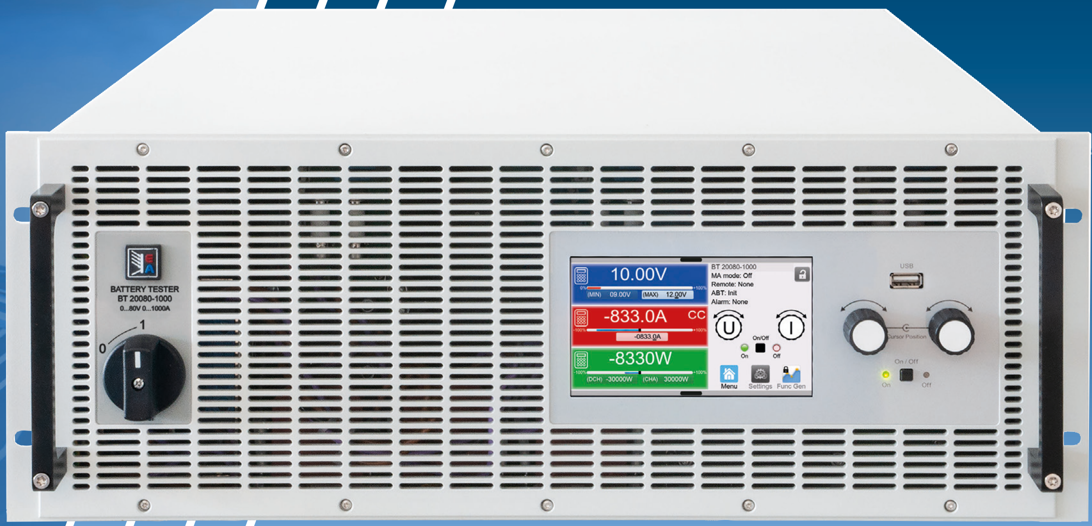


30 kW

USER MANUAL

EA-BT 20000 4U

Battery tester with regenerative energy recovery

Operation, remote control, function generator

Revision: 05

TABLE OF CONTENTS

Attention! The section of these instructions that deals with operation on the HMI only applies to devices with a firmware bundle from 2.0.0 or higher.

1. About this document

You must read this document before you operate the battery tester with energy recovery for the first time or if you are tasked with other work on the battery tester 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 the following models and their variants:

Model	Model	Model	Model
EA-BT 20010-1000 4U	EA-BT 20200-420 4U	EA-BT 20920-120 4U	EA-BT 22000-40 4U
EA-BT 20060-1000 4U	EA-BT 20360-240 4U	EA-BT 21000-80 4U	
EA-BT 20080-1000 4U	EA-BT 20500-180 4U	EA-BT 21500-60 4U	

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:

EA-BT 20080 - 1000 4U xxx

xxx	Options and special versions: **WC** = Water cooling installed
4U	Design/construction (only indicated on type plate): **4U** = 19" design with 4 U
1000	Maximum current of the device in Amperes
080	Maximum voltage of the device in Volts ("20080" = 80 V)
20	Series designation: **20** = Series 20000
BT	Type labeling: **BT** = Battery Tester

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 combination of a power supply unit and an electronic load. It can operate alternately in one of two higher-level operating modes, which must be differentiated in places below:

- **Source / Source mode / Source mode**
  - The device generates DC voltage as a power supply unit for an external DC load.
  - In this operating mode, the DC terminal is regarded as a DC output.
  - A source operation corresponds to a charge/charge operation in the battery test.
- **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.
  - Sink operation corresponds to discharge/discharge operation in the battery test.

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.

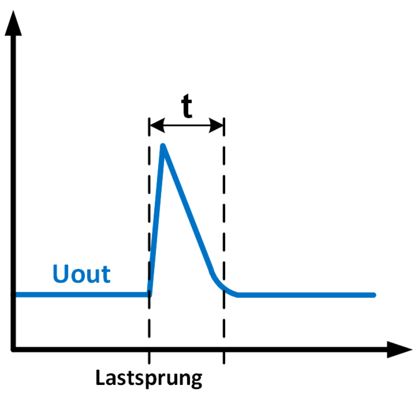
As long as the DC terminal is switched on and constant voltage operation is active, the "CV operation active" status is shown as the abbreviation **CV** on the graphic display, but can also be read out as a status via the digital interfaces.

2.1.2.1 Control peaks (source operation)

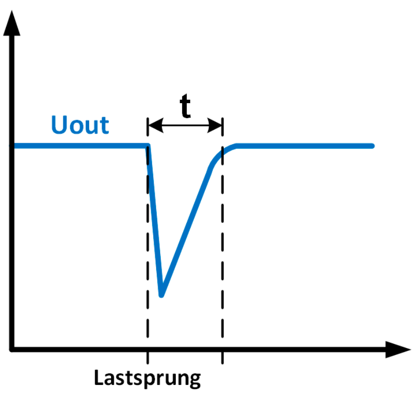
In CV mode and in source mode, the voltage regulator of the device needs some time after a load change to regulate the output voltage back to the set value. For technical reasons, a load jump from a low current to a high current (load) leads to a brief dip in the output voltage, and a load jump from a high current to a low current (unload) leads to a brief increase in the output 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 output voltage, the output capacitance and the actual load step and therefore cannot be specified precisely or in general terms.

Clarification:



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

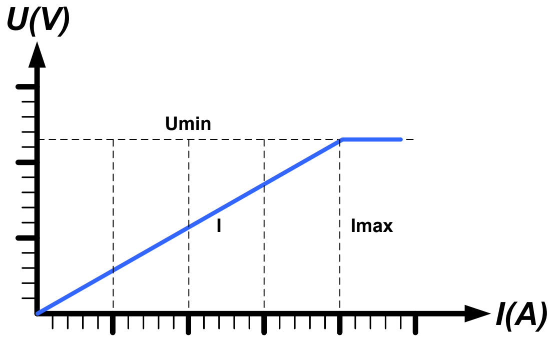


Example of load: the output voltage briefly drops below the set value. t = Stabilization time

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 $P = U^2 / R$ (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.

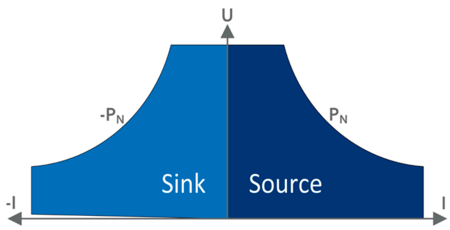


Figure 1 - Power output 30 kW models

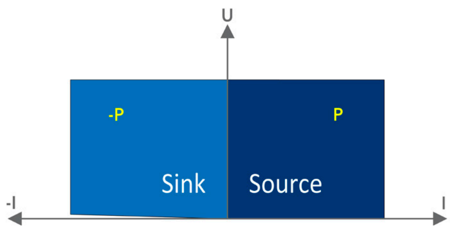


Figure 2 - Power output 10 kW model

2.1.4.1 Power reduction (derating) (30 kW models only)

To prevent the AC current from becoming too high when the 30 kW models in this series are operated at an AC voltage of 208 V (USA, Japan), they automatically reduce the available DC power to 18 kW.

The switch to "derating mode" occurs once after switching on and when the currently applied AC voltage is detected. This means that the device remains at reduced performance for as long as it is switched on, as the switchover does not take place dynamically during operation. The full rated power is therefore only available at a mains voltage of 380 V or higher.

As soon as a device is operating in derating mode, a message is permanently shown on the display. All power-related settings are then adjusted to the reduced power. This also applies to master-auxiliary operation of power-reduced devices.

2.1.5 Switching the source <-> sink operating mode

The two operating modes, source mode and sink mode, change automatically depending on the relationship between the actual voltage value at the DC terminal or at the remote sensor input (if used) and the voltage set value. This means that if an external voltage source is present, e.g. a battery, the voltage set value determines which operating mode is set. In the case of an external load that cannot generate its own voltage, only source mode is used.

Controls for applications with external voltage source:

- If the set value is higher than that from the external voltage source, the device switches to source mode (power supply unit)
- If the set value is lower, it switches to sink mode (electronic load)

If you want to run one of the two operating modes explicitly, i.e. without automatic switching, you would have to:

- For source-only operation, set the current set value for sink operation to 0
- Set the voltage set value to 0 for sink-only operation

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 *2.3.5*).

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:

10/60/80 V models: 1000uF....4700uF

200/360 V models: 100uF...470uF

500 V model: 47uF...150uF

920/1000 V models: 22uF...100uF

1500/2000 V models: 4.7uF...22uF

2.1.7 The battery tester mode

In battery tester or BT mode, the device switches dynamically between the CC and CV control modes. This is done on the basis of the terminal or battery voltage and the parametrized end-of-charge voltage/end-of-discharge voltage. When the end-of-charge voltage/end-of-discharge voltage is reached, the control mode automatically changes from CC to CV.

The CP control mode can be set by specifying the maximum charging/discharging power. If the product of terminal or battery voltage and current is greater than the enabled power and the battery voltage has not reached the end-of-charge voltage/end-of-discharge voltage, the battery is charged or discharged with constant power.

2.2 Other functions related to the DC terminal

2.2.1 Active idle mode

Active Idle Mode, or AIM for short, is a functionality related to the DC terminals of the device and the internal capacities available there. To discharge these during source operation and low load, there is a small internal electronic load that draws pulsed current. It would also do this with an external source such as a battery. This pulsed discharge of the capacitors puts a strain on a permanently connected battery, which would discharge slowly but steadily. The AIM is designed to prevent this gradual discharge when enabled in a targeted manner.

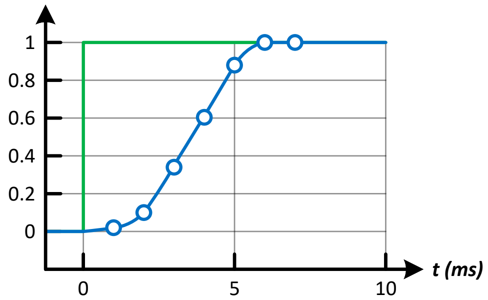
The following is given:

- AIM can only be activated remotely, regardless of the interface used, and only while the DC terminal is switched on
- Activation also switches off the DC terminal. The device then switches to a special standby mode in which the status of the switched-off DC terminal is displayed differently. The user can therefore select in the remote control how the DC terminal is switched off, i.e. with or without AIM activation.
- As long as AIM remains active, the HMI displays the status by keeping the green LED "On" next to the On/Off button lit, even if the DC terminal is switched off; this is for mode visualization only. In addition, the control mode (CV, CC, CP) is no longer displayed.
- AIM must be triggered repeatedly to keep the mode active, otherwise AIM stops and the device returns to the "normal" standby state
- The trigger interval must remain below 1 second; this maximum time cannot be changed
- Any type of device alarm, which can also occur in standby mode, will stop the AIM
- In a master-auxiliary system, the triggering of AIM is also passed on to the aux units via the master, so that all units of the MA system can keep AIM active at the same time

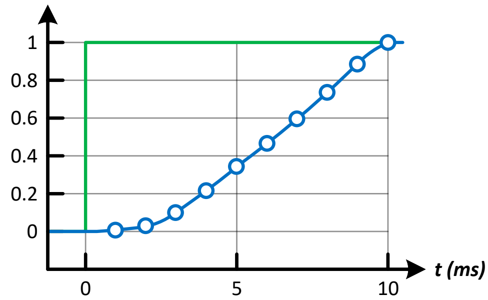
2.2.2 Actual value filtering

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.

2.2.3 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. Further details on battery testing are provided in the chapter *«2.5.7 Battery tester mode»*.

2.2.3.1 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.

