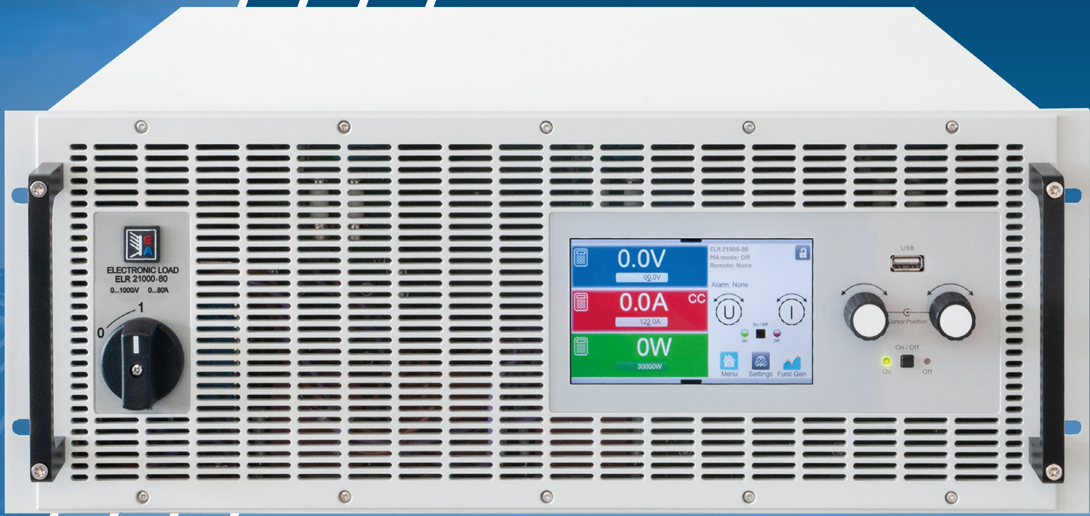


30 kW

USER MANUAL

EA-ELR 21000-80

High-speed regenerative load

Operation, remote control, function generator

Revision: 01

TABLE OF CONTENTS

1. About this document

You must read this document before you operate the high-speed regenerative load with energy recovery for the first time or if you are tasked with other work on the high-speed regenerative load with energy recovery.

1.1 General information

This document serves as a user manual for the device models listed in *«1.1.3 Application area»* and for their commissioning. The safety instructions in section *«2.5 Safety»* in the installation manual must be observed and implemented in particular.

1.1.1 Storage and use

This document should be kept for future reference and, if possible, in the vicinity of the device. It explains how to use the device. This document must be carried along when changing location and/or user.

The latest version of this document can be found online on our website.

1.1.2 Copyright protection

Reproduction, duplication or use of this document for purposes other than its intended purpose is not permitted and may result in legal action if this is not complied with.

1.1.3 Application area

This document applies to EA-ELR 21000-80:

1.1.4 Characters and symbols used in this document

The following signs and symbols are used in this document:

- List: The text after this symbol describes the list of individual points.

1. Numbers: The text after this symbol describes instructions that must be carried out in the specified order from top to bottom.

1.1.5 Structure of the warnings

Warnings, safety instructions and general notes in this document are always enclosed in a box and labeled with a symbol.

Signal word	Use for ...	Possible consequences if the safety instructions are not observed:
DANGER	Personal injury (imminent danger)	Death or serious injury!
WARNING	Personal injury (potentially dangerous situation)	Death or serious injury!
CAUTION	Personal injury	Slight or minor injuries!

The warnings are structured as follows:

- Pictogram with signal word corresponding to warning level
- Description of the hazard (type of hazard)
- Description of the consequences of the hazard (hazard consequences)

	**DANGER** **Type of hazard (text)** Consequences of danger (text) • Consequences of danger (Text)

Special safety instructions are provided at the relevant points. They are labeled with the following symbols.

	**Warning of dangerous electrical voltage -** This symbol indicates activities where there is a risk of electric shock, possibly with fatal consequences.
	**Information symbol for a risk of damage to the device -** If attached to the device, the symbol prompts the user to consult the device documentation.
	**General danger zone** - This sign is placed in front of activities where there is a risk of personal injury and extensive damage to property.
	*General note - Additional information*

1.2 Warranty and guarantee

EA Elektro-Automatik GmbH guarantees the functionality of the applied process technology and the specified performance parameters. The warranty period begins with defect-free handover. The warranty provisions can be found in the General Terms and Conditions (GTC) of EA Elektro-Automatik GmbH.

1.3 Limitations of liability

All information and instructions in this manual have been compiled taking into account applicable standards and regulations, the state of the art and our many years of knowledge and experience. The manufacturer accepts no liability for damage due to:

- Improper use
- Use of untrained and uninstructed personnel
- Unauthorized conversions
- Technical changes
- Use of unauthorized spare parts

The actual scope of delivery may differ from the explanations and illustrations described here in the case of special versions, the utilization of additional ordering options or due to the latest technical changes.

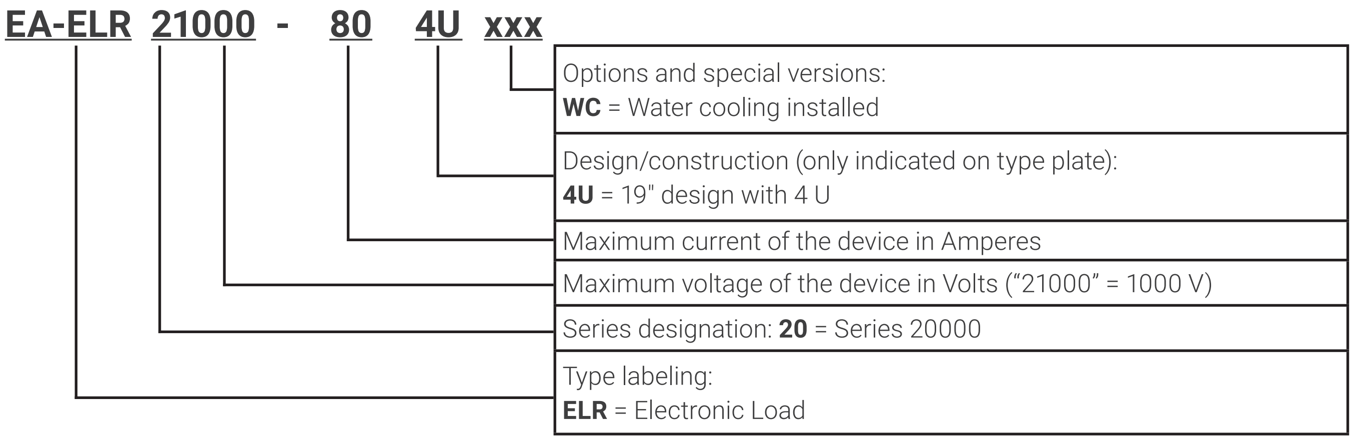
1.4 Disposal of the device

According to European laws and regulations (ElektroG, WEEE), a device that is intended for disposal must be taken back and disposed of by the manufacturer, unless the operator of the appliance or a person authorized by him does this himself. Our devices are subject to these regulations and are labeled accordingly with this symbol:

	The device contains a lithium battery. They are disposed of in accordance with the above specifications or in accordance with separate, local regulations.

1.5 Product key

Breakdown of the product designation on the rating plate using an example:



1.6 General safety regulations

See chapter *«2. General safety regulations»* in the installation manual.

2. Operation and use (2)

2.1 Control modes

A device like this contains one or more internal control loops that regulate the voltage, current and power to the set values by comparing the actual values and set values. The control loops follow the typical laws of control engineering. Each type of control mode has its own characteristics, which are described in detail below.

2.1.1 Terms

The device is a electronic load:

- **Sink / Sink mode / Sink mode**
  - The device operates as an electronic load and draws DC energy from an external DC source.
  - In this operating mode, the DC terminal is regarded as a DC-input.

2.1.2 Voltage control / constant voltage

Voltage control is also referred to as constant voltage operation (short: CV).

The voltage at the DC terminal is kept constant at the set value by the device if the current flowing into the load or from the source does not reach the set maximum current value or if the power according to P = U_{DC} * I does not reach the set maximum power value. If one of these cases occurs, the device automatically switches to current limiting or power limiting, whichever comes first. The voltage can no longer be kept constant and falls (in source mode) or rises (in sink mode) to a value resulting from Ohm's law. CV is available for both operating modes, source and sink, and which of the two results depends primarily on what voltage is present at the DC terminal and what the voltage set value is set to.

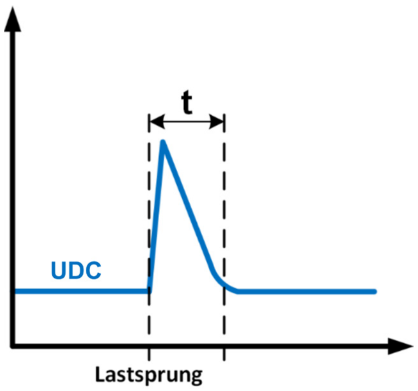
As long as the DC terminal is switched on and constant voltage operation is active, the “CV operation active” status is shown as the abbreviation **CV** on the graphic display, but can also be read out as a status via the digital interfaces.

2.1.2.1 Control peaks (CV operation)

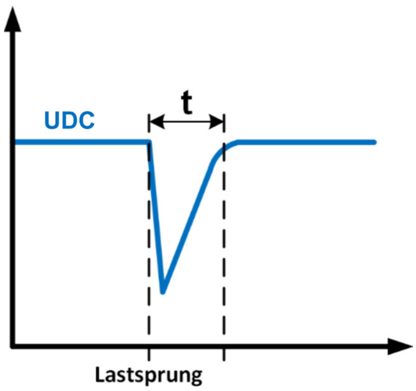
In CV mode, the voltage regulator of the device needs some time after a load change to regulate the DC voltage back to the set value. For technical reasons, a load jump from a low current to a high current (load) leads to a brief dip in the DC voltage, and a load jump from a high current to a low current (unload) leads to a brief increase in the DC voltage. The duration of the control can be influenced by switching the voltage regulator speed. See also *«2.1.6 Control behavior and stability criterion»* and *«2.3.1.1 “Settings” submenu»*. Compared to the setting **Normal** (default value), **Fast** reduces the duration and shortens the dip, but can result in overshoots. **Slow**, on the other hand, has the opposite effect.

The amplitude of the dip or increase depends on the model, the current DC voltage, the output capacitance and the actual load step and therefore cannot be specified precisely or in general terms.

Clarification:



Example for relief: the DC voltage briefly rises above the set value. t = Stabilization time

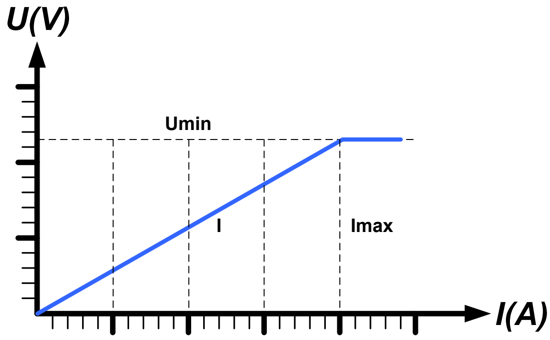


Example of load: the DC voltage briefly drops below the set value. t = Stabilization time

2.1.2.2 Minimum input voltage for maximum current (sink operation)

Due to technical conditions, each model in the series has a different minimum internal resistance (R_{MIN}), which means that a certain minimum input voltage (U_{MIN}) must be applied so that the device can draw the maximum current (I_{NOM}) in sink mode. This U_{MIN} is specified in the technical data, which can be found in the installation manual.

If less voltage is applied to the input, the device can draw correspondingly less current, even less than set. The curve is linear, so the maximum current that can be drawn at any input voltage below U_{MIN} can be easily calculated. A schematic diagram is shown on the right.



2.1.3 Current control / constant current / current limiting

Current control is also referred to as current limiting or constant current operation (abbreviated to **CC**).

The current at the DC terminal is kept constant at the set value by the device when the current flowing into the load (source mode) or out of the DC source (sink mode) reaches the set current set value. The current flowing out of the device during source operation results only from the set output voltage and the actual resistance of the load. If the current is below the set value, voltage control or power control takes place. When the current reaches the set value, the device automatically switches to constant current mode. However, if the power drawn from the load or the power drawn from the source reaches the adjusted power set value, the device automatically switches to power limitation and sets the voltage and current to P = U * I.

As long as the DC terminal is switched on and constant current mode is active, the status "CC mode active" is shown as the abbreviation **CC** on the graphic display, but can also be read out as a status via the digital interfaces.

2.1.3.1 Voltage overshoot

Voltage overshoots can occur in certain situations, e.g. if the device is in current limiting mode and the voltage is below the set value without control and if it is then suddenly discharged. This can be caused by a sudden increase in the current set value, which causes the device to leave CC, or by the load being switched off by an external disconnection unit. In both cases, the voltage overshoots the adjusted set value for an indefinite period of time. The level of the overshoot should not exceed 1-2% of the nominal voltage value of the device; the duration is determined by the size of the output capacitance and its current state of charge.

2.1.4 Power control / constant power / power limitation

Power control, also known as power limitation or constant power (short: CP), keeps the DC power constant at the set value when the current flowing into the consumer (source mode) or from the external source into the device (sink mode) reaches the maximum power in conjunction with the voltage at the DC terminal according to P = U * I (sink) or P = U² / R (source).

In source mode, the power limitation then regulates the current according to $I = \sqrt{(P / R_{LOAD})}$ at the set output voltage.

The power limitation works according to the auto-range principle, so that high current can flow at low voltage or low current can flow at high voltage in order to keep the power constant in the range P_N (see diagram on the right).

As long as the DC terminal is switched on and constant power mode is active, the status "CP mode active" is shown as the abbreviation **CP** on the graphical display, but can also be read out as a status via the digital interfaces.

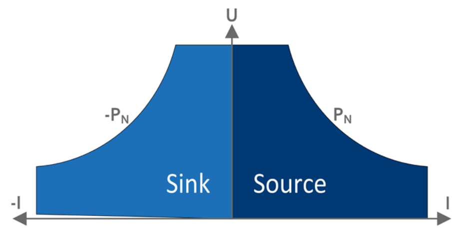


Figure 1 - Power output 30 kW models

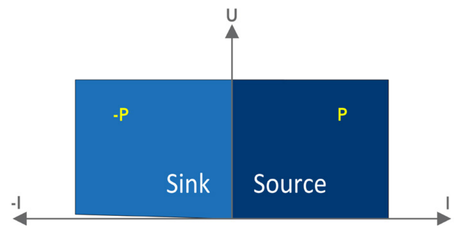


Figure 2 - Power output 10 kW model

2.1.5 Resistance control/constant resistance (sink operation)

In sink mode, when the device operates as an electronic load whose operating principle is based on a variable internal resistance, resistance control or constant resistance mode (CR for short) is an almost natural process. The load attempts to bring its own actual internal resistance to the value set by the user and to set the input current according to Ohm's law $I_{ON} = U_{ON} / R_{SOL}$ and as a function of the input voltage.

