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UM - Series

Multichannel Precision Voltage Source

Manual_UM_LN_SW_V2024a
6. June 2024

User Manual

2024, Rev. A

UM 1-14 (Options -LN, -SW), UM 1-32 LN

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TABLE OF CONTENTS

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1. General Description:

The UM-series of ultrastable voltage sources are intended for precision applications, in which very good short and long term constancy is required (see graphs in appendix and specifications for details). Very small fluctuation in time periods of seconds, minutes and hours on a 10^{-8} level are achieved. They surpass standard PC-controlled voltage sources and closely reach the limits of what is technically possible.
There are three primary channels (12V or 14V range, optionally 32V range), each of them can be programmed with a resolution of approx. 1 µV (or approx 4V in case of 32V range). Three "slave" or "secondary" outputs provide a smaller voltage range (diminished by approx. a factor of 4) and are coupled to the primary channels by internal (fixed) voltage dividers (note, that the 32V version features only primary channels). The version UM 1-14 features an unipolar output range (zero to -14V by default). The version UM 1-14 - LN (low noise) is an improved version with even smaller fluctuations and higher stability. The version UM 1-14 - LN-SW features a switchable polarity, e.g. for changing from positive to negative ions in an ion trap (e.g. matter ↔ antimatter).

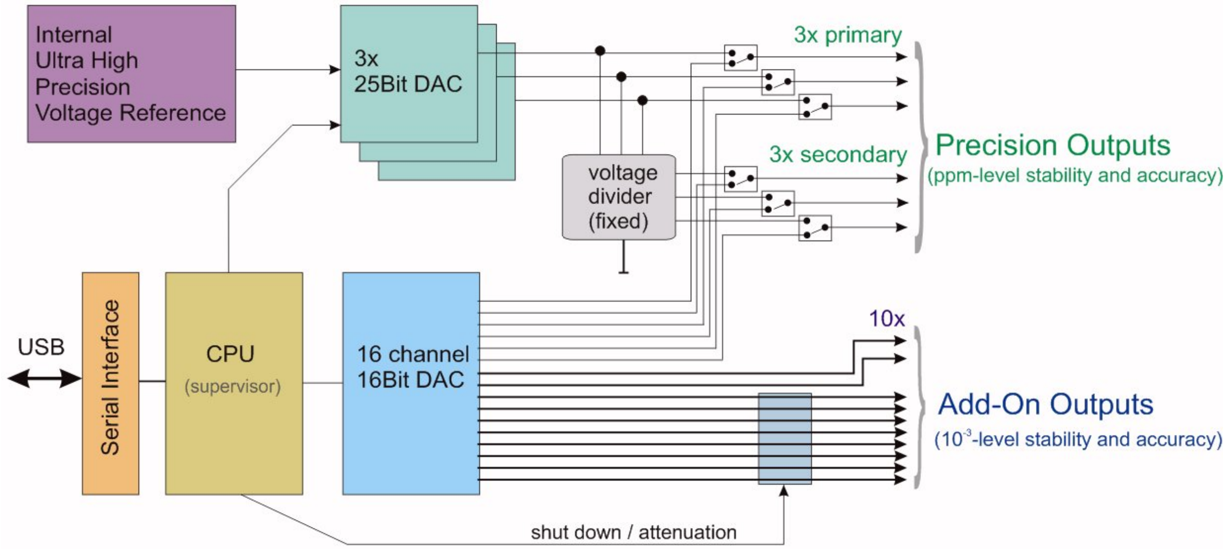

Fig. 1: Internal Block Diagram

Additionally, 10 add-on auxiliary channels with a coarse resolution are available, which are intended for applications, for which there is no need for high stability.
All output channels feature different operating modes. The ultra high precision channels can be used in an **"ultra high precision mode"** or a **"fast mode"**. The latter does not have high precision, but inhibits faster switching times. In ion trap experiments the "fast mode" is normally used for ion transport, whereas the "ultra high precision mode" is used in time periods when highest precision is required within the respective precision measurement cycles. Switching between the modes is accomplished by software commands.
Furthermore, the Add-On channels can be operated in a normal mode, a shut down mode and a low-noise "attenuated" mode. The latter provides smaller voltage steps (~1 µV) at expense of decreased voltage range.
For control of the device a **LabVIEW** based graphical user interface is provided, which has completely open source text and makes control and integration into existing projects easy and convenient. The ASCII based command language allows also for easy control of the device, using e.g. **MATLAB** or **Python** or even standard COMPORT-style text based terminal programs.
Taking the application of precision experiments like ion traps into consideration, the UM voltage source provides two additional features. One is the complete galvanic isolation of the control input (USB connection) connecting the device to a PC. This allows floating the device and avoids ground loops and antenna effects to a high degree. Secondly the housing and internal structure are designed aiming at small size and ruggedness against external magnetic fields. As a result, a high resistivity

against external magnetic fields up to of 50mT is achieved, allowing to locate the device in proximity to a superconducting magnet or other strong magnetic sources. This greatly minimizes antenna and specially thermoelectric effects caused by long cabling, which at precision ion trapping setups is often a major problem.

Fig. 2
The device consists of a mains adaptor and the voltage source itself. This split setup allows for positioning the voltage source in close proximity to sources of magnetic fields (the mains adaptor must not be placed into a magnetic field).

Below are examples of short term drifts depected, referring to the UM 1-14 standard version. The "LN"-Version features even lower voltage variations (see section 5). For further information please refer to specifications page and fluctuation graphs (p.16, 17).

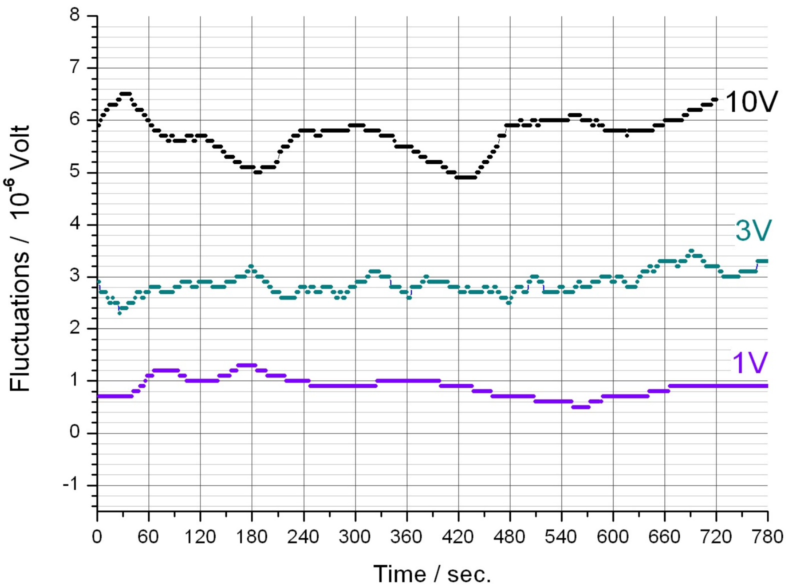

Fig. 3: UM 1-14, standard version, drift measurements. Data were taken within time periods of several minutes for various output voltages at primary and secondary outputs. Note, that real-world measurements (like shown above) intrinsically add additional noise or fluctuations. Therefore the true output fluctuations of the UM 1-14 devices are somewhat better than the measured data depicted above. Note also that the *low drift version* **'LN'** features further reduced fluctuations (see fig. 13 to 18 below).

The data shown above were taken using the following measurement schemes:
10V: Channel A of UM 1-14 versus 10V-Output of precision reference DC 1-10, measured with a Prema 5017 high precision multimeter in 0.3V range, 4s averaging time.
3V: Channel A' (secondary) of UM 1-14, directly measured with a Prema 5017 high precision multimeter in 3V range, 4s averaging time.
1V: Channel A' (secondary) of UM 1-14 versus 1V-Output of precision reference DC 1-10, measured with a Prema 5017 high precision multimeter in 0.3V range, 4s averaging time.

2. Installation

2.1. Mechanical and Electrical Installation

<u>General remarks</u>
As shown in fig. 2, the device consists of a mains adaptor and the voltage source itself. This split setup allows for positioning the voltage source in relatively close proximity to sources of magnetic fields, whereas the mains adaptor (like any other mains adaptor) needs to be located away from such, due to the necessity to avoid saturation in magnetic materials like the mains transformers. Provide free air cooling of the mains adaptor and do not block the case venting holes. The connection to the voltage source itself is provided through a customized DIN cable (with "type 8" connectors on both sides). Preferably use the cable mating to the corresponding voltage source (labelled with serial number).
The voltage source should be located in a place, which does not exhibit strong temperature variations. Values for residual voltage variations are given in the specifications. From them it can be seen that a temperature regulated environment (e.g. smaller 0.5K peak-peak variations) will result in superb small temporal voltage drifts. This results primarily from the reduction of thermoelectric effects.

<u>Connecting to mains power:</u>
Connect the mains adaptor to the mains power supply by using an appropriate power cord, being properly wired and providing a grounded outlet. The power cord must be suited with respect to possible load currents and should be rated to at least 2A current.

<u>Cabling of voltage outputs:</u>
The high precision output voltages (3 primary A, B, C and 3 secondary A', B', C', if present) are offered at six gold-plated 4mm (banana-type) sockets, and six pins of the 37pole connector (see pinout below). Note that the secondary outputs are not available for device versions exceeding +/-14V range on the primary channels.

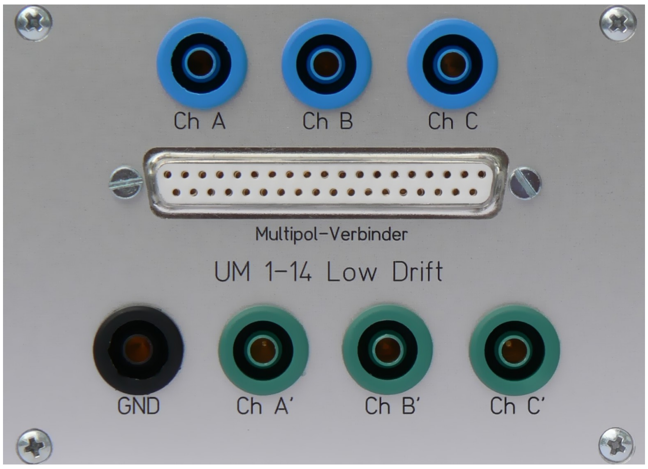

Fig 4: Front plate with output connectors

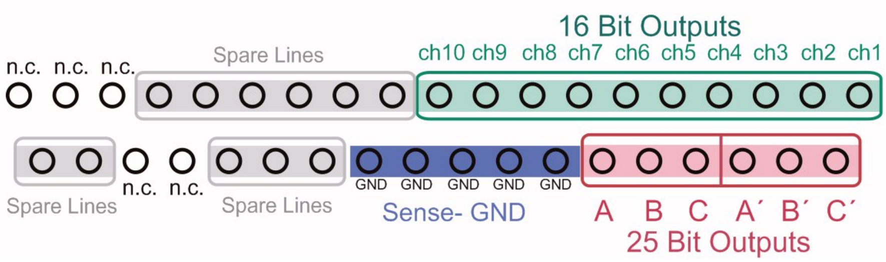

Fig 5: Pin assignment of 37-pole connector, view on front plate. Note that the secondary outputs A', B', C' are not available for device versions exceeding +/-14V range on the primary channels.

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The Sense-GND input is used to provide compensation of offsets, which might appear e.g. due to different temperatures at an experimental setup. The voltage which is programmed by the user always refers to Sense-GND (see also diagram in section 3.2). The latter therefore can also be used as offset-input. However, it should be noted that the maximum voltage difference between Sense-GND and the case cannot exceed about 0,7V due to clamping/protection diodes. Please contact manufacturer, in case higher offset voltages are required.
For optimum voltage stability (low drifts and low temporal degradation) cables of high quality should be used for connecting to this device. This applies for the 4mm connectors as well as for the 37pole connector. Lines leading to the 37pole connector may use a shielded cable in order to avoid unwanted noise pickup. The cable shield can alternatively be connected to case GND or Sense-GND.
To avoid thermoelectric effects, all connected cables should be made of the same material. This is an important point, since thermoelectric voltages are in many cases the main reason for residual voltage fluctuations on a time scale of seconds. Note, that even common copper alloys can easily exhibit thermoelectric coefficients of ~1µV/K, dissimilar metals around 10 to 20µV/K. That means in practice, that great care has to be applied to use exactely the same cable type (same manufacturer, same time of production) for GND and signal lines in order to suppress alloy-depending effects.

<u>USB connection:</u>
Use a standard type-A-B connection cable (USB 2.0 standard) to connect the device to the control computer. The cable is galvanically isolated from the rest of the UM device. After connecting to a PC under Windows XP, the "Found New Hardware Wizard" should open (see next section for detailed description), regardless if the device is already switched on, since the corresponding USB receiver inside the UM is powered by the USB bus itself, galvanically isolated from the remaining device and therefore autonomous. Cable length can be extended using an appropriate USB hub or repeater.