2.2.3.2 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)

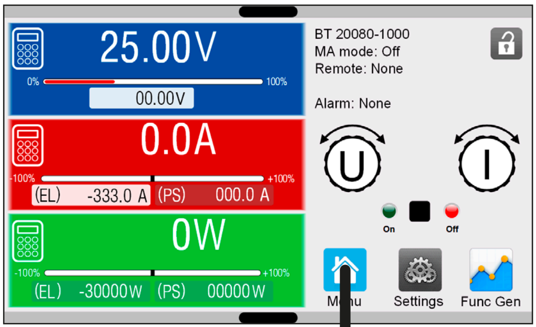
⚠	With manual operation and if the device is connected to a controlling unit (e.g. PC) via at least one of the available interfaces, the controlling unit could take over control at any time without warning or a confirmation prompt. For safety reasons, it is recommended to lock the remote by activating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

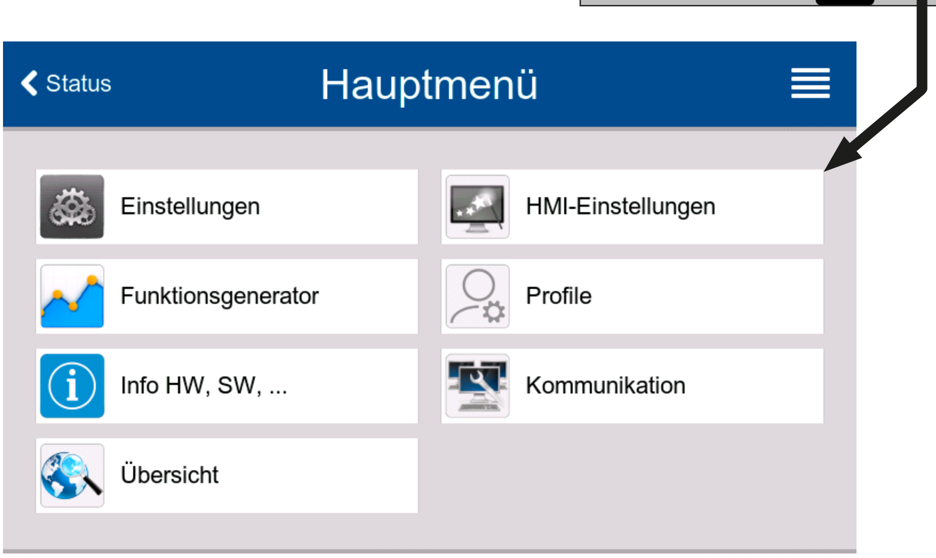
2.3.1 Configuration in the menu

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.
	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 *«2.2.2 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 *«2.3.4 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 over-load 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**
Ampere-hour counter	**Ah mode**
	Switching the Ah mode on or off. Can also be enabled/disabled via the quick menu, see chapter *«2.3.5 The quick menu»*.
	Mode
	Mode selection determines which method should be used to determine the ampere hours Delta (CHA - DCH) = The difference in ampere hours charged/discharged is recorded. The ampere hour value determined can therefore be positive or negative. • **Separate (CHA, DCH)** = Ampere hours of charging and discharging are recorded separately.
	Actual Ah (CHA - DCH)
	Current actual value of the Ah counter
	Ah limit (CHA)
	Charging ampere hour limit
	Ah limit (DCH)
	Discharge ampere hour limit
	Action
	Action when the ampere hour limit is reached. • **None** = No action • **Signal + Current 0A** = Sets the set value of current to 0 A and outputs a signal • **Warning** = Warning is displayed • **Alarm** = Switches output off and opens DC contactor
	Reset mode
	• **Disable** = Ah counter is not reset • **Manual** = User must actively reset the Ah counter • **Automatic** = The counter is reset to 0 Ah at DC-On
Ampere-hour counter	**Reset Ah counter**
	Resets the Ah counter to 0 Ah

Group	Setting & description
Battery test automation	**Reverse polarity protection**
	Enables reverse polarity protection during use of the feature
	Precharge
	Enables precharging while the feature is in use (DC contactor required)
	Contactor control
	Enables the DC contactor control during use of the feature (DC contactor required)
	Delay contactor control
	Defines the time between closing the DC contactor signal and the start test. Switching delay range: **0ms ...2000ms**
	Timeout contactor control
	When using contactor monitoring: Defines the time during which feedback from the contactor must be present. If there is no response, an alarm is generated. Feedback time range: **0ms...2000ms**
	Contactor monitoring
	Enables DC contactor monitoring while the feature is in use (DC contactor with feedback contact required)
	Zero current detection
	Enables zero-current cut-off during use of the feature (DC contactor required). The command to open the DC contactor is only given when 0A is reached. This serves to protect the DC contactor.

2.3.1.2 "Profiles" submenu

See *«2.3.6 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: Set Values (PS)	Enabling/disabling and time setting for automatic reading of the set values for source mode via the set **Base ID Cyclic Read + 2**. Setting range: 20...5000 ms. Default value: **0ms** (disabled).
	Cyclic Read Time: Limit Values 1 (PS)	Enabling/disabling and time setting for automatic reading of "Limits 1" (U, I) for source mode (PS) via the set **Base ID Cyclic Read + 3**. Setting range: 20...5000 ms. Default value: **0ms** (disabled)

IF	Setting	Description
CAN	**Cyclic Read Time: Limit Values 2 (PS)**	Enabling/disabling and time setting for automatic reading of "Limits 2" (P) for source mode (PS) via the set **Base ID Cyclic Read + 4**. Setting 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).
	Cyclic Read Time: Set Values (EL)	Enabling/disabling and time setting for automatic reading of the set values for sink mode (EL) via the set **Base ID Cyclic Read + 5**. Setting range: 20...5000 ms. Default value: **0ms** (disabled).
	Cyclic Read Time: Limit Values (EL)	Enabling/disabling and time setting for automatic reading of the "Limits" (I, P) for sink mode (EL) via the set **Base ID Cyclic Read + 6**. Setting range: 20...5000 ms. Default value: **0ms** (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 *«2.3.6 Load and save user profiles»*.

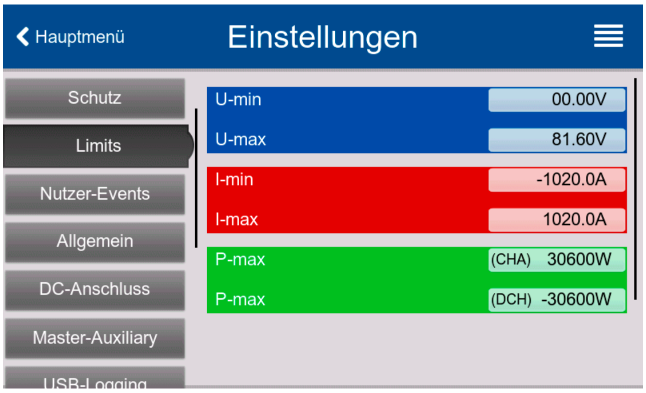
2.3.2 Adjustment limits

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%, with the exception of the voltage on the 60 V model, which can only be set up to 100%.

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), separately for charging and discharging operation.

There are two adjustment limits for the power (P) for charging (CHA) and discharging (DCH).



► 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 Changing the main operating mode

The device is primarily designed as a battery tester. There are two operating modes, the **battery tester** mode (BT mode) and the **power supply** mode (PSB mode). The latter is also called PSB mode, because the device then presents itself as a normal, bidirectional power supply unit. The operation of the devices in PSB mode is identical to the operation of devices from the PSB 10000 series, for example. The standard operating mode is BT mode.

► How to change the operating mode (two options)

1. If the DC terminals of all three channels are switched off, the device is not in remote control mode and the control panel is not locked, tap the lower gray bar to open the quick menu (see also section *"2.3.6 The quick menu"*). There is a button BT on the left-hand side. If it is displayed inverted (BT), BT mode is already active.
2. If the DC terminals of all three channels are switched off and the device is not in remote control mode and the control panel is not locked, tap Settings. Scroll down the groups on the left to **General**. There is then a selection **Main operating mode**, where you can choose between **Power supply** and **Battery tester**. The selection **Battery tester** corresponds to the BT enabled in the quick menu.

Switching to the other mode is done directly in the quick menu and in the settings menu after exiting it.

2.3.4 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.

2.3.4.1 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.

2.3.4.2 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.

2.3.4.3 The file format for USB logging (BT 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
1	U set (CHA)	U set (DCH)	U actual	I set (BT)	I actual	P set (CHA)	P set (DCH)	P actual	Output/Inpu	Device mode	Error	Time
2	4,00V	2,50V	0,00V	010,0A	0,0A	6000W	-6000W	0W	OFF	NONE	NONE	16:25:48.871
3	4,00V	2,50V	0,00V	010,0A	0,0A	6000W	-6000W	0W	OFF	NONE	NONE	16:25:49.371
4	4,00V	2,50V	0,00V	010,0A	0,0A	6000W	-6000W	0W	OFF	NONE	NONE	16:25:49.875
5	4,00V	2,50V	4,00V	010,0A	0,0A	6000W	-6000W	0W	ON	CV	NONE	16:25:50.324
6	4,00V	2,50V	4,00V	010,0A	0,0A	6000W	-6000W	0W	ON	CV	NONE	16:25:50.828

Legend:

U set (CHA) / U set (DCH): Set values of charging end voltage **(CHA)** and discharging end voltage **(DCH)**

U actual / I actual / P actual / C actual: Actual values (the **C actual** column is only recorded with active Ah counter, see chapter *"2.5.9 Capacity counter"*.

I set: Set values for I

P set (CHA) / P set (DCH): Set values of P charge / discharge

C set (CHA) / C set (DCH): Set values of capacity charging or discharging (these columns are only recorded with active Ah counter)

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.

2.3.4.4 The file format for USB logging (PSB 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
1	U set	U actual	I set (PS)	I actual	P set (PS)	P actual	I set (EL)	P set (EL)	Output/Input	Device mode	Error	Time
2	00,00	0,00	0,000	0,0	30000	0	-000.0	-30000	OFF	NONE	NONE	16:25:48.871
3	00,00	0,00	0,000	0,0	30000	0	-000.0	-30000	OFF	NONE	NONE	16:25:49.371
4	00,00	0,00	0,000	0,0	30000	0	-000.0	-30000	OFF	NONE	NONE	16:25:49.875
5	00,00	0,00	0,000	0,0	30000	0	-000.0	-30000	OFF	NONE	NONE	16:25:50.324
6	00,00	0,00	0,000	0,0	30000	0	-000.0	-30000	OFF	NONE	NONE	16:25:50.828

Legend:

U set: Preset voltage

U actual / I actual / P actual: Actual values

I set (PS) / P set (PS): Set values for I and P from source operation (PS)

I set (EL) / P set (EL): Set values for I and P from sink mode (EL)

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:

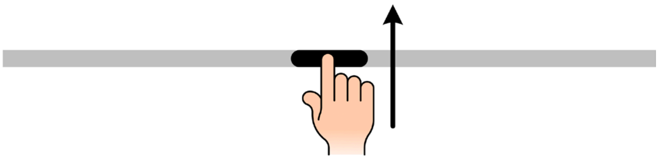
- In contrast to logging on the PC, each new log process in USB logging creates a further file with the naming scheme usb_log_1.csv etc., which is given an incremented number at the end of the file name; existing log files are taken into account here

2.3.4.5 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

2.3.5 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
Ah	Ah counter	Ampere-hour counter is enabled
	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
BT	Operating modes	Battery tester mode enabled
	Operating modes	Switching the voltage controller speed between **Slow**, **Normal** de-fault) 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