In the PSB 20000 series, the difference between the applied input voltage and the voltage set value determines the current. There are two situations:

a) The voltage applied to the DC-input is greater than the voltage set value

In this situation, the above formula expands to $\mathbf{I_{ON} = (U_{ON} - U_{SET}) / R_{SET}}$.

An example: the applied voltage is 200 V, the resistance R_{SET} for sink operation is set to 10 Ω and the voltage U_{SET} is set to 0 V. If the DC-input is now switched on, an actual current of 20 A should be calculated and the actual resistance R_{MON} should be approximately 10 Ω. If the voltage U_{SET} were now set to 100 V, the actual current would change to 10 A, but the actual resistance would remain the same.

b) The voltage applied to the DC-input is equal to or less than the voltage set value

In this case, the PSB 20000 would either not draw any current at all (CV mode) or, if the input voltage is equal to the voltage set value or fluctuates around it, it would constantly switch between CV and CR. It is therefore recommended that the voltage set value is always set differently to that of the external source.

There are natural limits to the internal resistance towards zero (current limitation or power limitation becomes active) and upwards (resolution of the current control is too imprecise). As the internal resistance cannot be 0, the adjustable initial value is limited to the feasible minimum.

This is also to ensure that the internal electronic load can draw a very high input current from the source at a very low input voltage, which in turn results in a very high input current at a low resistance, up to the current set on the device.

As long as the DC-input is switched on and constant resistance mode is active, the status "CR mode active" is shown as the abbreviation **CR** on the graphic display, but can also be read out as a status via the digital interfaces.

2.1.6 Control behavior and stability criterion

If the device operates as a sink, i.e. as an electronic load, it is characterized by fast current rise and fall times, which are achieved by a high bandwidth of the internal control.

If sources with their own control, such as power supply units or battery chargers, are tested with the electronic load, a control oscillation may occur under certain conditions. This instability occurs when the overall system (feeding source and electronic load) has too little phase and amplitude reserve at certain frequencies. 180° phase shift at >0dB gain fulfills the oscillation condition and leads to instability. The same can also occur with sources without their own control (e.g. battery) if the load supply line is highly inductive or inductive-capacitive.

If a control oscillation occurs, this is not caused by a defect in the electronic load, but by the behavior of the entire system. Improving the phase and amplitude reserve can remedy this. In practice, an attempt is first made to adjust the dynamics of the voltage regulator, which can be done by switching the control speed (**Slow**, **Normal**, **Fast**), where **Normal** is the default setting at which the oscillation occurred. The switch is found in the device settings (see section *2.3.1.1*) and in the quick menu (see section *2.3.4*).

The user can only find out which of the settings produces the desired effect by trial and error. If an effect can be seen, but it is not sufficient, a capacitor can be attached directly to the DC-input as an additional measure, possibly also to the remote sensor input if this is connected to the source. It is not possible to determine which value will have the desired effect.

We recommend:

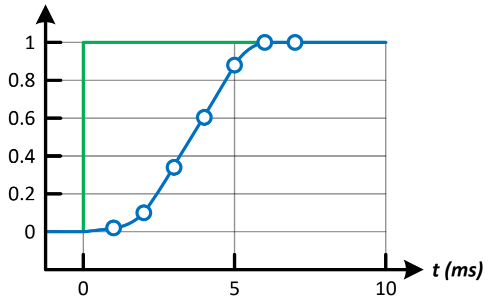
1000 V model: 22uF...100uF

2.2 Other functions related to the DC terminal

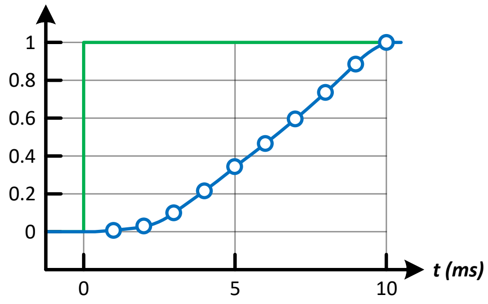
2.2.1 Actual value filtering

The filtering of the actual values measured at the DC terminal can be configured in the settings in the device menu using the parameter **Actual value filter**. By default, filtering is performed in **Fast** mode. Here, a new measured value is available every millisecond, which has no visible effect when operated manually and shown on the display. For remote control and querying via a fast, clocked interface such as EtherCAT, the 1 ms update rate of the actual values is an advantage. The actual values measured in **Fast** mode are already quite well filtered; if you want to obtain even better smoothed actual value curves, you can alternatively use **Precise** mode. This results in around half the number of samples per second compared to **Fast** mode.

Clarification:



Mode **Fast**: the set value jump (green) results in a step response (blue), recorded in steps of 1 ms, distributed over approx. 6 ms.



Mode **Precise**: the set value jump (green) results in a step response (blue), recorded in steps of 1 ms, distributed over approx. 10 ms.

2.2.2 Alarms and monitoring (2)

Safety-related alarms are described in chapter *«9.2.1. Alarm signals»* and also in *«7.4 Alarms and monitoring (1)»* of the installation manual.

2.2.2.1 External temperature monitoring

This monitoring refers to the temperature of external test objects, such as a battery to be tested. However, any other temperature-dependent object can also be monitored. Monitoring is carried out with a digital sensor (type DS18B20 or MAX31820 from Analog Devices, not included in the scope of delivery), which is connected to the "Digital In/Out Port" interface. For pin assignment, see chapter *«5.9.1 Technical data for the 'Digital In/Out port' connection»* in the installation manual.

The sensor has a detection range of -55 °C to 125 °C. The typical application would be mounting on the battery body. If the sensor is correctly connected via the plug to "Digital In/Out", it is recognized and its status is displayed in the menu. Monitoring can then be enabled and you can select whether a warning (ETW) should be displayed on the device screen before the DC terminal is about to be switched off by the ETP alarm. The warning itself does nothing more than inform the user.

The following applies to the configuration (see also *«2.3.1.1 "Settings" submenu»*):

- The value of the ETW threshold cannot be higher than the value of the ETP threshold
- The value of the ETW threshold is always at least 5 °C lower than that of the ETP threshold
- The default values after resetting the device are ETW = 30 °C and ETP = 35 °C
- You can choose whether the ETW warning is triggered before the ETP alarm or only the alarm

If both events, i.e. the ETW warning and the ETP alarm, have been enabled, only a warning is initially shown on the display when the temperature rises and as soon as the ETW threshold is reached, and the alarm may be triggered later. In order to continue working after the DC terminal has been switched off due to an alarm ETP, the sensed test object must cool down again to at least 5°C below the ETP threshold. Only then can the alarm be cleared and the DC terminal switched back on. It is similar with the warning, which can only be canceled after it has occurred if the temperature is at least 2°C below the ETW threshold.

2.2.2.2 Line overload monitoring

This line monitoring refers to the overload of lines and DC contactors. Line monitoring monitors the voltage drop between Sense 1 and the DC terminal of the device. The use of Sense 1 is therefore mandatory. The voltage difference is set in Volts. The monitoring principle is based on a delta analysis of the measured voltages Sense 1 and DC terminal. The difference is analyzed regardless of the sign.

Line monitoring can be activated and you can set whether a warning (COW) should appear on the device screen before the DC terminal is shut down by the alarm COP. This warning informs the user that the DC terminal has been switched off.

The following applies to the configuration (see also *«2.3.1.1 "Settings" submenu»*):

- The value of the COW threshold cannot be higher than the value of the COP threshold
- The value of the COW threshold is always at least 0.50 V lower than that of the COP threshold
- You can select whether the COW warning is triggered before the COP alarm or only the alarm

If both events, i.e. the COW warning and the COP alarm, have been enabled, only a warning is initially shown on the display when a voltage drop above the COW threshold is detected and the alarm may be triggered later. To continue operation after switching off the DC terminal due to a COP alarm, the alarm must be cleared and the DC terminal switched back on. If the COP alarm has been triggered, it is advisable to check the wiring from the DC terminal to the battery.

2.3 Manual operation (2)

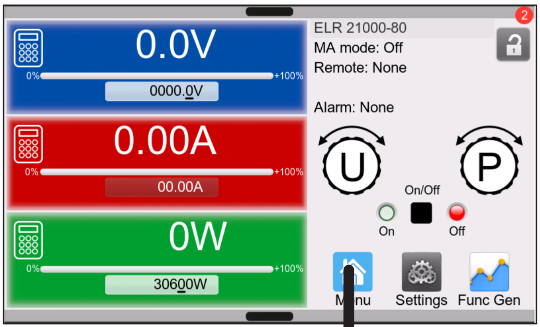
⚠	With manual operation and if the device is connected to a controlling unit (e.g. PC) via at least one of the available interfaces, the controlling unit could take over control at any time without warning or a confirmation prompt. For safety reasons, it is recommended to lock the remote by activating 'Local' mode, at least for the duration of manual operation.

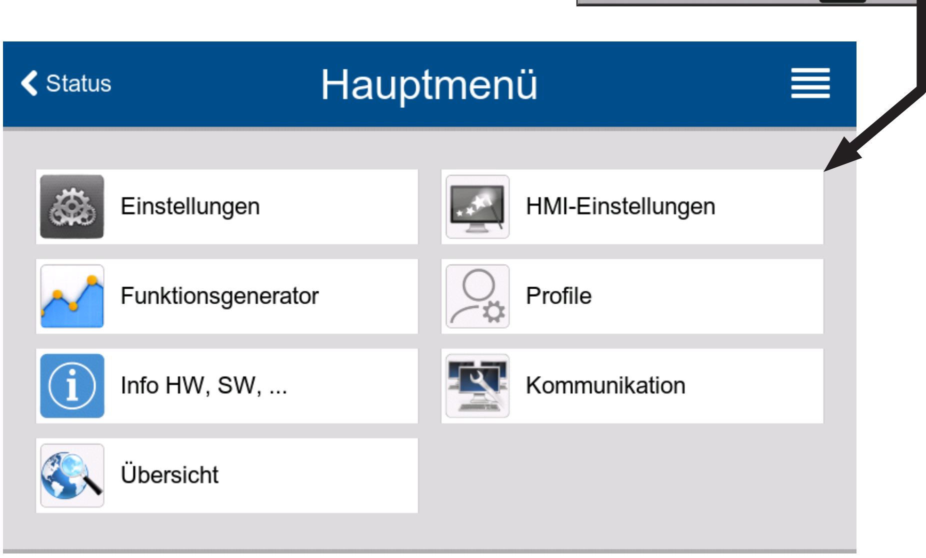
2.3.1 Configuration in the menu

The menu is used to configure all operating parameters that are not constantly required. It can be accessed by tapping the button **Menu**, but only if the DC terminal is **switched off**. See diagrams.

If the DC terminal is switched on, however, only status information is displayed instead of a settings menu.

Navigation in the submenus is by finger touch, values are set using an on-screen numeric keypad. These are explained in detail on the following pages.





2.3.1.1 "Settings" submenu

This submenu can also be accessed directly by tapping on the **Setting** field in the main display.

> *The availability of the settings listed here depends on the firmware version of the HMI. The manual always shows the set of settings contained in a certain firmware, which may be model-dependent and some may therefore not be displayed on all devices.*

Group	Setting & description
Presets	**U, I, P**
	Presetting of all set values via direct input with numeric keypad.
Protection	**OVP, OCP, OPP**
	Set protection limits. See also chapter *«9.2.1 Alarm signals»* in the installation manual.
Limits	**U-min, U-max** etc.
	Set adjustment limits. More on this is provided in *«2.3.2 Adjustment limits»* in this document.
User events	**UVD, OVD** etc.
	Set monitoring limits that trigger user-defined events (for more information, see chapter *«7.5 User-definable events (user events)»* in the installation manual).
General	**Allow remote control**
	If remote control is not permitted, the device cannot be operated remotely via one of the digital interfaces. The status that the remote control is locked is displayed in the status field of the main display with **Local**. See section *«5.2 The control unit (HMI)»* in the installation manual.
	Activate R mode
	Enables or disables the internal resistance control. When R mode is enabled, the internal resistance value is shown in the normal display.
	Voltage controller speed
	Can switch the internal voltage regulator between three speeds, which influence the voltage control. See also *«2.1.6 Control behavior and stability criterion»*. • **Slow** = the voltage regulator slows down slightly, the oscillation tendency decreases. • **Normal** = the voltage regulator is normally fast (default setting). • **Fast** = the voltage regulator becomes slightly faster, the oscillation tendency increases.
	Actual value filter
	Use **Fast** (default) or **Precise** to select the actual value filtering mode for the device. For more information, see *«2.2.1 Actual value filtering»*.
	Fast stop
	Determines whether and to which level at pin 1 of the "Digital In/Out port" interface the device reacts. For more information, see *«2.4.5 Fast stop»*. • **Disabled** = the **Fast stop** function is disabled, pin 1 is ignored. • **Active HIGH** = the **Fast stop** function is enabled, the device reacts to a HIGH level. • **Active LOW** = the **Fast stop** function is enabled, the device reacts to a LOW level. For the definition of the levels, see the technical data of the interface in section *«5.9.1 Technical data of the «Digital In / Out» port»* of the installation manual.

Group	Setting & description
DC terminal	**State after power ON**
	Determines what the status of the DC terminal should be after the device is switched on. • **Off** = The DC terminal is always off after switching on the device. • **Restore** = The status of the DC terminal is restored as it was when the device was last switched off. This option is "Off" according to the factory settings or after resetting the device. Activation at your own risk and peril. The device may switch on the DC terminal automatically after start-up!
	State after PF alarm
	Determines how the status of the DC terminal should behave after a power fail alarm: • **Off** = The DC terminal remains off. • **Auto** = The DC terminal switches back on automatically if it was also switched on before the alarm occurred.
	State after remote
	Determines what the status of the DC terminal should be after the remote control has been ended manually or by command. • **Off** = Always off after leaving the remote control. • **Auto** = State is retained.
	State after OT alarm
	Determines what the status of the DC terminal should be after an overtemperature alarm and cooling down: • **Off** = The DC terminal remains off. • **Auto** = The DC terminal switches back on automatically if it was also switched on before the alarm occurred.
Master-auxiliary	**Mode**
	The options **Master** or **Auxiliary** activate the master-auxiliary mode (MA) and simultaneously define the function of the device in the MA network. More information about MA mode can be found in the section *«4.1 Parallel connection as master-auxiliary system»*.
	Backlight off after 60s
	When enabled, the backlight settings switch off if the screen is not touched or no button or rotary knob is pressed for 60 seconds. This setting is mainly intended for auxiliary units if their screen should not be on all the time. It is identical to the one in the **HMI setup** menu.
	Initialize system
	The HMI reinitializes the master-auxiliary system, even in the event that the automatic detection of all auxiliary units by the master should not work and therefore less total power would be available.
USB logging	**Log file separator format**
	Defines the log file separator format of the CSV file for USB logging. See section *«2.3.5 Data recording on USB stick (logging)»* in this document, as well as *«5.2.5 USB port (front)»* in the installation manual: • **US** = Log file separator format is a comma (US format). • **Standard** = Log file separator format is a semicolon (German or European format).
	Logging with units (V,A,W)
	With USB logging, all values are recorded in the CSV file with unit by default. This can be disabled here.

