Návod k použití	CZ
Универсальный насос / насос-фонтан	RUS

Typ		1250		1250		3250	
No.		1250019 - 1250209		1250219 - 1250499		3250010 - 3250200	
–		No.		No.		No.	
230 V/50 Hz	EU	1250019	10 m	1250219	1,5 m	3250010	10 m
	D			1250229	1,5 m		
	CH	–	–	1250249	1,5 m	–	–
100 V/50 Hz	J	–	–	1250289	2,0 m	–	–
100 V/60 Hz		–	–	1250329	2,0 m	–	–
120 V/60 Hz	USA	1250099	5 m	1250319	2,0 m	–	–
240 V/50 Hz	GB	1250119	3 m	–	–	–	–
	AUS	1250129	5 m	–	–	–	–
24 V/50 Hz	–	–	–	1250389	1,5 m	–	–
220 V/60 Hz	USA	1250189	5 m	1250419	2,0 m	–	–

Abmessungen: H x B x T Dimensions: h x l x w Dimensions: haut. x larg. x prof. Afmetingen: h x l x b Måttuppgifter: h x b x d Dimensioni: alt. x larg. x prof.	121 x 178 x 96 mm 4.8 x 7.0 x 3.8 in.	345 x 140 x 96 mm 13.6 x 5.5 x 3.8 in.
Schlauchanschluss, Saugseite Threaded adaptor, suction side Embout fileté, coté aspiration Slangpilaar, zuigzijde Anslutningsstuds, inlopp Bocchettone filettato di aspirazione	Ø 18 mm / G 1/2´´ Ø 0.7 in. / G 1/2´´	G 1/2´´
Schlauchanschluss, Druckseite Threaded adaptor, pressure side Embout fileté, coté pression Slangpilaar, drukzijde Anslutningsstuds, utlopp Bocchettone filettato di mandata	Ø 13 mm / G 3/8´´ Ø 0.5 in. / G 3/8´´	G 3/8´´
Pumpenleistung Pump output Débit de la pompe Pompcapaciteit Pumpkapacitet Potenza della pompa	1200 l/h 264 Imp. gal./h 317 U.S. gal./h	
Förderhöhe H_{max} Delivery head wat. col. Hauteur de réf. m col. d'eau Opvoerhoogte m/wk Lyfthöjd m/vst Prevalenza m/ca	2,0 m 6 ft. / 7 in.	
Leistungsaufnahme Power consumption Consommation de courant Stroomverbruik Eleffekt Assorbimento	28 W	

Media Converters & Chassis



Overview

The Chassis-based Media Converters include a number of independent media converters and a chassis capable of housing up to 14 media converters. You can start with single media converters, each equipped with its own housing and AC power adapter. When you require more room, you can mount a chassis in your equipment rack and install your media converters in the chassis - the media converters can be slid into the chassis.

MC100CM

The MC100CM media converter converts 100BASE-FX fiber to 100Base-TX copper media or vice versa. It is designed for use with 850nm multi-mode fiber cable utilizing the SC-Type connector, transmitting data up to 2 kilometers. What's more, MC100CM can work as a stand alone device (no chassis required)or with TP-LINK's 19" system chassis, and is equipped with Link Fault Pass Through which minimizes the loss caused by link failure.

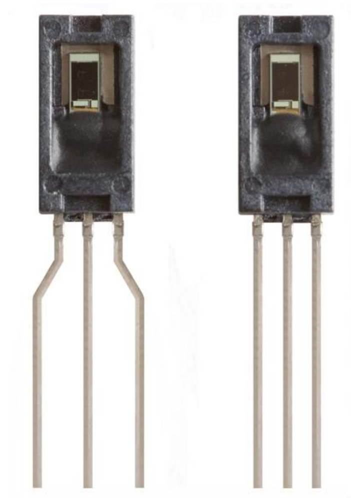
Features:

- Auto-negotiation of 10/100Mbps and Auto MDI/MDIX for TX port
- Provide switch configuration of Half-Duplex / Full-Duplex transfer mode for TX port
- Link Fault Pass Through and Far End Fault minimize the loss caused by link failure timely
- Extend fiber distance up to 2km
- Easy-to-view LED indicators provide status to monitor network activity easily

Specifications:

Standards	IEEE 802.3u, IEEE 802.3x
Basic Function	Half/Full-Duplex transfer mode for TX port Full Duplex Flow Control (IEEE 802.3x) Half Duplex Flow Control (Backpressure) Extends fiber distance up to 2km Link Fault Pass Through and Far End Fault minimize the loss caused by link failure timely
Interface	1 100Mbps SC port 1 100Mbps RJ45 port (Auto MDI/MDIX)
Network Media	10BASE-T: UTP category 3, 4, 5 cable (maximum 100m) EIA/TIA-568 100Ω STP (maximum 100m) 100BASE-T: UTP category 5, 5e cable (maximum 100m) EIA/TIA-568 100Ω STP (maximum 100m) 100BASE-FX: Multi-mode Fiber
LED Indicators	PWR, SPD, LFP, FDX/Col, Link/Act
Certifications	FCC, CE
Dimensions (W x D x H)	3.7 x 2.9 x 1.1 in. (94.5 x 73.0 x 27.0 mm)
Environment	Operating Temperature: 0°C~40°C (32°F~104°F) Storage Temperature: -40°C~70°C (-40°F~158°F) Operating Humidity: 10%~90% non-condensing Storage Humidity: 5%~90% non-condensing
Power Supply	External Power Adapter, 9V/0.6A or 5V/1A

Honeywell



HIH-4000 Series

Humidity Sensors

DESCRIPTION

The HIH-4000 Series Humidity Sensors are designed specifically for high volume OEM (Original Equipment Manufacturer) users.

Direct input to a controller or other device is made possible by this sensor's near linear voltage output. With a typical current draw of only 200 µA, the HIH-4000 Series is often ideally suited for low drain, battery operated systems.

Tight sensor interchangeability reduces or eliminates OEM production calibration costs. Individual sensor calibration data is available.

The HIH-4000 Series delivers instrumentation-quality RH (Relative Humidity) sensing performance in a competitively priced, solderable SIP (Single In-line Package).

Available in two lead spacing configurations, the RH sensor is a laser trimmed, thermoset polymer capacitive sensing element with on-chip integrated signal conditioning.

The sensing element's multilayer construction provides excellent resistance to most application hazards such as wetting, dust, dirt, oils and common environmental chemicals.

FEATURES

- Molded thermoset plastic housing
- Near linear voltage output vs % RH
- Laser trimmed interchangeability
- Low power design
- Enhanced accuracy
- Fast response time
- Stable, low drift performance
- Chemically resistant

POTENTIAL APPLICATIONS

- Refrigeration equipment
- HVAC (Heating, Ventilation and Air Conditioning) equipment
- Medical equipment
- Drying
- Metrology
- Battery-powered systems
- OEM assemblies

HIH-4000 Series

Table 1. Performance Specifications (At 5 Vdc supply and 25 ºC [77 ºF] unless otherwise noted.)

Parameter	Minimum	Typical	Maximum	Unit	Specific Note
Interchangeability (first order curve)	–	–	–	–	–
0% RH to 59% RH	-5	–	5	% RH	–
60% RH to 100% RH	-8	–	8	% RH	–
Accuracy (best fit straight line)	-3.5	–	+3.5	% RH	1
Hysterisis	–	3	–	% RH	–
Repeatability	–	±0.5	–	% RH	–
Settling time	–	–	70	ms	–
Response time (1/e in slow moving air)	–	5	–	s	–
Stability (at 50% RH)	–	1.2	–	% RH	–
Voltage supply	4	–	5.8	Vdc	2
Current supply	–	200	500	µA	–
Voltage output (1st order curve fit)	V_{OUT}=(V_{SUPPLY})(0.0062(sensor RH) + 0.16), typical at 25 ºC				
Temperature compensation	True RH = (Sensor RH)/(1.0546 – 0.00216T), T in ºC				
Output voltage temperature, coefficient at 50% RH, 5 V	–	-4	–	mV/ºC	
Operating temperature	-40[-40]	See Figure 1.	85[185]	ºC[ºF]	–
Operating humidity	0	See Figure 1.	100	% RH	3
Storage temperature	-50[-58]	–	125[257]	ºC[ºF]	–
Storage humidity	See Figure 2.			% RH	3

Specific Notes:
1. Can only be achieved with the supplied slope and offset. For HIH-4000-003 and HIH-4000-004 catalog listings only.
2. Device is calibrated at 5 Vdc and 25 ºC.
3. Non-condensing environment.

General Notes:
- Sensor is ratiometric to supply voltage.
- Extended exposure to ≥90% RH causes a reversible shift of 3% RH.
- Sensor is light sensitive. For best performance, shield sensor from bright light.

FACTORY CALIBRATION DATA

HIH-4000 Sensors may be ordered with a calibration and data printout. See Table 2 and the order guide on the back page.

Table 2. Example Data Printout

Model	HIH-4000-003
Channel	92
Wafer	030996M
MRP	337313
Calculated values at 5 V V_{OUT} at 0% RH V_{OUT} at 75.3% RH	 0.826 V 3.198 V
Linear output for 3.5% RH accuracy at 25 °C Zero offset Slope RH	 0.826 V 31.483 mV/%RH (V_{OUT} - zero offset)/slope (V_{OUT} - 0.826)/0.0315
Ratiometric response for 0% RH to 100% RH V_{OUT}	 V_{SUPPLY} (0.1652 to 0.7952)

Keysight 3458A Multimeter

Shattering performance barriers of speed and accuracy

Data Sheet

KEYSIGHT
TECHNOLOGIES

Section 1: DC Voltage

DC Voltage

Range	Full Scale	Maximum Resolution	Input Impedance	Temperature Coefficient (ppm of Reading + ppm of Range) / °C	
				Without ACAL[1]	With ACAL[2]
100 mV	120.00000	10 nV	> 10 GΩ	1.2 + 1	0.15 + 1
1 V	1.20000000	10 nV	> 10 GΩ	1.2 + 0.1	0.15 + 0.1
10 V	12.0000000	100 nV	> 10 GΩ	0.5 + 0.01	0.15 + 0.01
100 V	120.000000	1 µV	10 MΩ ± 1%	2 + 0.4	0.15 + 0.1
1000 V	1050.00000	10 µV	10 MΩ ± 1%	2 + 0.04	0.15 + 0.01

Accuracy[3] [ppm of Reading (ppm of Reading for Option 002) + ppm of Range]

Range	24 Hour[4]	90 Day[5]	1 Year[5]	2 Year[5]
100 mV	2.5 + 3	5.0 (3.5) + 3	9 (5) + 3	14 (10) + 3
1 V	1.5 + 0.3	4.6 (3.1) + 0.3	8 (4)+ 0.3	14 (10) + 0.3
10 V	0.5 + 0.05	4.1 (2.6) + 0.05	8 (4) + 0.05	14 (10) + 0.05
100 V	2.5 + 0.3	6.0 (4.5) + 0.3	10 (6)+ 0.3	14 (10) + 0.3
1000 V[6]	2.5 + 0.1	6.0 (4.5) + 0.1	10 (6) + 0.1	14 (10) + 0.1

Transfer Accuracy/Linearity

Range	10 Min, Tref ± 0.5°C (ppm of Reading + ppm of Range)
100 mV	0.5 + 0.5
1 V	0.3 + 0.1
10 V	0.05 + 0.05
100 V	0.5 + 0.1
1000 V	1.5 + 0.05

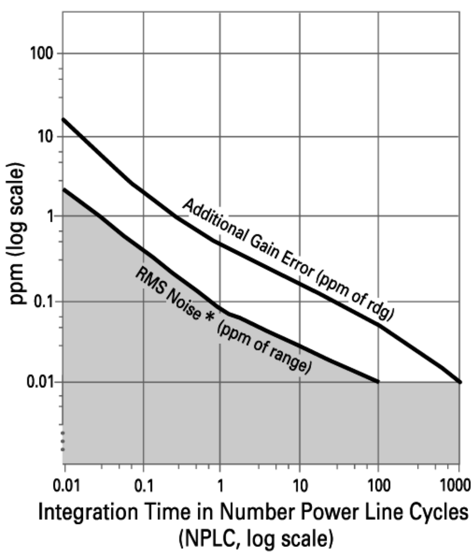
Conditions

- Following 4 hour warm-up. Full scale to 10% of full scale.
- Measurements on the 1000 V range are within 5% of the initial measurement value and following measurement settling.
- Tref is the starting ambient temperature.
- Measurements are made on a fixed range (> 4 min.) using accepted metrology practices.