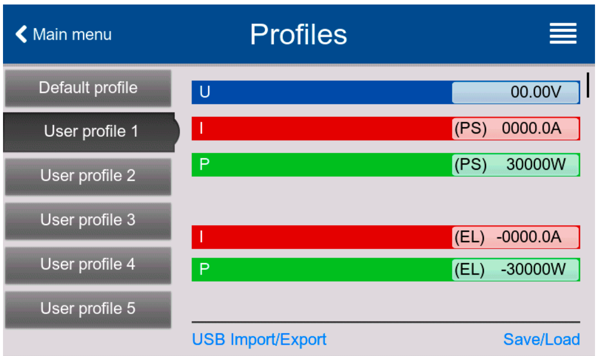
2.3.6 Load and save user profiles

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 Menu 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

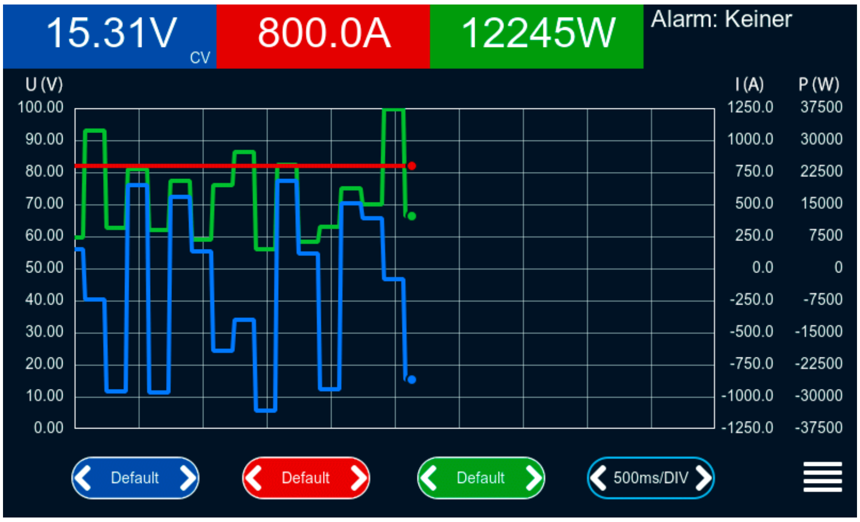
1. With the DC terminal switched off, tap on the Menu button on the main page.
2. On the main menu page, tap **Profile**.
3. In the selection that now appears, select the user profile that you want to change. The selected user profile is then displayed.
4. Tap on a value to be changed and enter a new 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?**.

2.3.7 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 output 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 functions related to the testing of batteries

2.5.1 Measurement of negative battery voltages

Due to an effect with fresh, so-called “green” batteries, their voltage can be negative before the first charge, but only very low, typically between 0 and -0.6 V. The device can measure and display this negative voltage at the DC terminal and at the “Sense” input, if connected. The latter is typically connected, for example, if a contactor is integrated into the DC circuit so that the battery voltage can be detected when the contactor is open.

Negative voltage measuring range: approx. -0.6 V...0 V.

If a voltage less than -0.6 V is present, the device can no longer measure this and the measured value -0.6 V would remain on the display. If this voltage is also present at the DC terminal, it would be critical, as reverse polarity could damage the device.

The additional “Sense 2” input can also measure negative voltage, but evaluates it differently, as it is used to recognize a battery that has already been charged once and is connected with reverse polarity. Such a battery would normally have a voltage of more than 0.6 V, which would exceed the limit of -0.6 V if the polarity were reversed and would trigger a polarity error on the device if measured at sense 2.

2.5.2 Polarity reversal protection

Genuine reverse polarity protection consists of two components: detection of negative voltage from a source connected to the battery tester, and a disconnect device (contactor, internal or external). This is to protect the device from damage caused by high battery current. This assumes that the device is configured to control the disconnecting device “external contactor” itself, it can also implement protection together with the contactor by not allowing a battery test to be started. There is no internal contactor.

The battery voltage is detected via the remote sensor input (sense 2) for reverse polarity protection. Unless clearly negative and therefore considered not to be reverse polarity, the contactor will release. If reverse polarity is detected, an alarm event is generated, which displays a message on the display and switches off the DC terminal, if present. The alarm also has the task of preventing the DC terminal from being switched on as long as the polarity reversal condition exists.

Once the cause of the alarm has been rectified, the DC terminal is reactivated.

2.5.3 Precharging

If a contactor is used, the so-called precharging during battery testing is used to precharge the DC terminal of the device to the voltage measured at the battery so that the contactor has a very small voltage difference on both sides of its contact and can switch on with virtually no current. The precharging function can be used in the automated battery test or manually.

2.5.4 Contactor control

If a contactor is used, this function is used to control the contactor using digital outputs. The contactor control can be used in the automated battery test or manually.

2.5.5 Contactor monitoring

If a contactor with signaling contact is used, this function is used to monitor whether the contactor has switched by means of digital inputs. The contactor control can be used in the automated battery test or manually. When this function is enabled, an alarm is triggered if there is a discrepancy between the set value and actual value of the signaling contact during the switching phase. Once the cause has been eliminated and the alarm acknowledged, the DC terminal is enabled again.

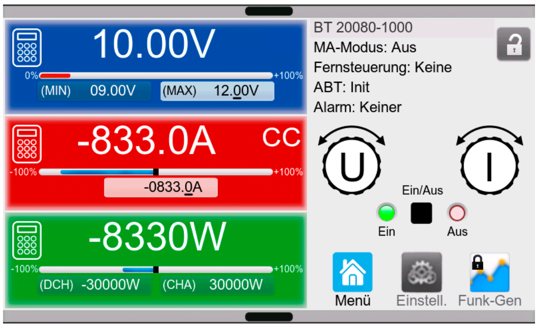
2.5.6 Zero current switch-off

If a contactor is used, this function is used to protect the contactor against high switch-off currents, which can have a negative impact on the service life of the contactor. If the function is enabled, the command to open the contactor is only given after a zero current (threshold value current < 1 % of the nominal current) is reached. If no zero current has been reached after 500 ms, the contactor is opened and an alarm is triggered. After the alarm has been acknowledged, the DC terminal is enabled again.

2.5.7 Battery tester mode

> Before using the device as a battery tester, it should be determined for the application whether the battery is to be connected with or without a contactor. If with contactor, then this must be controlled, either externally or by the device. For the wiring of a contactor, see section *«6.3.9 Precharge, contactor control, contactor monitoring and polarity detection»* in the installation manual.

The battery tester mode has been developed for the efficient testing of batteries. It contains the following set value specifications:



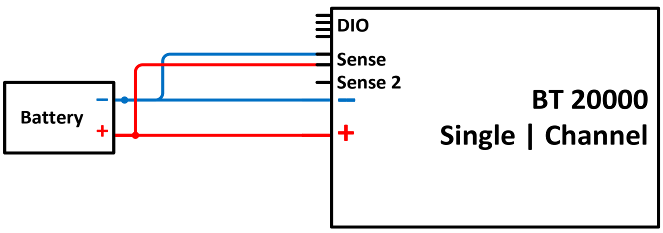
- There are two voltage set values:
  - The set value labeled **MIN** belongs to the battery discharge and defines the so-called final discharge voltage, i.e. a threshold at which the control mode switches from CC to CV.
  - The set value labeled **MAX** belongs to the battery charge and defines the so-called end-of-charge voltage, i.e. a threshold at which the control mode switches from CC to CV so that trickle charging is possible.
  - There is a current set value **BT**. This can be positive or negative and thus determines the direction of current flow. A negative current set value specifies current flow into the device, which means discharge for a connected battery.
- There are two power set values:
  - The set value labeled **DCH** (short for: discharge) belongs to the battery discharge and defines the maximum power when discharging the battery. If the set value is lower than the power resulting from the current voltage and current, the power set value acts as a power limitation.
  - The set value labeled **CHA** (short for: charge) belongs to the battery charge and defines the maximum power when charging the battery. If the set value is lower than the power resulting from the current voltage and current, the power set value acts as a power limitation.
  - Optionally, the specification of the power set values can be replaced by the Ah counter function (see chapter *«2.5.9 Ampere-hour counter»*).

2.5.7.1 General operation

Assuming that a battery to be tested is already connected to the battery tester with or without a contactor, testing can be started. After activating BT mode and setting the charge and discharge voltage thresholds, you can switch between charging and discharging by adjusting the current set value (**BT**). This means that only one value needs to be controlled during a test, either manually or remotely. The remote control of the current set value **BT** even allows pulsed charging or discharging, as well as dynamic charging/discharging profiles.

2.5.7.2 Set-up without contactor

A battery test without contactor is possible, but offers no protection against reverse polarity. The user must ensure that the battery is connected with the correct polarity. Direct contact can cause equalizing currents to flow between the device and the battery.



Assuming that the battery is to be discharged, the final discharge voltage (MIN) would be set to a value to which the battery is to be discharged so that the discharge stops at this point (change of control mode from CC to CV). The data sheet indicates how far a battery may be discharged.

An example of the configuration: the discharge current during testing should be 10C, a battery with a capacity of 3200 mAh would then have to be discharged with 32 A:

1. Set the end-of-charge voltage (MAX) if charging is to take place. For example 4.2 V.
2. Set the final discharge voltage (MIN) if discharging is to take place. For example 2.7 V.
3. Set the BT current, in this case negative, so that the test starts with discharge. For example 32 A as discharge current.
4. Switch on the DC terminal.

After switching on and if the set values for charging or discharging are correct, the test starts and discharges the battery at a constant current. The battery voltage drops more or less continuously in the direction of the final discharge voltage. As soon as this is reached, the control mode changes from CC to CV so that the discharge current decreases continuously.

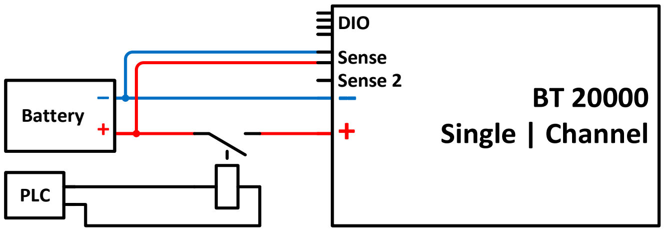
The next step would be to recharge the battery after discharging it:

5. Set the BT current to a positive value, in this case as the charge current.

2.5.7.3 Design with a contactor (externally controlled)

See also *«2.5.3 Precharging»*, *«2.5.6 Zero current switch-off»* and *«2.5.4 Contactor control»*.

This design provides for a contactor in the positive wiring of the battery, which is controlled externally, as shown in the diagram on the right.



The procedure prior to starting the actual test is identical to that described in section *2.5.7.2* in steps 1-3.

Only step 4 is divided into individual sub-steps, some of which would be implemented by the device. Further information can be found in the programming instructions. The additional sub-steps in step 4 represent the manual battery test:

4a. Activate precharging, if not already done.

4b. Switch on the DC terminal of the channel to be controlled so that it can be precharged.

4c. Read out the status of the precharge and only proceed to step 4d if positive.

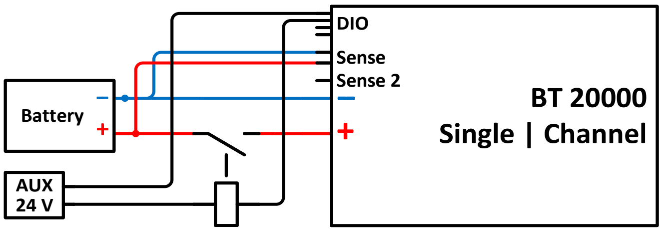
4d. Close the externally controlled contactor. Wait for time x or use the feedback contact on the contactor to ensure that it has switched.

4e. Disable precharging. The test can then be started.

2.5.7.4 Design with a contactor (internally controlled)

See also *«2.5.3 Precharging»*, *«2.5.6 Zero current switch-off»* and *«2.5.4 Contactor control»*.

This design includes a contactor in the positive wiring of the battery, which is controlled by the battery tester. The control setup can be carried out manually using remote control or automatically via the automated battery test (see *«2.5.8 Automated battery test»*). This then includes precharging, contactor on/off and feedback that the contactor is closed, as well as optional zero current shutdown.