Group	Setting & description
USB logging	**USB logging**
	Enables/disables data recording (logging) on USB stick. For more information, see section *«2.3.3 Data recording on USB stick (logging)»*.
	Logging interval
	Defines the time interval between two recorded data records. Selection: **500ms**, **1s**, **2s**, **5s.**
	Start/stop
	Defines when logging should start or stop. • **Manual** = Logging is started manually via button in the quick menu • **At DC on/off** = Logging starts and stops with every status change at the DC terminal, regardless of the cause and as long as logging is enabled. Please note: A new log file is created on the stick each time logging is started.
Reset / restart	**Reset device to defaults**
	Resets all settings (HMI, profiles, etc.) and set values to default values.
	Restart device
	Initiates a warm start of the device.
External temperature monitoring	**Monitoring mode**
	Activates temperature monitoring which, in conjunction with sensors connected to the rear "Digital In/Out Port", can trigger either a warning or an alarm. See also sections *«9.2 Troubleshooting / Fault diagnosis / Repair»* in the installation manual. Monitoring is disabled at the factory or after a reset. You can choose the following: • **Disable** = Monitoring disabled. • **ETP+ETW** = Both monitoring limits are taken into account. • **ETP** = Only the monitoring limit for alarm is taken into account.
	Temperature warning (ETW)
	Sets the monitoring limit for the temperature warning, which triggers a warning (message on the HMI) if exceeded (if value is positive) or undershot (if value is negative), provided that ETW has been enabled. This threshold must always be at least 5 °C below that of the temperature alarm. Setting range: **-55°C**...(ETP value -5°C), standard value: **30°C**
	Temperature alarm (ETP)
	Sets the monitoring limit for the temperature alarm, which triggers an alarm (switch-off of the DC terminal, message on the HMI) if exceeded (if value is positive) or undershot (if value is negative), provided that ETP is enabled. This threshold must always be at least 5 °C above the temperature warning. Setting range: (ETW value + 5°C)...**+125°C**, default value: **35°C**
	Sensor state
	Indicates the status of the sensor input of the rear interface "Digital In/Out Port" or returns the status of the sensor. • **Sensor uninitialized** = Sensor was not detected when the device was started. • **Ready** = Sensor has been recognized and is working. • **Sensor failure** = Sensor was removed after detection or has failed (cable break or similar). • **Alarm active** = ETW monitoring limit has been reached. • **Warning active** = ETP monitoring limit has been reached.
	Sensor value
	Temperature value measured by the sensor in degrees Celsius. This value is the reference for the two monitoring limits.

Group	Setting & description
Connection overload monitoring	**Monitoring mode**
	Activates connection overload monitoring, which monitors the voltage drop between input “Sense” and the DC terminal and can trigger either a warning or an alarm. See also sections *«7.4 Alarms and monitoring (1)»* and *«9.2.10 Cable overload alarm»* in the installation manual. Monitoring is disabled at the factory or after resetting the device to the factory settings. You can choose the following: • **Disable** = Monitoring disabled • **COP+COW** = Both monitoring limits are taken into account • **COP** = Only the monitoring limit for alarm is taken into account
	Connection overload warning (COW)
	Sets the monitoring limit for the line overload warning, which triggers a warning (message on the HMI) if exceeded, provided COW has been enabled. This threshold must always be at least 0.5 V below that of the line overload warning. Adjustment range: **0V**...(COP value - 0.5 V), standard value: **1.5V**
	Connection overload protection (COP)
	Sets the monitoring limit for the cable overload alarm, which triggers an alarm (switch-off of the DC terminal, message on the HMI) if COP is enabled. This threshold must always be at least 0.5 V above the connection overload warning. Adjustment range: (COW value + 0.5 V)...nominal voltage, default value: **2V**

2.3.1.2 “Profiles” submenu

See *«2.3.5 Load and save user profiles»*.

2.3.1.3 “Overview” submenu

This submenu displays an overview of the current set values (U, I, P), device alarm thresholds, event settings, adjustment limits and an alarm history (number of device alarms that have occurred since the device was switched on).

2.3.1.4 Submenu “About HW, SW, ...”

This submenu shows an overview of device-related data such as serial number, article number, etc.

2.3.1.5 “Function generator” submenu

See *«3. The function generator»*.

2.3.1.6 “Communication” submenu

Settings for digital communication via the built-in digital interfaces (USB, Ethernet, CAN) are made here. In addition, so-called “communication timeouts” can be customized. You can find out more about timeouts for remote control in the separate programming instructions supplied. The rear USB port and the EtherCAT ports do not require any settings.

Ethernet group: Settings for the Ethernet interface

IF	Setting	Description
Ethernet	**DHCP**	The IF can be assigned an IP and, if necessary, a subnet mask and gateway by a DHCP server. If there is no DHCP server in the network, the listed network parameters are set.
	IP address	The IP address of the device can be set manually here
	Subnet mask	A subnet mask can be set manually here
	Gateway	A gateway address can be specified manually here if required
	DNS address	The address of a domain name server can be specified here if required
	Port	Select port in the range 0...65535. Standard port: **5025** Reserved ports: 502, 537
	Host name	Any selectable host name
	Domain name	Any selectable domain name
	MAC address	of the Ethernet port

CAN group: Settings for CAN and CAN FD mode of the CAN interface

IF	Setting	Description
CAN	**Baud rate**	Set the CAN bus speed to typical values between **10kbps** and **1Mbps** for "normal" CAN, as well as **500kbps/2Mbps** and **500kbps/5Mbps** additionally for CAN FD if CAN FD mode has been activated previously. Default value: **500kbps.**
	ID format	Selection of the CAN ID format between **Standard** (11 bit IDs, 0h...7ffh) or **Extended** (29 bit IDs, 0h...1fffffffh)
	Bus termination	Switching the electronically switched bus terminating resistor in the module on or off. Default setting: off.
	Data length	Set the message length for all messages sent by the device (replies). • **Auto** = Length varies between 3 and 8 bytes depending on the object. • **Always 8 bytes** = Length is always 8 bytes, padded with zeros.
	CAN FD	Enables or disables the CAN FD functionality of the CAN port. The switch also enables two baud rate settings associated with CAN FD at **Baud rate**. CAN FD mode is disabled after resetting the device so that the port operates in normal CAN mode by default.
	Bit rate switching	Enables or disables bit rate switching (BRS) of the CAN FD mode. Messages in CAN FD format could then use the higher data rate, as selectable with setting **Baud rate**. This option is disabled after a reset.
	Base ID	Setting the CAN base ID (11 bits or 29 bits, hexadecimal format). Default value: **0h**
	Broadcast ID	Setting the CAN broadcast ID (11 bits or 29 bits, hexadecimal format). Default value: **7ffh.**
	Base ID Cyclic Read	Setting the CAN base ID (11 bits or 29 bits, hexadecimal format) for cyclic reading of multiple object groups. The device automatically sends the contents of the object groups via these IDs at the specified interval as long as they are enabled. More on this in the programming instructions. Default value: **100h.**
	Base ID Cyclic Send	Setting the CAN base ID (11 bits or 29 bits, hexadecimal format) for cyclic transmission of status and set values. The device receives the contents of two specific object groups in a more compact format via these IDs. More on this in the programming instructions. Default value: **200h.**
	Cyclic Read Time: Status	Enabling/disabling and time setting for automatic reading of the status via the set **Base ID Cyclic Read**. Adjustment range: 20...5000 ms. Default value: **0ms** (disabled).
	Cyclic Read Time: Actual Values	Enabling/disabling and time setting for automatic reading of actual values via the set **Base ID Cyclic Read + 1**. Setting range: 20...5000 ms. Default value: **0 ms** (disabled).

Group timeouts and protocols: Additional general communication settings

Group	Setting & description
Timeouts	**TCP keep-Alive**
	Enables/disables the TCP keep-alive network functionality for the built-in Ethernet port and uses this to maintain the socket connection. If keep-alive is supported in the network, the device disables the adjustable Ethernet timeout (see below **Timeout ETH**).
	Timeout USB/RS232
	Sets the maximum time (in milliseconds) that may elapse between the transfer of two bytes or blocks of bytes. More on this is provided in the separate programming instructions supplied. Default value: **5ms**, range: **5ms...65535ms.**
	Timeout ETH
	If there is no command communication with the device during the set time (in seconds), the socket connection is closed by the device. The timeout is ineffective as long as the **TCP Keep-Alive** option associated with the respective interface is enabled and is actively supported by the network. Setting value 0 permanently disables the timeout. Default value: **5s**, range: **0s** / **5s...65535s** (0 = timeout disabled).
	Interface monitoring / Timeout interface monitoring
	Enables/disables interface monitoring (see section *«2.4.4 Interface monitoring»*). Default values: off, **5s** / range: **5s...65535s.**
Protocols	**Communication protocols**
	Enable / disable the SCPI or ModBus communication protocols. One of each can be disabled if not required.
	ModBus specification compliance
	Can be switched from **Limited** (default setting) to **Full** so that the device sends messages in ModBus RTU or ModBus TCP format that are compatible with software libraries available on the market. With **Limited**, the previous, partly incompatible message format is used (see also programming instructions).

2.3.1.7 "HMI setup" menu

These settings relate exclusively to the operating unit (HMI).

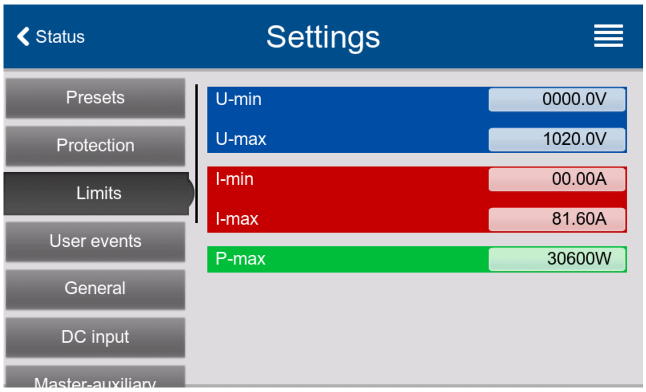
Group	Setting & description
Language	Switch the language displayed (default: English).
Sound	**Key sound**
	Enables or disables the sound output when a button or knob is pressed in the display.
	Alarm sound
	Enables or disables the additional acoustic signalling of a device alarm or user-defined event that has been set to **Action = Alarm**. See *«7.5User-definable events (user events)»* in the installation manual.
Clock	Setting the date and time of the internal, battery-backed clock.
Backlight	**Backlight off after 60s**
	Defines whether the backlight settings should switch off if no input is made via the touchscreen or rotary knob for 60 seconds. As soon as one occurs, the backlight switches on again automatically. The backlight brightness can also be adjusted.
Lock	See sections *«7.3.6 Locking the control unit (HMI)»* and *«7.3.7 Locking adjustment limits and user profiles»* in the installation manual, as well as *«2.3.5 Load and save user profiles»*.

2.3.2 Adjustment limits

⚠	The adjustment limits only apply to the corresponding set values, both for manual operation and remote control.

By default, all set values (U, I, P) can be set from 0...102%.

This range can be restricted, especially to protect against accidental adjustment to a much too high value. Lower and upper adjustment limits can be defined for voltage (U) and current (I).



► How to configure the adjustment limits

1. With the DC terminal switched off, tap  Settings.
2. Tap the **Limits** group on the left. Related values are grouped here and separated by color. These are selected by tapping a value to set. Values hidden further down can be accessed by swiping vertically with your finger.
3. Set using the displayed numeric keypad and confirm with Enter.

❗	*The adjustment limits are linked to the set values. This means that the upper setting limit (-max) of the set value cannot be set lower or the lower setting limit (-min) cannot be set higher than the current set value.* *If you want to set the power setting limit (P-max) to 6000 W and the power set value is still set to 8000 W, then you would first have to set the power set value to 6000 W or lower in order to be able to set P-max to 6000 W.*

2.3.3 Data recording on USB stick (logging)

Data can be recorded from the device using a standard USB stick (USB 3.0 works, but not all memory sizes). For more detailed specifications on the stick and the files, please read section *«5.2.5 USB port (front)»* in the installation manual. CSV files created by logging have the same format as those created by the “Logging” app in the **EA Power Control** software, which is used for logging on the PC. The advantage of logging to a stick is that the device does not need to be connected to the PC. The function only needs to be configured and enabled in the settings menu.

2.3.3.1 Configuration

See also section *“2.3.5 Data recording on USB stick (logging)”*. After activating the USB logging function and setting the **Logging interval** and the **Start/stop** behavior, logging can be started after exiting the settings menu.

For the CSV files generated by logging, you can specify which log file separator format (German/European or **US**) should be used and whether values in the individual columns should be recorded with or without a physical unit. Disabling the latter simplifies the processing of log files in MS Excel, for example.

2.3.3.2 Operation (start/stop)

If setting **Start/Stop** is set to **At DC on/off**, logging starts when the DC terminal is switched on, which can be done either by manually pressing the “On/Off” button on the front of the device or controlling the same function via digital interface. If **Manual** is set, logging can only be started and stopped in the quick menu (see image on the right).

The button (only visible if USB logging has been activated) starts recording and then changes to , which can be used to stop recording.

Once recording has started, the symbol appears on the display. If an error occurs during the logging process (stick full, stick removed), a corresponding symbol is displayed. Each time the DC terminal is stopped or switched off manually, logging is ended and the recorded log file is closed.

2.3.3.3 The file format for USB logging (ELR mode)

Type: Text file in European or US CSV format (depending on settings). Structure:

	A	B	C	D	E	F	G	H	I	J	K	L	M
1	U set	U actual	I set	I actual	P set	P actual	R set	R actual	R mode	Output/Input	Device mode	Error	Time
2	0000,0V	58,7V	00,00A	0,00A	30000W	0W	N/A	N/A	OFF	OFF	NONE	NONE	21:21:12.953
3	0000,0V	58,7V	00,00A	0,00A	30000W	0W	N/A	N/A	OFF	OFF	NONE	NONE	21:21:13.460
4	0000,0V	58,7V	00,00A	0,00A	30000W	0W	N/A	N/A	OFF	OFF	NONE	NONE	21:21:13.960
5	0000,0V	58,7V	00,00A	0,00A	30000W	0W	N/A	N/A	OFF	OFF	NONE	NONE	21:21:14.460
6	0000,0V	58,7V	00,00A	0,00A	30000W	0W	N/A	N/A	OFF	OFF	NONE	NONE	21:21:14.960

Legend:

U set: Set value for U

U actual / I actual / P actual / R actual: Actual values.