Settling Characteristics

For first reading or range change error, add 0.0001% of input voltage step additional error.
Reading settling times are affected by source impedance and cable dielectric absorption characteristics.

Additional Errors



Noise Rejection (dB)[7]

	AC NMR[8]	AC ECMR	DC ECMR
NPLC < 1	0	90	140
NPLC ≥ 1	60	150	140
NPLC ≥ 10	60	150	140
NPLC ≥ 100	60	160	140
NPLC = 1000	75	170	140

***RMS Noise**

Range	Multiplier
0.1V	x20
1V	x2
10V	x1
100V	x2
1000V	x1

For RMS noise error, multiply RMS noise result from graph by multiplier in chart. For peak noise error, multiply RMS noise error by 3.

1 Additional error from Tcal or last ACAL ± 1°C.

2 Additional error from Tcal ± 5°C.

3 Specifications are for PRESET; NPLC 100.

4 For fixed range (> 4 min.), MATH NULL and Tcal ± 1°C.

5 Specifications for 90 day, 1 year and 2 year are within 24 hours and ± 1° C of last ACAL; Tcal ±5°C; MATH NULL and fixed range.

ppm of Reading specifications for High Stability (Option 002) are in parentheses.

Without MATH NULL, add 0.15 ppm of Range to 10 V, 0.7 ppm of Range to 1 V, and 7ppm of Range to 0.1V. Without math null and for fixed range less than 4 minutes, add 0.25 ppm of Range to 10 V, 1.7 ppm of Range to 1 V and 17 ppm of Range to 0.1 V.

Add 2 ppm of reading additional error for factory traceability to US NIST. Traceability error is the absolute error relative to National Standards associated with the source of last external calibration.

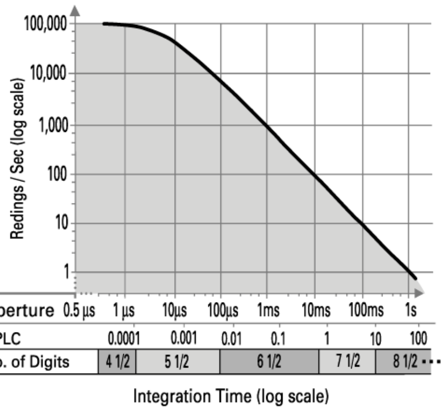
6 Add 12 ppm X (Vin / 1000)^2 additional error for inputs > 100 V.

7 Applies for 1 kΩ unbalance in the LO lead and ± 0.1% of the line frequency currently set for LFREQ.

8 For line frequency ± 1%, ACNMR is 40 dB for NPLC ≥ 1, or 55 dB for NPLC ≥ 100. For line frequency ± 5%, ACNMR is 30 dB for NPLC ≥ 100.

Section 1: DC Voltage continued

Reading Rate (Auto-Zero Off)



Temperature Coefficient (Auto-Zero Off)

For a stable environment ± 1°C add the following additional error for AZERO OFF

Range	Error
100 mV - 10 V	5 µV/°C
100 V - 1000 V	500 µV/°C

Selected Reading Rates [1]

NPLC	Aperture	Digits	Bits	Readings / Sec A-Zero Off	Readings / Sec A-Zero On
0.0001	1.4 µs	4.5	16	100,000[3]	4,130
0.0006	10 µs	5.5	18	50,000	3,150
0.01	167 µs[2]	6.5	21	5,300	930
0.1	1.67 ms[2]	6.5	21	592	245
1	16.6 ms[2]	7.5	25	60	29.4
10	0.166 s[2]	8.5	28	6	3
100		8.5	28	36 / min	18 / min
1000		8.5	28	3.6 / min	1.8 / min

1 *For PRESET;DELAY 0; DISP OFF; OFORMAT DINT; ARANGE OFF.*

2 *Aperture is selected independent of line frequency (LFREQ). These apertures are for 60 Hz NPLC values where 1 NPLC = 1 / LFREQ. For 50 Hz and NPLC indicated, aperture will increase by 1.2 and reading rates will decrease by 0.833.*

3 *For OFORMAT SINT.*

Maximum Input

	Rated Input	Non-Destructive
HI to LO	± 1000 V pk	± 1200 V pk
LO to Guard[4]	± 200 V pk	± 350 V pk
Guard to Earth[5]	± 500 V pk	± 1000 V pk

4 *>10^{10} Ω LO to Guard with guard open.*

5 *>10^{12} Ω Guard to Earth.*

Input Terminals

Terminal Material: Gold-plated Tellurium Copper

Input Leakage Current: <20 pA at 25°C

Section 2: Resistance

Two-wire and Four-wire Ohms (OHM and OHMF Functions)

Range	Full Scale	Maximum Resolution	Current Source[4]	Test Voltage	Open Circuit	Maximum Lead Resistance (OHMF)	Maximum Series Offset (OCOMP ON)	Temperature Coefficient (ppm of Reading + ppm of Range) / °C Without ACAL[5]	Temperature Coefficient (ppm of Reading + ppm of Range) / °C With ACAL[6]
10 Ω	12.00000	10 µΩ	10 mA	0.1 V	12 V	20 Ω	0.01 V	3 + 1	1 + 1
100 Ω	120.00000	10 µΩ	1 mA	0.1 V	12 V	200 Ω	0.01 V	3 + 1	1 + 1
1 kΩ	1.2000000	100 µΩ	1 mA	1.0 V	12 V	150 Ω	0.1 V	3 + 0.1	1 + 0.1
10 kΩ	12.000000	1 mΩ	100 µA	1.0 V	12 V	1.5 kΩ	0.1 V	3 + 0.1	1 + 0.1
100 kΩ	120.00000	10 mΩ	50 µA	5.0 V	12 V	1.5 kΩ	0.5 V	3 + 0.1	1 + 0.1
1 MΩ	1.2000000	100 mΩ	5 µA	5.0 V	12 V	1.5 kΩ		3 + 1	1 + 1
10 MΩ	12.000000	1 Ω	500 nA	5.0 V	12 V	1.5 kΩ		20 + 20	5 + 2
100 MΩ[7]	120.00000	10 Ω	500 nA	5.0 V	5 V	1.5 kΩ		100 + 20	25 + 2
1GΩ[7]	1.2000000	100 Ω	500 nA	5.0 V	5 V	1.5 kΩ		1000 + 20	250 + 2

4 *Current source is ± 3% absolute accuracy.*

5 *Additional error from Tcal or last ACAL ± 1° C.*

6 *Additional error from Tcal ± 5° C.*

7 *Measurement is computed from 10 M Ω in parallel with input.*

LA-160-24-02-00-00

Liquid-to-Air Thermoelectric Assembly

Thermoelectric cooling unit for medical and industrial applications

The Liquid-to-Air Series thermoelectric assembly (TEA) offers dependable, compact performance by cooling objects via liquid to transfer heat. Heat is absorbed through a liquid heat exchanger and dissipated thru a high density heat sink equipped with an air ducted shroud and brand name fan. The thermoelectric modules are custom designed to achieve a high coefficient of performance (COP) to minimize power consumption. This product series is available in a wide range of cooling capacities and voltages. Custom configurations are available, however, MOQ applies.

FEATURES

- Compact form factor
- Precise temperature control
- Reliable solid-state operation
- DC operation
- RoHS compliant

APPLICATIONS

- Medical Diagnostics
- Industrial Lasers
- Medical Lasers
- Analytical Instrumentation

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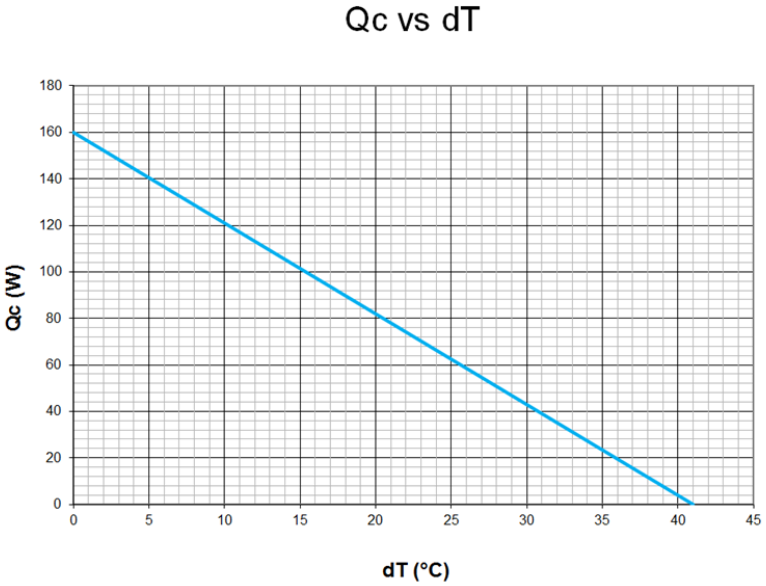
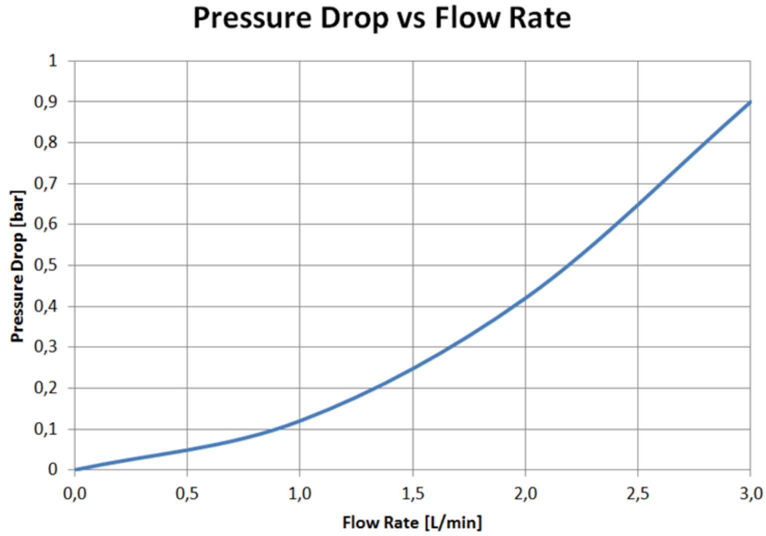
LA-160-24-02-00-00