<u>RS 232-Connection</u>
In case this option is installed a serial connection via RS 232 cable may be used to control the device. The UM acts in this case as a DCE device. It uses the standard 3-wire protocol (only RxD, TxD and GND) with data format 9600 8N1 (i.e. baud rate at 9600 bits per second, 8 data bits, no parity bit, 1 stop bit) and no flow control. Use a standard RS 232 connection cable (e.g. SubD 9, male-female) in order to connect to a control PC (acting as DTE device). Cable length should not exceed 8m to ensure safe data transmission. Note that the RS 232 connection socket is <u>not</u> galvanically isolated from the rest of the device, in contrast to the USB connector.

Eventually use a commercially availabe RS232 optical isolator to provide galvanical isolation in case required. Intentionally, the data transmission rate is with 9600 Baud kept very low, to provide good compatibility with practically all commercially availabe RS232 optical isolators.

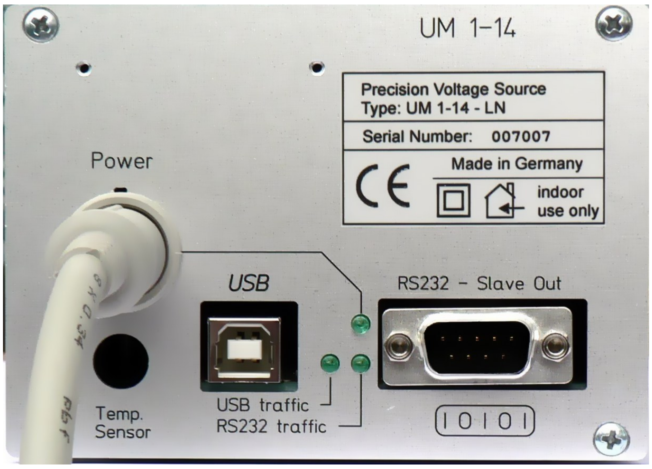

Fig 6: Rear side of voltage source. The power connector to mains supply is visible, the USB socket, the hole for an optional temperature sensor and the input/output for serial RS 232 communication.
3 LEDs indicate correct power supply and traffic on the communication lines.

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Power Connection
Connect the voltage source with its mains adaptor with the provided 8-lead power connector cable (DIN type 8). Please observe that a very *gentle* handling of these cables is required in order not to create cable breaks or short cuts. Attention: Measuring the voltages on the non-isolated Pins of the cable connectors with a Multimeter may easily lead to short cuts, blowing the protection fuses.

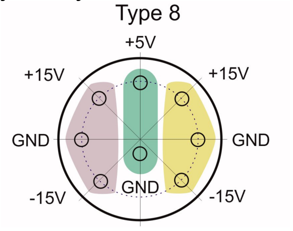

Fig 7: Pinout of power connector (DIN type 8). Actual voltages may vary depending on device version.

Note, that UM devices with range higher than 14V are being delivered with a specialized 25pole Sub-D supply cable.

2.2 Software installation

2.2.1 USB-Driver

The UM device uses the USB bus for connecting to a control PC. After connecting the UM device with a standard USB cable (USB 2.0 compatible) to the control PC, latest Window^{TM} versions (Win10, Win11) automatically detect the USB receiver inside the UM device and install corresponding drivers automatically. Note, that this may take about 60 seconds. Beware, **not to interrupt this process**.
In case of older Windows^{TM} versions, like XP the "Found New Hardware Wizard" under Windows may open up. Follow the instructions to identify the connected device and install drivers, or follow the described steps below. This installation will install the USB CDM drivers from FTDI Ltd., which is the manufacturer of the USB bus interface circuitry.
The supplied installation CD provides suitable drivers for operation under Windows XP. Later drivers, also for different other operating systems (Linux, Mac OS, Windows 7 oder later) can be downloaded from https://ftdichip.com/drivers/

USB driver installation on older Windows^{TM} versions:

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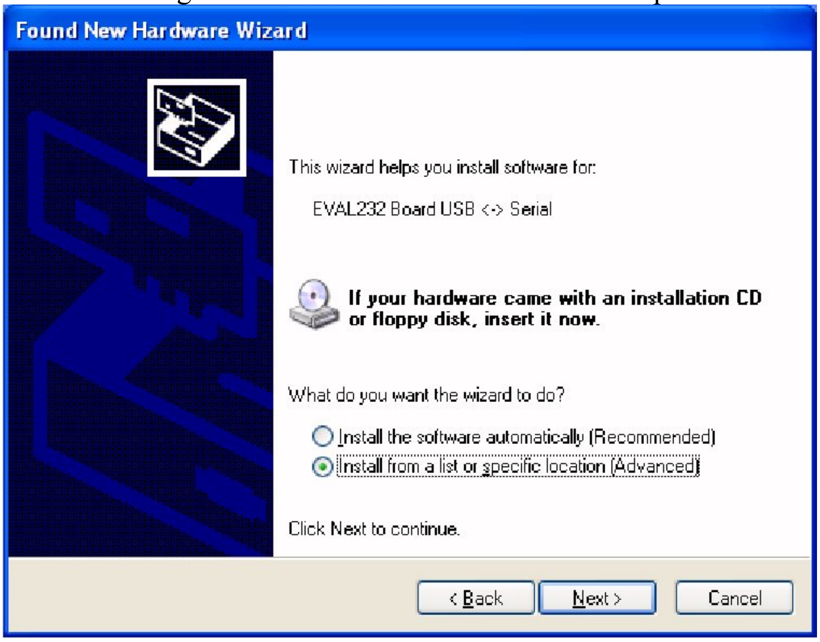
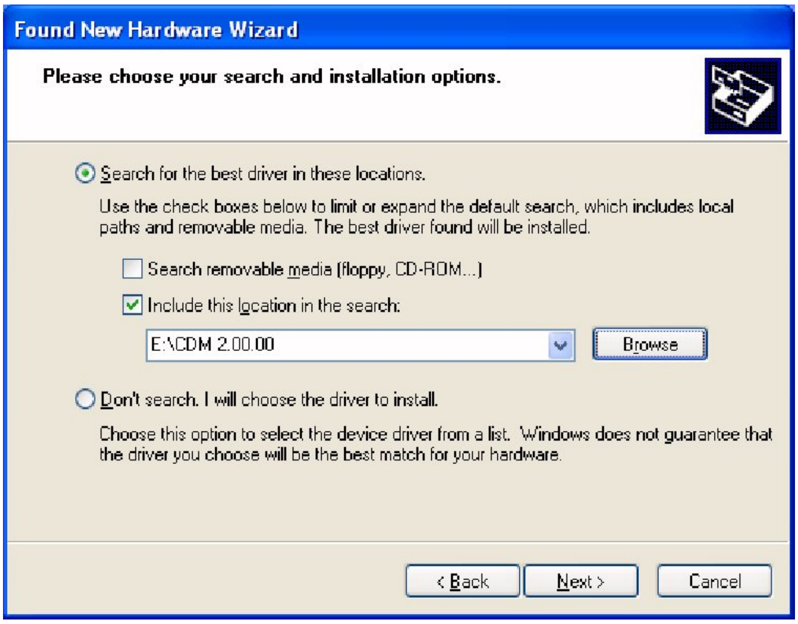
In the depicted window you need to activate the last button “**No, not this time**” and continue with “Next” in order to take the driver from a certain location.
In the following window choose “Install from a list or specific location” => “Next”



Afterwards choose “Search for the best driver in these locations” and “Include this location in the search”. Browse now the Installation CD and select the appropriate path (…/ USB-Driver/CDM 2.00.00) with USB drivers.



Click “OK” and “Finish” to complete the first driver installation.

After a few seconds the first window will show up <u>again</u> (“Found New Hardware Wizard”). This is because the drivers come in <u>two</u> separate parts, which **both** have to be installed. Go through the installation steps in the same way as before. After completion, the USB drivers are ready for use. Windows usually recommends restarting Windows now, but for immediate use one can skip this point. Nevertheless the PC should be restarted at a later point and latest before installing any other new piece of hardware or software.

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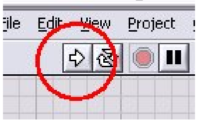
2.2.2 LabVIEW™ control program

Assuming that the LabVIEW™ development environment is available on the control PC, copy the path containing the LabVIEW™ source code VI's from the installation CD to a proper place of your choice on a local drive. By double-clicking on the file "UM 1-14 v2015.vi"
the control panel for the device will open, which can immediately be started by clicking on the



start-arrow in the upper left corner.

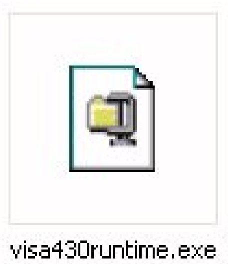
See next section for more details about operating the control program.

Runtime Version
In case that the LabVIEW™ development software is **not** available on the PC controlling the device, there is a second option. The so-called "LabVIEW™ run time engine" can be installed and the application program (containing the control software for the device) can be run subsequently as executable file. In this case modifications of the control software or implementation in own programs are not possible but the completed software can be run unchanged in the version as it is. Please contact manufacturer for more details and possibilities.
To install, run the **LabVIEW™ Runtime Installer Wizard**, and follow the corresponding instructions.

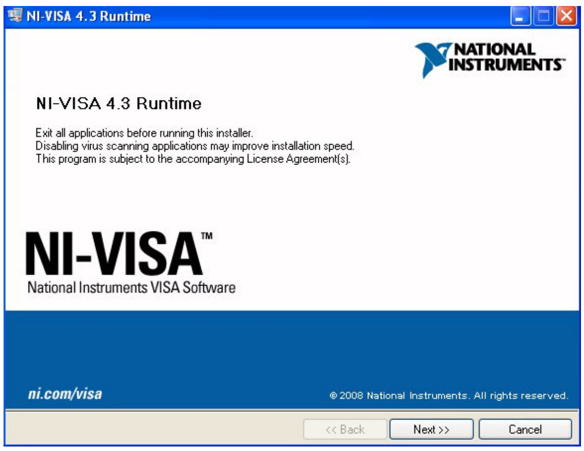
RuntimeEngine File Icon

You will be requested to choose an installation directory and location for unzipping the required files.

Furthermore (in case not installed before) the **National Instruments VISA drivers** need to be



RuntimeEngine File Icon



installed, which enable the LabVIEW™ software access to the PCs hardware resources.
After completion of these two installations, the control program can be run as executable file.

2.2.3 Self-written control programs

After establishing the USB connection, one may communicate from a control PC with the UM device using simple ASCII commands. Programming languages like **Python** or **MATLAB** support communication through COMPORTs (USB in COMPORT mode), in which ASCII text strings are being sent and received. A detailed description of all commands can be found in the appendix. Most importantly, the **set-voltage** command sets a certain voltage on a specified output.
Its structure looks like:
DDDD CHXX Y.YYYYYYY

where DDDD identifies a certain UM device being connected to the PC (like DDDD = UM43 for a device with serial number 0070**43**),
where CHXX identifies a certain channel (e.g. XX = 17 for channel number 17)
and where Y.YYYYYYY is a decimal 8-digit number between 0 and 1, which represents the 'scaled' voltage.

"0.0000000" represents the minimum voltage (e.g. -14V in case of a device with -14V to 0V range), "1.0000000" the maximum possible value (e.g. 0V).
The manufacturer provides a calibration file, in which parameters are stored, in order to correct deviations (offset, non-linearities) from an ideal behaviour.

The formular, to create the Y.YYYYYYY value using the correction parameters is:

$$Y.YYYYYYY = \left((U_{out}-a_0)/a_1 \ - \ a_2 \left((U_{out}-a_0)/a_1\right)^2 \right) / (-14)$$

where U_{out} is the desired voltage (unit: volts), which is expected on a certain channel.
The three parameters a_0, a_1, a_2 are stored in clear ASCII decimal numbers in the corresponding calibration file, which is found on the CD, and memory stick accompanying the UM delivery.
The calibration text file can also be retrieved from the manufacturer in case it got lost.

The principle, to store calibration data outside the device (and not inside) makes it in many cases convenient, to perform a re-calibration later and furthermore makes it easier to correct for finite output resistances without changing the UM device memory.

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3. Operation and Control

3.1 Software

3.1.1 LabVIEW Control

After starting the LabVIEW™ main VI file (named UM 1-14 v2015.vi) or compiled executable program, the following user surface will appear, which can be operated in a mostly intuitive style.