I set: Set values for I

P set: Set values of P

Output/Input: DC terminal status

Device mode: Current control mode (see also *“2.1 Regulation modes”*)

Error: Device alarms

Time: Time from start of logging

Notes:

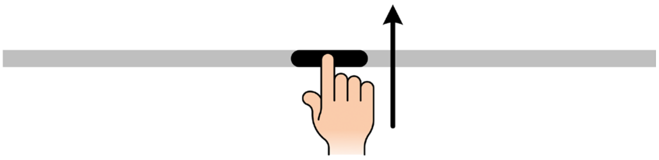
- In contrast to logging on the PC, each new log process in USB logging creates another file with the naming scheme usb_log_1.csv etc., which is given an incremented number at the end of the file name; existing log files are taken into account.

2.3.3.4 Special notes and restrictions

- Maximum file size of a recording file, limited by FAT32: 4 GB
- Maximum number of recording files in the HMI_FILES folder: 1024
- If **Start/Stop** is set to **At DC on/off** in the settings, logging also stops for alarms or events with action **Alarm** because these switch off the DC terminal
- If **Start/Stop** is set to **Manual**, the device continues to record during alarms so that, for example, the duration of temporary alarms such as OT and PF can be determined

2.3.4 The quick menu

The device offers a quick menu for direct access to the most important settings. It can be accessed at any time in the main display by swiping your finger upwards from the bottom of the screen or tapping the bar:



Overview:

The corresponding function is enabled or disabled by tapping it. Symbols with black on white indicate a currently enabled function:

Symbol	Belongs to	Meaning
	HMI	Alarm sound = on
	HMI	Key sound = on
	USB logging	USB logging is running (icon is only available if USB logging has been enabled in the menu **Settings**)
M	Master-auxiliary	Master-auxiliary enabled, device is master
A	Master-auxiliary	Master-auxiliary enabled, device is auxiliary
Aus	Master-auxiliary	Master-auxiliary not enabled
	Operating modes	Switching the voltage controller speed between **Slow**, **Normal** (default) and **Fast** (see *«2.1.6 Control behavior and stability criterion»*)
	HMI	Sets the backlight brightness
	HMI	Opens the graph
Menu	HMI	Opens the main menu

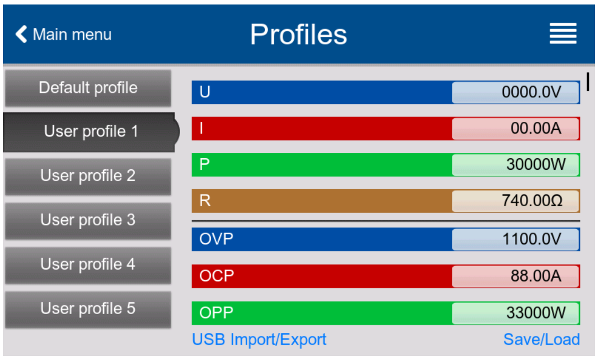
2.3.5 Load and save user profiles

The **Profile** menu is used to select a profile for loading or to switch between a standard profile and 5 user profiles. A profile is a collection of all settings and all set values. When the device is delivered or after a reset, all six profiles have the same settings and most of the set values are set to 0. If the user then makes settings and changes values, this is done in a **work profile**, which is also saved when the device is switched off. This work profile can be saved in one of the five user profiles or loaded from these five user profiles or from the default profile. The default profile itself can only be loaded.

The purpose of profiles is to quickly load a set of set values, adjustment limits and monitoring limits, for example, without having to set them all again and again. As all settings for the HMI are saved in the profile, including the language, it would also be possible to change the language of the HMI when switching from one profile to another.

When calling up the **Profiles** menu page and selecting a profile, its most important settings, such as set values, adjustment limits, etc., can be viewed and also adjusted.

► How to save the current settings (work profile) in a user profile

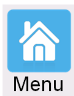


1. With the DC terminal switched off, tap on the  button on the main page.
2. On the main menu page, tap **Profile**.
3. In the selection that now appears (see example on the right), choose between user profiles 1-5 to which you want to save. The selected user profile is then displayed. You can check the settings and values again here.
4. Press the button **Save/Load** and in the following query save **Save profile?** with **Save**.

> *If any changes are made to a user profile, the profile cannot be loaded or saved initially. The user must either accept the change by clicking "Save changes" or reject it by clicking "Cancel".*

Loading a user profile into the work profile is done in the same way, except that at the end you have to tap **Load** under **Load profile?**. The user profiles can also be saved to or loaded from a USB stick. This is done via **USB Import/Export**.

► How to edit a user profile

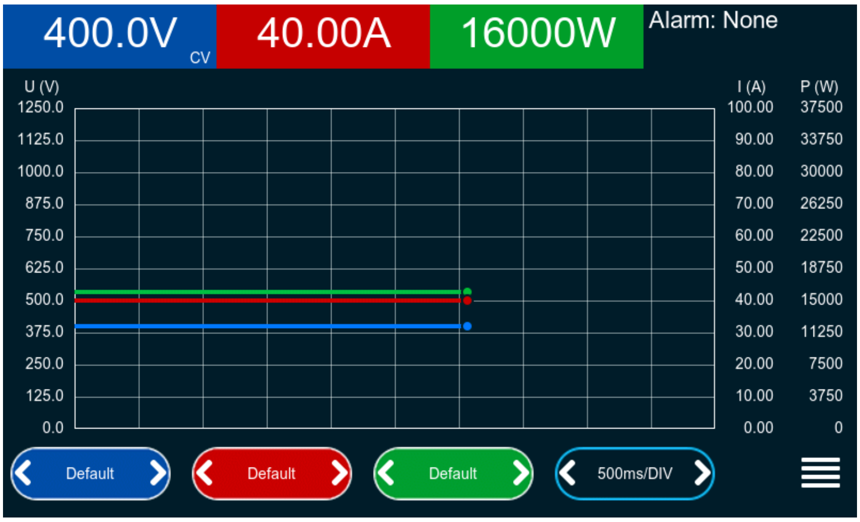
1. With the DC terminal switched off, tap on the  button on the main page.
2. On the main menu page, tap **Profile**.
3. In the selection that now appears, select the user profile that you want to change. The selected user profile is then displayed.
4. Tap on a value to be changed and enter a new one. As soon as one of the values has been changed, the **Save/Load** button changes to **Save changes**.
5. When finished, tap **Save changes** to save the profile. It is not yet active at that moment.
6. Optional: to use the profile that has just been changed, it must be loaded into the work profile. This is done by tapping **Save/Load** and **Load** in the subsequent query **Load profile?**.

2.3.6 The Graph

The device has a visual display of the voltage, current and power history, called the **Graph**, which can only be accessed when operating the HMI. This is not a recording function. The graph can be started in normal mode (no function running) and via the quick menu, in function generator mode via a separate screen with the same appearance. Once called up, the graph is displayed in full.

⚠	Only limited status and operating options on the graph screen! However, for safety reasons, it is possible to switch off the DC terminal at any time using the **On/Off** button.

Overview:



Operating options:

- Tapping on the graph area pauses the graph or tapping it again restarts it
- Tapping on the **center** of the three red/green/blue control buttons disables or enables the corresponding plot
- Tapping on **the sides** (left/right arrows) of the three red/green/blue control buttons changes the vertical resolution
- Tapping on **the sides** (left/right arrows) of the black control surface changes the time resolution
- Swipe on the three scales (Y-axis) to move them
- Tap the menu icon ( ) to exit the graph at any time

2.4 Remote control

2.4.1 General information

Remote control is always possible via one of the built-in interfaces (USB, Ethernet, CAN, EtherCAT). It is important that only one of the interfaces can be engaged. This means, for example, that if you tried to switch to remote control via EtherCAT when remote control via Ethernet is active, the device would reject this. In this case, it would be necessary to exit remote control via Ethernet first.

Monitoring, i.e. monitoring the status or reading out values, is always possible, even via several interfaces at the same time.

2.4.2 Control locations

Control locations are the locations from which a device is controlled. There are basically two: on the device (manual operation) and outside (remote control). The following control locations are defined:

Control location according to display	Explanation
Remote: None	If neither of the other two control locations is displayed in the status field, manual control is active and access via the digital interfaces is enabled.
Remote: <Interface name>	Remote control via one of the interfaces is active
Local	Remote control is locked, device can only be operated manually

Remote control can be permitted or blocked via the setting **Allow remote control** (see *«2.3.1.1 "Settings" submenu»)*. When locked, the status **Local** can be read in the status field at the top right of the display. Activating the lock can be useful if software or electronics normally control the device remotely all the time, but you need to tamper with it to make a setting or in an emergency, which would otherwise not be possible with remote control.

The lock or the **Local** status can only be enabled on the control panel (HMI). If this happens while the remote control is already active, you will be asked whether you want to end it, which you will be asked to do as soon as you select **Yes**. However, the remote control is then not locked by **Local** and you would first have to go to the menu to lock it there. This can be interrupted by the control software.

2.4.3 Programming

Details on programming the rear interfaces, the communication protocols etc. can be found in the separate programming instructions, which are supplied with the device on a USB stick or can be downloaded from the device manufacturer's website.

2.4.4 Interface monitoring

The **Interface monitoring** function is used to monitor the digital communication connection between a controlling unit (PC, PLC, etc.) and the device. The aim of monitoring is to ensure that the device does not continue to work undefined if the communication connection is interrupted. An interruption can occur if a data line is physically disconnected (defect, poor contact, cable removed), the interface in the device no longer functions as expected or an intermediate unit (server) has disconnected the connection.

Only the digital interface via which the device is currently being controlled is monitored. This also means that this monitoring is inactive as long as a device is not under remote control. Monitoring can only work if the device is communicated with at least once within a definable period of time. For this purpose, the user sets a timeout that is reset by the device each time a message is received.

However, if the time window expires, the following is defined as the reaction of the device:

- The remote control is terminated
- The DC terminal, if switched on, is either switched off or remains switched on, as specified by the setting **DC terminal -> State after remote** (see section *«2.3.1.1 "Settings" submenu»*)

Instructions for use:

- The interface monitoring timeout can be changed at any time; the changed value only becomes effective after the time of the current timeout has expired
- The interface monitoring does <u>not</u> disable the Ethernet timeout, see section *«2.3.1.6 "Communication" submenu»*, so both timeouts can overlap

2.4.5 Fast stop

The Fast stop is a remote-controlled, direct shutdown of the DC terminal via the “Digital In/Out” port, with either a normally open or normally closed contact and a two-wire cable, which can be used as required.

To be able to control the Fast stop, two things must be in place:

a) Pins 1 and 2 of the “Digital In/Out” port (see section *5.9.1* in the installation manual) are connected to a controlling application by cable (two-wire). The application must apply a voltage to the pins.

b) The Fast stop function is enabled for the device (see *«2.3.1.1 “Settings” submenu»*). Otherwise, triggering the fast stop via pin 1 would be ignored.

!	*This fast stop should not be confused with an emergency stop!*

The following always applies to the enabled Fast stop:

- If the Fast stop is triggered while the DC terminal is switched on, it is switched off regardless of what the device is currently doing; in addition, an alarm is displayed which can only be deleted when the level at pin 1 changes again and must be deleted before the DC terminal can be switched on again
- Pin 1 is either active HIGH or active LOW; this means that if active HIGH is selected, a HIGH signal at the pin would trigger the Fast stop and if active LOW is selected, a LOW signal would be triggered, which would also be active in this case if nothing is connected to pin 1
- If the DC terminal is switched off while the level on pin 1 changes to or is already at the level that was selected as the active level, the DC terminal can no longer be switched on for the time being, either manually or by digital remote control; this is a kind of switch-on blockade that can prevent the DC terminal from being switched on if necessary. If an attempt is made, a corresponding message appears on the display.
- Activating the master-auxiliary mode disables the fast stop function on all aux units initialized by the master; these would then ignore the signal on pin 1

2.5 Other features related to HS ELR

2.5.1 I-Boost

The I-Boost feature improves the dynamic response of the DC current during current transitions. During a current step, the controller temporarily applies an increased current setpoint for a user-defined duration. This results in a faster response at the output terminals and a higher effective slew rate.

I-Boost is intended for applications requiring fast current transitions between two current levels.

Topic	Description
Operating principle	When a current step is commanded (e.g. through the function generator), the controller temporarily increases or decreases the current setpoint beyond the requested value. After the configured boost time has elapsed, the controller returns to the programmed current level.
Effects of I-Boost	• Increased current transition speed • Improved terminal response • Higher effective slew rate • Possible current overshoot depending on load conditions and parameter settings
Operating Requirements	• I-Boost functionality is activated • A current transition between two levels occurs • A bosst time greater than zero is configured
I-Boost Parameter	• I-Boost Activator • Boost Time Rising Edge • Boost Time Falling Edge • Enable Minimum Boost • Enable limit Maximum Boost
Recommended Asjustment Procedure	1. Disable I-Boost during the initial test. 2. Apply a current pulse using the Function Generator. 3. Monitor the current response using an oscilloscope. 4. Enable I-Boost and gradually increase the boost parameters. 5. Observe the resulting current waveform. 6. Adjust the parameters until an acceptable balance between response speed and overshoot is achieved.
Notes and limitations	• The feature is active only during current transitions. • The feature has no effect when no current step occurs. • Positive and negative current transitions can be configured independently. • Optimum settings depend on the application and load conditions.

2.5.2 Vmon Damping

The damping parameters are designed to work together with the I-Boost function. If I-Boost is not enabled, damping should normally also remain disabled. For applications with cable lengths below 1 m, it is likewise advisable to leave damping disabled, since otherwise the dynamic behavior may worsen and the risk of instability can increase.

When adjusting these parameters, proceed with great care and avoid large or abrupt changes. A practical approach is to keep the function disabled during the initial test run and then increase the damping values step by step in later tests. This method makes it easier to identify the optimum setting and can help reduce overshoot during step load changes.

2.5.3 Aux trigger

The digital input at pin 2 can be configured as an external trigger for starting or stopping selected functions. Once a function has been assigned to this input, a high signal level activates the function in the same way as a corresponding Modbus command. If the signal level returns low or the input is left open, the function is deactivated again.

This feature is only available under certain operating conditions. The device must be in remote control mode, no active alarm condition may be present, and the input cannot be used for auxiliary units within a master-auxiliary system.

The assignment of the trigger behavior is defined in the Feature Setup register. A value of 0x0001 configures pin 2 so that the DC terminal is activated by a high level, corresponding to the behavior known from WSC 405. A value of 0x0002 assigns the high-level trigger to start and stop the function generator, equivalent to the behavior of WSC 850.