The procedure prior to starting the actual test is identical to that described in section *2.5.7.2* in steps 1-3.

Only step 4 is divided into individual sub-steps. Further information can be found in the programming instructions. The additional sub-steps in step 4 should cause the contactor to switch on when de-energized. Step 4 would therefore be divided into:

4a. Activate precharging, if not already done.

4b. Switch on the DC terminal of the channel to be controlled so that it can be precharged.

4c. Read out the status of the precharge and only proceed to step 4d if positive.

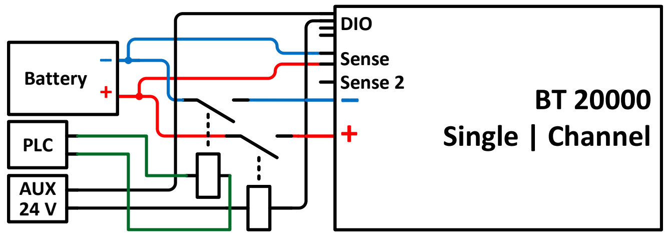
4d. Close the contactor (command, the device controls the contactor). Wait for time x to ensure that it has switched.

4e. Disable precharging. The test can then be started.

2.5.7.5 Set-up with two contactors (externally controlled)

See also *«2.5.3 Precharging»*, *«2.5.6 Zero current switch-off»* and *«2.5.4 Contactor control»*.

This design provides for one contactor each in the negative and positive wiring of the battery. However, the BT 20000 device can only control one of the contactors itself, so that external control of the other contactor is required. Alternatively, both contactors can be controlled by the user. Basically, the operation of the battery test is completely shifted to the remote control, because a mix of manual operation and remote control would be too complicated.



The procedure before starting the actual test is identical to that described in *2.5.7.2*in steps 1-3. Only step 4 is divided into individual sub-steps, some of which would be implemented by the device. Further information can be found in the programming instructions. The additional sub-steps in step 4 should cause the contactor to switch on when de-energized. Step 4 would therefore be divided into:

4a. Close the externally controlled contactor in the negative connection to the battery. This is necessary because the Sense connection measures the battery voltage for the purpose of precharging and needs the DC minus as a reference.

4b. Activate precharging, if not already done.

4c. Switch on the DC terminal of the channel to be controlled so that it can be precharged.

4d. Read out the status of the precharge and only proceed to step 4e if positive.

4e. Close the externally controlled contactor in the positive connection to the battery. Then wait for a time x or use the feedback contact on the contactor to ensure that it has switched.

4f. Disable precharging. The test can then be started.

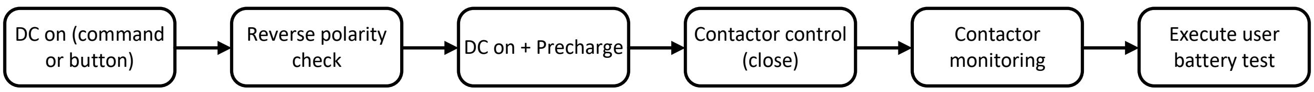
2.5.8 Automated battery test

The automated battery test (short: ABT) enables batteries to be tested simply and effectively and offers extended control and monitoring functionalities thanks to its flexibility. The configuration can be used to activate/deactivate individual functions so that the ABT's control setup can be customized to the application. The functions are executed sequentially in logical order when the DC output is switched on/off. If none of the ABT functions are enabled, the DC output switches on/off as usual. To use the ABT function, the device must be in battery tester mode. In addition to the execution of functions, the ABT also offers additional protective functions (precharge monitoring, DC contactor monitoring).

2.5.8.1 Configuration and control setup of the automated battery test

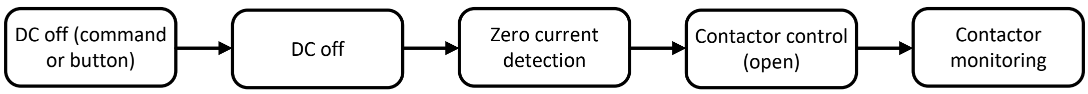
The ABT can be set via the HMI as follows. The functions that are enabled can become active either when the test is started or when it is ended. The reverse polarity protection and precharge functions are run through in the start sequence (switch on DC output). The zero current cut-off takes effect during the stop sequence (switch off DC output). Contactor Control and Contactor Monitoring are active both when switching on and off.

Start sequence



If individual functions are not enabled, they are skipped.

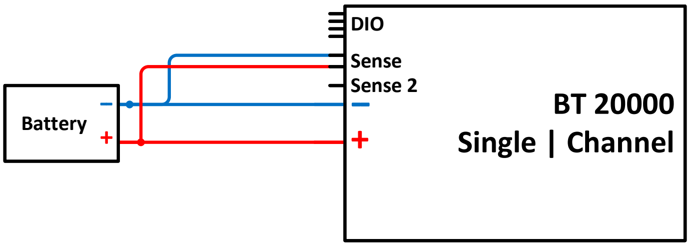
Stop sequence



Some configuration examples of the ABT are listed below:

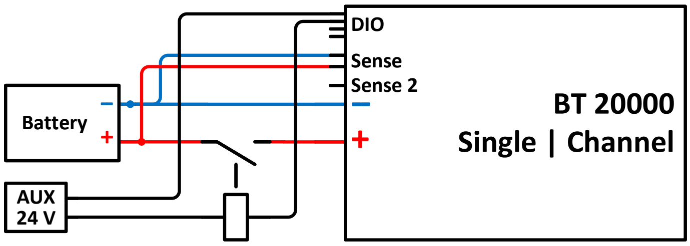
- Simple application without additional external components such as DC contactors. Sense 1 is used for load balancing

Function	Active	Remark
Reverse polarity protection	no	Can only be used when installing a DC contactor and wiring Sense 2
Precharge	no	Can only be used when installing a DC contactor
Contactor Control	no	Can only be used when installing a DC contactor
Contactor Monitoring	no	Can only be used when installing a DC contactor with a feedback contact
Zero current detection	no	Can only be used when installing a DC contactor



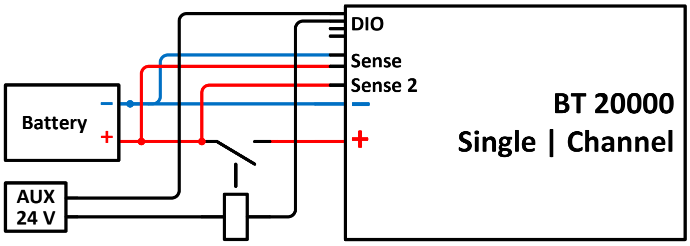
- Application with DC contactor and Sense 1

Function	Active	Remark
Reverse polarity protection	no	Can only be used when installing a DC contactor and wiring Sense 2
Precharge	yes	The DC terminal is charged to the measured voltage via Sense 1 before the DC contactor is closed
Contactor Control	yes	When switching on, the DC contactor is closed after successful precharging. When switching off, the DC contactor is opened when 0 A is reached
Contactor Monitoring	no	Can only be used when installing a DC contactor with a feedback contact
Zero current detection	yes	Can only be used when installing a DC contactor



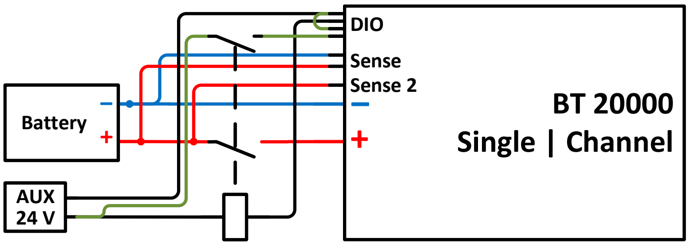
- Application with DC contactor, Sense 1 and Sense 2

Function	Active	Remark
Reverse polarity protection	yes	Can only be used when installing a DC contactor and wiring Sense 2
Precharge	yes	The DC terminal is charged to the measured voltage via Sense 1 before the DC contactor is closed
Contactor Control	yes	When switching on, the DC contactor is closed after successful precharging. When switching off, the DC contactor is opened when 0 A is reached.
Contactor Monitoring	no	Can only be used when installing a DC contactor with a feedback contact
Zero current detection	yes	Can only be used when installing a DC contactor



- Application with DC contactor including feedback contact, Sense 1 and Sense 2

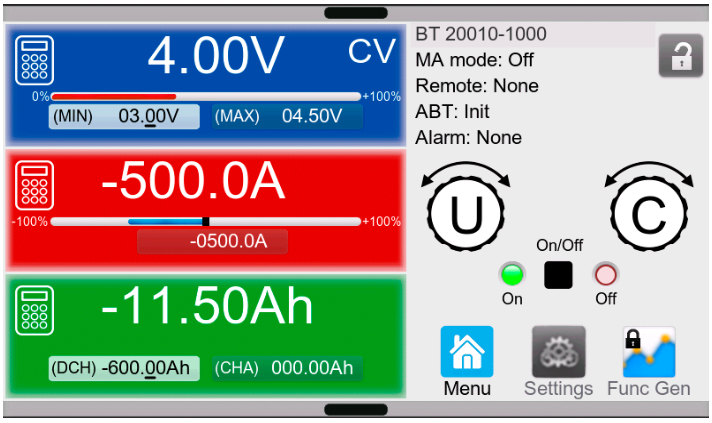
Function	Active	Remark
Reverse polarity protection	yes	Can only be used when installing a DC contactor and wiring Sense 2.
Precharge	yes	The DC terminal is charged to the measured voltage via Sense 1 before the DC contactor is closed.
Contactor Control	yes	When switching on, the DC contactor is closed after successful precharging. When switching off, the DC contactor is opened when 0 A is reached.
Contactor Monitoring	yes	Can only be used when installing a DC contactor with a feedback contact.
Zero current detection	yes	Can only be used when installing a DC contactor

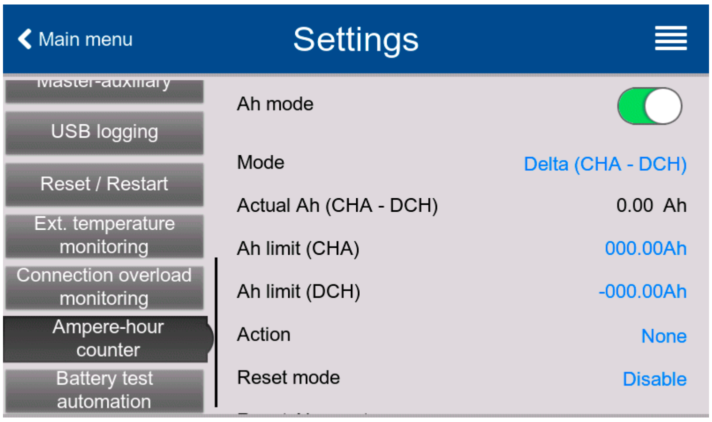


2.5.9 Ampere-hour counter

The Ah counter enables a defined amount of charge to be drawn from or charged to the battery. Activating the Ah counter replaces the power setting, so it is not possible to use both operating modes at the same time.

There are various setting options, which are explained in more detail below. Mode can be used to select the way in which the Ah counter is aggregated. The **Delta (CHA - DCH)** mode is enabled by default, in which the sum of the charged and discharged charge is calculated and output as a signed value. With **Separate (CHA, DCH)**, two independent values are determined, one for CHA and one for DCH.





Ah limit (CHA) and Ah limit (DCH) can be used to define set values which, when reached, trigger an action. With **None**, the device continues to run according to the set values without any additional action, **Signal + current 0A** sets the set value current to 0 A and outputs a signal. If a **Warning** is enabled, a warning is generated when the set values are reached and the alarm switches the output off and generates an alarm message. If a DC contactor is connected and contactor control is enabled, it is opened.