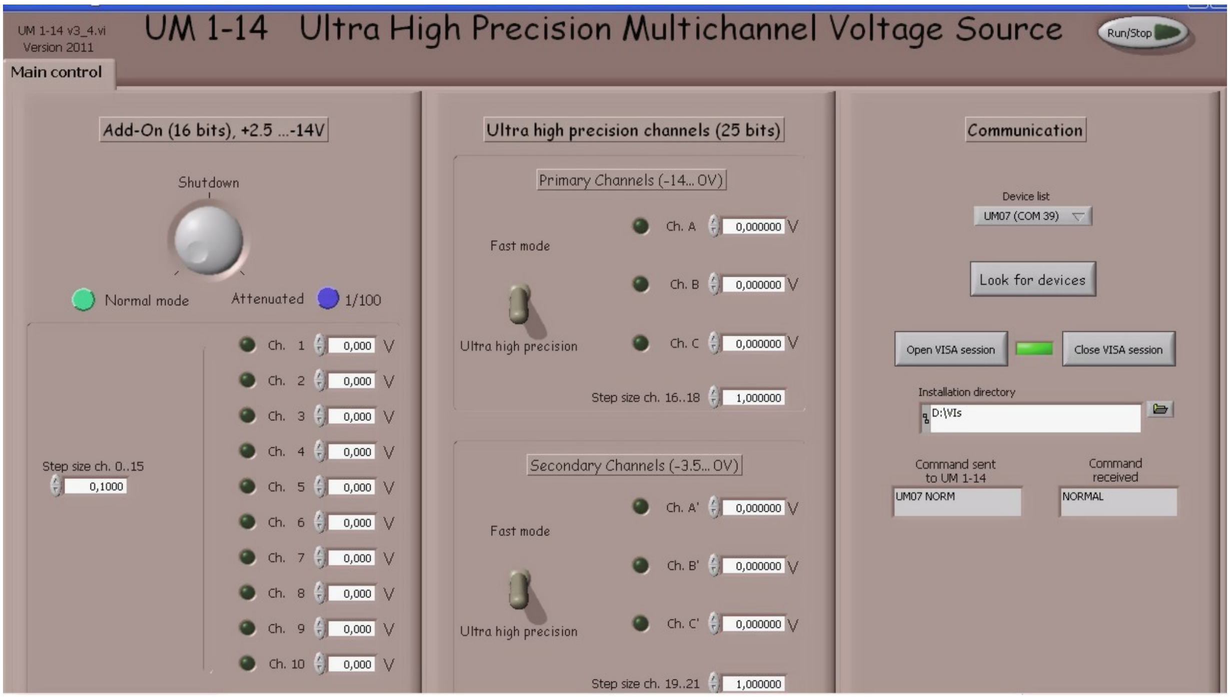
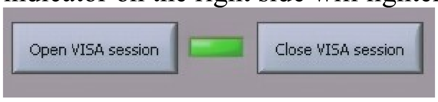


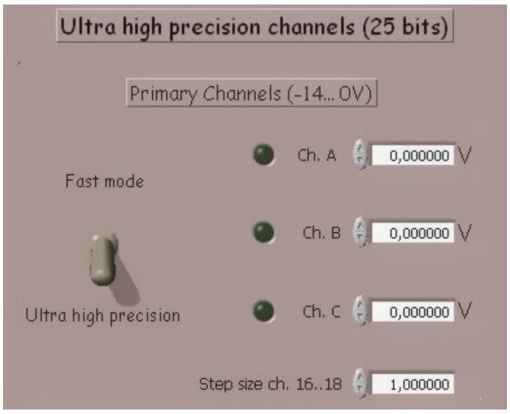
Fig. 8: Screenshot of the user surface.

While starting up, the program will search for devices, which are connected to the PC. Once found, the indicator on the right side will lighten up green.



Communication from the PC to the device can be interrupted or restarted using the corresponding buttons beside the indicator.

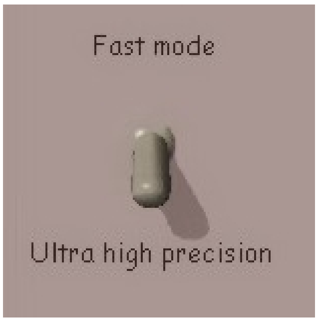
Note, that the USB driver on PCs will enumerate detected USB devices automatically. This COM port number may vary from PC to PC and does not depend on the connected device itself.



In the center of the user surface the main (ultra high precision) output voltages A, B, C can be set manually. This can be done either using the up/down buttons or entering a number (unit is Volt) in the numerical entry fields with a resolution of 1 micro Volt. Also a certain digit can be chosen with the mouse and changed with the up/down buttons subsequently.
Below the entry field for the primary channels, those for the secondary channels A', B', C' are located. They are operated in the same manner. Please note, that each primary channel is connected to a secondary channel by a fixed internal voltage divider. Therefore a change in one channel (primary or secondary) will imply a change on the related other one (secondary or primary). A is correspondingly related to A', B to B', C to C'.

Note that in device version LN-SW these outputs provide approx. 3.9 kOhms of output resistance, therefor any multimeter for voltage checking should be used in a ‘high-Z’ - mode (R_{IN} >> 10MOhms) for optimal accuracy. Otherwise, please take into account the voltage drop at the outputs caused by a less expensive multimeter. UM-type DC sources with an output voltage range larger than +/-14V feature much smaller output resistances in case the floatable GND option is chosen. Note that for this class of DC sources, the secondary channels are not available.

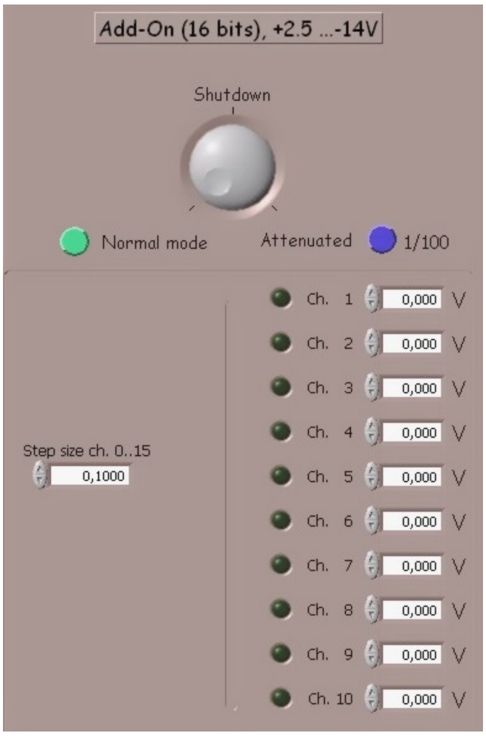
The subsequently depicted software switch changes these high precision channels from highest precision “Ultra high precision” mode to “Fast mode” and vice versa. In the “Fast mode” the outputs react much faster (few Millisec.) on programmed voltage changes.



In this mode the output properties (of A, B, C, A’, B’, C’) are identical to those of the add-on channels (see below). Voltage range is also larger. However, in the fast mode the effective resolution of voltages is only in the mV-range (13Bits effectively), in contrast to the highly resolved ultra high precision mode with 25Bit internal resolution.

In “Ultra high precision” mode (applies to channels A, B, C, A’, B’, C’) a change of voltage settings typically needs a few seconds to achieve stable conditions on a ppm level (see also specifications).

Important remark:
You may set a voltage in “Fast mode” and *independendly* a different voltage in the “Ultra high precision” mode. This feature is specially dedicated to high precision Penning Trap experiments. The advantage is in the fact, that after returning from “Fast mode” (e.g. for ion transport) to “Ultra high precision”, the voltage, which had previously been set in the “Ultra high precision” mode is obtained in only a few millisec., instead of several seconds with respect to chances of ultra high precision settings otherwise. This saves time in favor of lower temporal magnetic field drifts and therefor better experimental accuracy.



At left hand side the tab is located, which allows for accessing the Add-On channels. They feature in contrast to the precision channels a much coarser resolution and stability. Accuracy is typically +/-3mV and setting resolution 1milliVolt. Voltages can be changed by using the up/down buttons or by direct entry into the entry fields.
The turning wheel located at the top changes the mode of the add-on channels from “Normal mode” to “Shut down” and to “Attenuated”. “Normal mode” stands for normal operation as described above. In the “Shut down” mode the add-on channels are switched off, reducing the residual noise, which might appear otherwise at the outputs. Note that this feature has become less important for device versions later than production date 12/2013 because of improved internal filters, but the existence of this mode is being kept for compatibility reasons. The remaining DC voltage is around ±250µV, max. 500µV.
In the “Attenuated mode” the voltage range of the Add-on channels is reduced by a factor of approx. 100 and such is also the absolute resolution. This allows for applying small voltages in the Millivolt range over a smaller span. Please refer to specifications table for accuracy data.
Note that these mode changes only apply to channels 1 to 8, not 9 and 10.

In case any change is set by the user regarding the modes or voltages, the commands which are sent may be checked in the control field at right hand side of the visible user surface. Receive errors are also displayed in the right display section. Any command, being sent to the device is prompted by an answer. For syntax details please refer to the appendix.

Please make sure to use the right software version for controlling the device. For the version UM 1-14 LN-SW (version with polarity switching) from 2015 on, there is one version, whereas the previous (2014 and earlier) had separate software version for negative output voltages. The versions differ in the voltage sign and calibration parameters. All calibration parameters can be retrieved from the manufacturer for implementation into own programs and are normally also listed in the corresponding calibration files on the CD or Memory Stick, accompanying the device.

Initialisation

After powering up the UM device, please switch the Add-On channels from normal mode to attenuated mode and back, and switch the primary and secondary channels from ultra high precision mode to fast mode and back to ultra high precision mode. This ensures proper initialisation of internal registers.

Voltage Ramping

The main channels, switched to “Fast Mode” as well as the 10 Add-On channels can be operated in a ramping mode, which is useful for ion transportation. In this mode the user defines a start and an end voltage and upon pressing the ramp-button the ramp will start. The device will then perform a linear voltage ramp at the selected channel, which is resolved in 1 millisec. time steps. After the specified time interval (e.g. 150ms, corresponding to 150 steps, max. 60sec. are possible) the end voltage (= target voltage) will be reached. Apart from the user LabVIEW surface (see below) the ramp command can also be used in self-written programs, see syntax description in appendix.
(Note: the main channels need to be set to “Fast Mode” for ramping.)

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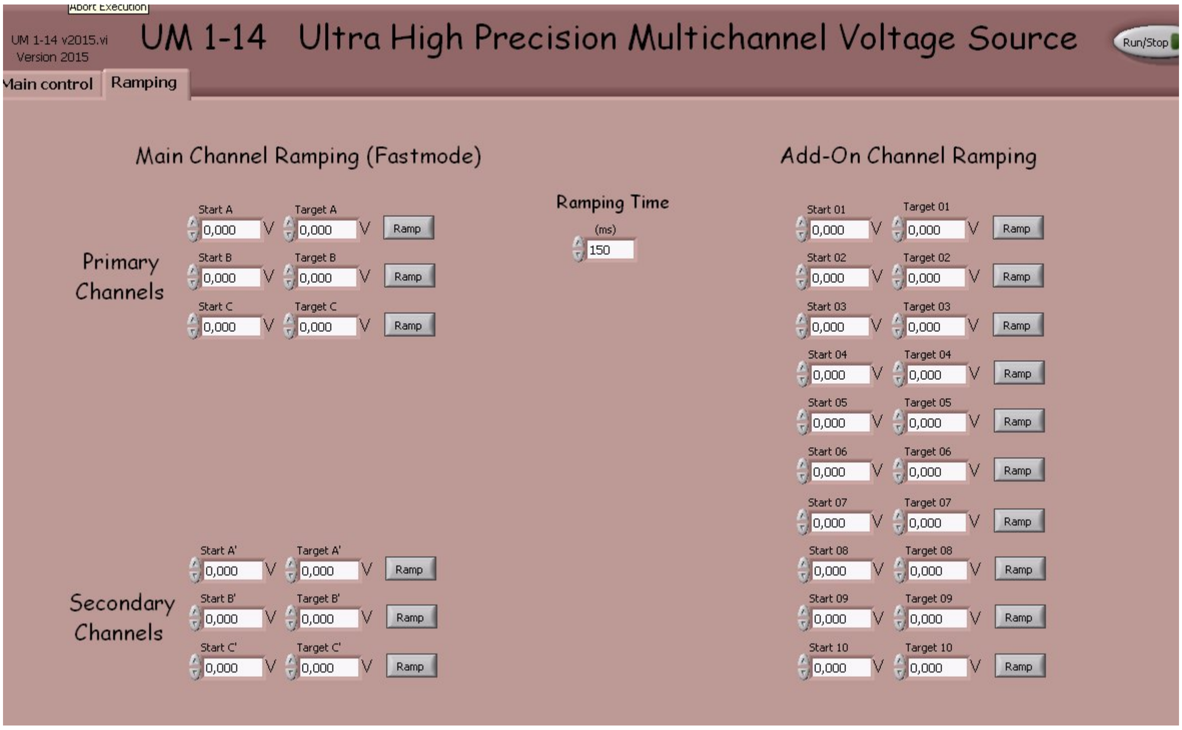

<u>General Remark:</u>
In case the user prefers to use own programs to control the device, it should be ensured, that the calibration parameters for all channels are properly set. Otherwise the specified accuracy ratings will not be met. The calibration parameters can be found in the supplied source code CD or Memory Stick and are also available from the manufacturer (mail to: info@stahl-electronics.com).