For electrical characteristics and pin details of the digital I/O interface, refer to the official interface documentation.

2.5.4 Overpower feature

The Dynamic Power Rating function has been developed for the 20 k High-Speed ELR Series to address the demanding requirements of datacenter power supply testing. Modern server and AI power supplies can generate highly dynamic load profiles that temporarily exceed the nominal power rating of the electronic load. To accurately emulate these operating conditions, the ELR system supports controlled short-term overpower operation while maintaining long-term thermal protection and system reliability.

The implemented solution allows power peaks above the nominal rating for defined periods while ensuring that the average power remains within a safe operating range. The algorithm operates automatically and does not require users to select predefined test profiles, simplifying operation and reducing the risk of configuration errors.

- Up to 125 % power is allowed for a maximum of 500 ms.
- A subsequent relaxation period of 500 ms allows only 100 % power.
- The average power within a 1-second observation window can not exceed 112.5 %.
- Dynamic events up to 10 kHz can be handled correctly.
- Current boost events are included in the calculation.
- The feature operates independently of the active operating mode.
- The activation of the Overpower feature workes as follows:
    1. The overpower protection needs to be set to a value between 103-125%
    2. The Limit of the Power needs to be set between 30-37.5 kW
    3. The power needs to be set between 30-37.5 kW

2.5.5 Zero current voltage

2.5.5.1 Scope and intended Audience

This chapter summarizes the usage of the Zero current voltage feature of the ELR 21000-80 electronic load devices.

2.5.5.2 Feature Description

The Zero current voltage feature acts as a current limiter based on the measured DC input voltage.

Behavior:

- The user defines a voltage threshold volatage set value
- If the input voltage at the DC terminals falls below the volatage set value, the device:
    - Automatically transitions to zero current
    - Does not enter standby mode
- When the input voltage rises above volatage set value, the device:
    - Automatically returns to the previously defined current setpoint

Important notes:

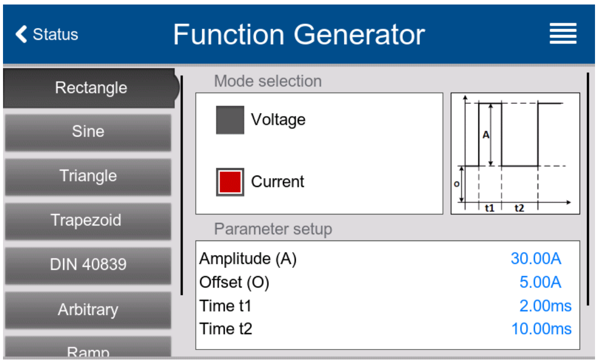
- This feature does not change the device state between Active and Standby.
- It only limits the output current in case of a voltage drop.
- The transition is automatic and transparent to the operating mode

2.5.5.3 Usage in Function Generator Mode

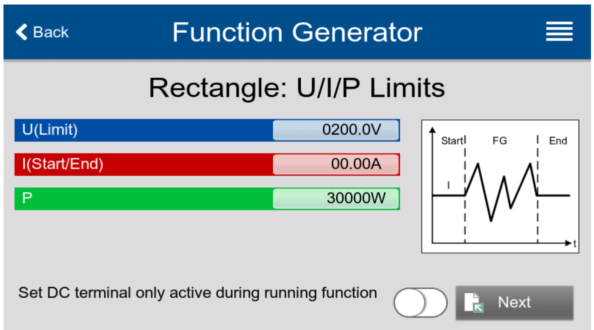
HMI and Modbus Configuration

In Function Generator mode, the voltage set value can be configured on the second configuration page via U(Limit):

Select waveform type



Enter the desired voltage set value



Once the function generator is running:

- Current sinking occurs only if the counterpart voltage exceeds the voltage set value

The voltage set value remains configurable also via Modbus:

- Register Address: 500 (0x01F4)
- Value Range: 0x0000 – 0xCCCC
  - Adjustable from 0–100% of nominal voltage

Feature Activation (Required)

The zero current voltage feature must be explicitly enabled for Function Generator mode.

- Coil Address: 30310 (0x7666)
  - 0xFF00 ▯ Feature enabled
  - 0x0000 ▯ Feature disabled

Hysteresis Configuration

A hysteresis value can be added to the voltage setpoint to define an upper threshold, preventing oscillation around the switching point.

- Register Address: 30311 (0x7667)
- Value Range: 0x0000 – 0xCCCC
  - Corresponds to 0–100% of nominal voltage

2.5.5.4 Summary

- The zero current voltage feature is a voltage-dependent current enable/disable mechanism
- It works in both steady-state and function generator modes
- It does not affect device operating states
- Proper activation is mandatory in Function Generator mode
- Hysteresis support ensures stable operation under fluctuating voltages during dynamic operation

3. The function generator

3.1 Introduction

The built-in **function generator** (short: FG) is capable of generating various waveforms and applying them to either the voltage (U) or the current (I).

The default functions are based on a variable **arbitrary generator.** With manual operation, the functions can be selected, configured and operated individually. With remote control, these can only be configured and implemented indirectly via several sequence points, each with 8 parameters.

Other functions are based on an **XY generator**, which works with a table (4096 values) loaded into the device or calculated by the device.

The following functions can be called up, configured and controlled manually:

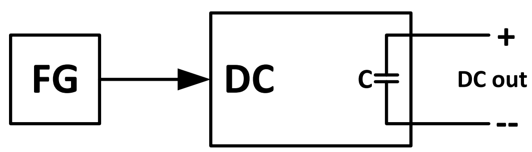
Function	Brief explanation
Sine	Sine wave signal generation with adjustable amplitude, offset and frequency
Triangle	Triangular signal generation with adjustable amplitude, offset, rise and fall time
Rectangle	Rectangular signal generation with adjustable amplitude, offset and pulse-pause ratio
Trapezoid	Trapezoidal signal generation with adjustable amplitude, offset, rise time, pulse time, fall time, pause time
DIN 40839	Emulated vehicle engine start curve according to DIN 40839 / EN ISO 7637, divided into 5 curve segments (sequence points), each with start voltage, end voltage and time
Arbitrary	Generation of a sequence of up to 99 freely configurable curve points, each with start value (AC/DC), end value (AC/DC), start frequency, end frequency, phase angle and duration
Ramp	Generation of a linearly increasing or decreasing ramp with start value, end value, time before and after the ramp
XY table	XY generator, current curve loadable from USB stick (table, CSV)

3.2 General information

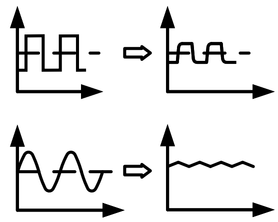
3.2.1 Structure

The device has a built-in Function Generator, but is not a high-performance function generator in its entirety and must not be regarded as such. The power stages are only connected downstream of the generator. The typical characteristics of voltage and current in terms of rise times and capacitor discharge are retained. While the FG is capable of generating 10,000 Hz with a sine wave, the device cannot follow this 1:1.

Clarification:



Effect of the output capacitance on functions:



The resulting curve at the DC terminal depends heavily on the frequency or period, generated signal shape, amplitude and device model. The effects of the performance levels can only be partially compensated for.

3.2.2 Resolution

For the functions generated by the arbitrary generator, the device can calculate and set a maximum of 52428 steps between 0...100% set value. With very low amplitudes and long times, only a few or no changing values may be calculated during a value increase or decrease and therefore several identical values are set one after the other, which can lead to a certain staircase effect. Not all possible combinations of time and a variable amplitude (gradient) are feasible.

3.2.3 Working method

To understand how the Function generator works and how the set values affect each other, the following must be observed:

The device always works with the three set values U, I and P, even in Function Generator mode.

The selected function can be applied to one of the two set values U and I, the others are then constant and have a limiting effect. For example, if you connect a source with a voltage of 100 V in sink mode and want to apply the sine function to the current with an amplitude of 80 A and an offset of 80 A, the Function Generator will generate a sine wave of the current between 0 A (min.) and 160 A (max.). At the same time, this would result in an input power of between 0 W (min.) and 16000 W (max.). However, the power is always limited to its set value. If it were set to 12000 W, for example, the current would be limited to 120 A by calculation and if it were displayed on an oscilloscope using a current clamp, it would be capped at 120 A and never reach the desired 160 A.

To further understand how the device works in dynamic operation, be sure to read the following:

- The device also includes a sink that discharges the capacities of the device at its own DC terminal in the event of negative voltage steps, i.e. higher voltage to lower voltage, so that the output voltage drops more quickly. This requires a certain current and therefore also a certain power, both of which can or should be set for almost all of the functions listed below, specifically “I” and “P”. For safety reasons, the current value “I” is initially set to 0 at the start of the configuration of the function, which disables the sink mode for the time being.
- The sink current, as can be set with “I”, will also load an external source or discharge any capacitance on a load if it is not set to 0 and must therefore be selected with particular care, as the current also affects the cable cross-sections of the lines to the load/source. Recommendation: Set “I” to at least I_{peak} of the resulting curve.

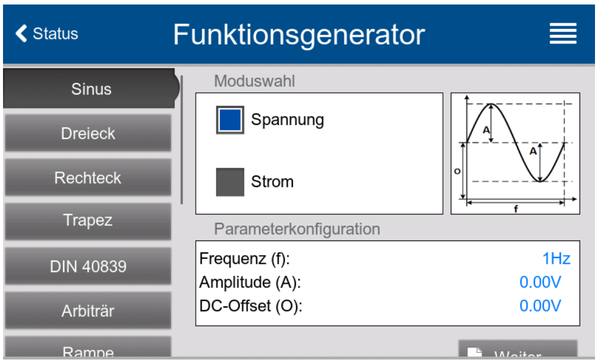
Master-auxiliary systems have additional features:

At the end of the configuration of a function, if it has already been loaded and the screen now shows the main display of the function generator, set values, known as “U/I/P limits”, can be set in this display. These values are transmitted to all auxiliary units as global set values in master-auxiliary systems. It is recommended that these be set carefully and appropriately so that the Aux units cannot negatively affect the curve progression.

3.3 Manual operation

3.3.1 Selection and control of a function

One of the functions listed in *«3.1 Introduction»* can be called up, configured and controlled via the touch screen. Selection and configuration are only possible when the DC terminal is switched off.



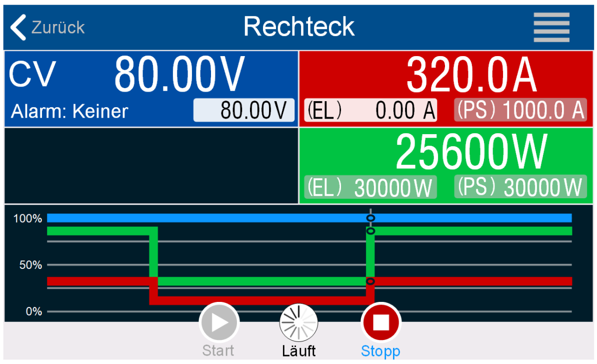
► How to configure a function

1. With the DC terminal switched off, tap the button Func Gen.
2. Select the desired function from the menu on the left. For some, you must first select the set value to which you want to apply the function, **Voltage** or **Current**.
3. Now set the values as required and go to Next.
4. The next step is to set the static set values for voltage and power or current and power, separately for source and sink operation. This is particularly important for Master-auxiliary operation because the auxiliary units receive these limit values. These values are effective before the start and stop of the function.

> • *If the function is only to run in sink mode, it is recommended to set the limit values of the other operating mode to 0.*
>
> • *The limit values for U, I and P act immediately after reaching the main screen because the DC terminal is automatically switched on after the function is loaded in order to establish the start situation. This is helpful if a function is not to start at 0 V or 0 A. However, if you want the function to start at 0, the static set value would have to be set to 0, which is not permitted in a master-auxiliary system, as the auxiliary units would then have a set value of 0. Switching on the DC terminal after the function has been loaded can be prevented by activating the "Set DC terminal only active during running function" switch.*

5. Exit the configuration and switch to the function generator screen with Next.

The individual parameters of the functions are described below. Once the settings have been made, the function is loaded, the DC terminal is switched on and can then be started. The global limit values and function-related values can be set before and while the function is running.



► How to start and stop a function

1. You can **start** the function by either tapping on the button or, if the DC terminal is currently off, pressing the button **On/Off**.
2. **Stop** the function using either the button or the **On/Off** button, but there is different response here:

   a) Control panel: Function stops only, the DC terminal remains on, with static values.

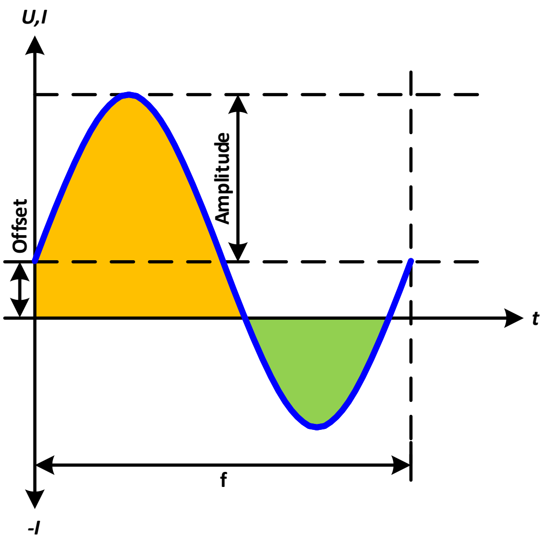
   b) Button **On/Off**: Function stops and the DC terminal is switched off.

> *In the event of device alarms (power failure, overtemperature, etc.), protective functions (OPP, OCP) or events with action = alarm, the function sequence stops automatically, the DC terminal is switched off and the alarm is signaled.*

3.4 Sine function

The following parameters can be configured for the sine function:

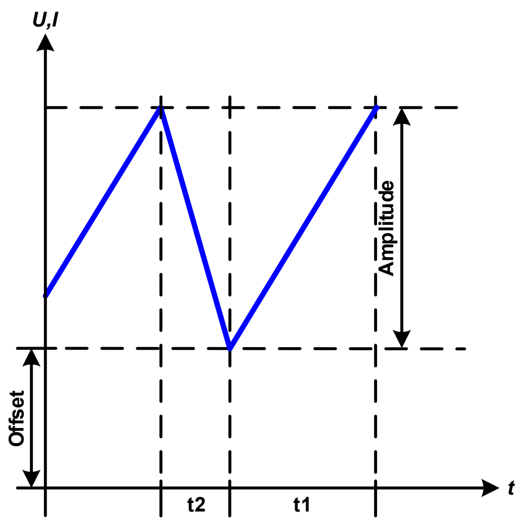
Parameters	Setting range	Explanation
Frequency (f)	**1Hz...10000Hz**	Static frequency of the sine signal to be generated
Amplitude (A)	0...(nominal value of U or I - |**Offset**|)	Amplitude of the signal to be generated
Offset (O)	**0V**... (U_{Nom} - **Amplitude**) or +(I_{Nom} - **Amplitude**)	Offset, related to the zero crossing of the mathematical sine curve

Pictorial representation:	Application and result:
	A normal sinusoidal signal is generated and applied to the selected set value, for example current. To calculate the maximum power resulting from the curve, the set current amplitude must first be added to the offset. With a voltage of 100 V and sin(I), you set the amplitude to 80 A with an offset of +50 A. The resulting maximum power when the highest point of the sine curve is reached would then be (80 A + 50 A) * 100 V = 13000 W in the source component and (50 A - 80 A) * 100 V = -3000 W in the sink component.