The reset mode defines the conditions under which the Ah counter is reset. Here, **Disable** means that the Ah counter is not reset. With **Manual**, the user must actively reset the Ah counter. This can be done via the HMI or via an interface. **Automatic** means that the counter is reset to 0 Ah when the DC output is switched on.

3. The function generator

3.1 Introduction

The function generator is not available if the device is operating in "Battery tester" mode (BT mode, see «2.5.7 Battery tester mode»)

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, such as fuel cell simulation, 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:

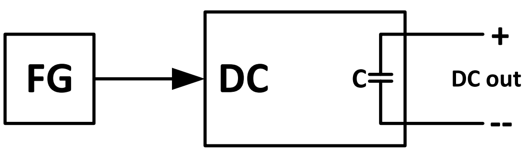
Function	Brief explanation
Sine	Sine wave signal generation with adjustable amplitude, offset and frequency
Triangle	Triangular signal generation with adjustable amplitude, offset, rise and fall time
Rectangle	Rectangular signal generation with adjustable amplitude, offset and pulse-pause ratio
Trapezoid	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)
FC table (PS)	Function for simulating fuel cells, with calculation based on parameters
Battery test	Battery charging and discharging with constant or pulsed current, as well as time, Ah and Wh measurement

3.2 General information

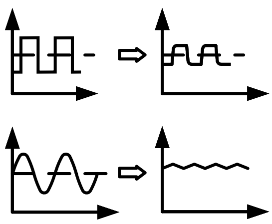
3.2.1 Structure

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, especially in source mode. While the FG is capable of generating 10,000 Hz with a sine wave, the device cannot follow this 1:1 when operated as a source. Sink operation is similar, but fundamentally better, because the current is in the foreground here.

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. In source operation and with dynamic voltage generation, on which the capacitances have the greatest influence, an additional load on the DC terminal can lead to shorter rise and fall times of the voltage. This modification has a positive effect on periodically repeated functions such as rectangles or sines.

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 Possible technical complications

If the device is operated as a voltage source, applying a function to the set voltage value can damage the device if this changes very quickly and with a large stroke, as the capacitors at the output would also be constantly recharged, which would lead to heating and eventually overheating during continuous operation.

3.2.4 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:

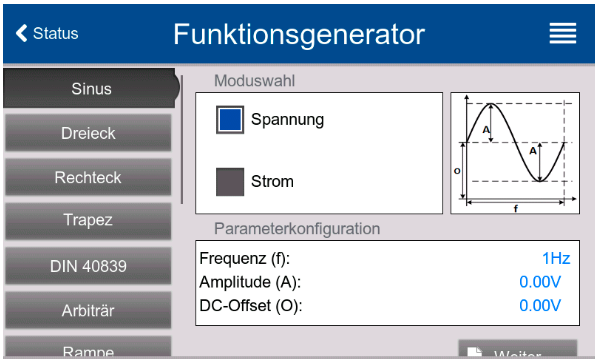
- The device also includes a sink that discharges the capacities of the device at its own DC terminal in the event of negative voltage steps in source operation, i.e. higher voltage to lower voltage, so that the output voltage drops more quickly. This requires a certain current and therefore also a certain power, both of which can or should be set for almost all of the functions listed below, specifically "I (EL)" and "P (EL)". For safety reasons, the current value "I (EL)" 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 (EL)", 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 (EL)" 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.

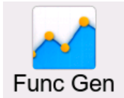
3.3 Manual operation

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.

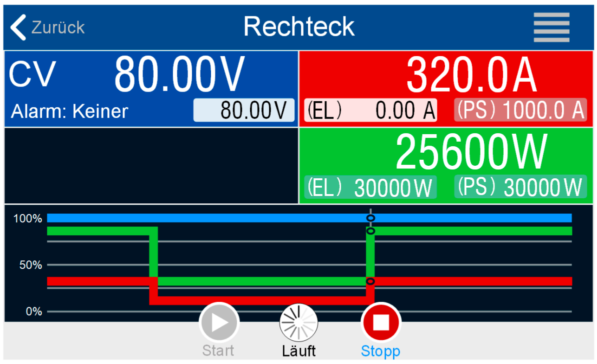
► How to configure a function

1. With the DC terminal switched off, tap the button  .
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  .
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 source or 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 on the load or external source 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  .

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.*

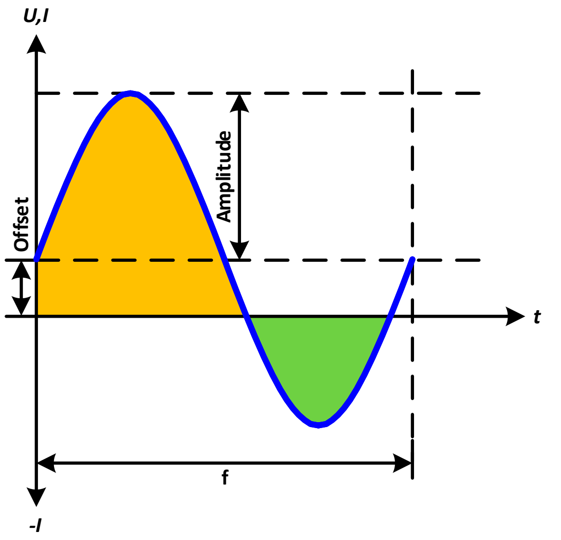
3.4 Sine function

Restrictions related to this function:

- It is not possible to preselect only source or only sink operation; the setting values determine which of the two the curve affects, i.e. whether only source operation, only sink operation or both alternately
- When applied to the voltage, the device can only operate in sink mode if the voltage applied to the DC terminal is higher than the highest point (offset + amplitude) of the curve and the current "I (EL)" is not 0

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**)...+(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. By selecting the appropriate setting values, the device can only apply the sine wave to either source mode or sink mode, but can also switch dynamically. The picture on the left illustrates the curve (yellow = source, green = sink) with change of operating mode at the zero crossing. While the amplitude is always an absolute value, the offset can also be shifted into the negative range in I mode. 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.

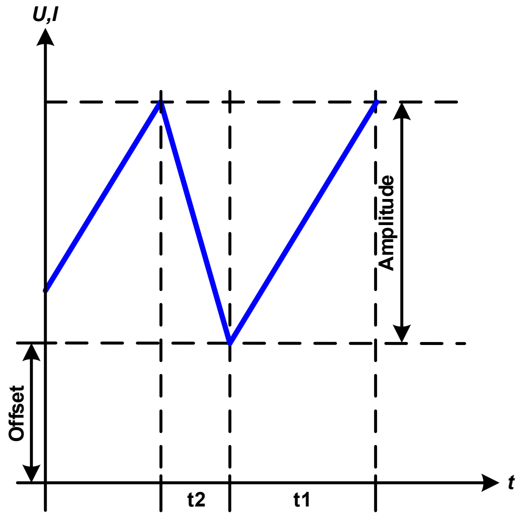
3.5 Triangle function

Restrictions related to this function:

- It is not possible to preselect only source or only sink operation; the setting values determine which of the two the curve affects, i.e. whether only source operation, only sink operation or both alternately
- When applied to the voltage, the device can only operate in sink mode if the voltage applied to the DC terminal is higher than the highest point (offset + amplitude) of the curve and the current "I (EL)" is not 0

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**)...+(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).

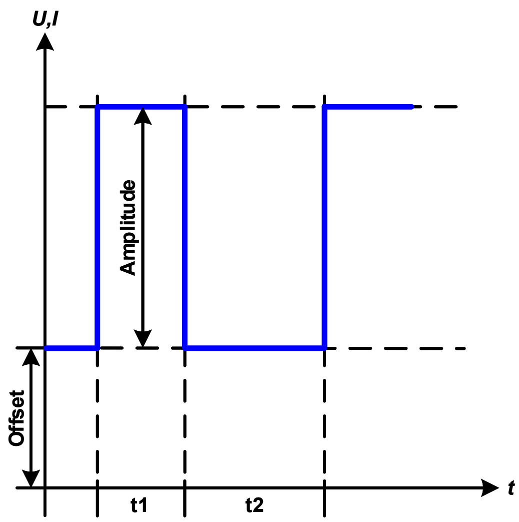
3.6 Rectangle function

Restrictions related to this function:

- It is not possible to preselect only source or only sink operation; the setting values determine which of the two the curve affects, i.e. whether only source operation, only sink operation or both alternately
- When applied to the voltage, the device can only operate in sink mode if the voltage applied to the DC terminal is higher than the highest point (offset + amplitude) of the curve and the current "I (EL)" is not 0

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**)...+(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

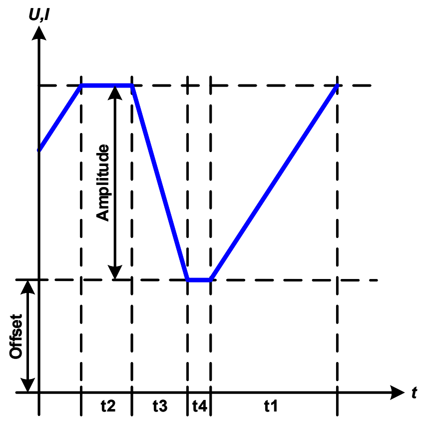
Restrictions related to this function:

- It is not possible to preselect only source or only sink operation; the setting values determine which of the two the curve affects, i.e. whether only source operation, only sink operation or both alternately
- When applied to the voltage, the device can only operate in sink mode if the voltage applied to the DC terminal is higher than the highest point (offset + amplitude) of the curve and the current "I (EL)" is not 0

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**)...+(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.

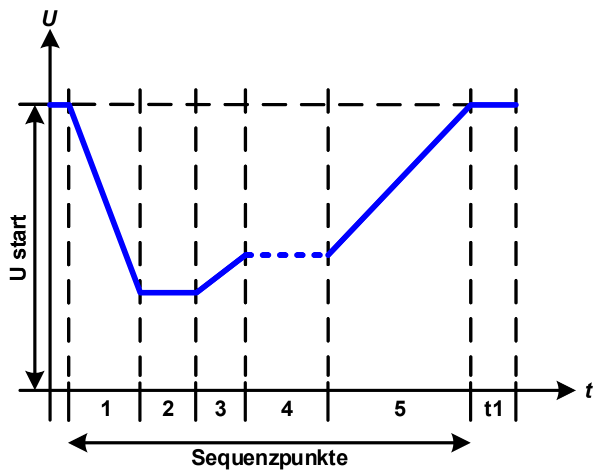
Here, the period duration and the repetition frequency are formed from the four adjustable time values. With the appropriate settings, two triangular or two rectangular pulses are produced instead of a trapezoid. This function is therefore quite universal.

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 (PS)	0A...$I_{nominal}$ / 0W...$P_{nominal}$	-	Global set values for current and power in source mode. If I=0 or P=0, the device would only operate in sink mode.
I/P (EL)	0A...$I_{nominal}$ / 0W...$P_{nominal}$	-	Global set values for current and power in sink mode. If I=0 or P=0, the device would only operate in source mode.