Liquid-to-Air Thermoelectric Assembly





SPECIFICATIONS

TECHNICAL	
Technology	Thermoelectric based
Cooling at ΔT = 0°C	160 W
Voltage (nominal / maximum)	24/30 VDC
Current draw, ±10% (nominal / startup)	6.6/9.3 A
Weight	3.7 kg
Power Input	137 W
MTBF (fans)	50,000 hours
ENVIRONMENTAL	
Temperature range	-10°C to +46°C
Over temp Thermostat	75°C±5°C on hot side heat sink surface

SPECIFICATIONS

NI cRIO-9063

Embedded Real-Time Controller with Reconfigurable FPGA for C Series Modules

This document lists the specifications for the NI cRIO-9063. The following specifications are typical for the -20 °C to 55 °C operating temperature range unless otherwise noted.

Caution Do not operate the cRIO-9063 in a manner not specified in this document. Product misuse can result in a hazard. You can compromise the safety protection built into the product if the product is damaged in any way. If the product is damaged, return it to NI for repair.

Processor

Type	Xilinx Zynq-7000, XC7Z020 All Programmable SoC
Architecture	ARM Cotex-A9
Speed	667 MHz
Cores	2
Flash reboot endurance[1]	100,000 cycles

Operating System

Note For minimum software support information, visit *ni.com/info* and enter the Info Code `swsupport`.

Supported operating system	NI Linux Real-Time (32-bit)

[1] You can increase the flash reboot endurance value by performing field maintenance on the device. If you expect that your application may exceed the maximum cycle count listed in this document, contact NI support for information about how to increase the reboot endurance value.

Reconfigurable FPGA

Type	Xilinx Zynq-7000, XC7Z020 All Programmable SoC
Number of logic cells	85,000
Number of flip-flops	106,400
Number of 6-input LUTs	53,200
Number of DSP slices (18 × 25 multipliers)	220
Available block RAM	4480 kbits
Number of DMA channels	16
Number of logical interrupts	32

Battery

Note The battery is not user-replaceable. Refer to the *Battery Replacement and Disposal* section for information about replacing the battery.

Note Battery life may drop dramatically in extreme temperatures.

Typical battery life with power applied to power connector	10 years
Typical battery life in storage at 55 °C	5 years

Power Requirements

Voltage input range	9 VDC to 30 VDC
Reverse-voltage protection	30 VDC maximum
Maximum power input, with four C Series modules	18 W
Maximum power input, without C Series modules	14 W

DATASHEET

NI 9216

8 RTD, 0 Ω to 400 Ω, 24 Bit, 400 S/s Aggregate, PT100

- DSUB or spring-terminal connectivity
- 50 Hz/60 Hz noise rejection
- 250 Vrms, CAT II, channel-to-earth isolation (spring terminal); 60 VDC, CAT I, channel-to-earth isolation (DSUB)

The NI 9216 RTD analog input C Series module features eight channels and 24 bits of resolution for PT100 RTD measurements. The NI 9216, compatible with 3- and 4-wire RTD measurements, automatically detects the type of RTD (3- or 4-wire) connected to the channel and configures each channel for the appropriate mode. The module provides 1 mA of current excitation per channel and has less than a ±1.0 °C accuracy error over its entire operating temperature range. NI provides calibration services for the NI 9216.

Kit Contents	• NI 9216 • NI 9216 Getting Started Guide
Accessories	• NI 9974 Spring-Terminal Block (with Spring-Terminal)

Input Characteristics

Number of channels	8 analog input channels
ADC resolution	24 bits
Type of ADC	Delta-sigma
Sampling mode	Scanned
Measurement range	
Temperature	-200 °C to 850 °C
Resistance	0 Ω to 400 Ω
Conversion time	
High-resolution mode	200 ms per channel, 1600 ms total for all channels
High-speed mode	2.5 ms per channel, 20 ms total for all channels

Table 1. Temperature Accuracy (including noise)[1], 4-wire mode

Measured Value	Typical (25 °C)	Maximum (-40 °C to 70 °C)
-200 °C to 150 °C	±0.15 °C	±0.4 °C
150 °C to 850 °C	±0.20 °C	±1.0 °C

Table 2. Temperature Accuracy (including noise)[1], 3-wire mode[2]

Measured Value	Typical (25 °C)	Maximum (-40 °C to 70 °C)
-200 °C to 150 °C	±0.20 °C	±0.5 °C
150 °C to 850 °C	±0.30 °C	±1.0 °C

Table 3. Resistance measurement accuracy (including noise)[3], 4-wire mode

Measurement Conditions	Offset Error	Gain Error
Typical (25 °C)	±0.006 Ω	±0.007%
Maximum (-40 °C to 70 °C)	±0.083 Ω	±0.048%

1 For high-speed mode, add 0.1 °C of error.
2 The 3-wire specification assumes equal wire length connecting RTD+ terminal to RTD sensor and COM terminal to RTD sensor. If the lengths are unequal or there is a mismatch between the path resistances, use the following formula to evaluate additional error: °C error = $R_{mismatch}$ * 3.42 °C/Ω
3 For high-speed mode, add 0.027 Ω of error.

Table 4. Resistance measurement accuracy (including noise)[3], 3-wire mode

Measurement Conditions	Offset Error	Gain Error
Typical (25 °C)	±0.012 Ω	±0.007%
Maximum (-40 °C to 70 °C)	±0.101 Ω	±0.048%

Table 5. Stability

Mode	Offset Drift	Gain Drift
4-wire	±3 mΩ/°C	±7 ppm/°C
3-wire	±3.3 mΩ/°C	±7 ppm/°C

Noise	
High-resolution mode	0.001 °Crms (0.3 mΩrms)
High-speed mode	0.02 °Crms (6 mΩrms)
Excitation current	1 mA per channel
Noise rejection	
Normal mode (50/60 Hz)	
High-resolution mode	85 dB
High-speed mode	None
Common-mode rejection, channel-to-earth ground (50/60 Hz)	
High-resolution mode	>170 dB
High-speed mode	122 dB
Input bandwidth (high-resolution mode)	3.3 Hz

DATASHEET

NI 9221

8 AI, ±60 V, 12 Bit, 800 kS/s Aggregate

- DSUB, screw-terminal, or spring-terminal connectivity
- 250 Vrms, CAT II, channel-to-earth isolation (screw and spring terminal); 60 VDC, CAT I, channel-to-earth isolation (DSUB)
- -40 °C to 70 °C operating range, 5 g vibration, 50 g shock

The NI 9221 is an analog input module for CompactDAQ and CompactRIO systems. The NI 9221 provides eight channels of ±60 V input with 800 kS/s sample rate.

Kit Contents	• NI 9221 • NI 9221 Getting Started Guide
Accessories	• NI 9927 Backshell Connector Kit (Screw Terminal) • NI 9981 Backshell Connector Kit (Spring Terminal) • NI 9924 Screw-Terminal Block (DSUB)

NI 9221 Specifications

The following specifications are typical for the range -40 °C to 70 °C unless otherwise noted. All voltages are relative to COM unless otherwise noted.

Caution Do not operate the NI 9221 in a manner not specified in this document. Product misuse can result in a hazard. You can compromise the safety protection built into the product if the product is damaged in any way. If the product is damaged, return it to NI for repair.

Input Characteristics

Number of channels	8
ADC resolution	12 bits
Type of ADC	Successive approximation register (SAR)
Maximum Sample Rate (Aggregate)	
R Series Expansion Chassis	475 kS/s
All Other Chassis	800 kS/s
Input range	±60 V
Measurement voltage, channel-to-COM (V)	
Minimum	±61.4
Typical	±62.50
Maximum	±63.8
Overvoltage protection, channel-to-COM	±100 V

Table 1. NI 9221 Accuracy (Excludes Noise)

Measurement Conditions		Percent of Reading (Gain Error)	Percent of Range[1] (Offset Error)
Calibrated	Typical (25 °C, ±5 °C)	±0.04%	±0.07%
	Maximum (-40 °C to 70 °C)	±0.25%	±0.25%

1 Range equals 62.50 V

Table 1. NI 9221 Accuracy (Excludes Noise) (Continued)

Measurement Conditions		Percent of Reading (Gain Error)	Percent of Range[1] (Offset Error)
Uncalibrated[2]	Typical (25 °C, ±5 °C)	±0.26%	±0.43%
	Maximum (-40 °C to 70 °C)	±0.67%	±1.06%

Stability	
Gain drift	±34 ppm/°C
Offset drift	±580 µV/°C
Input bandwidth (-3 dB)	950 kHz min
Input impedance	
Resistance	1 MΩ
Capacitance	5 pF
Input noise, code-centered	
RMS	0.7 LSBrms
Peak-to-peak	5 LSB
No missing codes	12 bits
DNL	-0.9 to 1.5 LSB
INL	±1.5 LSB
Crosstalk, at 10 kHz	-75 dB
Settling time, to 1 LSB	1.25 µs
MTBF	1,092,512 hours at 25 °C; Bellcore Issue 2, Method 1, Case 3, Limited Part Stress Method

Power Requirements

Power consumption from chassis	
Active mode	1 W maximum
Sleep mode	1 mW maximum
Thermal dissipation (at 70 °C)	
Active mode	1 W maximum
Sleep mode	32 mW maximum

1 Range equals 62.50 V
2 Uncalibrated accuracy refers to the accuracy achieved when acquiring in raw or unscaled modes where the calibration constants stored in the module are not applied to the data.

DATASHEET

NI 9263

4 AO, ±10 V, 16 Bit, 100 kS/s/ch Simultaneous

- Screw-terminal or spring-terminal connectivity
- 250 Vrms, CAT II, channel-to-earth isolation

The NI 9263 is an analog output module for any CompactDAQ and CompactRIO systems. It also features ±30 V overvoltage protection, short-circuit protection, low crosstalk, fast slew rate, high relative accuracy, and NIST-traceable calibration. The NI 9263 module includes a channel-to-earth ground double isolation barrier for safety and noise immunity.