3.5 Triangle function

The following parameters can be configured for the triangle function:

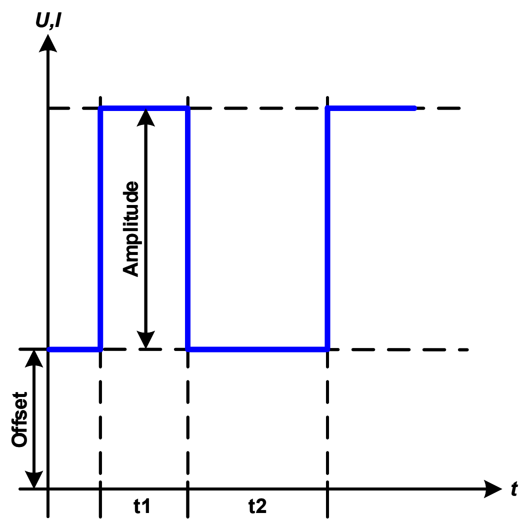
Parameters	Setting range	Explanation
Amplitude (A)	0...(nominal value of U or I - |**Offset**|)	Amplitude of the signal to be generated
Offset (O)	**0V**... (U_{Nom} - **Amplitude**) or +(I_{Nom} - **Amplitude**)	Offset, related to the base of the triangle
Time t1	**0.1ms...36000000ms**	Time Δt of the rising edge of the triangular signal
Time t2	**0.1ms...36000000ms**	Time Δt of the falling edge of the triangular signal

Pictorial representation:	Application and result:
	A triangular signal is generated for application to the current or voltage. The rising and falling edge times can be set separately. The offset shifts the signal on the Y-axis. The sum of the times t1 and t2 is the period duration and its reciprocal is the frequency. For example, if you wanted to achieve a frequency of 10 Hz, this would result in a period of 100 ms at T = 1/f. These 100 ms can now be divided into t1 and t2 as required. For example,. with 50 ms:50 ms (isosceles triangle) or 99.9 ms:0.1 ms (right-angled triangle, also known as a sawtooth).

3.6 Rectangle function

The following parameters can be configured for the rectangle function:

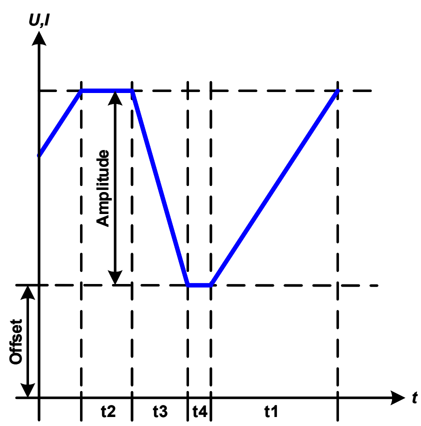
Parameters	Setting range	Explanation
Amplitude (A)	0...(nominal value of U or I - |**Offset**|)	Amplitude of the signal to be generated
Offset (O)	**0V**... (U_{Nom} - **Amplitude**) or +(I_{Nom} - **Amplitude**)	Offset, related to the base point of the rectangle
Time t1	**0.1ms...36000000ms**	Time (pulse) of the upper value (=amplitude + offset) of the square wave signal
Time t2	**0.1ms...36000000ms**	Time (rest) of the lower value (=offset) of the square wave signal

Pictorial representation:	Application and result:
	A rectangular signal is generated for application to the current or voltage. The times t1 and t2 determine how long the value of the amplitude (associated with t1) and the rest (amplitude = 0, only offset effective, associated with t2) is effective. The offset shifts the signal on the Y-axis. The so-called pulse-rest ratio or duty cycle (**duty cycle**) can be set with the times t1 and t2. The sum of the times t1 and t2 is the period duration and its reciprocal is the frequency. For example, if you wanted to achieve a square wave signal on the current at 25 Hz and a duty cycle of 80%, the sum of t1 and t2, i.e. the period, would have to be calculated as T = 1/f = 1/25 Hz = 40 ms. For the pulse, this would result in t1 = 40 ms*0.8 = 32 ms at 80% duty cycle. The time t2 would then be set to 8 ms.

3.7 Trapezoid function

The following parameters can be configured for the trapezoid function:

Parameters	Setting range	Explanation
Amplitude (A)	0...(nominal value of U or I - |**Offset**|)	Amplitude of the signal to be generated
Offset (O)	**0V**... (U_{Nom} - **Amplitude**) or +(I_{Nom} - **Amplitude**)	Offset, related to the base point of the trapezoid
Time t1	**0.1ms...36000000ms**	Time of the rising edge of the trapezoidal signal
Time t2	**0.1ms...36000000ms**	Time of the high value (hold time) of the trapezoidal signal
Time t3	**0.1ms...36000000ms**	Time of the falling edge of the trapezoidal signal
Time t4	**0.1ms...36000000ms**	Time of the low value (=offset) of the trapezoidal signal

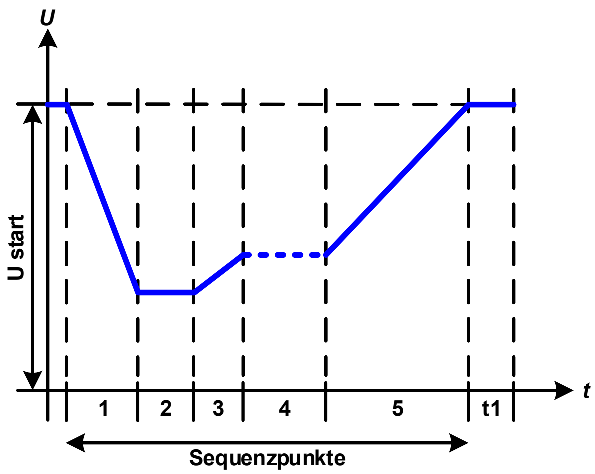
Pictorial representation:	Application and result:
	As with the other functions, the trapezoidal signal can be applied to the voltage U or current I set value. With the trapezoid, the angles can be different due to the separately adjustable rise and fall times. Here, the period duration and the repetition frequency are formed from the four adjustable time values. With the appropriate settings, two triangular or two rectangular pulses are produced instead of a trapezoid. This function is therefore quite universal.

3.8 DIN 40839 function

This function is based on the curve defined by DIN 40839 / EN ISO 7637 (test pulse 4) and is only applied to the voltage. It is designed to simulate the curve of the car battery voltage when starting a car engine. The curve is divided into 5 sections (see figure below), each of which has the same parameters. The default values from the standard are already entered as default values for the five sequence points.

This curve is usually run in source mode, but can also be run in sink mode if the voltage applied to the DC terminal is higher than the highest point (offset + amplitude) of the curve and the external source cannot supply more current than that set for sink mode (I sink). Otherwise, the device would not be able to regulate the voltage values resulting from the curve. The global set values ("U/I/P limits") can also clearly define the operating mode. The following parameters can be configured for the individual sequence points or globally:

Parameters	Setting range	Seq.	Explanation
Start	**0V**...$U_{nominal}$	1-5	Initial voltage value of the partial section (sequence point) of the curve
End	**0V**...$U_{nominal}$	1-5	End voltage value of the subsection (sequence point)
Time	**0.1ms...36000000ms**	1-5	Time for the descending or ascending ramp
Sequence cycles	**0** / **1...999**	-	Number of sequences of the entire curve (0 = infinite processes)
Time t1	**0.1ms...36000000ms**	-	Time after the curve has elapsed before repeating (cycles <> 1)
U(Start/End)	**0V**...$U_{nominal}$	-	Voltage value at the DC terminal before the curve is started and afterwards
I/P	**0A**...$I_{nominal}$ / **0W**...$P_{nominal}$	-	Global set values for current and power

Pictorial representation:	Application and result:
	The curve corresponds to test pulse 4 of DIN 40839. Other test pulses can also be simulated with the appropriate settings. If the curve at sequence point 4 is to contain a sine, it would alternatively have to be converted using the arbitrary generator. The global start and end voltage is set as the "U(Start/End)" setting value in the "U/I/P Limits" menu page, but does not affect the voltage values in the sequence points. It should match the start voltage (U start) at sequence point 1.

3.9 Arbitrary function

The arbitrary function (arbitrary = any) offers the user an extended range of options. There are 99 curve segments (here: sequence points) available for assignment to the current or voltage, all of which have the same parameters but can be configured as desired to “assemble” complex function sequences. These points form subsections of a curve. Any number of the 99 available sequence points can run one after the other. This results in a sequence point block. The block can then be repeated 1...999 times or infinitely often. Since the sequence of the function is assigned to either the voltage or the current, a mixed assignment to both is not possible.

The arbitrary curve can superimpose a linear curve (DC) with a sinusoidal curve (AC) whose amplitude and frequency are formed between the initial value and the final value. If the start frequency and end frequency are set to 0 Hz, the AC component becomes ineffective and only the DC component is generated. For each sequence point, a time can be defined within which the curve section (sequence point) is generated from start to end.

The following parameters can be configured for each sequence point of the arbitrary function:

Parameters	Setting range	Explanation
AC start **AC end**	+50% I_{Nom} or 0V...50% U_{Nom}	Start and end amplitude of the sinusoidal component
DC start	±(**AC start**...(nominal value - **AC start**))	
DC end	±(**AC end**...(nominal value - **AC end**))	Final value of the DC component of the curve
Start frequency **End frequency**	0Hz...10000Hz	Start or end frequency of the sinusoidal component
Angle	0°...359°	Starting angle of the sinusoidal component
Time	0.1ms...36000000ms	Time for the selected sequence point

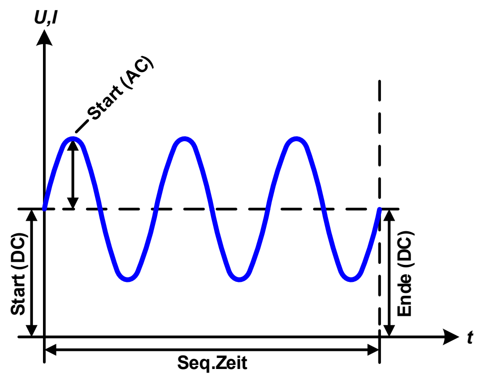
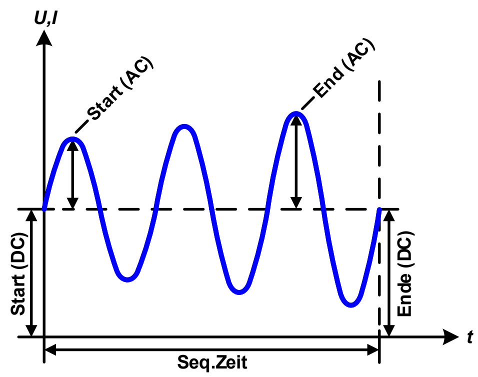
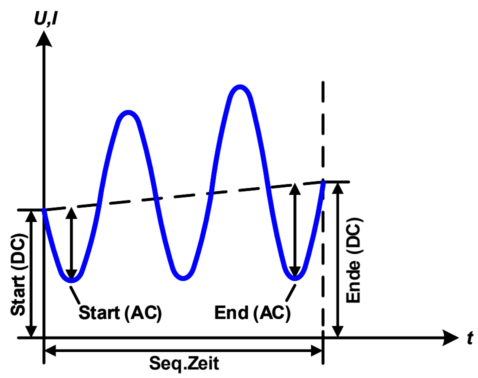
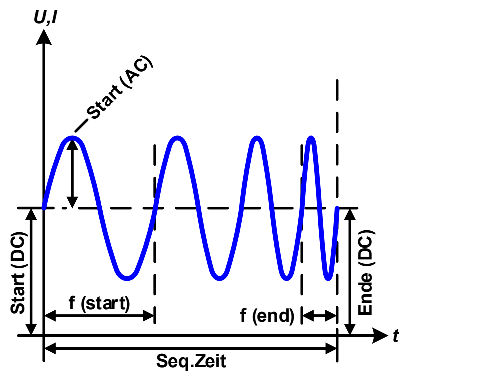
The sequence point time and the start frequency/end frequency are related. There is a minimum Δf/s of 9.3. So, for example, a setting with start frequency = 1 Hz, end frequency = 11 Hz and time = 5 s would not be accepted because the Δf/s would then only be 2. At time = 1 s, it lines up again, or you would have to set at least one end frequency = 51 Hz at time = 5 s.

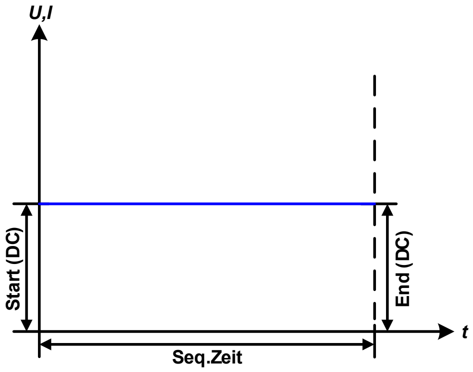
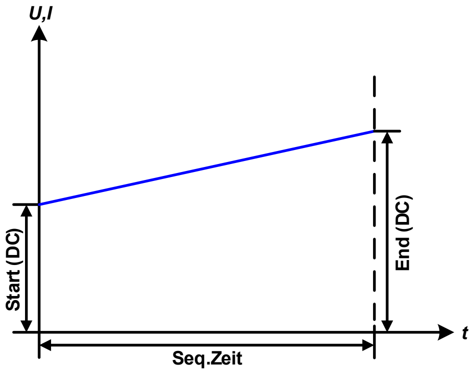
The change in amplitude between start and end is related to the sequence point time. You cannot generate an arbitrarily small change over an arbitrarily large period of time. In such a case, the device rejects unsuitable settings with a message.