Pictorial representation:	Application and result:
	When the function runs in source mode, the built-in sink function of the PSB power supply unit ensures the rapid voltage drop required in some parts of the curve so that the voltage curve at the DC output corresponds to the DIN curve. 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%...+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

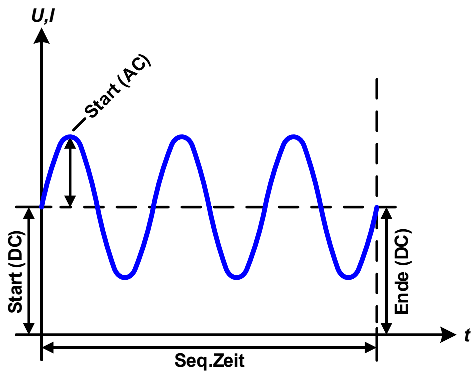
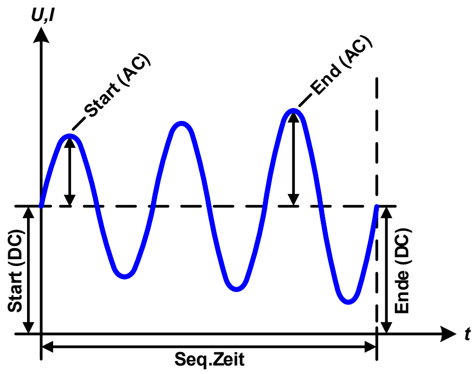
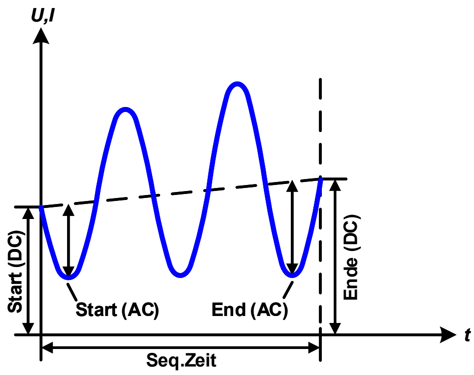
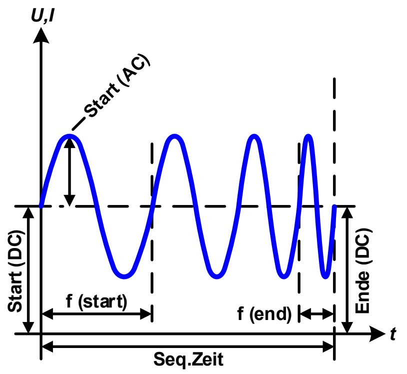
!	*The sequence point time and the start frequency/end frequency are related. There is a minimum Δf/s of 9.3. So, for example, a setting with start frequency = 1 Hz, end frequency = 11 Hz and time = 5 s would not be accepted because the Δf/s would then only be 2. At time = 1 s, it lines up again, or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

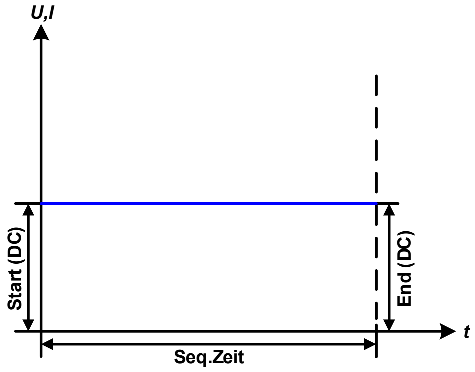
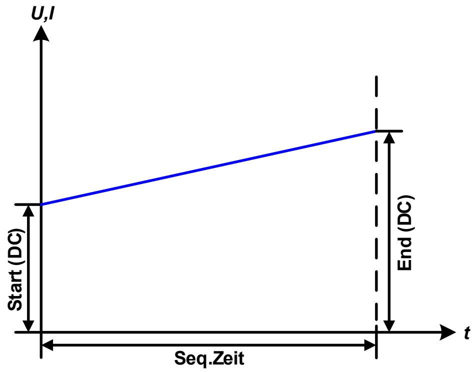
!	*The change in amplitude between start and end is related to the sequence point time. You cannot generate an arbitrarily small change over an arbitrarily large period of time. In such a case, the device rejects unsuitable settings with a message.*

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:

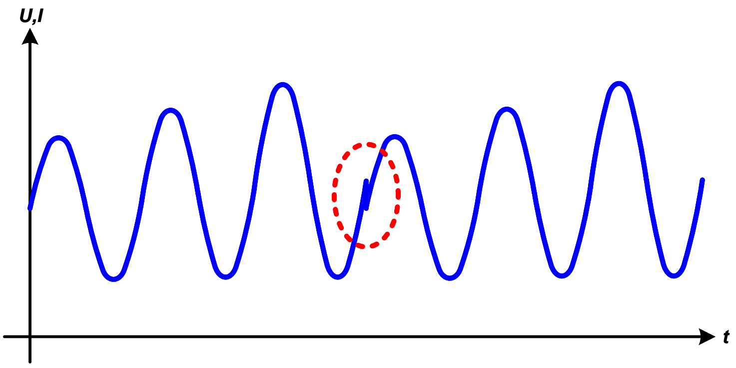
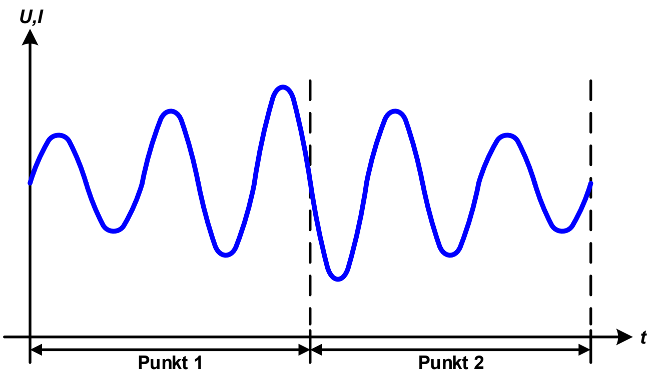
Parameters	Setting range	Explanation
Sequence cycles	**0 / 1...999**	Number of sequences in the sequence point block (0 = infinite)
Start sequence	**1...End sequence**	First sequence point of the sequence point block
End sequence	**Start sequence...99**	Last sequence point of the sequence point block

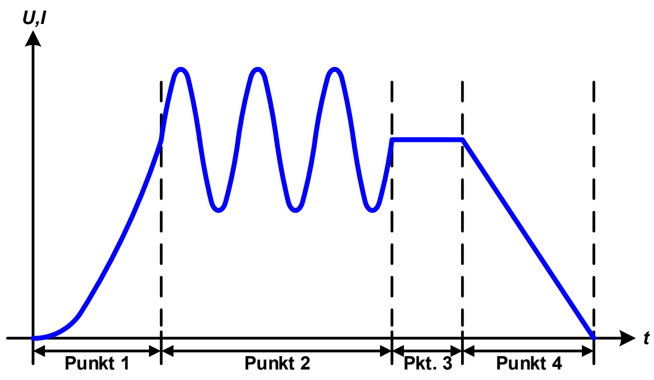
After pressing Next, global set values (U/I/P limits) must be defined for the function sequence.

<table>
<tr><th>Pictorial representations:</th><th>Applications and results:</th></tr>
<tr><td>
</td><td>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.</td></tr>
<tr><td>
</td><td>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.</td></tr>
<tr><td>
</td><td>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.</td></tr>
<tr><td>
</td><td>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.</td></tr>
</table>

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)

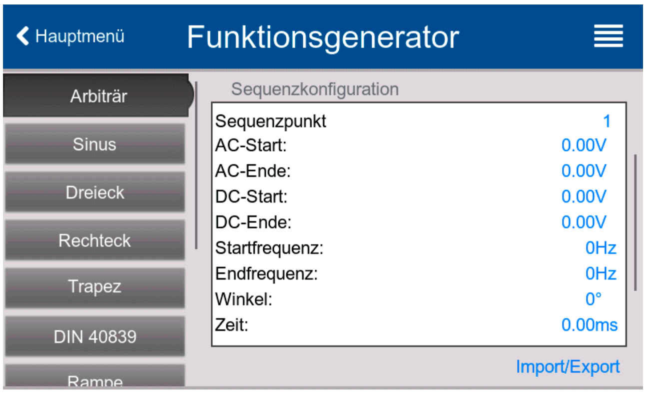
For a more detailed description of the parameters and the arbitrary function, see *«3.9 Arbitrary function»*.

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 Func Gen, 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 Func Gen 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

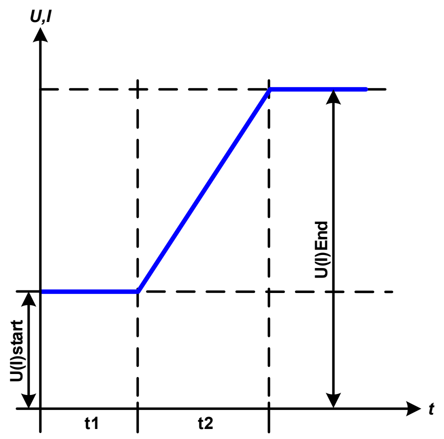
Restrictions related to this function:

- It is not possible to preselect only source or only sink operation; the setting values determine which of the two the curve affects, i.e. whether only source operation, only sink operation or both alternately
- When applied to the voltage, the device can only operate in sink mode if the voltage applied to the DC terminal is higher than the highest point (offset + amplitude) of the curve and the current "I (EL)" is not 0

The following parameters can be configured for the ramp function:

Parameters	Setting range	Explanation
Start **End**	0V...U_{Nom} or $-I_{Nom}$...$+I_{Nom}$	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 either in source mode (PS) or 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:

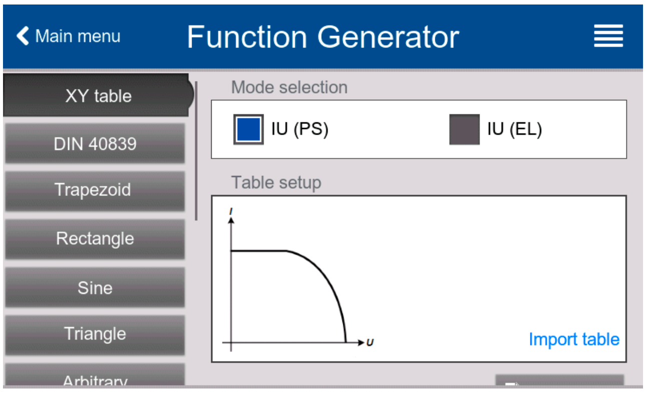
IU function: I = f(U) -> the device operates in CC mode (in source operation with a load in CV mode)

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

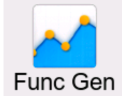
The so-called IU tables can be loaded from a USB stick (FAT32 formatted) via the USB interface on the front of the device. To be able to do this, the file to be loaded must fulfil certain requirements:



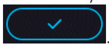
- The file name always starts with IU (case insensitive)
- The file must be a text file of type CSV and may only contain one column with exactly 4096 real values (without gaps)
- None of the 4096 values may exceed the nominal current value. For example, if you have a 420 A model and load an IU table 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 

and select group **XY table**.

2. At the top, select between **IU (EL)** for sink operation or **IU (PS)** for source operation.
3. 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.

4. In the next window, which you can access with 

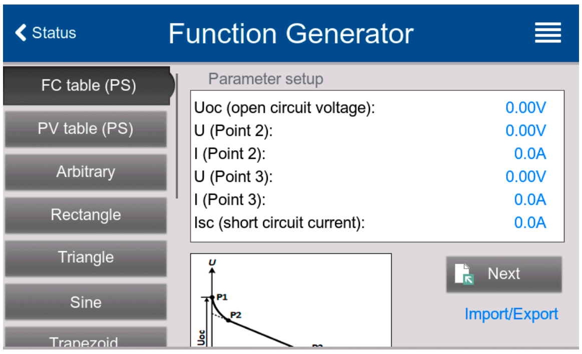
, you can adjust the global set values.

5. Load the function with 

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

3.12 FC table function (fuel cell)

3.12.1 Introduction



The “FC table” (fuel cell) function is used to simulate a fuel cell and its characteristics. This is achieved by adjustable parameters that represent several points on the typical characteristic curve of a fuel cell.

The user must enter values for four interpolation points of the FC curve. These are formed from three voltage and three current values. The characteristic curve is calculated from this.