Kit Contents	• NI 9263 • NI 9263 Getting Started Guide
Accessories	• NI 9927 backshell connector kit (screw terminal) • NI 9981 backshell connector kit (spring terminal)

Type of DAC	String
Power-on output state	Channels off
Startup voltage[1]	0 V
Power-down voltage[2]	0 V
Output voltage range	
Nominal	±10 V
Minimum	±10.4 V
Typical	±10.7 V
Maximum	±11 V
Current drive	±1 mA per channel maximum
Output impedance	2 Ω

Table 1. Accuracy

Measurement Conditions		Percent of Reading (Gain Error)	Percent of Range[3] (Offset Error)
Calibrated	Maximum (-40 °C to 70 °C)	0.35%	0.75%
	Typical (25 °C, ±5 °C)	0.03%	0.1%
Uncalibrated[4]	Maximum (-40 °C to 70 °C)	2.2%	1.7%
	Typical (25 °C, ±5 °C)	0.3%	0.25%

Stability	
Gain drift	11 ppm/°C
Offset drift	110 μV/°C
Protection	
Overvoltage	±30 V
Short-circuit	Indefinitely

1 When the module powers on, a glitch occurs for 20 μs peaking at -1.5 V.
2 The power-down voltage peaks at 1.8 V before exponentially discharging to 0 V in 100 μs. You can add a 10 kΩ load to reduce the peak voltage.
3 Range equals ±10.7 V
4 Uncalibrated accuracy refers to the accuracy achieved when acquiring in raw or unscaled modes where the calibration constants stored in the module are not applied to the data.

Table 2. Update Time

Number of Channels	Update Time for All Other Chassis	Update Time for NI cRIO-9151 R Series Expansion Chassis
1	3 µs min	3.5 µs min
2	5 µs min	6.5 µs min
3	7.5 µs min	9 µs min
4	9.5 µs min	12 µs min

Noise	
Updating at 100 kS/s	600 µVrms
Not updating	260 µVrms
Slew rate	4 V/µs
Crosstalk	76 dB
Settling time (100 pF load, to 1 LSB)	
Full-scale step	20 µs
1 V step	13 µs
0.1 V step	10 µs
Capacitive drive	1,500 pF minimum
Monotonicity	16 bits
DNL	±1 LSB maximum
INL (endpoint)	±12 LSB maximum
MTBF	1,732,619 hours at 25 °C; Bellcore Issue 2, Method 1, Case 3, Limited Part Stress Method

Power Requirements

Power consumption from chassis	
Active mode (at -40 °C)	500 mW maximum
Sleep mode	25 µW maximum
Thermal dissipation (at 70 °C)	
Active mode	750 mW maximum
Sleep mode	25 µW maximum

PROLOGIX

GPIB-ETHERNET CONTROLLER

USER MANUAL

VERSION 1.6.6.0

May 14, 2013

PROLOGIX.BIZ

1. Introduction

Prologix GPIB-ETHERNET controller converts any computer with a network port into a GPIB Controller or Device.

In Controller mode, Prologix GPIB-ETHERNET controller can remotely control GPIB enabled instruments such as Oscilloscopes, Logic Analyzers, and Spectrum Analyzers.

In Device mode, Prologix GPIB-ETHERNET controller converts the computer into a GPIB peripheral for downloading data and screen plots from the instrument front panel.

In both modes, Prologix GPIB-ETHERNET controller interprets high level commands received from the host computer and performs the appropriate low-level GPIB protocol handshaking.

2. Installation

Connect Prologix GPIB-ETHERNET controller to any network enabled computer using an Ethernet cable. No special drivers are required. The type of cable to use depends on the computer. If the computer supports auto-MDIX, which almost all newer ones do, use a straight Ethernet cable. If the computer does not support auto-MDIX, use a cross-over Ethernet cable. If a cross-over Ethernet cable is not available, or does not work, connect both Prologix GPIB-ETHERNET controller and computer to a network hub (or switch).

3. Firmware Upgrade

Prologix GPIB-ETHERNET controller firmware is field upgradeable. Latest firmware and upgrade installations are available at prologix.biz

4. Host Software

A wide variety of host software may be used to communicate with Prologix GPIB-ETHERNET controller:

Terminal programs – any terminal emulation program such as HyperTerminal, Tera Term Pro, or Minicom can be used to communicate with the controller and instruments connected to it.

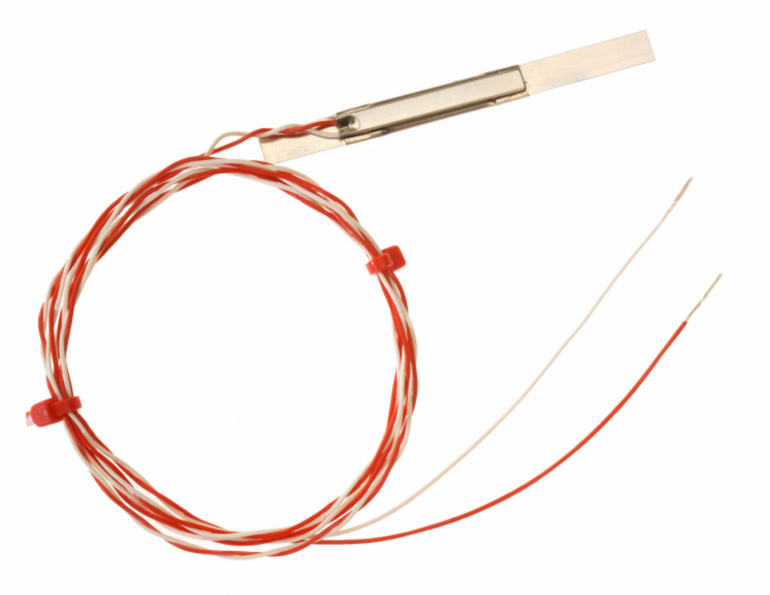
Custom applications – any programming language or environment that provides network access may be used to develop custom applications. Graphical programming environments like National Instruments LabView and Agilent VEE may be used as well.

ENGLISH

Datasheet

Platinum Resistance Pt100 Sheathed Thin Film Strip Sensor

2 wire sensor sheathed in a thin stainless steel shim body – ideal for surface measurement



What is the difference between a RTD and PRT sensor?
Nothing. RTD means resistance thermometer detector (the sensing element) and PRT means Platinum resistance thermometer (the whole assembly) i.e. a PRT uses a RTD.

- Sheathed Pt100 element in a thin, flat stainless steel body
- Small physical size
- Quick thermal response while element remains protected
- Ideally suited for surface temperature measurement
- 2 wire, Class B to IEC 751
- Temperature range -50°C to +250°C
- 1 metre 7/0.2mm Teflon® insulated twin twisted lead

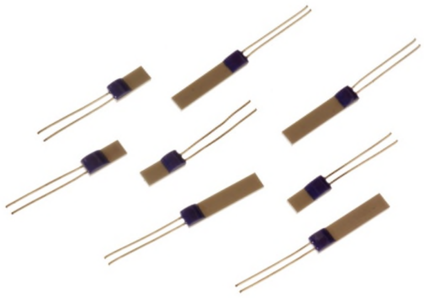
Specifications

Sensor type:	Pt100 (100 Ω @ 0°C), thin film
Construction:	Element sealed in a thin stainless steel strip & body
Overall Strip/Body dimensions:	L35mm x W6mm x thickness 2mm
Lead type:	1metre 7/.02mm Teflon® insulated twin twisted lead
Temperature range:	-50°C to +250°C

PT100 Sheathed Thin Film Strip Sensor

RS order code:	**237-1613**
Allied code:	70641763

Platinum Resistance Pt100 & Pt1000 Thin Film Detectors Platinum Sensing Resistors – Thin Film (Pt100 & Pt1000 Ohm)



Pt100 Elements, Thin Film (100 Ohm)

- Pt100 elements to IEC751 Class A, B and 1/3DIN
- For use from –50°C to +500°C
- Thin film construction
- Suitable for surface & immersion applications where protected
- Vibration resistant

Specifications:

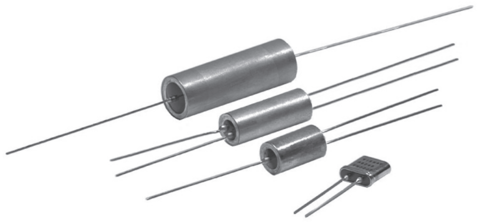
Sensor type:	Pt100 (100 Ohms @ 0°C)
Construction:	Thin film, 10mm tails
Temperature range:	-50°C to +500°C
Ice point resistance:	100Ω
Fundamental interval (0°C to 100°C):	38.5Ω (nominal)
Self-heating:	<0.5°C/mW
Thermal response:	0.1s
Stability:	±0.05%

Resistance	**Dimensions** (width x length)	**Tolerance Class**	**Allied code**	**RS order code**
Pt100	2 x 5.0mm	Class A	70646146	**611-7788**
Pt100	2 x 5.0mm	Class B	70646148	**611-7801**
Pt100	2 x 5.0mm	Class B	70642888	**290-5070** (Packet of 5)
Pt100	2 x 10mm	Class A	70643577	**362-9799**
Pt100	2 x 10mm	Class B	70641762	**237-1607**
Pt100	2.0 x 10mm	1/3DIN	70643578	**362-9812**
Pt100	2.0 x 2.3mm	Class A	70643579	**362-9834**
Pt100	2.0 x 2.3mm	Class B	70643580	**362-9840**
Pt100	2.0 x 2.3mm	1/3DIN	70643581	**362-9856**

Pt100 Elements (continued)

Resistance	**Dimensions** (width x length)	**Tolerance Class**	**Allied code**	**RS order code**
Pt100	1.2 x 1.6mm	Class A	70646834	**666-7362**
Pt100	1.2 x 1.6mm	Class B	70646831	**666-7353**

New Generation of Secondary Standards Hermetically Sealed High Precision Bulk Metal® Foil Technology Resistors with TCR of ± 2 ppm/°C, Tolerance of ± 0.001 % and Load Life Stability of ± 0.005 % (Metrology, Laboratory, Instrumentation, Industrial)



INTRODUCTION

The H series resistors are oil-filled, hermetically sealed ultra precision resistors and are used as secondary standards for metrology applications.

The hermetic sealing eliminates the ingress of moisture and oxygen, while the oil acts as a thermal conductor, thus eliminating the long-term degradation elements of unsealed resistors, while at the same time allowing the device to accept short periods of overload without degradation.

Vishay's Bulk Metal® Foil outperforms all other resistor technologies available today for applications that require precision and stability. When combined with the hermetic sealing and oil filling, the H series resistors become **the most precise and stable resistors available**.

With accuracies of 0.001 %, a resistance range from 5 Ω to 1.84 MΩ, and long term shelf life of less than 2 ppm, these devices are virtually secondary standards that can be carried in sets for daily or periodic calibration of factory measurement equipment.