3.1.2 Calibration Data

Precision calibration of absolute accuracy and temperature drift cancellation is accomplished by a procedure, which is individually performed for each manufactured UM and every channel within the manufacturing process. The calibration data for span, offset and non-linear (quadratic) terms are recorded and available in a text file, named UMxxcal.txt, where 'xx' stands for the serial numbers last two digits. Upon program start, LabVIEW checks for the device (being connected to the PC) serial number and picks the proper section of entries in the calibration file.
Note that characteristics of output stability and fluctuations are <u>not</u> influenced by the calibration data (as long as the output does not reach saturation levels) and are therefor independend.

3.2 Usage of Sense Ground / Reference Ground

The device features a "Sense Ground" input in order to allow sensing the voltage level at the experiment and referencing the output voltages to that external potential. Sense Ground, also sometimes referred to as 'reference GND', is connected to the corresponding pins (see fig. 5) at the 37pole connector and to the black GND-socket at the front plate (fig. 4). Applying a voltage to sense GND equals putting an offset to all outputs, since the device always defines the voltage *difference* between sense-GND and the output lines. Please note that for safety reasons the case GND of the aluminium enclosure is normally connected to Sense Ground using protection diodes, which become conducting at voltages larger roughly 0.6V. This limits the maximum voltage difference between case GND (i.e. the metal of the enclosure) and Sense Ground to small values but allows for compensating 50Hz hum and thermoelectric effects. In models after production date Jan 2023, optionally, a stronger isolation is available. This allows for floating the Sense Ground by max. 50V with respect to the case/enclosure GND. Both GNDs are in this case connected by a 1µF polymer capacitor for AC coupling and shielding purposes, being in parallel with a 4.7MOhm discharge resistor.

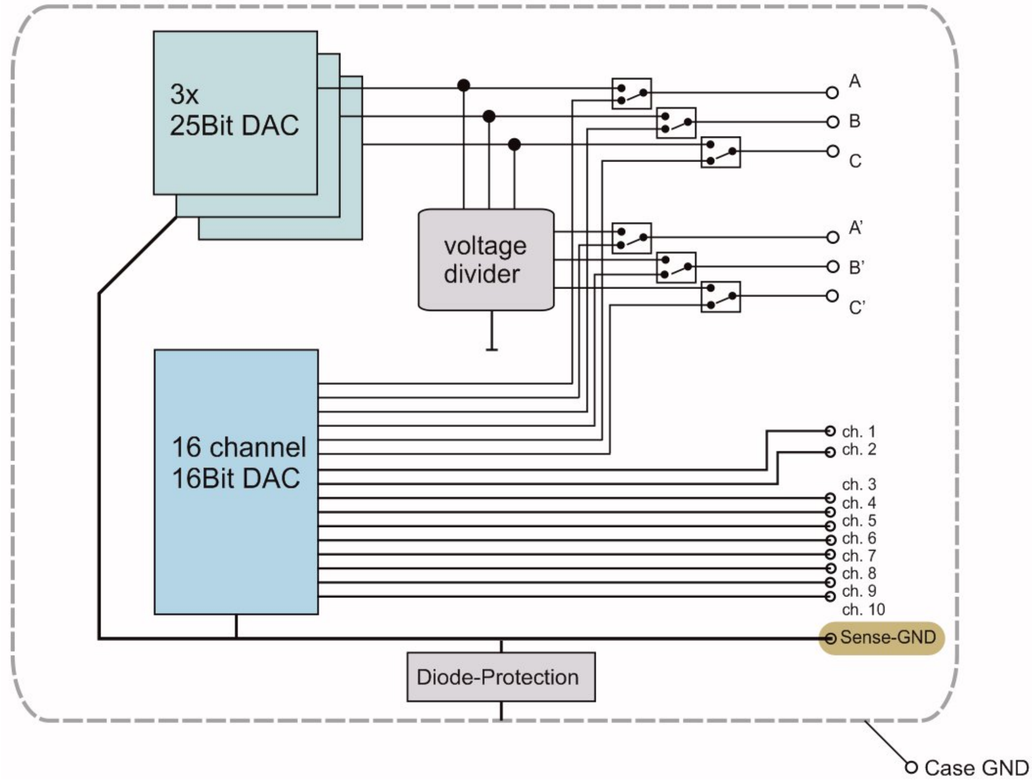

Fig. 11: Scheme of Sense Ground, output lines and Case GND.
Note that versions with output voltages larger +/-14V d not feature secondary channels A', B', C'.

3.3 Polarity switching

The version UM 1-14-LN-**SW** features a switch to change the polarity of the main outputs (A, B, C, A', B', C'). This switch can be operated manually, or (if the lever is placed to central position) by a external control signal, which is galvanically isolated from the rest of the UM device (BNC socket is floating) to avoid ground loops and other EMC interference. A logic 1 (5V) switches to positive voltages, a logic zero (0V) to negative voltages. LED indicators on the case side of the UM show the selected polarity (green for negative voltages, blue for positive voltages). The switching time (time needed from the device to establish the new polarity with high accuracy on ppm level) is in the order of 20 seconds.

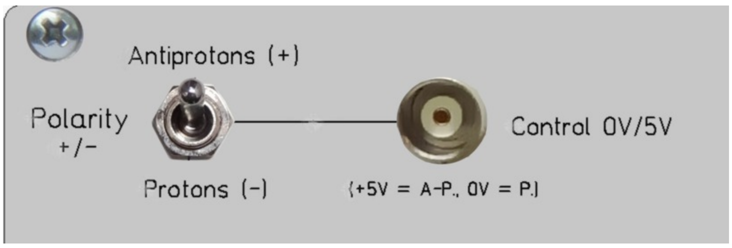

Fig. 12: The polarity switch allows for changing the output voltage polarity in version UM 1-14 LN-**SW**.

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Note that in case of polarity change the voltage commands have to be resent to the device in order to force the software to pick the right calibration data set. For safety reasons the manual switch as well as the software-based switch on the user surface have **both** to be set accordingly.

4. Specifications:

Main channels *(25 Bit-Channels ch A, ch B and ch C)*

Voltage range (special ranges on request)

UM 1-14	:	0.1 V… -14 V	primary channels A, B, C
		25 mV… -3.5 V	secondary channels A', B', C'
UM 1-14 LN	:	0 V… -14 V ***)	primary channels A, B, C
		0 V… -3.5 V ***)	secondary channels A', B', C'
UM 1-14 LN-SW	:	-0.4 V… +12 V or	
		+0.4V …- 12 V	primary channels A, B, C
		overrange (reduced accuracy):	
		-0.4 V… +14 V or	
		+0.4 V… -14 V	
		-0.1 V… +3 V or	
		+0.1 V… - 3 V	secondary channels A', B', C'
UM 1-32 neg LN	:	+1V… -32 V	32V version
		(UM 1-32 neg in fast mode: range +1V to -14V)	
UM 1-32 LN-SW	:	+1V… -32 V and -1V…+32V	bipolar 32V version

Programming resolution : 1 µV (LabVIEW default value, internal 25 Bit resolution), 4 µV in case of the device version UM 1-32

Output resistance :
4k Ohm +/-1% (UM 1-14, primary channels)
5k Ohm +/-1% (UM 1-14, secondary channels)
3.92 kOhm +/-1% (UM 1-14 LN (-SW) primary channels)
490 Ohm +/-1.5% (UM 1-14 LN (-SW) secondary channels);
100 Ohm +/-1.5% (UM 1-32);
optionally lower output resistances on demand (floating GND)

Absolute Accuracy - high impedance load assumed -		Standard Version	Low Drift Option
12V / 14V-range	:	25ppm of output value +/- 25 µV offset	10ppm of output value +/-15 µV offset
3V / 3,5V-range	:	25ppm of output value +/-15 µV offset	10ppm of output value +/-12 µV offset
32V	:	25ppm of output value +/-50 µV offset	

Fluctuations		Standard Version	Low Drift Option[1)]	Low Drift Option [2)] T = const.
- in time period of 1 minute - (observe also figures on next pages)				
@ 10V, primary channel	:	typ. 0.75 µVpp	typ. 0.5 µVpp	

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@ 3V, secondary channel	:	typ. 0.45 µVpp	typ. 0.23 µVpp	
@ 1V, secondary channel	:	typ. 0.20 µVpp	typ. 0.15 µVpp	
@ 30V (32V-version only)	:	typ. 2.8 µVpp (i.e. approx 1.0µV rms)		

- fluctuations in time period of 1 day -

@ 10V, primary channel	:	typ. +/- 0.8 ppm	typ. +/- 0.4 ppm	typ. +/- 0.21 ppm
@ 3V, secondary channel	:	typ. +/- 0.9 ppm	typ. +/- 0.6 ppm	typ. +/- 0.18 ppm
@ 1V, secondary channel	:	typ. +/- 1.3 ppm	typ. +/- 1.0 ppm	
@ 30V (32V-version only)	:	typ. +/-1.0 ppm		

Settling time (response on voltage steps)[3)]

primary/secondary channels	:	typ. 5s [3)]	(to reach 99.995 % of final step size)
add-on-channels	:	typ. 50…150ms	(to reach 99.5 % of final step size)

Ageing

in case of continuous long term operation, measured after 1 year of operation

		Standard Version	Low Drift Option
change of output set value	:	typ. 25 ppm/yr	typ. 6 ppm/yr, max.18 ppm/yr

change of output offset, typ.

UM 1-14, UM 1-14 LN/-SW	:	+/- 5 µV/yr	+/- 4 µV/yr
UM 1-5b	:	+/- 75 µV/yr	better +/- 35 µV/yr
UM 1-32	:	+/- 70 µV/yr	

Change of Offset and Span with Cycling of Power (Mains Power off/on)

Offset	:	typ.+/-5µV each cycle (UM 1-14 versions, second. channels)
		typ.+/-12µV each cycle (UM 1-32neg)
Span	:	typ +3ppm each cycle

Polarity switching

referring to version UM 1-14-LN-<u>SW:</u>
Manual switch lever or remotely controlled by DC level.
Apply 0V/5V DC levels to BNC socket in order to switch the polarity of the main outputs (A, B, C, A', B', C'). The isolated BNC socket is internally connected to a opto coupler.

Level thresholds	:	< 0.6V → negative output voltages
		> 3.6V → positive output voltages
Input resistance	:	nom. 2 kOhm
max. floating voltage of polarity control input vs. case GND	:	+/- 350V

Temperature Stability

at 21°C - 24°C ambient temperature

		Standard Version	Low Drift Option
Offset (14V version)			
primary channels	:	typ. +/-4 µV/K	typ. +/-2.4 µV/K
secondary channels	:	typ. +/-2 µV/K	typ. +/-1.4 µV/K
Offset (32V version)			
primary channels	:	typ. +/-12 µV/K	

Influence relative to output setting,			
primary channels	:	typ. +/- 0.6 ppm / K	typ. +/- 0.5 ppm / K
		max. +/-1.6 ppm / K	max. +/-1.3 ppm / K
secondary channels	:	typ. +/- 0.4 ppm / K	typ. +/- 0.3 ppm / K
		max. +/-1.2 ppm / K	max. +/-0.8 ppm / K

Grounding

The internal GND (= Sense-GND) is connected to the GND of the case enclosure via antiparallel Silicon diodes in parallel with a 100kΩ resistor in order to avoid charge up, or, on request with higher resistance (e.g. 4.7MOhm in parallel with 1µF) in favour of higher offset voltages (see also text above)
Important Note: Sense-GND is not galvanically connected to the mains protection GND in order to avoid ground loops.

remarks:
1) operation in usual laboratory conditions T = 22°C, temperature fluctuations ΔT ≤ 3K
2) operation in temperature stabilized environment T = 22°C, ΔT ≤ 0.5K
3) remark: "fast mode" transients may reduce substantially settling time for the primary/secondary channels in certain applications, see page 11.