In general, the following rules apply during input:

- $U_{OC} > U_{point2} > U_{point3} > U_{point4}$
- $I_{SC} > I_{point3} > I_{point2} > I_{point1}$
- Zero values are not accepted

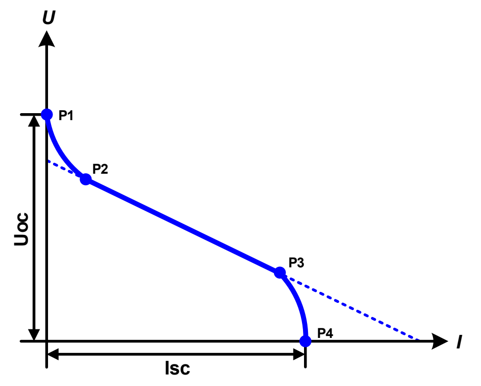
This means that the voltage must decrease from U_{oc} to U_{point4} and the current must increase. If the above rules are not adhered to, an error message appears and the values entered are reset to 0.

3.12.2 Application

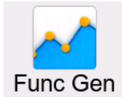
The following parameters can be configured for the FC table function:

Parameters	Setting range	Explanation
Point 1: Uoc	0V...U_{Nom}	Maximum voltage of the cell (open circuit voltage)
Points 2+3: U	0V...U_{Nom}	Voltage and current of the two points in the XY coordinate system. They represent two interpolation points on the characteristic curve to be calculated
Points 2+3: I	0A...I_{Nom}	
Point 4: Isc	0A...I_{Nom}	Maximum current of the cell (short-circuit operation)
U	0V...U_{Nom}	Global voltage limit, should be ≥Uoc
P	0W...P_{Nom}	Global performance limit, must not be 0 so that the function can run

!	*Due to the freely adjustable parameters, it is possible that the curve cannot be calculated correctly. This would be indicated by an error message. In this case, the parameters entered should be checked and corrected.*

Pictorial representation:	Application and result:
	After entering the parameters of the four interpolation points point 1 to point 4, whereby point 1 is defined at Uoc and 0 A and point 4 at Isc and 0 V, the device calculates an XY curve which is transferred to the XY generator. At runtime and depending on the load of the power supply unit with a current between 0 A and Isc, the device provides a variable output voltage whose curve between 0 V and Uoc corresponds approximately to the curve shown on the left. The gradient between point 2 and point 3 depends on the values entered and can be varied as required as long as point 3 is below point 2 in terms of voltage and above point 2 in terms of current.

► How to configure the FC table

1. With the DC terminal switched off, open the function selection menu from the main display by tapping on 

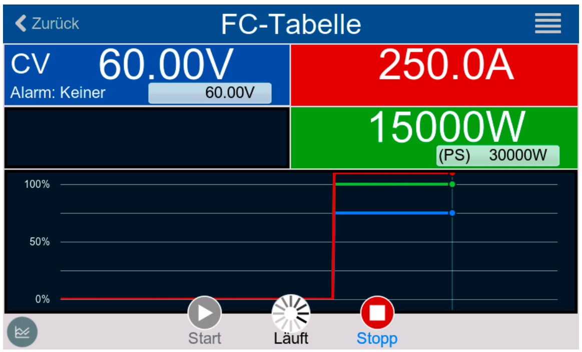
and select group **FC table (PS)**.
2. Set the parameters of the four interpolation points according to the data to be simulated.
3. Be sure to set the global limit values for voltage and power in the next screen, which you can access by touching 

.
4. Once you have set the values, tap 

.

After calculating and loading the function, you can also go back to the FC configuration page and save the calculated table to a USB stick via **Import/Export**. A button in the prompt that appears is no longer locked. The FC table saved in this way can be used, for example, for analysis or visualization purposes in Excel or similar.

► How to work with the FC table function



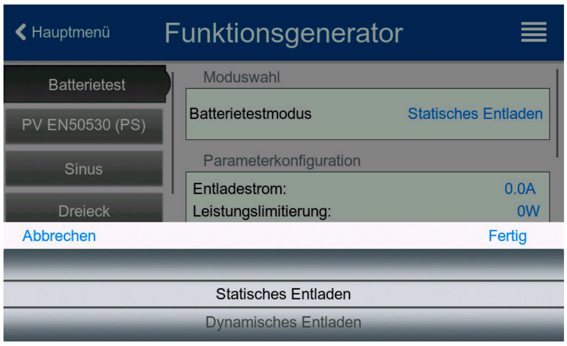
1. With a load connected, e.g. a DC-DC converter as a typical load for a fuel cell, start the function by switching on the DC output.
2. The output voltage is set as a function of the output current, which is defined by the applied variable load, and decreases as the current increases. Without load, the voltage goes to the value Uoc.
3. Stop at any time using the stop button or by switching off the DC output.

3.13 Battery test function

The battery test is only used to test batteries. The device has no battery management on board and therefore cannot monitor individual battery cells. If at least one cell in a battery to be tested is defective and it is nevertheless charged or discharged with the device, the battery may be destroyed. It may therefore be necessary to use external battery management hardware and software.

When working with batteries, at least one fuse must be integrated into the DC circuit; this fuse must correspond to the nominal current of the device or less!

The battery test function is used for the targeted charging and discharging of different types of batteries in industrial product tests or in laboratory applications. In addition to separate modes for charging and discharging a battery, a combination of both is also available, the so-called dynamic test.



You can choose from these six test modes:

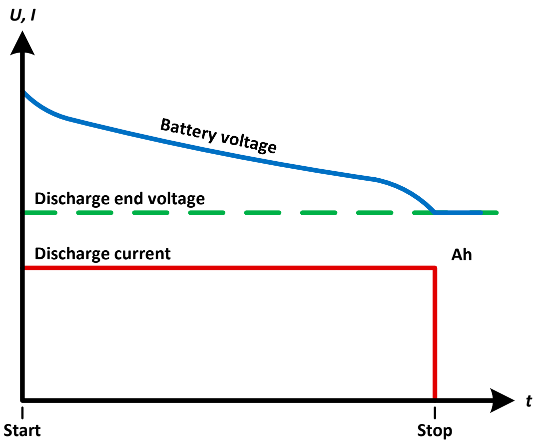
- **Static discharge** (constant current)
- **CC-CV discharge** (like **Static discharge**, but with additional final discharge current)
- **Dynamic discharge** (pulsed current)
- **Static charge** (constant current)
- **CC-CV charge** (like **Static charge**, but with additional adjustable charge termination voltage)
- **Dynamic test** (sequence of static charge/discharge)

In **static** or **CC-CV discharge mode**, both of which are very similar and run at constant current (CC), a battery is discharged in a targeted manner. While in **Static discharge** mode only the discharge end voltage is defined as the stop criterion, in **CC-CV discharge** mode there is an additional adjustable discharge end current and therefore both values, i.e. discharge end current and voltage, must be reached for the test to stop.

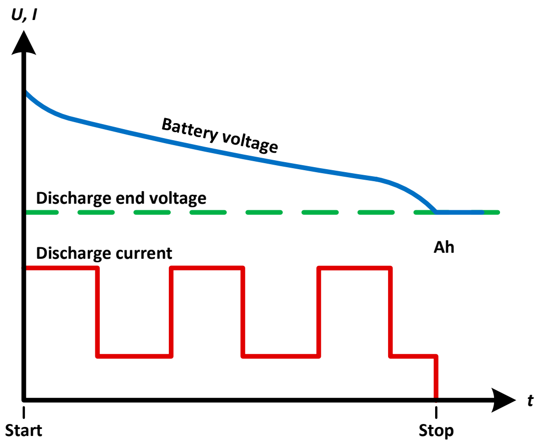
The **dynamic discharge mode** also has an adjustable power value. Although this cannot be used to run the dynamic battery test with pulsed power, the result could be different than expected if the power is limited in the test. It is therefore recommended that this value is always set high enough.

During battery tests with high pulse currents, the battery voltage may briefly fall below the end-of-discharge voltage threshold (U_{DV}) due to the pulse-like load and the test may be terminated immediately. The U_{DV} should therefore be set correspondingly lower.

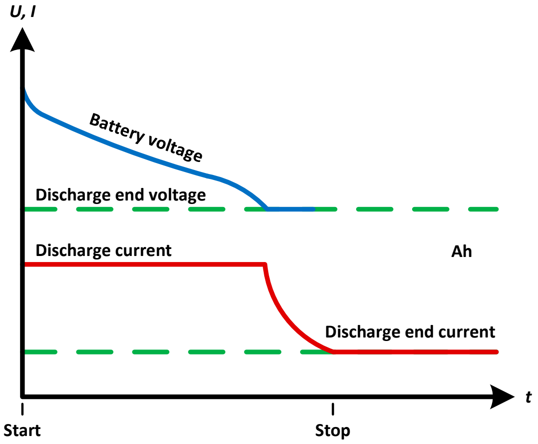
Graphic visualization of the discharge modes:



Static discharge



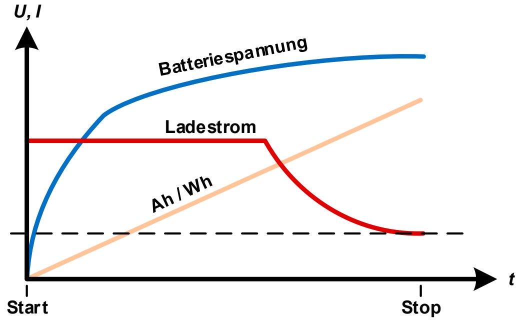
Dynamic discharge



Static discharge with CC-CV

The **static** or **CC-CV charging** corresponds to the simple charging profile for lead batteries. The connected battery is charged with a constant current until either the specified end-of-charge voltage or a specified time has been reached or the charge current has fallen below an adjustable limit. A graphic illustration of the static charge is shown on the right.

In the sixth mode, the **dynamic test**, you can choose whether the entire test should be repeated cyclically (1-999x or infinitely often) and which phase of the test, charging or discharging, starts first in each run. There is furthermore an adjustable rest phase before each repetition.



Static charge

The setting value for the power is also available for the static modes. If configured accordingly, it can also run the function sequence at constant power (CP). As with normal operation of the device, the set values determine which control mode (CC, CP) results.