The H series is available with laboratory and metrology level precision and long-term stability with additional in-house oriented processes such as: chip stabilization, special TCR plotting, additional treatments for ultra stability and special post manufacturing operations (PMO). (Please refer to the last page)

FEATURES

- Temperature coefficient of resistance (TCR): ± 2 ppm/°C typical (- 55 °C to + 125 °C, + 25 °C ref.). For ultra high performances (instrumentation and metrology) please refer to the last page
- Resistance range: 5 Ω to 1.84 MΩ (higher or lower values of resistance available)
- Vishay Foil resistors are not restricted to standard values; specific "as required" values can be supplied at no extra cost or delivery (e.g. 1K2345 vs. 1K)
- Power rating: 0.3 W to 2.5 W at + 25 °C (depending on model - see table 2)
- Tolerance: to ± 0.001 % (10 ppm)
- Load life stability to ± 0.002 % (20 ppm) at 25 °C, 2000 h at rated power
- **Load life stability can be considerably improved through in-house stabilization**
- **Shelf life stability: ± 2 ppm for at least 6 years (unaffected by humidity)**
- Electrostatic discharge (ESD) up to 25 000 V
- Rise time: 1 ns effectively no ringing
- Thermal stabilization time < 1 s (nominal value achieved within 10 ppm of steady state value)
- Current noise: 0.010 μV_{RMS}/V of applied voltage (< - 40 dB)
- Thermal EMF: 0.05 µV/°C typical
- Voltage coefficient: < 0.1 ppm/V
- Non-inductive: < 0.08 µH
- Non-inductive, non-capacitive design
- Non hot spot design
- Terminal finish available: lead (Pb)-free or tin/lead alloy
- Impervious to harmful environments - oil-filled
- Compliant to RoHS directive 2002/95/EC
- Prototype quantities available in just 5 working days or sooner. For more information, please contact foil@vishaypg.com
- For better performances (values, TCR, tolerance, stability), please see the HZ series

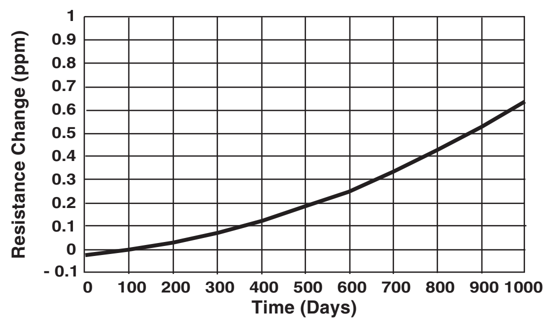
Pb-free Available
RoHS* COMPLIANT

TABLE 1 - TCR VS. RESISTANCE VALUE

RESISTANCE VALUE (Ω)	TYPICAL TCR AND MAX. SPREAD (- 55 °C to + 125 °C, + 25 °C ref.) (ppm/°C)
100 to < 1M84	± 2 ± 2.5
50 to < 100	± 2 ± 3.5
5 to < 50	± 2 ± 4.5

Note
- For maximum TCR < 1 ppm/°C, see VHP100 and contact application engineering

FIGURE 1 - SHELF LIFE - VHA518-11 12K9 VS. QHE



* Pb containing terminations are not RoHS compliant, exemptions may apply

FIGURE 2 - POWER DERATING CURVE

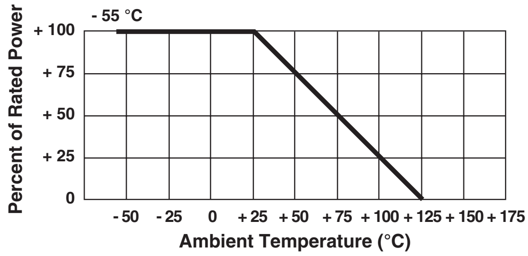
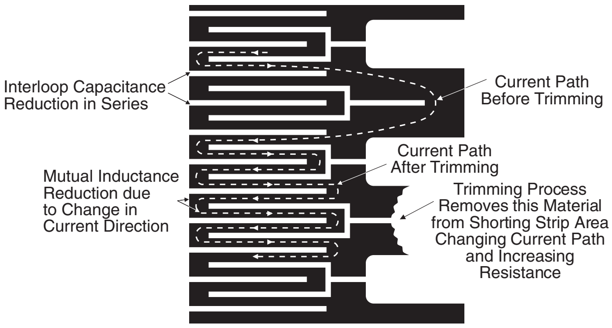


FIGURE 3 - TRIMMING TO VALUES

(Conceptual Illustration)



Note: Foil shown in black, etched spaces in white

FIGURE 4 - TYPICAL RESISTANCE/ TEMPERATURE CURVE

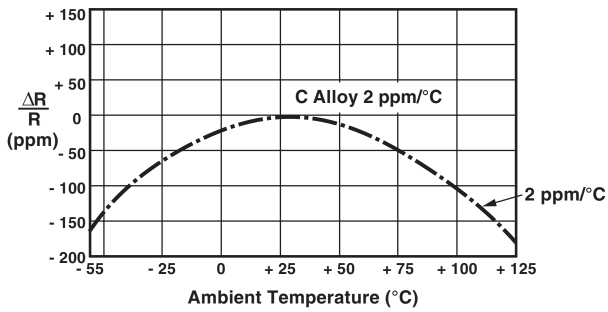


TABLE 2 - MODEL SELECTION

MODEL NUMBER	RESISTANCE RANGE (Ω)	STANDARD RESISTANCE TOLERANCE PER RANGE		MAXIMUM WORKING VOLTAGE (2)	POWER RATING at + 25 °C	AVERAGE WEIGHT (g)	CONSTRUCTION BRIEF	DIMENSIONS (3)	
		RANGE (Ω)	TIGHTEST (%)					INCHES	mm
VHP202	5 to 100K > 100K to 150K	1K to □ (1) 500 to < 1K 50 to < 500 30 to < 50 20 to < 30 10 to < 20 5 to < 10	± 0.001 ± 0.0025 ± 0.005 ± 0.01 ± 0.02 ± 0.05 ± 0.1	300	0.3 W 0.2 W	1.4	Oil-filled, tinned copper leads, nickel shell, kovar and glass header	W: 0.162 ± 0.020 L: 0.415 ± 0.020 H: 0.430 ± 0.020** LL: 1.000 ± 0.125 LS: 0.150 ± 0.010 (4) ST: 0.095 max.	4.11 ± 0.51 10.54 ± 0.51 10.92 ± 0.51 25.4 ± 3.18 3.81 ± 0.25 2.41 max.
VHA412	5 to 100K > 100K to 150K			250	0.3 W 0.2 W	4.6	Oil-filled, tinned copper leads, tinned brass shell, kovar and glass end bells	L: 0.625 ± 0.031 D: 0.375 ± 0.031 LL: 1.000 min.	15.88 ± 0.79 9.53 ± 0.79 25.4 min.
VHA414	5 to 200K > 200K to 335K			350	0.5 W 0.3 W	7.3		L: 1.000 ± 0.031 D: 0.375 ± 0.031 LL: 1.000 min.	25.4 ± 0.79 9.53 ± 0.79 25.4 min.
VHA512*	5 to 300K > 300K to 500K			350	0.75 W 0.4 W	6.3		L: 0.625 ± 0.031 D: 0.500 ± 0.031 LL: 1.000 min.	15.88 ± 0.79 12.7 ± 0.79 25.4 min.
VHA516-4* VHA516-5* VHA516-6*	5 to 400K > 400K to 668K 5 to 500K > 500K to 835K 5 to 600K > 600K to 1M			500	1.0 W 0.5 W 1.25 W 0.6 W 1.5 W 0.7 W	9.2		L: 1.000 ± 0.031 D: 0.500 ± 0.031 LL: 1.000 min.	25.4 ± 0.79 12.7 ± 0.79 25.4 min.
VHA518-7* VHA518-8* VHA518-9* VHA518-10* VHA518-11*	5 to 700K > 700K to 1M17 5 to 800K > 800K to 1M34 5 to 900K > 900K to 1M5 5 to 1.0M > 1.0M to 1M67 5 to 1.0M > 1.0M to 1M84			600	1.75 W 0.8 W 2.0 W 0.9 W 2.25 W 1.0 W 2.5 W 1.1 W 2.5 W 1.2 W	13.5		L: 1.500 ± 0.031 D: 0.500 ± 0.031 LL: 1.000 min.	38.1 ± 0.79 12.7 ± 0.79 25.4 min.

Notes

* Available in a 4-lead terminal

** 0.375 H available

See next page for numbered footnotes

FIGURE 5 - STANDARD IMPRINTING AND DIMENSIONS

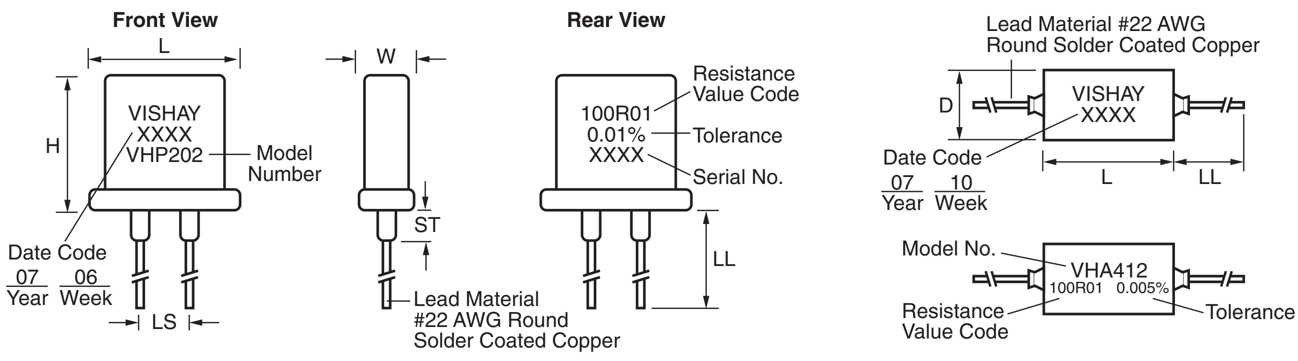


TABLE 3 - "H" SERIES SPECIFICATIONS

Stability (8)	
Load life at 2000 h	± 0.002 % (20 ppm) at 25 °C at rated power
Shelf life	± 2 ppm (0.0002 %) for at least 6 years
Current Noise	< - 40 dB
High Frequency Operation	
Rise time	1.0 ns without ringing
Inductance (L) (5)	0.1 µH maximum; 0.08 µH typical
Capacitance (C)	1.0 pF maximum; 0.5 pF typical
Voltage Coefficient	< 0.1 ppm/V (6)
Thermal EMF (7)	0.1 µV/°C maximum; 0.05 µV/°C typical; 1 µV/W maximum
Hermeticity	10^{-7} atmospheric cc/s maximum

Notes

(1) Upper end of resistance range varies with model selected (i.e. VHP202; the range is to 150 kΩ; VHA518-10, the range is to 1M67 Ω) per table 2
(2) Not to exceed power rating of resistor
(3) Insulating sleeve - a special case insulating plastic sleeve is available on VHA models. See table 4 for instructions on how to specify
(4) 0.200" (5.08 mm) lead spacing available - specify VH202J
(5) Inductance (L) due mainly to the leads
(6) The resolution limit of existing test equipment (within measurement capability of the equipment, or "essentially zero")
(7) µV/°C relates to EMF due to lead temperature difference and µV/W due to power applied to the resistor
(8) Load life ΔR maximum. Can be reduced through in-house oriented processes

POST MANUFACTURING OPERATIONS OR PMO FOR IMPROVED END OF LIFE

Many analog applications can include requirements for performance under conditions of stress beyond the normal and over extended periods of time. This calls for more than just selecting a standard device and applying it to a circuit. The standard device may turn out to be all that is needed but an analysis of the projected service conditions should be made and it may well dictate a routine of stabilization known as post manufacturing operations or PMO. The PMO operations that will be discussed are only applicable to Bulk Metal Foil resistors. They stabilize Bulk Metal Foil resistors while they are harmful to other types. Short time overload, accelerated load life, and temperature cycling are the three PMO exercises that do the most to remove the anomalies down the road. Vishay Bulk Metal Foil resistors are inherently stable as manufactured. These PMO exercises are only of value on Bulk Metal Foil resistors and they improve the performance by amounts that are small but significant when compared to the very tight tolerances. Users are encouraged to contact Vishay Foil applications engineering for assistance in choosing the PMO operations that are right for their application.