***) Model with serial number 007008 features +/-3.5V (A, B, C) and +/-1V (A', B', C') ranges.

Low Resolution Add-On-Channels:

Voltage range add-on channels (standard, others on request)

UM 1-14	:	0.01 V…-14 V	
UM 1-32, UM 1-14 LN-SW	:	-14 V… +14 V	remark: contact manufacturer for specific voltage range
absolute Accuracy, typ.	:	+/-18 mV	
effective resolution	:	13 Bit	
Output resistance, typ.	:	120 Ohm +/-1%, ch1 to ch8	
	:	12k Ohm +/-1%, ch9, ch10	
Fluctuations of Add-On channels at 10V	:	typ. 50 µVpp, max 150 µVpp (time period 1 minute)	
Shut-Down-Mode Output DC Voltage	:	typ 250µV, 500µV max.	
Attenuated Mode			
Range	:	-120mV … +120mV	
Accuracy	:	+/-0.3% (max. 0.6%) deviation of set value +/-typ. 200µV (max. +/-500µV) offset	
Voltage Ramping	:	see page 12	

Channel Crosstalk:

between primary or	:	typ. 130 dB suppression;
secondary channels	:	worst case 125 dB suppression
between Add-On Channels	:	typ. -106dB
Remote Control Interface	:	USB 2.0 full speed compatible, USB - B connector socket, galvanically fully isolated, max. 150V isolation voltage vs. case GND or sense GND

		RS 232 conection: 3 wire (TxD, RxD, GND), no flow control, data format 9600, 8N1. Lines are not isolated to case GND or sense GND. Female 9pole SubD-Socket (DCE mode) with standard pinout: GND = Pin 5 RxD = Pin 2 (output at UM) TxD = Pin 3 (input at UM). Command Syntax via USB or RS232: see Appendix,
Warm-Up Time	:	Time required to reach accuracy specifications mentioned above: 60min. Time required to reach low fluctuations mentioned above: typ. 10 hours
Software Control	:	Open source LabView™ -VI's are available, LabVIEW™ 8.2 compatible; executable file also available. Requires National Instruments VISA support.
Dimensions	:	length x width x height: (excluding mains adaptor) 210 mm x 105 mm x 75 mm (UM 1-14) 240 mm x 105 mm x 75 mm (UM 1-5) 260 mm x 105 mm x 85 mm (UM 1-14 LN) 285 mm x 105 mm x 85 mm (UM 1-14 LN-SW, production dates until 12/2014) 335mm x 105 mm x 85 mm (UM 1-14 LN and LN-SW, production dates 2015, 2016, 2017)
Output Connector	:	37-pole Sub-D, 4 mm laboratory sockets, others on demand
Weight	:	approx. 2 kg without external mains adaptor
External B-field Tolerance	:	max. 50mT (UM device only, for mains adaptor see below)

<u>Mains Adaptor, standard size</u>

Power Consumption	:	approx. 15 W, 230Vac 50Hz or 115Vac, 60Hz (US / Japanese version)
Fuse	:	medium fast, 800mA (EU version) medium fast, 1.6A (US / Japanese version)
Dimensions	:	length x width x height: 276 mm x 105 mm x 75 mm (UM 1-14), 19" based case for output voltages larger +/-14V
Connector	:	8 pole DIN type 8, pinout see figure 7, or 25pole Sub-D (32V version)
Grounding	:	Sense-GND of the output voltages is <u>not</u> galvanically connected to the mains protection GND in order to avoid ground loops. The mains adaptor enclosure is connected to mains protection GND
External B-field Tolerance	:	max. 5mT (mains adaptor)

Note that the mains adaptor may suffer severe damage in case exposed (even once) to B-fields higher than 5mT. Overheating and fire can arise from exceeding the maximum admissible B-field.

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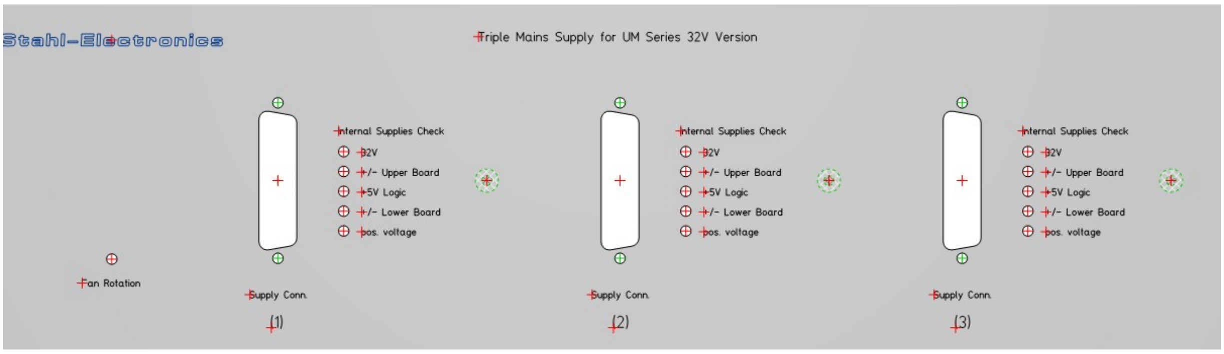
Triple Mains Adaptor, 19'' size

Power Consumption	:	approx. 39 W, 115Vac 50Hz/60Hz
Fuse	:	medium fast, 2.5A
Dimensions	:	length x width x height: 495 mm x 440 mm x 149 mm
Connector	:	female 25pole Sub-D to each UM DC source
Grounding	:	Sense-GND of the output voltages is not galvanically connected to the mains protection GND in order to avoid ground loops. The mains adaptor enclosure is connected to mains protection GND
External B-field Tolerance	:	max. 5mT (mains adaptor)

Note that the mains adaptor may suffer severe damage in case exposed (even once) to B-fields higher than 5mT. Overheating and fire can arise from exceeding the maximum admissible B-field.

Front plate appearance of triple supply, 19" size



5. Fluctuation Data, Version UM 1-14 - LN (also: version -LN- SW), Version UM 1-32 shows corresponding fluctuations, in terms of same *relative* fluctuations δU/U

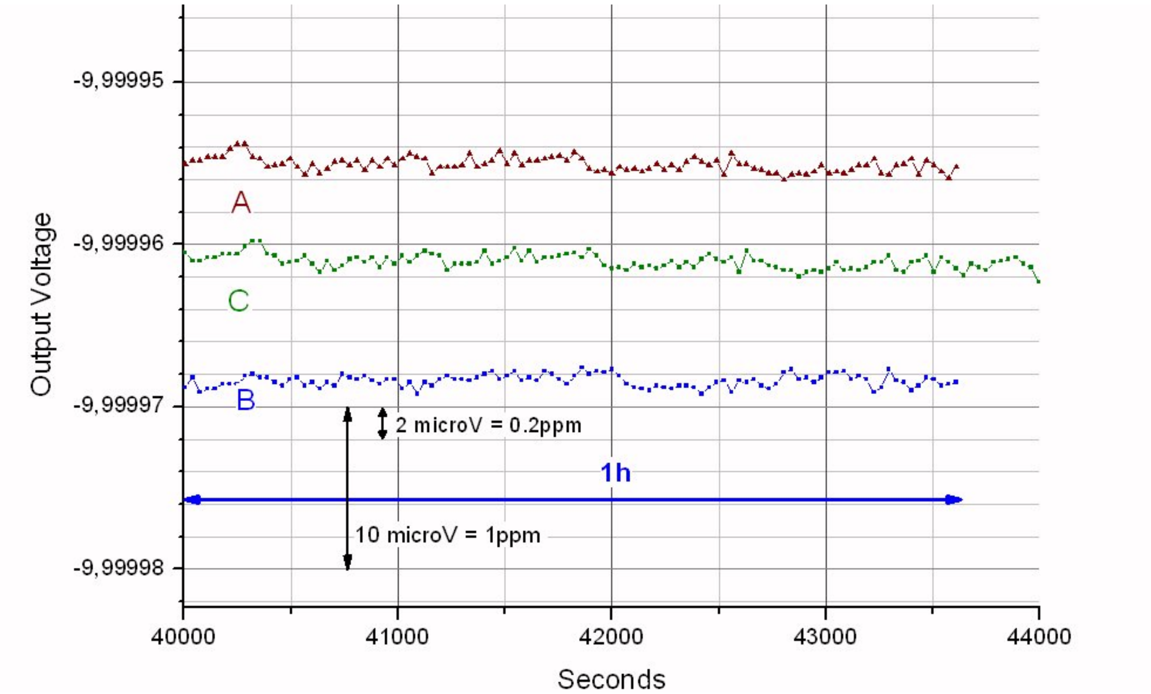


Fig 13: Version UM 1-14 - LN; short term fluctuations of primary outputs at -10V; environmental temperature (T = 298K) has been stabilized to 0.5K. The traces have been shifted by small offsets (few µV) for better visibility in this graph. Measurement device: Fluke 8508A Multimeter.

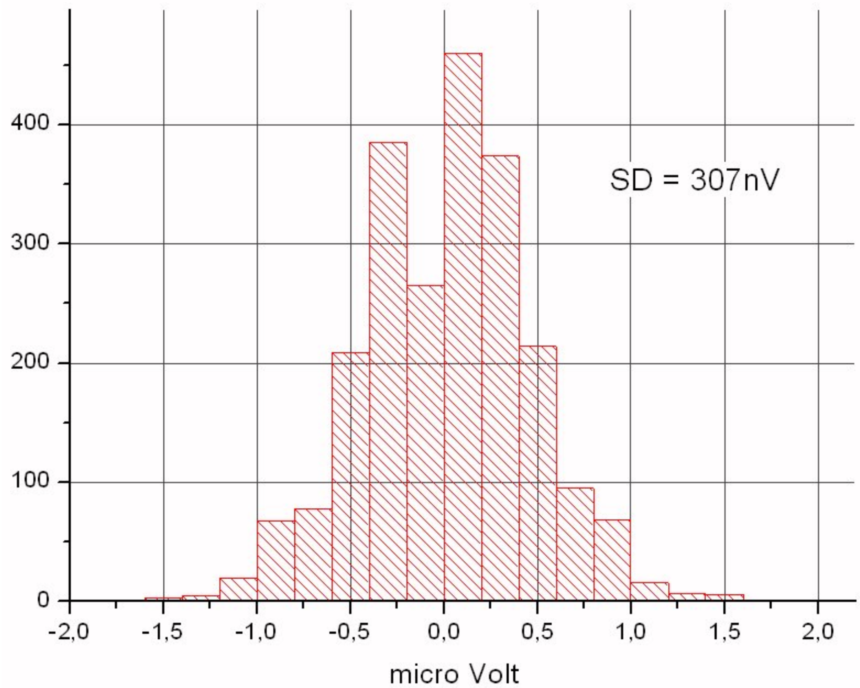


Fig 14: Version UM 1-14 - LN; short term fluctuations of primary output A at V = -10V; environmental temperature (T = 298K) has been stabilized to 0.5K. The histogram shows the distribution of voltage differences of subsequent time intervals, with ΔT = 1 minute.

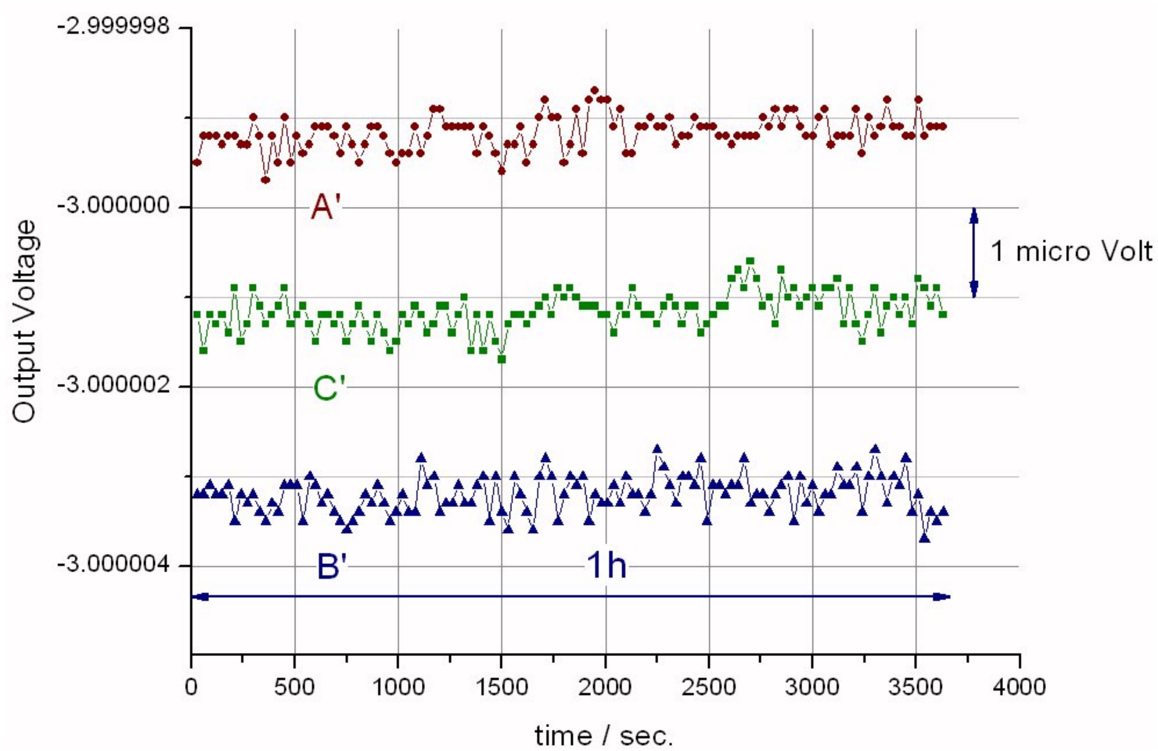


Fig 15: Version UM 1-14 - LN; short term fluctuations of secondary outputs at -3V; environmental temperature (T = 298K) stabilized to 0.5K. The individual traces have been shifted by small offsets for better visibility in this graph (measurement device: Fluke 8508A Multimeter).