3.13.1 Parameters for Static discharge

The following parameters can be configured for static discharge:

Value	Setting range	Explanation
Discharge current	0A...I_{nom}	Maximum discharge current (in Amperes)
Power limitation	0W...P_{nom}	Maximum discharge power (in Watts)

3.13.2 Parameters for CC-CV discharge

The following parameters can be configured for static CC-CV discharge:

Value	Setting range	Explanation
Discharge current	0A...I_{nom}	Maximum discharge current (in Amperes)
Discharge end voltage	0V...U_{nom}	Threshold (in Volts) at which the discharge phase stops

3.13.3 Parameters for Dynamic discharge

The following parameters can be configured for dynamic discharge:

Value	Setting range	Explanation
Discharge current 1	0A...I_{nom}	Lower or upper current value for pulsed operation (the higher setting value of the two automatically becomes the upper one) (in Amperes)
Discharge current 2	0A...I_{nom}	
Power limitation	0W...P_{nom}	Maximum discharge power (in Watts)
Time t1	1s...36000s	Time t1 = time for the upper current value (pulse)
Time t2	1s...36000s	Time t2 = time for the lower current value (rest)

3.13.4 Parameters for Static charge

The following parameters can be configured for static charging:

Value	Setting range	Explanation
Charge voltage	0V...U_{nom}	Charge voltage (in Volts)
Charge current	0A...I_{nom}	Maximum charge current (in Amperes)
Charge end current	0A...I_{nom}	Threshold (in Amperes) at which the charge stops

3.13.5 Parameters for CC-CV charge

The following parameters can be configured for static CC-CV charge:

Value	Setting range	Explanation
Charge voltage	0V...U_{nom}	Charge voltage (in Volts)
Charge current	0A...I_{nom}	Maximum charge current (in Amperes)
Charge end current	0A...I_{nom}	Threshold (in Amperes) at which the charge stops

3.13.6 Parameters for Dynamic test

The following parameters can be configured for the dynamic test:

Value	Setting range	Explanation
Charge end current	0A...I_{nom}	Threshold (in Amperes) at which the charging phase stops
Charge voltage	0V...U_{nom}	Charge voltage (in Volts)
Charge current	0A...I_{nom}	Maximum charge current (in Amperes)
Charge time	1s...36000s	Duration of the charge phase (max. 10 h)
Discharge end voltage	0V...U_{nom}	Threshold (in Volts) at which the discharge phase stops
Discharge current	0A...I_{nom}	Maximum discharge current (in Amperes)
Discharge time	1s...36000s	Duration of the discharge phase (max. 10 h)
Start with	Charge | Discharge	Determines where the test begins, with the charging or discharging phase
Test cycles	1...65535 | 0	Number of runs of the battery test (0 = ∞)
Rest time	1s...36000s	Duration of the rest before the next phase or cycle

3.13.7 Stop conditions

These parameters generally apply to all modes and also define stop conditions:

Value	Setting range	Explanation
Discharge end voltage	0V...U_{nom}	Threshold (in Volts) at which discharge stops (only for discharge modes)
Action: Ah limit	None, Signal, End of test	Enables/disables an Ah counter that stops the test when the removed battery capacity is reached
Discharge capacity **Charge capacity** **Test capacity**	0.00Ah...99999.99Ah	Maximum battery capacity to be removed, after which the test can stop automatically. This stop criterion is optional, so that more battery capacity can also be added or removed.
Action: Time limit	None, Signal, End of test	Enables/disables a time counter that stops the test when the test time is reached
Discharge time **Charge time** **Test time**	00:00:00...10:00:00	Maximum duration in HH:MM:SS format after which the test can stop automatically. This stop criterion is optional, so that a test can run for longer than 10 hours.
USB logging	On/Off	Enables USB logging, which records data during the battery test if a correctly formatted USB stick is inserted into the front USB port. The data has a slightly different format than that of "normal" USB logging.
Logging interval	100ms - 1s, 5s, 10s	Sets the writing cycle for USB logging

3.13.8 Display values

During the test, the device display shows the following values:

- Current battery voltage at the DC terminal
- Final discharge voltage U_{DV} (only in one of the discharge modes)
- Final discharge current I_{DC} (only in CC-CV discharge mode)
- Charge voltage (only in one of the charging modes)
- Current discharge current
- Actual performance
- Total battery capacity (charging & discharging)
- Total battery energy (charging & discharging)
- Test time
- Controller status (CC, CP, CV)

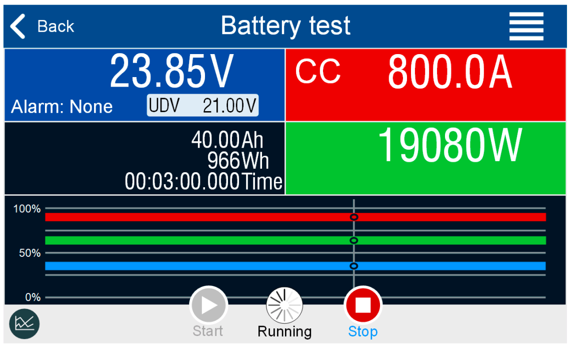


Figure 3 - Display example of static discharge

3.13.9 Abort conditions

The battery test function can be stopped intentionally or unintentionally:

- Manually press the **Stop** button on the HMI
- Any device alarm such as OT, etc.
- Reaching the maximum set test time if End of test is set as the action
- Reaching the maximum set Ah value if End of test is set as the action
- Reaching the discharge end voltage (UDV)
- Reaching the end-of-charge current or end-of-discharge current

3.13.10 Data recording on USB stick

There is a data logging functionality available for all test modes which, by default, is deactivated. After it has been activated while a USB stick in the required format (see section *«5.2.5 USB port (front)»* in the installation manual) is plugged on the control panel, the device would record measured values for the test duration and in the defined interval. This is indicated on the screen by a small diskette symbol. After a test end, the recorded data will be available as text file (CSV format).

Layout of the log file:

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q
1																	
2	Date	Mode	Charging voltage	Charging current	Charging end current	Dynamic discharging t1	Dynamic discharging t2	Discharging end voltage	Discharging current 1	Discharging current 2	Charging power	Discharging power	Discharging resistance	Charging time	Discharging time	Rest time	Test cycles
3	12.12.2024	static discharge	N/A	N/A	N/A	N/A	N/A	9,5V	50,0A	N/A	N/A	N/A	N/A	N/A	10:00:00	N/A	N/A
4																	
5	U battery	I battery	P battery	R actual	Ah	Wh	Regulation mode	Alarm	Time	Phase							
6	12,88V	-50,0A	640W	N/AR	0	0	CC	None	10:48:42.949	Discharging							
7	12,88V	-50,0A	640W	N/AR	0	0	CC	None	10:48:43.050	Discharging							
8	12,88V	-50,0A	640W	N/AR	0	0	CC	None	10:48:43.156	Discharging							
9	12,88V	-50,0A	640W	N/AR	0	0	CC	None	10:48:43.156	Discharging							

The upper three rows form the header. The lower part contains the actual log data.

Legend (header):

Date = Log date

Mode = Battery test mode of the particular channel

Charging voltage = max. charging voltage

Charging current = max. charging current

Charging end current = Charging end current

Dynamic discharging t1 = time t1 for the dyn. discharging

Dynamic discharging t2 = time t2 for the dyn. discharging

Discharging end voltage = charging end voltage

Discharging current 1/2 = discharging current

Charging power = power limit for a charging phase

Discharging power = power limit for a discharging phase

Discharging resistance = max. internal resistance for a discharging phase

Charging time = max. time for a charging phase

Discharging time = max. time for a discharging phase

Rest time = between a charging and a discharging phase

Test cycles = number of cycles to run the test

Legend (log part):

U battery = measured battery voltage

I battery = measure battery current

P battery = calculated charging/discharging power

R actual = calculated charging/discharging resistance

Ah = charged or discharged battery capacity

Wh = charged or discharged battery energy

Control mode = CC, CV, CP or CR

Alarm = in case any occurred, it will be logged here

Time = time stamp of the log entry from the internal clock

Phase = actual test phase, “Charging” or “Discharging”

3.14 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)

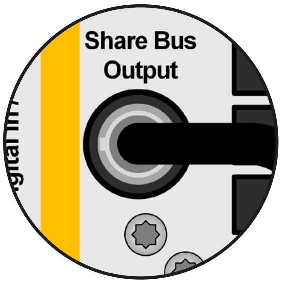
4.1 Parallel connection as master-auxiliary system

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 BT 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.

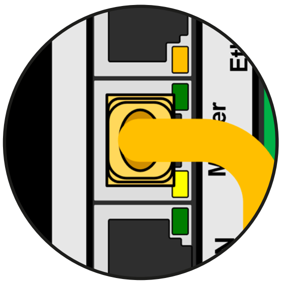
The Share-Bus, in turn, is used for dynamic control of the voltage at the DC terminal of the devices, i.e. in CV mode, especially if the function generator is to be used on the master device.

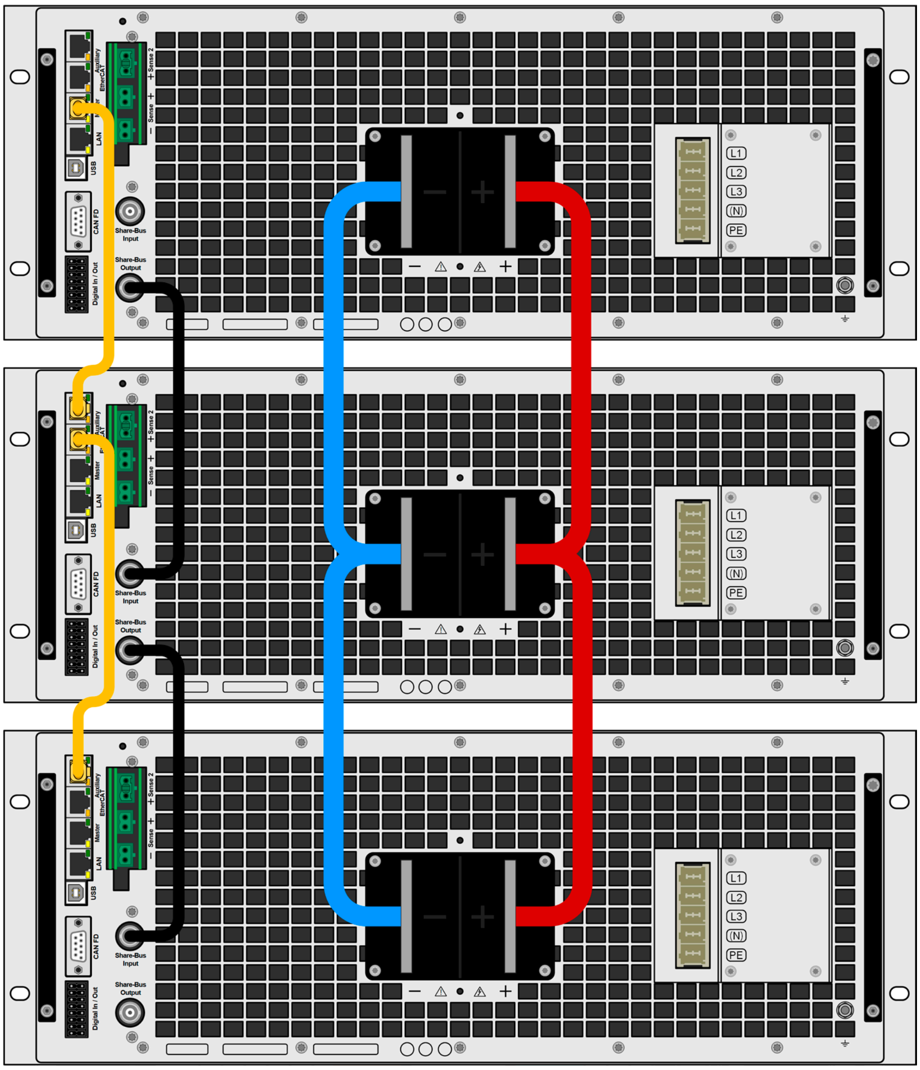
Principle illustration without load or external source:

Share-Bus connection



Master-Auxiliary bus





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 BT 20000 series

4.1.2 Wiring the DC terminals

The DC terminal of each device involved is connected to the next device with the correct polarity, and so on. The shortest possible cables or copper rails with a sufficient cross-section (= low inductance) should be used. The cross-section depends on the total current of the parallel circuit.

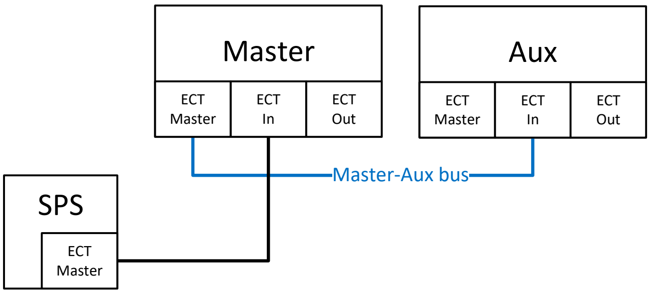
4.1.3 Wiring of the share-bus

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 

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 «2.3.6 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

EA Elektro-Automatik GmbH
Helmholtzstr. 31-37
41747 Viersen
Germany

Phone: +49 (0) 2162 3785 - 0
ea1974@elektroautomatik.com

www.elektroautomatik.com

www.tek.com