4/16/2019 8:05:47 AM

www.swagelok.com

Integral Bonnet Needle Valves

Part No.

B-1RS6MM-A

Part Description

Brass Integral Bonnet Angle-Pattern Needle Valve, 6 mm Swagelok Tube Fitting, Regulating Stem

Specifications

General	
Body Material	Brass
Cleaning Process	Standard Cleaning and Packaging (SC-10)
Connection 1 Size	6 mm
Connection 1 Type	Swagelok® Tube Fitting
Connection 2 Size	6 mm
Connection 2 Type	Swagelok® Tube Fitting
eClass (4.1)	37010203
eClass (5.1.4)	37010201
eClass (6.0)	37010203
eClass (6.1)	37010203
Feature	Angle Pattern
UNSPSC (10.0)	40141602
UNSPSC (11.0501)	40141602
UNSPSC (13.0601)	40141602
UNSPSC (15.1)	40141602
UNSPSC (17.1001)	40141600
UNSPSC (4.03)	40141602
UNSPSC (PGE)	401416AL
UNSPSC (SWG01)	40141602

! The complete catalog contents must be reviewed to ensure that the system designer and user make a safe product selection. When selecting products, the total system design must be considered to ensure safe, trouble-free performance. Function, material compatibility, adequate ratings, proper installation, operation, and maintenance are the responsibilities of the system designer and user.

Caution: Do not mix or interchange valve components with those of other manufacturers.

Industrial, Low-Pressure

Part No.

PGI-63L-FG250-LAOX

Part Description

Low Pressure Industrial Pressure Gauge, 63 mm, 0 to 250 mBar, Lower Mount, 1/4 in. MNPT

Specifications

General	
Body Material	316 Stainless Steel
eClass (4.1)	27200601
eClass (6.0)	27371814
Liquid Fill	Unfilled
Mounting Style	Lower Mount
Process Connection	1/4 in. Male NPT
UNSPSC (17.1001)	41110000
UNSPSC (4.03)	41112400
UNSPSC (PGE)	411124

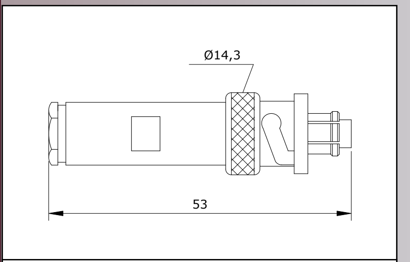
! The complete catalog contents must be reviewed to ensure that the system designer and user make a safe product selection. When selecting products, the total system design must be considered to ensure safe, trouble-free performance. Function, material compatibility, adequate ratings, proper installation, operation, and maintenance are the responsibilities of the system designer and user.

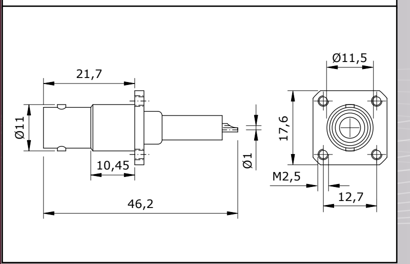
Caution: Do not mix or interchange valve components with those of other manufacturers.

Connectors

HIGHTECH

Bis 10kV / *Up to 10kV*





Stecker HVS10
Hochspannungsstecker
bis 10kV DC **00.220.858.9**

Stecker HVS10 komplett konfektioniert mit 3 Meter HV-Kabel HVC10 (wie im Original-Lieferumfang der HV-Netzgeräte bis 10kV enthalten)
00.220.858.901

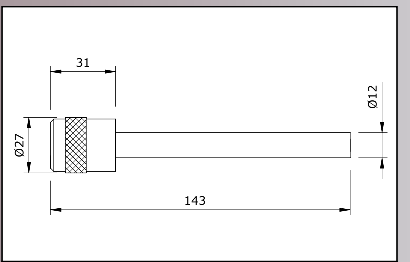
Plug (male) HVS10
high voltage plug up to 10kV DC
00.220.858.9

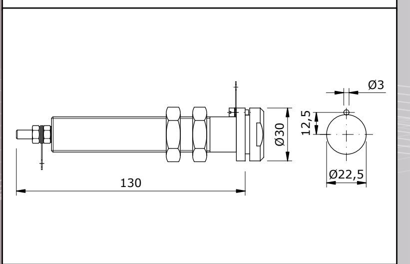
Plug (male) HVS10 ready-made with 3 meter HV cable 3 HVC10 (as included in the extent of delivery of HV power supplies up to 10kV)
00.220.858.901

Buchse HVB10
Hochspannungs-Einbaubuchse bis 10kV DC **00.220.854.9**

Plug (female) HVB10
high voltage panel jack up to 10kV
00.220.854.9

Bis 35kV / *Up to 35kV*





Stecker HVS35
Hochspannungsstecker bis 35kV DC
00.220.859.9

Stecker HVS35 komplett konfektioniert mit 3 Meter HV-Kabel HVC30 (wie im Original-Lieferumfang der HV-Netzgeräte bis 30kV enthalten)
00.220.859.901

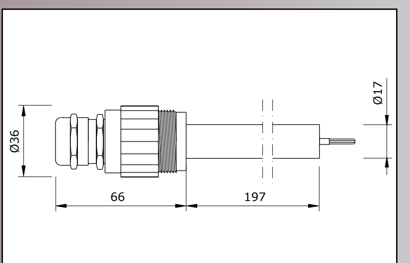
Plug (male) HVS35
high voltage plug up to 35kV DC
00.220.859.9

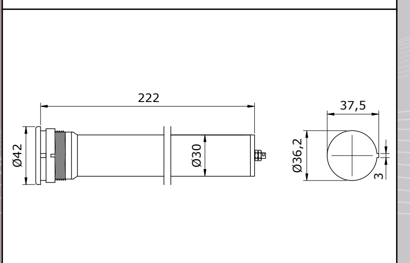
Plug (male) HVS35 ready-made with 3 meter HV cable 3 HVC30 (as included in the extent of delivery of HV power supplies up to 30kV)
00.220.859.901

Buchse HVB35
Hochspannungs-Einbaubuchse bis 35kV DC **00.220.855.9**

Plug (female) HVB35
high voltage panel jack up to 35kV
00.220.855.9

Bis 65kV / *Up to 65kV*





Stecker HVS65
Hochspannungsstecker bis 65kV DC
00.220.860.9

Stecker HVS65 komplett konfektioniert mit 3 Meter HV-Kabel HVC65 (wie im Original-Lieferumfang der HV-Netzgeräte bis 60kV enthalten)
00.220.860.901

Plug (male) HVS65
high voltage plug up to 65kV DC
00.220.860.9

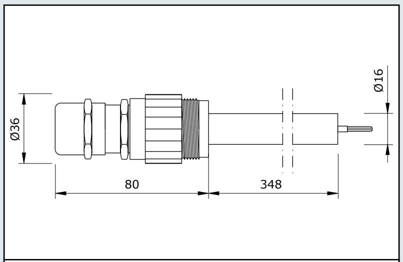
Plug (male) HVS65 ready-made with 3 meter HV cable 3 HVC65 (as included in the extent of delivery of HV power supplies up to 60kV)
00.220.860.901

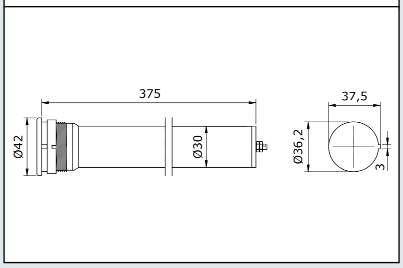
Buchse HVB65
Hochspannungs-Einbaubuchse bis 65kV DC **00.220.856.9**

Plug (female) HVB65
high voltage panel jack up to 65kV
00.220.856.9

HIGHTECH

Bis 100kV / *Up to 100kV*





Stecker HVS100	*Plug (male) HVS100*
Hochspannungsstecker bis 100kV DC **00.220.861.9**	*high voltage plug up to 100kV DC* ***00.220.861.9***
Stecker HVS100 komplett konfektioniert mit 3 Meter HV-Kabel HVC100 (wie im Original-Lieferumfang der HV-Netzgeräte bis 100kV enthalten) **00.220.861.901**	*Plug (male) HVS100 ready-made with 3 meter HV cable 3 HVC100 (as included in the extent of delivery of HV power supplies up to 100kV)* ***00.220.861.901***

Buchse HVB100	*Plug (female) HVB100*
Hochspannungs-Einbaubuchse bis 100kV DC **00.220.857.9**	*high voltage panel jack up to 100kV* ***00.220.857.9***

Stecker, Buchsen und Kabel für höhere Spannungen sind auf Anfrage ebenfalls verfügbar.
Auf Wunsch liefern wir Stecker und Kabel vorkonfektioniert in jeder gewünschten Länge.

Bei Nachbestellung von Steckern oder Buchsen für ältere Heinzinger-Netzgeräte geben Sie bitte immer die Typenbezeichnung und Seriennummer des Netzgerätes mit an.

Plugs (male and female) rated for higher voltages are available on request. On request, we supply preassembled plugs and cables in every required length.

When re-ordering male or female plugs for older Heinzinger power supplies, please always specify type and serial number of the power supply.