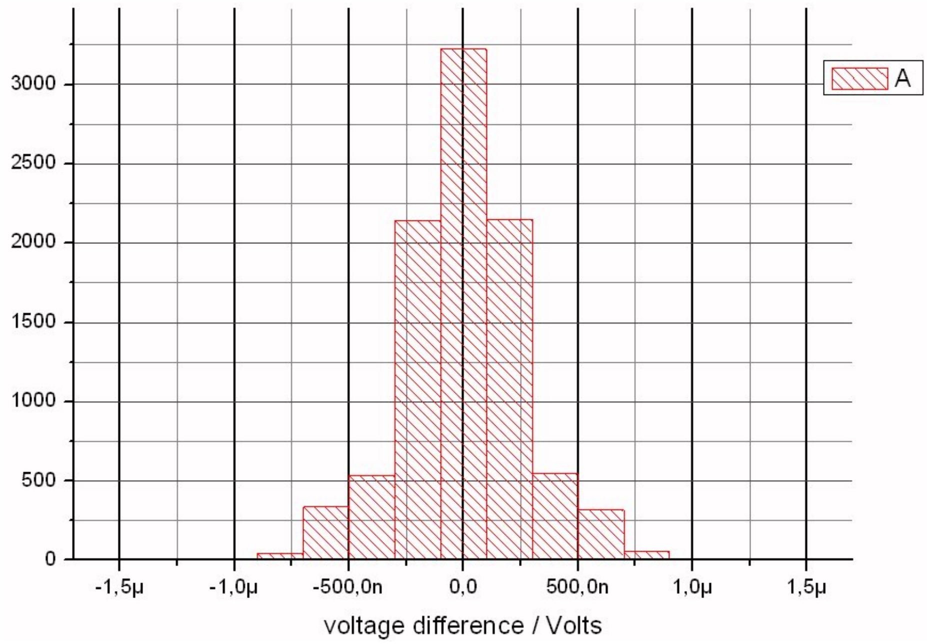


Fig 16: Version UM 1-14 - LN; short term fluctuations of secondary output A' at V = -3V; environmental temperature (T = 298K) has been stabilized to 0.5K. The histogram shows the distribution of voltage differences of subsequent time intervals, with ΔT = 1 minute. Data point averaging has been applied over 30s.

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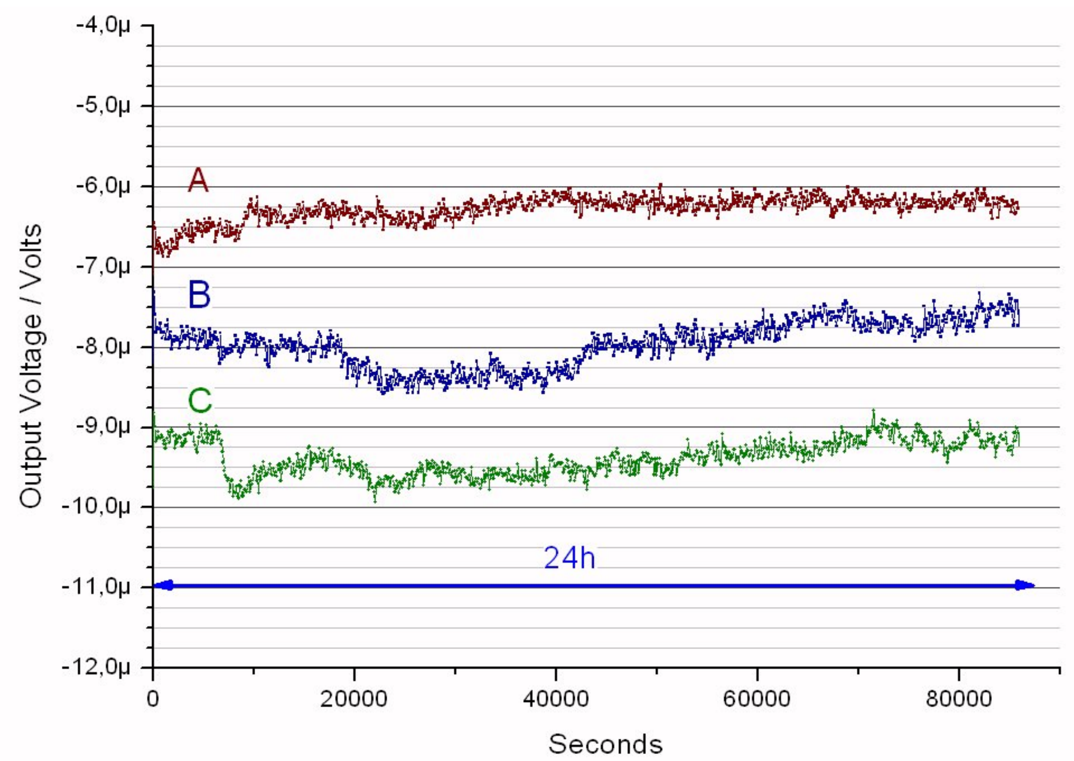

Fig. 17: Version UM 1-14 - LN; 1-day fluctuations of offset voltages of primary channels; environmental temperature (T = 298K) has been stabilized to 0.5K. The traces are shifted by several micro volts for better visibility.

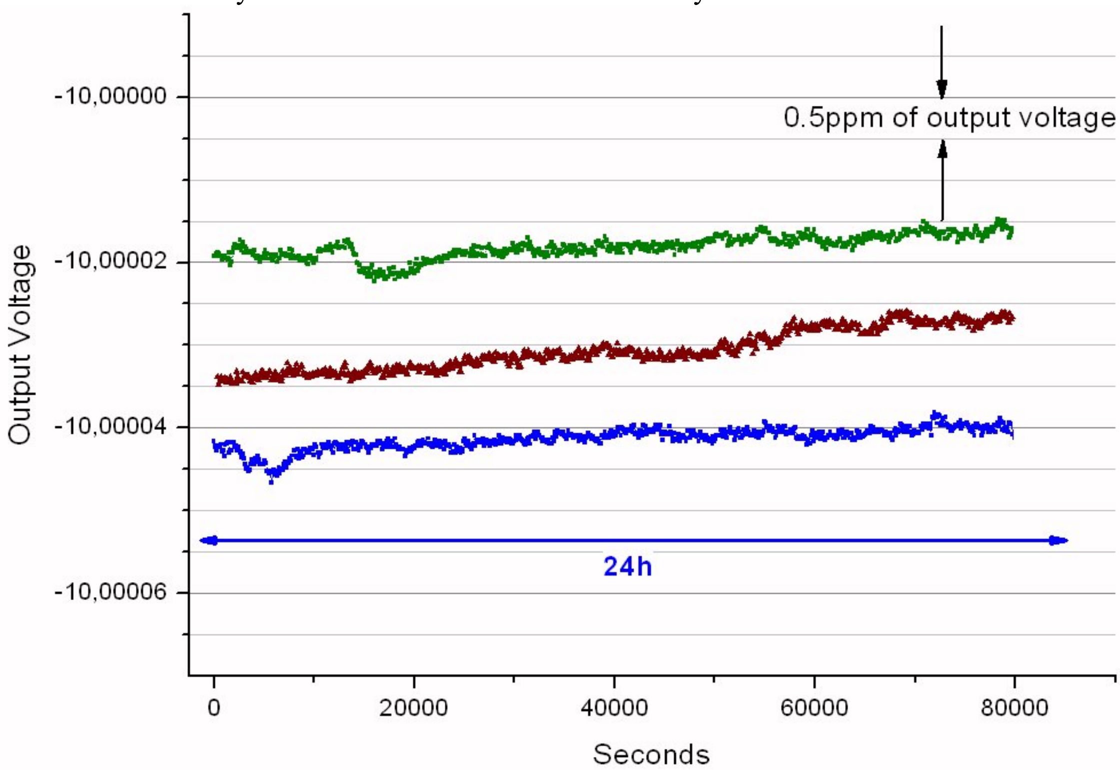

Fig. 18: Version UM 1-14 - LN; 1-day fluctuations of 10V-output voltage (primary channels); environmental temperature (T = 298K) has been stabilized to 0.5K. The traces are shifted by several micro volts for clearer visibility.

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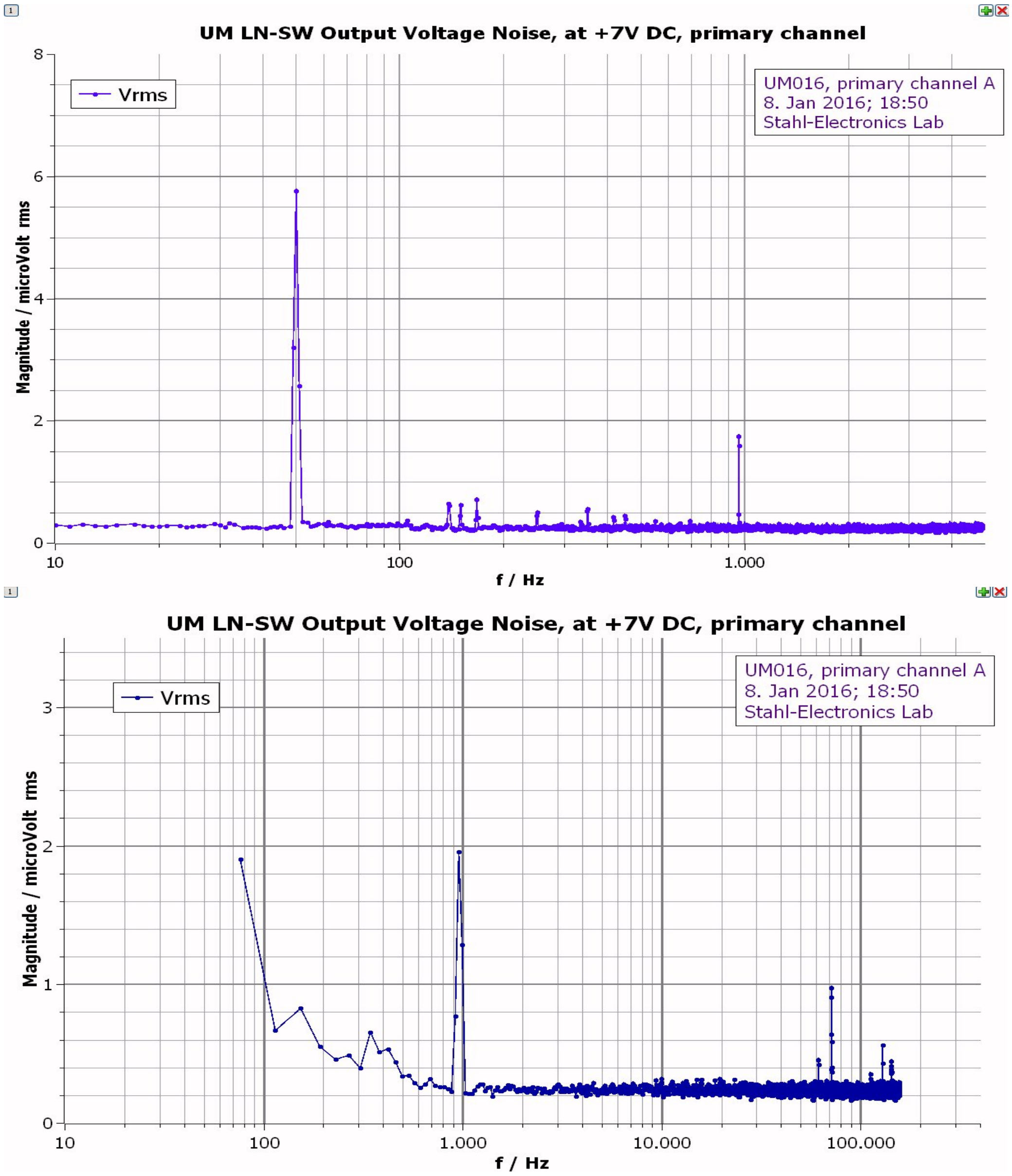

Fig. 19, 20
Version UM 1-14 - LN and LN-SW typical output FFT spectra at mid-range (+7V or -7V); upper graph: 10Hz to 5 kHz, lower graph: 80 Hz to 150kHz range. Measurement device: Picoscope 3224, FFT-mode. The signal around 1kHz stems from the internal ultra-high precision DAC (with 25Bit resolution), the peak around 50Hz is mains supply crosstalk. The latter may not necessarily be created from the UM device but can rather occur within the test setup. Therefore the signal depicted can serve as a coarse upper limit measure. Note that mid-range voltage choice represents the worst case regarding the 1kHz-remains (see below).