If these settings have been set for the currently selected sequence point, further settings can be configured. Further down are global settings for the overall process of the arbitrary function:

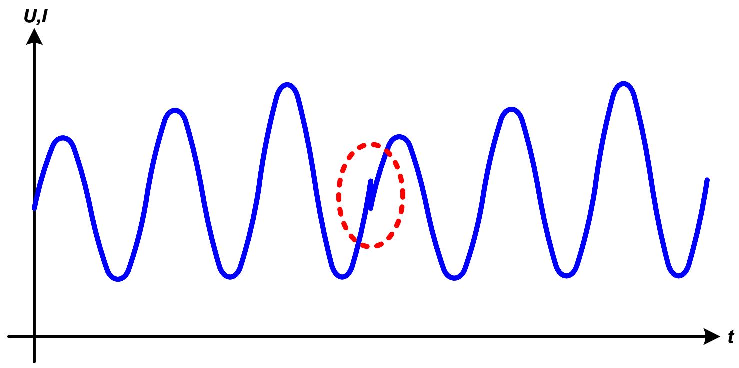
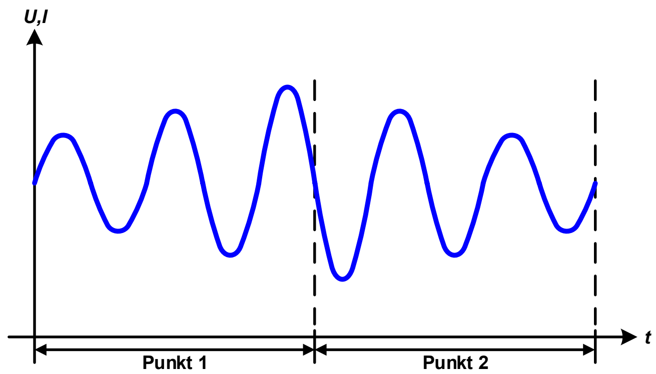
Parameters	Setting range	Explanation
Sequence cycles	0 / 1...999	Number of sequences in the sequence point block (0 = infinite)
Start sequence	1...**End sequence**	First sequence point of the sequence point block
End sequence	**Start sequence**...99	Last sequence point of the sequence point block

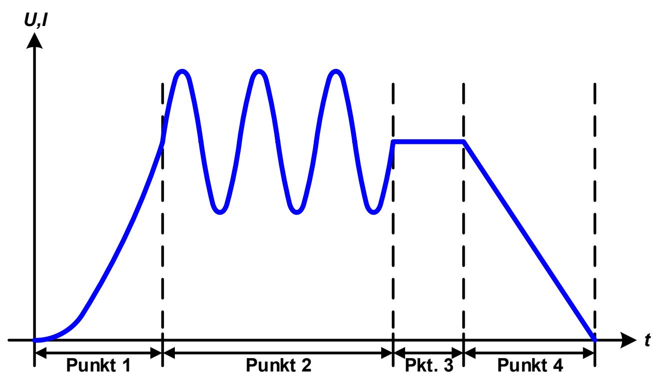
After pressing **Next**, global set values (U/I/P limits) must be defined for the function sequence.

Pictorial representations:	Applications and results:
	**Example 1:** Consideration 1 of flow 1 sequence point: The DC start and DC end values are the same, as are the AC values (amplitude). A non-zero frequency, where start frequency = end frequency, results in a sinusoidal curve of the set value with a specific amplitude, frequency and Y-shift, also known as offset. The number of sine periods per sequence point run depends on the time and frequency. For example, if the sequence point time were 1 s and the frequency 1 Hz, exactly 1 sine wave would be generated. If the time were only 0.5 s at the same frequency, only a sine half-wave would be generated.
	**Example 2:** Consideration 1 of process 1 sequence point: The DC start and DC end values are the same, but the AC values (amplitude) are not. The end value is greater than the start value, so the amplitude increases continuously between the start and end of the sequence with each new sine half-wave. However, this only becomes visible if the sequence point time together with the frequency allows several sine waves to be generated during the course of a sequence. At f = 1 Hz and time = 3 s, for example, this would result in three whole waves (at angle = 0°), and vice versa at f = 3 Hz and time = 1 s.
	**Example 3:** Consideration 1 of process 1 sequence point: The values of DC start and DC end are not the same, nor are the AC values (amplitude). The end value is always greater than the start value, so the offset between start (DC) and end (DC) increases linearly, as does the amplitude with each new sine half-wave. In addition, the first sine wave starts with the negative half-wave because the angle has been set to 180°. The start angle can be shifted between 0° and 359° in 1° increments.
	**Example 4:** Consideration 1 of process 1 sequence point: Similar to example 1, but here with a different end frequency. This is greater than the start frequency. This has an effect on the period of a sine wave, which becomes smaller with each new sine wave started, over the period of the sequence run with sequence point time x.

Pictorial representations:	Applications and results:
	**Example 5:** Consideration 1 of process 1 sequence point: Similar to example 1, but with a start and end frequency of 0 Hz. Without a frequency value unequal to 0, no sine component (AC) is generated and only the setting of the DC values is effective. A ramp with a horizontal course is created, which could also be part of a trapezoidal or rectangular function, for example.
	**Example 6:** Consideration 1 of process 1 sequence point: Similar to example 3, but with a start and end frequency of 0 Hz. Without a frequency value not equal to 0, no sine component (AC) is generated and only the DC value setting is effective. These are unequal here at the start and end. A ramp with an ascending curve is generated.

Complex sequences can be created by stringing together several differently configured sequence points. By skillful configuration, the arbitrary generator can simulate the other functions such as triangle, sine, rectangle or trapezoid and thus generate a sequence of rectangle functions with different amplitudes or duty cycles per sequence, for example.

Pictorial representations:	Applications and results:
	**Example 7** Observation of 2 sequences of 1 sequence point: A sequence point, configured as in example 3, runs. As the settings specify that DC end is greater than DC start, the start value of the second sequence of the sequence point jumps back to the same start value as the first sequence, regardless of where the generated value of the sine wave was at the end of the first sequence. This creates a certain distortion in the overall process (red marking) and can only be compensated for with carefully selected settings.
	**Example 8** Observation of 1 sequence of 2 sequence points: Two sequence points run one after the other. The first generates a sinusoidal curve with increasing amplitude, the second one with decreasing amplitude. This results in the curve shown on the left. To ensure that the sine wave with the highest amplitude only appears once in the center of the overall curve, the start amplitude (AC) of the second sequence point must not be the same as the end amplitude (AC) of the first, or the first must end with the positive half-wave and the second must begin with the negative half-wave, as shown on the left.

Pictorial representations:	Applications and results:
	**Example 9** Observation of 1 sequence of 4 sequence points: Point 1: 1/4 sine wave (angle = 270°) Point 2: Three sine waves (ratio of frequency to sequence point time: 1:3) Point 3: Horizontal ramp (f = 0) Point 4: Falling ramp (f = 0)

3.9.1 Loading and saving arbitrary functions

The 99 sequence points of the arbitrary function, which can be manually configured on the device and are applicable to voltage U or current I, can be saved to or loaded from a USB stick (FAT32 formatted) via the USB interface on the front of the device. All 99 points are always saved to or loaded from a CSV text file. The number is checked during loading.

The following requirements apply for loading a sequence point table

- The table must contain exactly 99 rows, each with 8 consecutive values (8 columns) and must not have any gaps
- The column separator (semicolon, comma) to be used is defined in the setting under **USB logging -> Log file separator format** in the device menu and also determines the decimal separator (comma, full stop)
- The file must be located in the HMI_FILES folder, which must be in the root directory (root) of the USB stick
- The file name must always begin with WAVE_U or WAVE_I (case insensitive)
- All values in each column and row must correspond to the specifications (see below)
- The columns in the table have a specific sequence that must not be changed

For the table with the 99 rows, the following structure is specified based on the setting parameters that can be defined for the arbitrary generator during manual operation (column naming as in Excel):

Column	Corresponds to HMI parameters	Value range
A	AC start	See table in *«3.9 Arbitrary function»*
B	AC end	See table in *«3.9 Arbitrary function»*
C	Start frequency	0...10000 Hz
D	End frequency	0...10000 Hz
E	Angle	0...359°
F	DC start	See table in *«3.9 Arbitrary function»*
G	DC end	See table in *«3.9 Arbitrary function»*
H	Time	100...36,000,000,000 µs (36 billion)

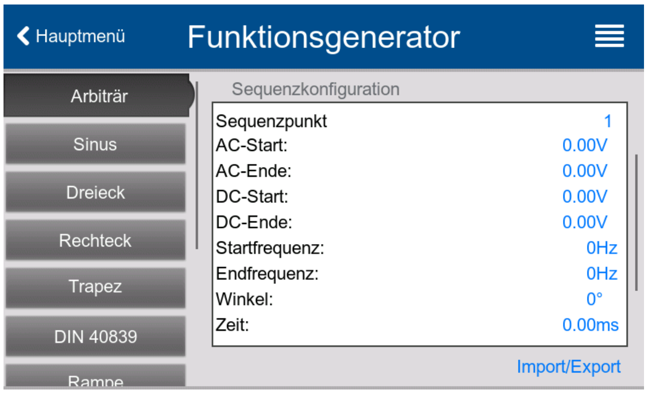
For a more detailed description of the parameters and the arbitrary function, see *«3.9 Arbitrary function»*.

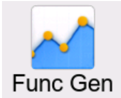
Example CSV:

	A	B	C	D	E	F	G	H
1	20,00	30,00	5	5	90	50,00	50,00	50000000
2	30,00	20,00	5	5	90	50,00	50,00	30000000
3	0,00	0,00	0	0	0	0,00	0,00	1000
4	0,00	0,00	0	0	0	0,00	0,00	1000
5	0,00	0,00	0	0	0	0,00	0,00	1000
6	0,00	0,00	0	0	0	0,00	0,00	1000

In the example, only the first two sequence points are configured, the others are all set to default values. For the BT 20080-1000 model, for example, the table could be loaded via a WAVE_U for the voltage or a WAVE_I for the current, as it is suitable for both. However, the naming is made unique by a filter, i.e. you cannot select **Arbitrary** --> **U** in the function generator menu and then load a WAVE_I. This would not even be listed.

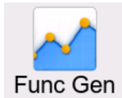
► How to load a sequence point table from a USB stick



1. Do not insert the USB stick yet or pull it out first.
2. With the DC terminal switched off, open the function generator menu from the main display with 

, and select the group **Arbitrary**. The display shown on the right appears.
3. Swipe down to **Sequence setup** and tap **Import/Export**, then **Load** and follow the instructions. If at least one valid file was found for the current process, a list is displayed for selection, from which the file to be loaded must be selected.
4. Tap  at the bottom right. The selected file is now checked and loaded if it is OK. If there are format errors, a corresponding message is displayed. The file must then be corrected and the process repeated.

► How to save the sequence point table from the device to a USB stick

1. Do not insert the USB stick yet or pull it out first.
2. Open the function selection menu of the function generator from the main display with 

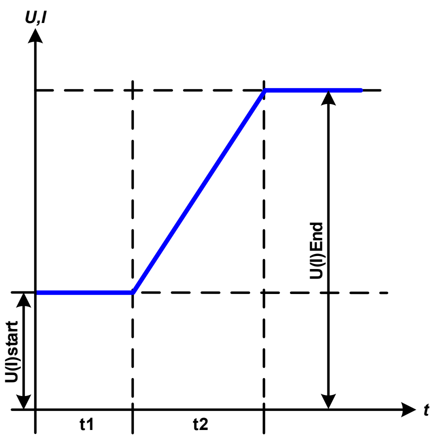
and select Group **Arbitrary**.
3. Swipe down to **Sequence setup** and tap **Import/Export**, then tap **Save**. You will be prompted to insert the USB stick. The device then searches for the HMI_FILES folder on the memory stick and for any existing WAVE_U or WAVE_I files and lists those found. If an existing file is to be overwritten with the data to be saved, select it, otherwise do not select any. One is then generated.
4. Save, new or overwrite, then with .

3.10 Ramp function

The following parameters can be configured for the ramp function:

Parameters	Setting range	Explanation
Start **End**	0V...U_{Nom} or +I_{Nom}	Start and end point of the ramp. Both can be larger, equal or smaller than the other, as a result of which the ramp either rises, falls or runs horizontally
Time t1	0.1ms...36000000ms	Time before the rising or falling edge of the ramp
Time t2	0.1ms...36000000ms	Rise and fall time of the ramp

!	*The time after reaching the end of the ramp cannot be set. The device stops the function automatically after max. 10 h and sets I = 0 A if the current ramp has not already been stopped elsewhere.*

Pictorial representation:	Application and result:
	This function generates a rising, falling or horizontal ramp between the start value and end value over the time t2. The other time t1 is used to define a delay before the ramp starts. The function runs once and then stops at the end value. To achieve a repeating ramp, the trapezoid function would have to be used (see *«3.7 Trapezoid function»*). It is also important to consider the static value I or U, which defines the initial value before the ramp is generated. It is recommended to set the static value equal to the value **Start**, unless the load is not to be supplied with voltage before the start of the ramp time (t1) in source mode or no current is to flow in sink mode. The static value would then have to be set to 0.

3.11 IU table function (XY table)

The IU function allows the user to set a specific DC current depending on the voltage at the DC terminal. The function can work in sink mode (EL). A table must be loaded that contains exactly 4096 current set values, which are divided into the measured voltage at the DC terminal in the range 0...125% U_{Nom}, although only approx. 3342 values from the table can be effective due to the upper limit of 102% nominal current value.

This table can be loaded into the device either from a USB stick via the USB port on the front of the device or via remote control (ModBus protocol or SCPI) and then used. The following applies:

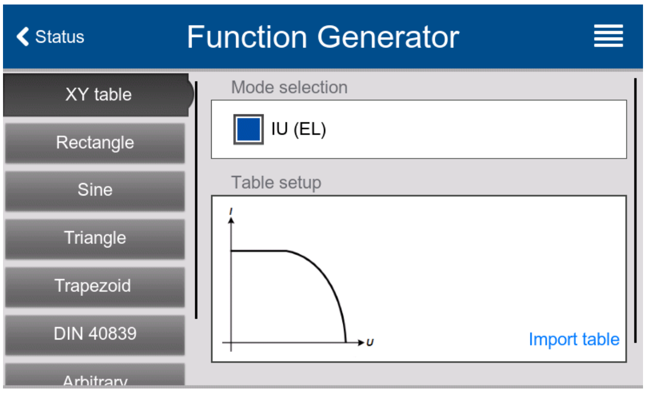
IU function: I = f(U) -> the device operates in CC mode (in source operation with a load in CV mode)

When loading a table from the USB stick, only text files of type CSV (.csv) are accepted. The table is checked for plausibility when loading (values not too large, number of values correct) and any errors are reported and then the table is not loaded.*

The 4096 values within the table are only checked for correct size and number. If all values were displayed in a diagram, a specific curve would result, which could also contain very large current jumps from one entry to the next. This can lead to complications for the connected load or source if, for example, the internal measured voltage value fluctuates slightly and leads to constant oscillation between two current values from the table, where in the worst case one is 0 A and the other is maximum current.