Heinzinger® power supplies supplies your world

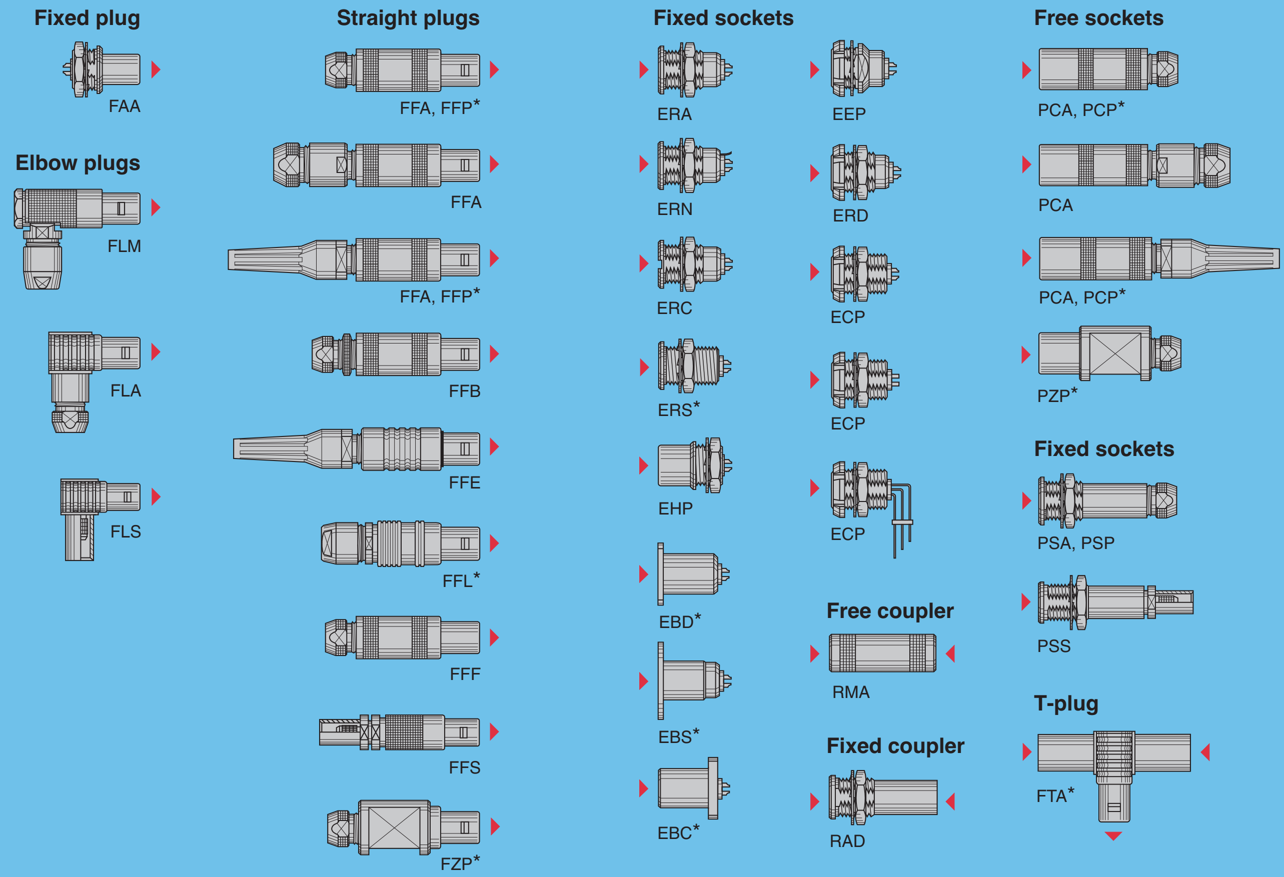
Anton-Jakob-Strasse 4
83026 Rosenheim
GERMANY

Tel.: +49 - 8031 - 2458 - 0
Fax: +49 - 8031 - 2458 - 58
www.heinzinger.com

S Series

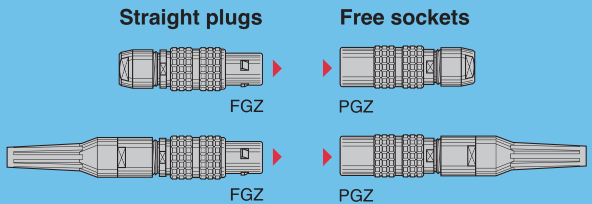
S series connectors have main features as follows:
- security of the Push-Pull self-latching system
- unipole types transmitting current up to 230 A and multipole types with up to 106 contacts
- 360° screening for full EMC shielding.
- solder or print contacts (straight or elbow)
- polarisation by stepped insert (half-moon) fitted with male and female contacts

Metal housing models (page 76)

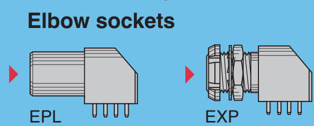


Note: * Contact LEMO for details.

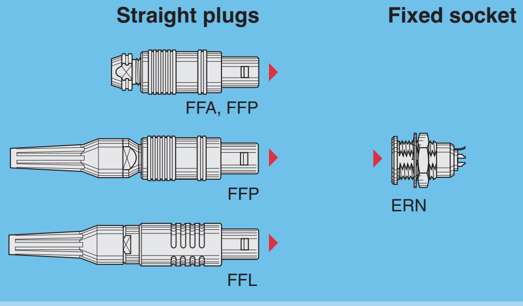
New design models (page 86)



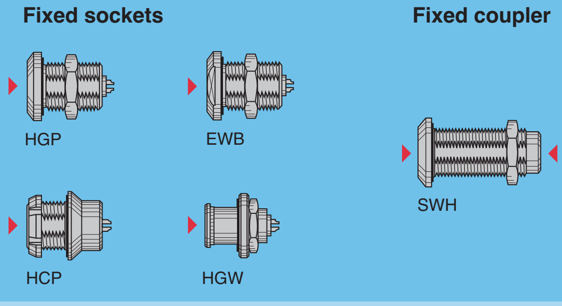
Elbow socket models (page 87)



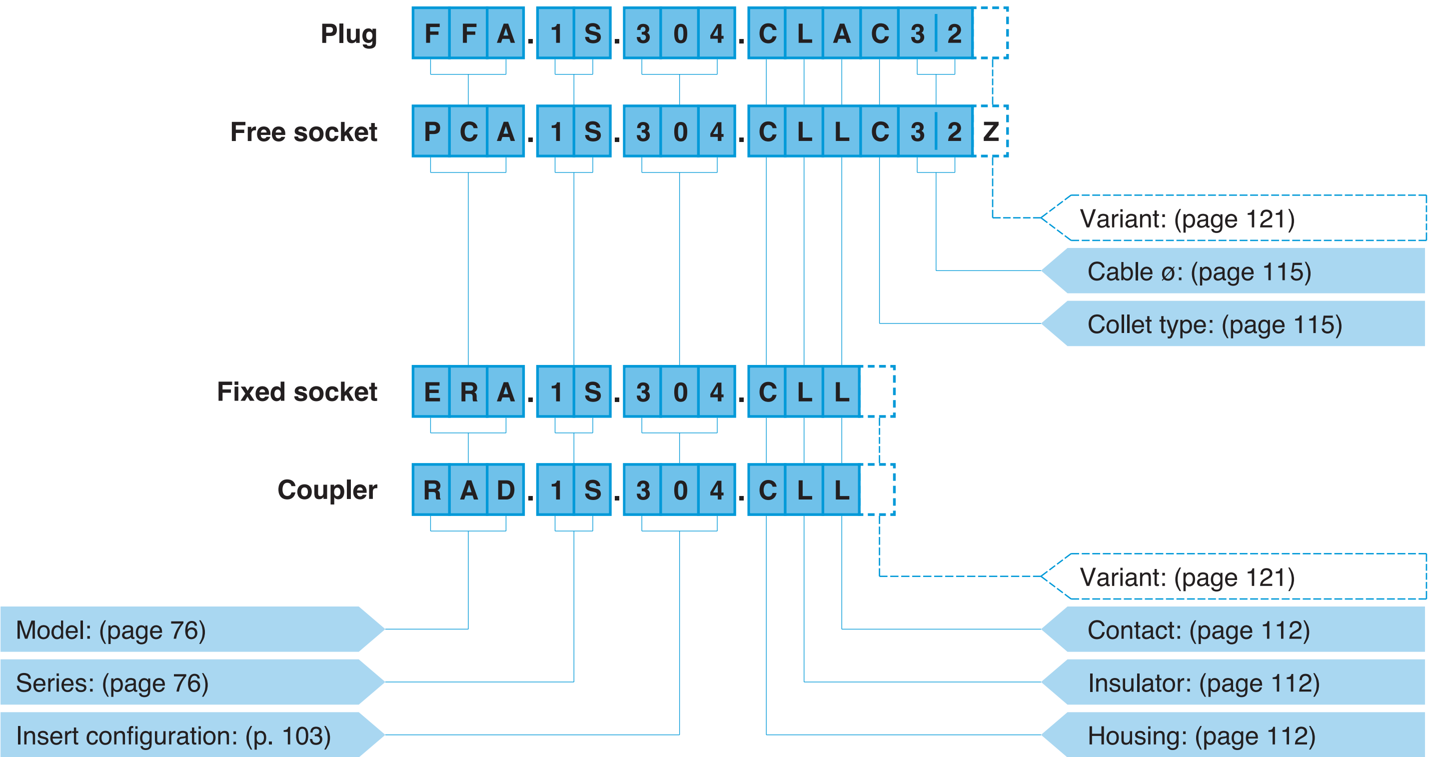
Plastic housing models (page 89)



Watertight or vacuumtight models (page 91)



Part Numbering System



FFA.1S.304.CLAC32 = straight plug with cable collet, 1S series, multipole type with 4 contacts, outer shell in chrome-plated brass, PEEK insulator, 2 male and 2 female solder contacts, C type collet for a 3.2 mm diameter cable.

PCA.1S.304.CLLC32Z = free socket, with cable collet, 1S series, multipole type with 4 contacts, outer shell in chrome-plated brass, PEEK insulator, 2 female and 2 male solder contacts, C type collet for a 3.2 mm diameter cable and nut for fitting a bend relief.

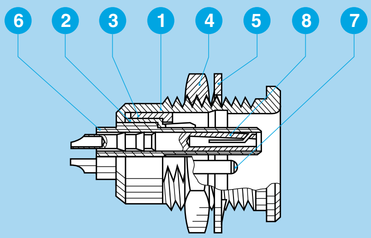
ERA.1S.304.CLL = fixed socket, nut fixing, 1S series, multipole type with 4 contacts, outer shell in chrome-plated brass, PEEK insulator, 2 female and 2 male solder contacts.

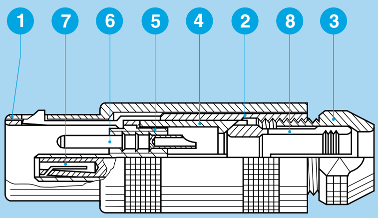
RAD.1S.304.CLL = straight coupler, nut fixing, 1S series, multipole type with 4 contacts, outer shell in chrome-plated brass, PEEK insulator, 2 female and 2 male contacts each end.