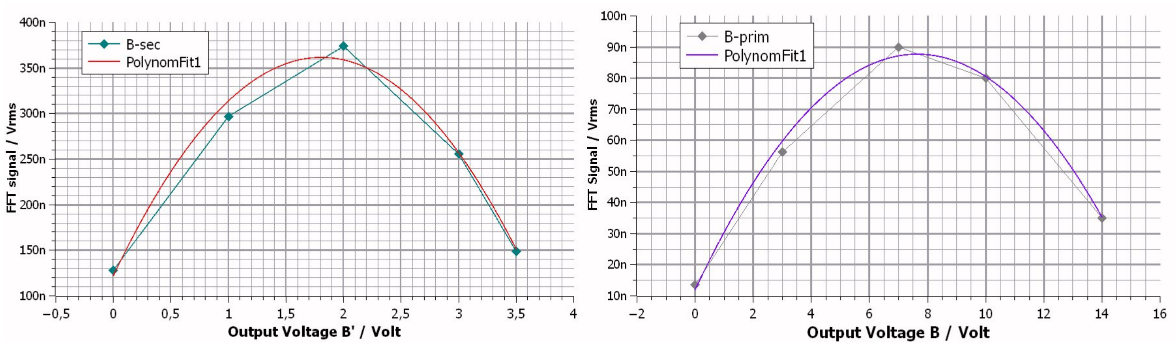

Fig. 21: Signal component at approx. 1kHz as function of output voltage of secondary (left graph) and primary (right graph) output chnanel B, including qudratic fit (Y-axis: nanoVolts rms); device with Ser.Nr. 007022

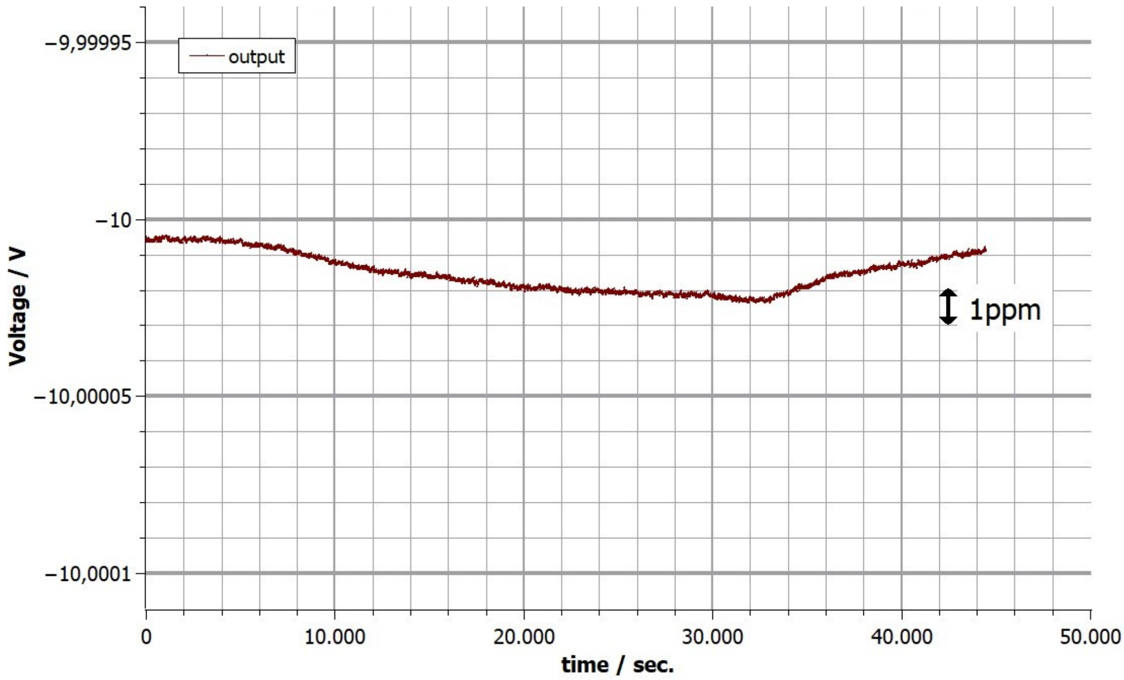

Fig. 22: Typical day/night variation of output voltage, 32V-UM device, set at -10V; output voltage changes reflect the ambient temperature change of approx. 1.5K during the night. Measurement device: Fluke 8558A multimeter, 10s acquisition time. Temperature coefficient T_c is around 0.75ppm/K

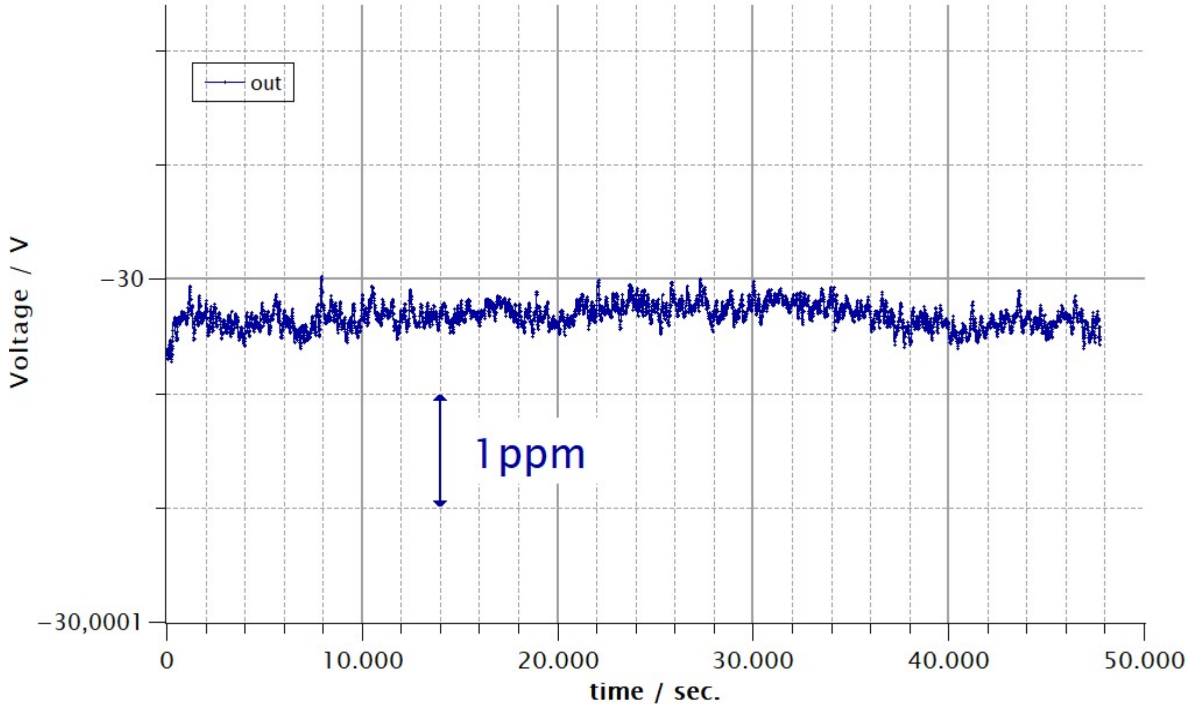

Fig. 22: Typical 12 hour drift, output voltage of 32V-UM device, set to -30V; ambient temperature constant to about ΔT = 0.5°C. Measurement device: Fluke 8558A multimeter, 60s averaging.

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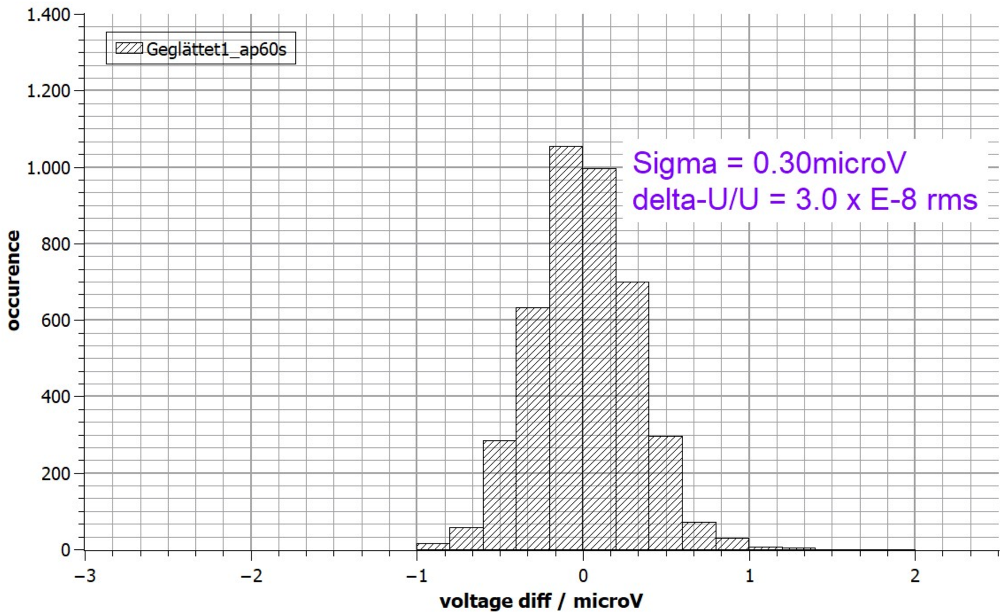

Fig. 23: Typical distribution of measured 1-minute voltage differences, resulting from short term fluctuations. UM -32V version, voltage set to -10V over a 12h interval. The environmental temperature (T = 298K) has been stabilized to 0.5K. The histogram shows the distribution of voltage differences of subsequent time intervals, with ΔT = 1 minute and 60s averaging. Measurement device: Fluke 8558A multimeter.
Note that the multimeter contributes to fluctuations intrinsically by about 1.7 E-8 rms.

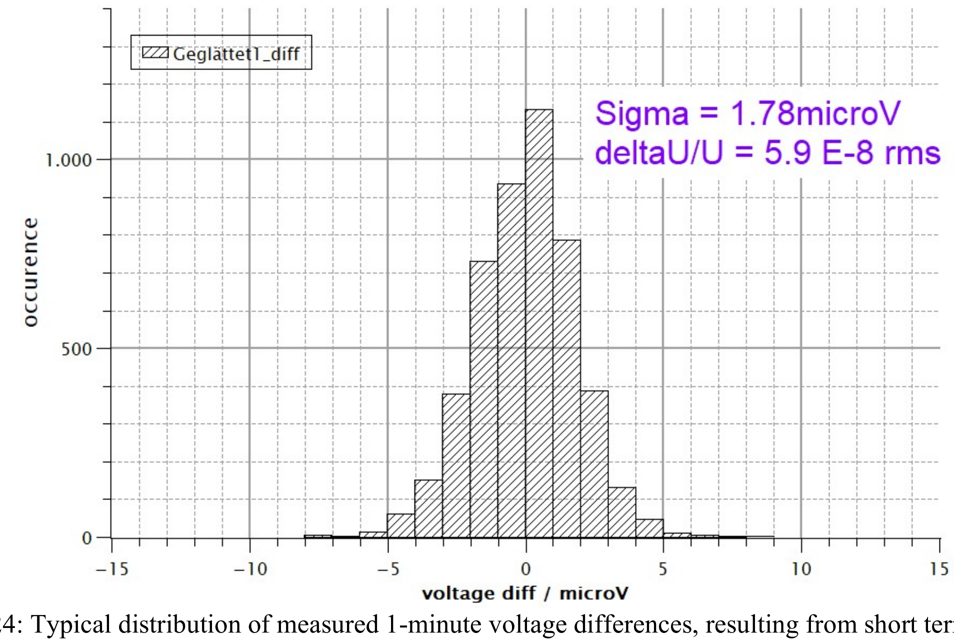

Fig. 24: Typical distribution of measured 1-minute voltage differences, resulting from short term fluctuations. UM -32V version, voltage set to -30V over a 12h interval. The environmental temperature (T = 298K) has been stabilized to 0.5K. The histogram shows the distribution of voltage differences of subsequent time intervals, with ΔT = 1 minute and 60s averaging. Measurement device: Fluke 8558A multimeter.
Note that the multimeter contributes to fluctuations intrinsically by about 2.7 E-8 rms.