3.11.1 Loading IU tables via USB

The so-called IU tables can be loaded from a USB stick (FAT32 formatted) via the USB interface on the front of the device. To be able to do this, the file to be loaded must fulfil certain requirements:



- The file name always starts with IU (case insensitive)
- The file must be a text file of type CSV and may only contain one column with exactly 4096 real values (without gaps)
- None of the 4096 values may exceed the nominal current value. For example, if you have a 420 A model and load an IU table with current values, none of the values may be greater than 420 (adjustment limits do not apply here)
- Values with decimal places must have a decimal separator that corresponds to the selection **Log file separator format** in the menu **USB logging**, which also distinguishes between a comma and a full stop as decimal separators (the comma is used in the European standard)
- The file must be located in the HMI_FILES folder, which must be in the root directory (root) of the USB stick

If the above conditions are not met, the device reports this by means of corresponding error messages and does not accept the file. A stick can of course contain several IU tables as differently named files from which one can be selected.

► How to load an IU table from a USB stick

1. With the DC terminal switched off, open the function selection menu from the main display by tapping on Func Gen and select group **XY table**.

2. Insert the USB stick, if you have not already done so, then press **Import table** and as soon as the selection appears, select one of the listed files and load it with ✓. If the file is not accepted, it does not meet the requirements. Then correct and repeat.

3. In the next window, which you can access with Next, you can adjust the global set values.

4. Load the function with Next to then start and operate it as usual. See also *«3.3.1 Selection and control of a function»*.

3.12 Remote control of the Function Generator

The function generator can be controlled remotely, although the remote configuration and control of functions using individual commands is fundamentally different from manual operation. The programming instructions supplied on a USB stick explain the procedure.

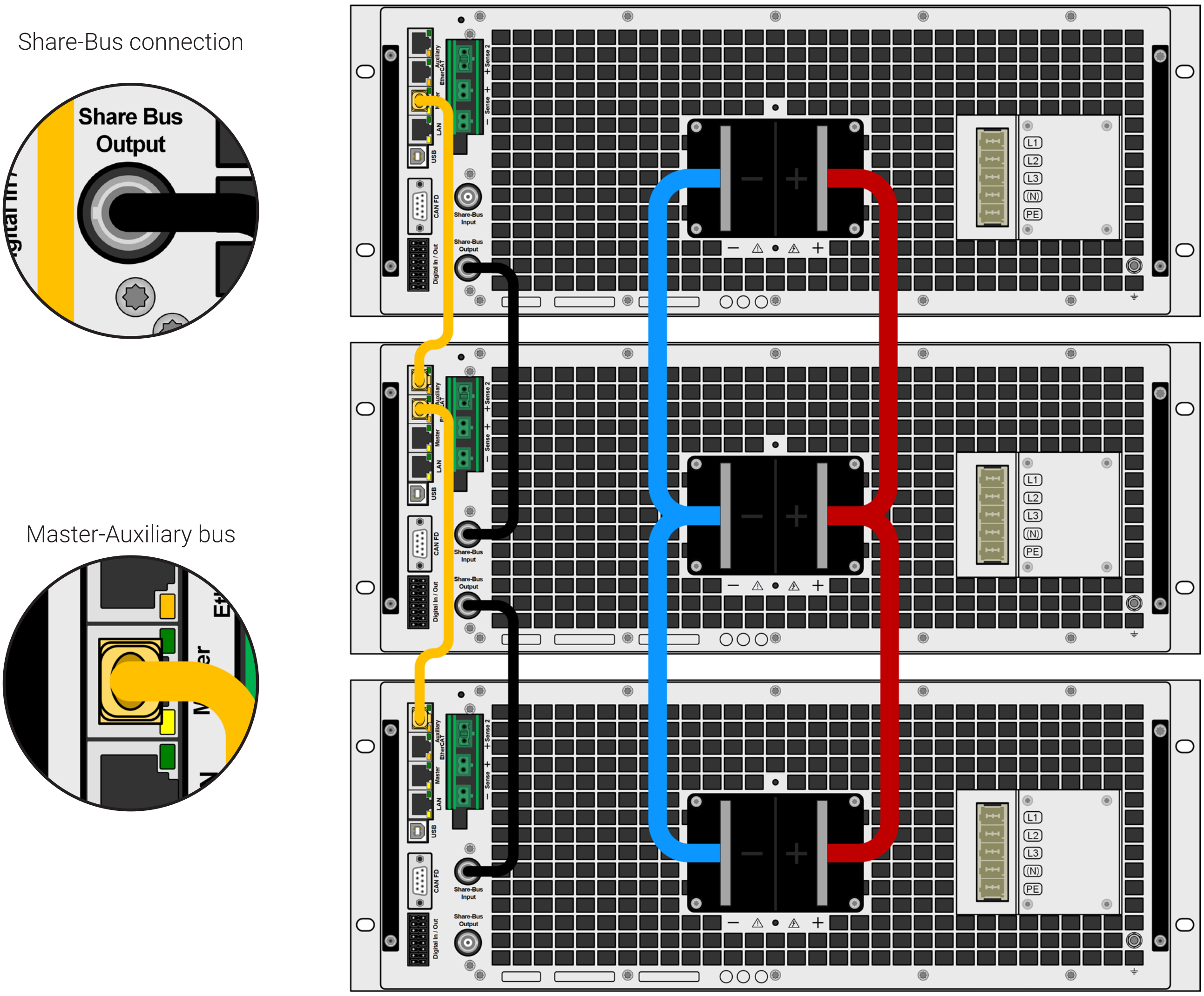
4. Other applications (2)

4.1 Parallel connection as master-auxiliary system

Several devices of the same type can be connected in parallel to achieve a higher overall performance. For parallel connection, all units are usually connected to their DC terminals, the Share-Bus and a Master-Auxiliary bus. In the ELR 20000 series, this is based on EtherCAT. The device network can then be viewed and treated as a single system, like a larger device with more power.

The Share-Bus, in turn, is used for dynamic control of the voltage at the DC terminal of the devices, i.e. in CV mode, especially if the function generator is to be used on the master device.

Principle illustration without load or external source:



4.1.1 Restrictions

Compared to normal operation of a single device, Master-auxiliary operation has the following limitations:

- Only connection between identical models of the ELR 20000 series

4.1.2 Wiring the DC terminals

The DC Terminal of each device invlved is connected to the DUT (Power Supply) with the correct polarity. For performance reasons the wires should be max. 3m and the connection has to be on the DUT, not on the ELR side. The cross-section depends on the total current of the parallel circuit.

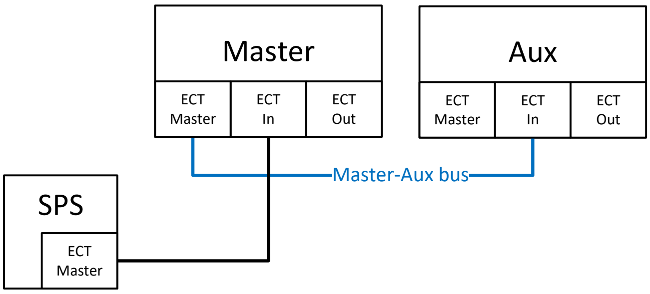
4.1.3 Wiring of the share-bus

The Share-Bus is connected from device to device using standard BNC cables (coaxial cable, type 50 Ω) with a length of 0.5 m, for example. The two connections are interconnected and do not represent dedicated inputs and outputs. The labeling is for orientation purposes only.

- *A maximum of 64 devices can be connected via the Share-Bus.*
- *If the Share-Bus is connected to another switched device while Master-Auxiliary is enabled (setting: Auxiliary or Master) but has not yet been initialized, an SF alarm will occur*

4.1.4 Wiring of the master-auxiliary bus

The master-auxiliary bus is a digital communication link between devices and is defined via three connections that are permanently integrated in the device. It must be connected via a standard network cable (≥CAT3, patch cable) for configuration and then configured manually or remotely. The connection labeled **EtherCAT master** (1x available) forms the master, which controls the next auxiliary unit(s) via their port labeled **EtherCAT In**. An isolated EtherCAT network is formed. The master itself, if it is to be remote-controlled, has its free EtherCAT In/Out ports for this purpose. Clarification:



The following must always be observed:

- The master-auxiliary bus must not be connected via crossover cables!
- Therefore, the subordinate units must not be connected to any other network.

The following then applies to the subsequent operation of the MA system:

- The actual values of all devices are totaled and displayed on the master or can be read remotely
- The setting ranges of the set values, adjustment limits, protection limits (OVP etc.) and user events are adapted to the number of initialized Aux units in the master. If, for example, five units with a power rating of 30 kW each are connected to form a 150 kW system, the power set value can be set to 0...150 kW on the master (manually or via remote control)
- The aux units cannot be operated as long as they are controlled by the master
- Auxiliary units display the alarm **MAP**) on the display until they have been initialized by the master. The same alarm is issued if the connection to the master is lost

4.1.5 Setting up master-auxiliary operation

The last step is to configure a master and at least one aux unit. We recommend configuring all aux devices first and the master device last.

► Step 1: How to configure the aux devices

1. With the DC output switched off, tap 

on the main display, then swipe up in the group selection on the left until **Master-Auxiliary** appears and then tap.
2. A selection appears on the right by tapping the **Mode** setting. By selecting **Auxiliary**, if not already set, you activate MA mode and simultaneously define the device as an auxiliary unit.
3. Exit the settings menu.

The first Aux unit is now fully configured. Repeat for each additional Aux unit.

► Step 2: How to configure the master device

1. With the DC output switched off, tap on Settings in the main display and then scroll down the selection on the left to **Master-Auxiliary**'.
2. A selection appears on the right by tapping the **Mode** setting. By selecting **Master**, if not already set, you enable the MA mode and simultaneously set the device as the master device.

► Step 3: Initialize master

By switching to **Master** mode, an initialization of the MA system is started immediately and the result is displayed in the same window. If the initialization is not successful, which can be seen from the number of Aux units or the overall performance, you can also repeat the initialization here:

Initialization state	Initialized
Number of slaves	1
System voltage	80.00V
System current	2000.0A
System power	60.00kW
	Initialize system

Pressing **Initialize system** repeats the initialization if not all aux units have been detected, the system has been reconfigured, e.g. if there is a connection error on the EtherCAT bus or not all subordinate devices have been configured as **Auxiliary**. The window lists how many Aux units were found, as well as the total power and total current resulting from the network. If no aux unit is found, the MA system is used with only the master.

As long as MA mode is activated, the master and MA system are initialized automatically each time the master device is switched on. Initialization can be repeated at any time via the "Settings" menu of the master device in the "Master-Auxiliary" group.

4.1.6 Operating the master-auxiliary system

After successful initialization of the master and all aux units, they display their status on the display. The master displays **MA mode: Master (n Aux)** in the status field, the Aux units correspondingly **MA mode: Auxiliary**, as well as **Remote: EtherCAT**, as long as they are remotely controlled by the master.

The aux units cannot be operated manually and cannot be controlled remotely via a digital interface. However, if necessary, they can be monitored via these interfaces by reading out the actual values and status. After initialization and return from the menu, the master now displays the actual and set values of the overall system. Depending on the number of devices, the setting range for current and power multiplies. The following then applies:

- The master can be operated like a single device
- The master transmits the set values, etc., to the auxiliary units and controls them
- The master can be remotely controlled via all its digital interfaces that are designed for remote control
- All settings for the set values U, I and P, as well as all related values such as monitoring, adjustment limits, etc., are adjusted to the new overall values on the master
- For all initialized aux units, adjustment limits (U_{Min}, I_{Max} etc.), monitoring limits (OVP, OPP etc.) and event settings (UCD, OVD) are reset to default values so that they do not interfere with control by the master. If these limits are adjusted on the master, they are transferred 1:1 to the aux units. During later operation, aux units can trigger alarms such as OCP, OVP or events etc. instead of the master alarm due to uneven load distribution and different response times.

To be able to restore all these values quickly after exiting MA mode, the use of user profiles is recommended (see section «2.3.5 Load and save user profiles»).

- If one or more auxiliary units report a device alarm, this is displayed on the master and must also be acknowledged there so that the system can continue to operate. Since an alarm always switches off all DC terminals of the system and the master can only switch them on again automatically after an alarm PF or OT, which is also dependent on setting parameters, intervention by the operator of the device or remote control software may be necessary under certain circumstances.
- For safety reasons, disconnection from one or more auxiliary units also results in all DC terminals being switched off and the master reports this status as "Master-auxiliary protection". The MS system must then be reinitialized by pressing the **Initialize** button, with or without the aux unit(s) that caused the connection failure. This also applies to remote control.

4.1.7 Alarm and other problem situations

In MA operation, the connection of several devices and their co-operation can lead to additional problem situations that would not occur when operating individual devices. The following stipulations have been made for such cases:

- If the master loses connection to any auxiliary unit, a MAP (Master Auxiliary Safety Mode) alarm is always triggered, which causes the master's DC terminal to be switched off and a requester to appear on the display. All Aux units revert to individual operation and also switch off their DC terminal. The MAP alarm can be canceled by reinitializing the master-auxiliary mode. This can be done directly in the requester window of the MAP alarm or in the menu of the master or via remote control. Alternatively, MA mode can also be disabled to clear the alarm.
- If the master device fails on the AC side (switched off at the mains switch, power failure) and comes back later, it automatically reinitializes the MA system and integrates all detected aux units. In this case, MA operation can be continued automatically.

In situations where one or more devices generate a device alarm such as OVP or similar, the following applies:

- Each device alarm of an aux unit is shown on its display and on that of the master
- If alarms from several aux units occur simultaneously, the master only displays the last alarm that occurred. In this case, the actual alarms could only be recorded on the aux units themselves, e.g. by reading out the alarm history via software.
- All subordinate devices in the MA system monitor their own values with regard to overcurrent (OCP) and other thresholds and report alarms to the master. It can therefore also happen, mainly if for some reason the current is not evenly distributed between the devices, that a device already reports OCP, even if the global OCP threshold of the MA system has not yet been reached. The same applies to OPP.

5. Maintenance and servicing

5.1 Firmware updates

Firmware updates should only be carried out if they can rectify errors in the previous firmware of the device!

The firmware of the HMI operating unit, the KE communication unit and the DR digital controller can be updated via the Ethernet interface on the rear. This requires the EA Power Control software, which is supplied with the device but is also available as a download from the manufacturer's website, together with a firmware file.

However, users are warned not to install updates without hesitation. Every update harbors the risk of rendering the device or entire test systems unusable for the time being. It is therefore recommended that you only install updates if...

- so that an existing problem with the device can be solved directly, especially if this was suggested by us as part of the troubleshooting support
- new functions that want to be used are listed in the firmware history. In this case, updating the device is at your own risk!

The following should also be noted in connection with firmware updates:

- Simple changes in firmware can result in time-consuming changes to control applications for the end user. It is recommended that you read the firmware history carefully with regard to changes
- For new functions, updated documentation (manual and/or programming instructions, as well as LabView VIs) is sometimes only available much later

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