Part Section Showing Internal Components

Fixed socket

1. outer shell
2. earthing crown
3. retaining ring
4. hexagonal nut
5. locking washer
6. insulator
7. male contact
8. female contact





Straight plug

1. outer shell
2. latch sleeve
3. collet nut
4. centre-piece
5. insulator
6. male contact
7. female contact
8. collet

Metal housing models

Technical Characteristics

Mechanical and Climatical

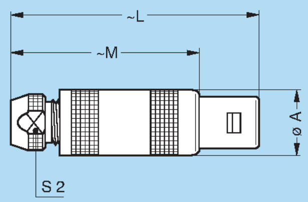
Characteristics	Value	Standard
Endurance[1]	> 5000 cycles	IEC 60512-5 test 9a
Humidity	up to 95% at 60° C	
Temperature range	- 55° C, + 250° C	
Resistance to vibrations	10-2000 Hz, 15g	IEC 60512-4 test 6d
Shock resistance	100 g, 6 ms	IEC 60512-4 test 6c
Salt spray corrosion test	> 1000h	IEC 60512-6 test 11f
Protection index (mated)	IP 50	IEC 60529
Climatical category	55/175/21	IEC 60068-1

Electrical

Characteristics		Value	Standard
Shielding efficiency	at 10 MHz	> 75 dB	IEC 60169-1-3
	at 1 GHz	> 40 dB	IEC 60169-1-3

Note:
The various tests have been carried out with FFA and ERA connector pairs, with chrome-plated brass shell and PEEK insulator.
Detailed electrical characteristics, as well as materials and treatment are presented in the chapter Technical Characteristics on page 182.
[1] see page 189, contact resistance after mating cycles. See page 185, mechanical endurance latching force.

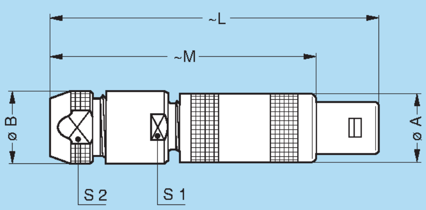
FFA Straight plug, cable collet



Reference		Dimensions (mm)			
Model	Series	A	L	M	S2
FFA	**00**	6.4	26.0	18.0	4.5
FFA	**0S**	9.0	34.5	24.5	6.5
FFA	**1S**	12.0	42.5	31.5	8.5
FFA	**2S**	14.8	52.0	40.0	11.0
FFA	**3S**	17.8	61.0	46.0	14.0
FFA	**4S**	24.8	77.0	59.0	19.0
FFA	**5S**	35.0	103.0	78.0	29.0
FFA	**6S**	46.0	106.0	81.0	38.0

M1 Cable assembly (pages 175 to 177)

FFA Straight plug with oversize cable collet [1]

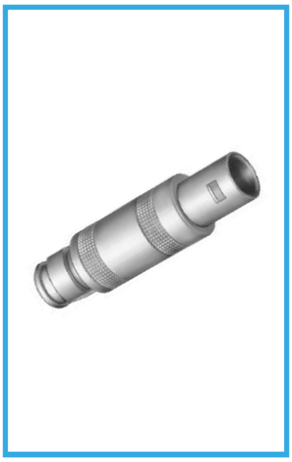


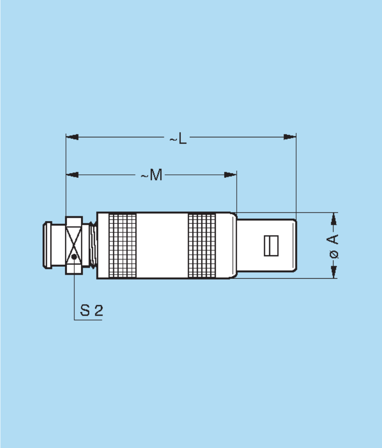
Reference		Dimensions (mm)					
Model	Series	A	B	L	M	S1	S2
FFA	**00**	6.4	8.0	34.0	26.0	7.0	6.5
FFA	**0S**	9.0	10.0	45.5	35.5	9.0	8.5
FFA	**1S**	12.0	13.0	57.0	46.0	12.0	11.0
FFA	**2S**	14.8	18.0	67.0	55.0	14.0	14.0
FFA	**3S**	17.8	21.0	85.0	70.0	19.0	19.0
FFA	**4S**	24.8	31.8	107.0	89.0	28.5	29.0
FFA	**5S**	35.0	41.8	138.0	113.0	37.5	38.0

M2 Cable assembly (pages 175 and 178)

Note: [1] correspond to K type of collet, the fitting of oversize collets onto this model allows them to be fitted to the cables that can be accommodated by the next housing size up (see page 115).

FFA Straight plug, cable collet and nut for fitting a bend relief [1)]



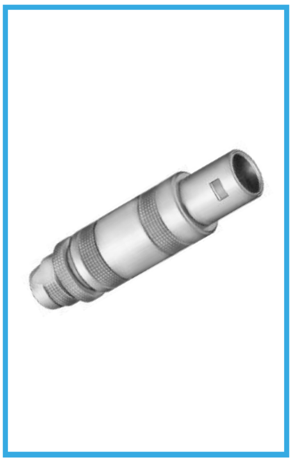


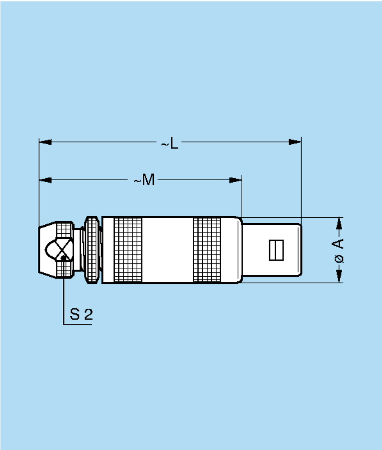
Reference		Dimensions (mm)			
Model	Series	A	L	M	S2
FFA	**00**	6.4	26.0	18.0	6
FFA	**0S**	9.0	34.5	24.5	7
FFA	**1S**	12.0	42.5	31.5	9
FFA	**2S**	14.8	52.0	40.0	12
FFA	**3S**	17.8	61.0	46.0	14
FFA	**4S**	24.8	77.0	59.0	20

M1 Cable assembly (pages 175 and 176)

Note: 1) to order, add a «Z» at the end of the reference.
The bend relief must be ordered separately (see page 145).

FFB Straight plug, cable collet and safety locking ring



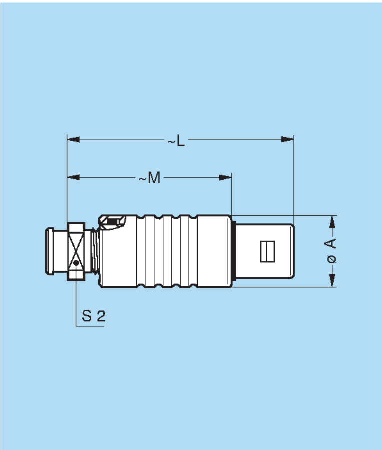


Reference		Dimensions (mm)			
Model	Series	A	L	M	S2
FFB	**0S**	9.0	36.8	26.8	6.5
FFB	**1S**	12.0	45.0	34.0	8.5
FFB	**2S**	14.8	55.5	43.5	11.0
FFB	**3S**	17.8	65.0	50.0	14.0

M1 Cable assembly (pages 175 and 176)

Note: nut for fitting a bend relief (available only for size 1S).

FFE Straight plug, cable collet, front seal and nut for fitting a bend relief [1)] (protected to IP54 when mated)



Reference		Dimensions (mm)			
Model	Series	A	L	M	S2
FFE	**00**	7.4	26.0	18.0	6
FFE	**0S**	10.0	34.5	24.5	7
FFE	**1S**	13.0	42.5	31.5	9
FFE	**2S**	16.0	52.0	40.0	12
FFE	**3S**	19.0	61.0	46.0	14

M1 Cable assembly (pages 175 and 176)

Note: 1) to order, add a «Z» at the end of the reference.
The bend relief must be ordered separately (see page 145).

Multiconductor cables PTFE

Mehradrige PTFE Kabel

Multiconductor shielded cable
Teflon Polytetrafluorethylene
according to MIL W 16878/4 and MIL W 27500

Wire cross section	AWG 24 – 19
Operating voltage	600 V
Testing voltage	3400 V
Sheath colour	white
Wire colours	according to UL-Style
Operating temperature	-50 °C to +200 °C

Mehradrige geschirmte
Teflon-PTFE-Leitungen
In Anlehnung an MIL W 16878/4 und MIL W 27500

Aderquerschnitt	AWG 24 – 19
Betriebsspannung	600 V
Prüfspannung	3400 V
Mantelfarbe	weiß
Aderfarbfolge	nach UL-Style
Betriebstemperatur	-50 °C bis +200 °C

Part No. Bestell-Nr.	Wire number Aderanzahl	Structure I Leiteraufbau		Screen / Abschirmung		Outer diameter Außen-Ø	Suitable sizes passende Größen
		Art	mm	Mat.	Coverage Bedeckung %	mm	
020 240	2	CuAg	0,6	CuAg	85	3,30	0 – 2
040 240	4	CuAg	0,6	CuAg	85	3,70	0 – 3
106 240	6	CuAg	0,6	CuAg	85	4,40	1 – 3
108 240	8	CuAg	0,6	CuAg	85	5,10	1 – 4
110 240	10	CuAg	0,6	CuAg	85	5,70	1 – 4
112 240	12	CuAg	0,6	CuAg	85	6,40	1 – 4
214 240	14	CuAg	0,6	CuAg	85	6,00	2 – 4

Multiconductor shielded cable
Teflon Polytetrafluorethylene
according to MIL W 16878/4 and MIL W 27500

Wire cross section	AWG 26 – 19
Operating voltage	600 V
Testing voltage	3400 V
Sheath colour	white
Wire colours	according to UL-Style
Operating temperature	-50 °C to +200 °C

Mehradrige geschirmte
Teflon-PTFE-Leitungen
In Anlehnung an MIL W 16878/4 und MIL W 27500

Aderquerschnitt	AWG 26 – 19
Betriebsspannung	600 V
Prüfspannung	3400 V
Mantelfarbe	weiß
Aderfarbfolge	nach UL-Style
Betriebstemperatur	-50 °C bis +200 °C

Part No. Bestell-Nr.	Wire number Aderanzahl	Structure I Leiteraufbau		Screen I Abschirmung		Outer diameter Außen-Ø	Suitable size passende Größen
		Art	mm	Mat.	Coverage Bedeckung %	mm	
002 260	2	CuAg	0,5	CuAg	80	2,80	0 – 2
004 260	4	CuAg	0,5	CuAg	80	3,50	0 – 2
060 260	6	CuAg	0,5	CuAg	80	4,10	0 – 3
108 260	8	CuAg	0,5	CuAg	80	5,15	1 – 3
110 260	10	CuAg	0,5	CuAg	80	5,20	1 – 4
112 260	12	CuAg	0,5	CuAg	80	5,30	1 – 4
114 260	14	CuAg	0,5	CuAg	80	5,50	1 – 4

Please request for the active available lengths.

Bitte fragen Sie nach den aktuell verfügbaren Längen.