6. Safety Hints

Observe all installation, operation, and safety instructions	Prior to operation, thoroughly review all safety, installation, and operating instructions accompanying this equipment.
Rear side switch turns device completely off	If the device is not in use for a longer time, it is recommended to turn the mains switch at the mains supply box off and also pull the mains plug, otherwise the device will not be completely separated from the supply grid.
This equipment must be connected to an earth safety ground	This product is grounded through the grounding conductor of the power cord. To avoid electrical hazard, the grounding conductor must be connected to protective earth ground.
Do not operate in wet/damp conditions	To avoid electric shock hazard, do not operate this product in wet or damp conditions. Protect the device from humidity or direct water contact.
Disconnect power before servicing	To avoid electric shock hazard, disconnect the main power by means of the power switch and power cord prior to any servicing.
Do not block chassis ventilation openings	Slots and openings in the chassis are provided for ventilation purposes to prevent overheating of the equipment and must not be restricted, in order to prevent overheating.
Only operate with working air fan	The ventilation fan located at the rear side of the device always needs to work to ensure proper cooling.
Beware of external magnetic fields	External magnetic fields can impair, damage or even destroy this device. A maximum external field strength of 50mT for the voltage source, 5mT for its mains adaptor are admissible and must *never* be exceeded. This statement applies for static as well as alternating fields. If in doubt, check possible external field e.g. with a hall probe before switching the device on. Overheating and fire can arise from exceeding the maximum admissible B-field.
No outdoor operation	Outdoor operation of the device is not admissible.

7. Maintenance

This UM voltage source device is designed for years of reliable operation. Under normal operating conditions, it should not require electrical maintenance, only routinely cleaning of dust, and in longer time intervals, replacement of rear fan inside the mains adaptor. If any further question should arise, please contact the manufacturer. A routinely re-calibration of the (absolute) accuracy is easily possible and recommended every three years. Please contact manufacturer in this case.

Routine cleaning

All ventilation openings on the Mains Adapter Unit should be checked periodically and kept free of dust and other obstructions. A vacuum cleaner may be used to clean these vents when the unit is powered off. Do not use compressed air to clear the vents.

Fan life time

The ventilation fan at the rear side of the mains supply housing is a part which shows deterioration in time. Exchange of this part is recommended after latest 50.000 hours of operation. Please contact manufacturer for replacement after long term operation. Complete failure might lead to overheating of the mains unit.

Fire hazard

Please note that excessive accumulation of dust inside the case of the Mains Adaptor Unit can lead to overheating and fire hazard. Routinely cleaning the device from dust minimizes this risk. It is therefore recommended to send the device to the manufacturer routinely in 3-year intervals for internal cleaning from dust, or to have it cleaned by an accordingly qualified electronical workshop.

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Appendix

Establishing communication and description of commands

USB Control

The subsequently described commands are sent/received in order to communicate between the UM series precision voltage source and a control device, like a standard PC. The commands are sent in plain ASCII text strings over a standard USB-connection (1.1 protocol, but also 2.0 compatible). In case LabVIEW™ (Version 8.0 or higher) is used, a complete driver program with open source SubVI's is provided by the manufacturer. Self-written programs or other commercial software can be used as well, respecting the command structure described below. Note that the USB connection is galvanically isolated from the rest of the device through an optical link in order to avoid ground loops and antenna effects.

Before sending any command, the USB connection to the device has to be established. This is done by installing an appropriate USB driver (Virtual COMPort driver, see also corresponding section above). Drivers for Windows (XP, Vista, 7), Mac OS and Linux are provided. Please contact manufacturer or see the USB-manufacturers homepage (www.ftdichip.com) for latest updates.

RS 232 Control

In case this option is used, a serial connection via RS 232 cable controls the device. The UM acts in this case as a DCE device. It uses a 3-wire protocol (only RxD, TxD and GND) with data format 9600 8N1 (i.e. baud rate at 9600 bits per second, 8 bits, no parity bit, 1 stop bit) and no flow control (neither hardware nor software). Use a standard RS 232 connection cable (SubD 9, male-female, only RxD, TxD and GND required) in order to connect to a control PC (DTE). Note that the RS 232 connection is NOT galvanically isolated from the rest of the device. For avoidance of ground loop, please use a galvanically isolated (e.g. an optical) cable.

The following table lists the available text commands either using a USB or RS 232 based connection. The abbreviation "DDDD" represents for the name of the device including its serial number, e.g. "UM07" means UM device with serial number "07". All commands must be terminated with an RETURN (13 in ASCII code) only. After establishing the USB link to the device and turning it on, the IDN identifier should be sent in order to retrieve the serial number, since it will be used to address the device. Subsequently the devices voltages can be set, according to the table below.

Command	String to be sent to device	Received from device	Observations
Identify	IDN	UM01	The device replies with its name and serial number
Set high precision mode	DDDD ULTRA XV	ULTRA XV	Puts outputs A, B, C or A', B', C' to precision mode. X must be either H, for A, B, C, or L, for A', B', C'
Set fast mode	DDDD FAST XV	FAST XV	Puts outputs A, B, C or A', B', C' to fast mode. X must be either H, for A, B, C, or L, for A', B', C'
Set voltage	DDDD CHXX Y.YYYYYYY	CHXX Y.YYYYYYY	Sets a certain output voltage. XX is an internal channel number (00 up to 21), Y.YYYYYYY is a decimal number between 0 and 1 which represents the scaled voltage. "0" represents the minimum voltage (e.g. -14V), "1" the maximum possible value. 7 digits after the comma have to be provided in case of the precision channels A, B, C, A', B', C', 4 digits in case of the Add-On channel, or in case of the fast mode of the precision channels. Please see channel number assignment below to

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			relate the channel number XX to the respective output. Please note, that the number of scaled output voltage Y.Y….Y must be corrected properly (offset, linearity) with calibration coefficients. They are stated inside the provided LabVIEW program code. XX output channel 00 A, fast mode 01 A', fast mode 02 B, fast mode 03 B', fast mode 04 C, fast mode 05 C', fast mode 06 Add-On channel 9 07 Add-On channel 10 08 Add-On channel 1 09 Add-On channel 2 10 Add-On channel 3 11 Add-On channel 4 12 Add-On channel 5 13 Add-On channel 6 14 Add-On channel 7 15 Add-On channel 8 16 A, precision mode 17 B, precision mode 18 C, precision mode 19 A', precision mode 20 B', precision mode 21 C', precision mode
Set shutdown mode	DDDD SHUT	SHUT	Sets all Add-On channels to be inactive. Note that the main channels (A … C') cannot be run in fast mode, when this "Shut down" mode is enabled. Note: changed behaviour in device with serial number and higher 015: Sets Add-On channels 1 to 8 to a voltage smaller 1mV and main channels (A … C') can now be run in fast mode
Set attenuated mode	DDDD ATT	ATT	Add-On channels 1 to 8 are operated in the attenuated mode, voltages are about two orders of magnitude smaller
Set normal mode	DDDD NORM	NORM	Escapes from the attenuation and shutdown modes.
Ramping Command	**(see below)**	**(see below)**	

Detail Note:
Ramping Command Syntax: "UMnn Rxx yyyyy zzzzzzzzzz ttttt"
"nn" is the serial number of the device. e.g: "UM16" for device with serial number 16 (decimal).
"xx" is the channel number (applicable to all main channels in 'fast mode' and the Add-On channels, for enumeration see table above).
"yyyyy" refers to the initial voltage.

This figure, represented in positive integer decimal format is calculated by multiplying the scaled voltage (-14V corresponds to 0, and +14V corresponds to 1) with 2^{16}-1.

"zzzzzzzzzz" is the scaled step size.

This figure, represented in positive integer decimal format is calculated as:
Step size = $2^{32} - ((V_i - V) / t * (2^{32} - 1))$

V_i is the initial voltage, V is the target voltage and t is the number of steps.

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V_i and V are scaled voltages (-14V corresponds to 0, and +14V corresponds to 1)
"ttttt" is the number of steps, represented in decimal format.
Remark: since one step is performed in a time interval of 1ms =>
the number of steps equals the ramping time expressed in ms.
Maximum value: 60'000 (1 Minute).

Note that the UM device returns only 'Rxx ttttt', i.e. channel number and step count (time in millisec) in order to minimize the devices response time in favor of faster PC-device communication.

List of Error Codes:

The subsequent error codes may be returned from the device upon occurrence of certain problems:

ERROR01 - Command not recognized (either wrong command itself of wrong number of digits)

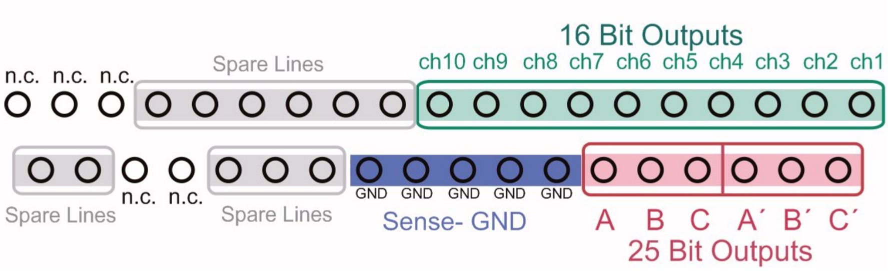
ERROR02 - Channel number out of range (0..21)

ERROR03 - Voltage out of range

ERROR04 - Cannot set voltage in channels 0..15 in Shutdown Mode

ERROR05 - Internal communication or connector problem

Output connector (37pole Sub-D, female)



The 10x 16 Bit resolved Add-On channels are routed to pins 1 to 10, to pins 20 to 26 are the highly resolved (25Bit channels) A, B, C, A', B', C' connected. Pins 27 to 31 may be connected to the local experimental mass as reference ground (Sense-GND).
Note that A', B', C' are not available in versions with output voltage range exceeding 14V.

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Trouble Shooting

Observed Error **Proposed Procedure**

Device does not react on commands

Is the 'traffic' LED on the UM device blinking during sent commands?
└─Yes: Does the device return an error code textstring?
    └─Yes: please analyze error code
    └─No: check for correct cabling on main outputs (whether they are correctly connected and no short cuts) and check if all 'power good' LEDs are green on UM device and also on Mains Adaptor. If not all 'power good' LEDs are green, there may have been an overload incident, causing a replacable melting fuse to blow. Remove error cause before replacing a fuse (e.g. short cuts in the cable connecting the mains adaptor to the UM device or on the output lines).
    Otherwise contact manufacturer.

└─No: Obviously there is no connection to the control PC. If a **USB line** is used, first check cabling. If cabling seems to be ok, check (in case of a Windows™ system) inside the 'system control'→'system' →'device manager' window of the control PC, whether the system recognizes the UM device as (virtual) COM port. By clicking on the 'properties' of the respective COM port you should see the identifier of the UM device (UMxxx, where xxx stands for the last three digits of the serial number). If not, update the device driver (FTDI virtual COM-port driver and try again.
Some PC also have problems with too long USB cables. This is mostly indicated by a question mark in the 'device manager' window.

If the UM device is already correctly recognized by the operating system of the PC, the problem must be on a higher software level. Please check whether your software really sends any commands. Some programs have limits in the maximum COM-port number, which may be easily exceeded in case the PC controls many devices at an experimental setup. In case of a Windows™ system, you can change the COM-port number inside the 'system control'→'system' →'device manager'→ 'COM-ports' in the 'extended properties' window to a lower number (a number which is not currently used).

In case this does not help, check whether the VISA software (applies for LabVIEW and similar software) from 'National Instruments' is correctly installed or eventually install the latest update. Note that unfortunately LabVIEW systems do NOT neccessarily indicate explicite errors if they happen inside their VISA software components.

If a **RS232 line** is used, first check cabling. If cabling seems to be ok, check, e.g. with an oscilloscope, if Bits are really transmitted. They should have the correct data format and speed (Baud rate, see above) and sufficiently steep edges on the waveform.

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Output voltages are not correct

Does the device return any error code (plain ASCII string)?
└─Yes: analyze error code (see above, list of error codes)
│
└─No: check if all 'power good' LEDs are green on UM device and also on Mains Adaptor. If not <u>all</u> 'power good' LEDs are green, there may have been an overload incident, causing a replacable melting fuse to blow. Try to remove error cause before replacing a fuse (e.g. short cuts in the cable connecting the mains adaptor to the UM device or on the output lines).

If <u>all</u> 'power good' LEDs are green, check whether the device and Mains adaptor are located in sufficiently low B-fields (UM-device $\leq$ 50mT, Mains Adaptor $\leq$ 5mT) and the output current loads are appropriate (see also section 4) and are not expected to create large voltage drops.
Otherwise contact manufacturer.

Remark: devices with option LN-SW feature approx. 3.9 kOhm output lines (primary channels), and 490 Ohm (secondary channels) causing a slight voltage drop if the voltages are measured with a multimeter with few MΩ-input resistance. It is preferabe to use a high-quality multimeter with GΩ-input resistance in cases of very high required absolut accuracy.

Declaration of Conformity

CE

Manufacturer Stahl-Electronics
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We declare that the product

BS Series Voltage Source, Type UM 1-14, UM 1-32
Options: all options included

complies with the European Union provisions with respect to directives

2014/35/EU applicable standard DIN EN 61010-1
2014/30/EU regarding electromagnetic compatibility (EMC), applicable standard EN 61326-1:2013,
2011/65/EU RoHS, including EU 2015/863, applicable standard EN 50581:2013

Authorized person: Dr. Stefan Stahl

Place, date	
Mettenheim, Sept. 1, 2021	signature