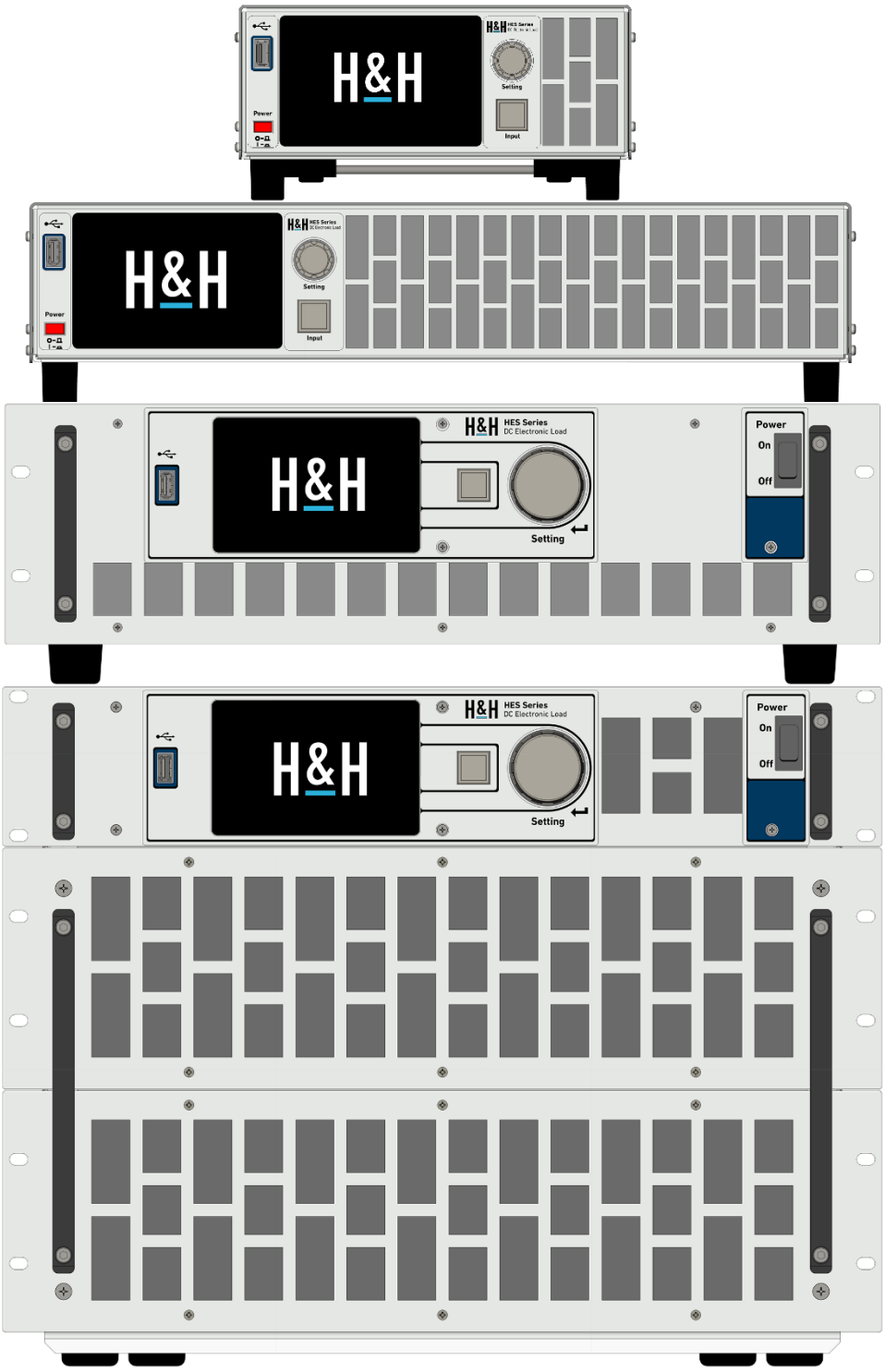

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Contents

1 Introduction and Safety

1.1 About This User Manual

This user manual describes the functionality and operation of the HES series electronic loads from Höcherl & Hackl GmbH (hereinafter also referred to as H&H). This manual contains a description of the hardware and firmware functions.

Before commissioning the electronic load, you must have carefully read and understood this operating manual. Observe the instructions in this manual when operating the electronic load.

This operating manual must always be available near the corresponding device. If the location of the device is changed, the operating manual must also be taken along or be available in an electronically readable form.
H&H reserves the right to make changes or updates to operating instructions at any time. The latest revisions are available on the homepage www.hoecherl-hackl.com. The operating instructions provided on the homepage are only valid for devices with the current hardware and firmware version. If you need an operating manual for a used device, please contact H&H Support support@hoecherl-hackl.com for a valid version that corresponds to your device (provide the serial number).

1.2 Description of the Symbols Used

This symbol indicates information in the user manual that the user must follow to avoid injury to persons or damage to the device.

This symbol indicates a prohibition.

This symbol indicates a note from the manufacturer that is useful for the use of the device.

1.3 Definition of Terms and Intended Use

The HES series electronic load is a device that is used as a substitute for an (ohmic) load resistor. The electrical energy absorbed by the electronic load is converted into heat by power semiconductors. Fans provide cooling and dissipate the waste heat. An electronic load is an electrical consumer. It is therefore not a current or voltage source, but a current sink.
The electronic loads of the HES series are suitable for loading DC voltage sources such as batteries, fuel cells, solar cells, generators, power supplies, and control units. The electronic load of the HES series is designed for direct current and must not be connected to alternating voltages or the AC mains with the DC inputs.

The electronic load is not suitable for drying objects, animals, or human hair with the warm air it emits.
Keep ventilation slots clear.
Do not climb on the device.
Do not use as a base for other parts.

Using the devices in a manner other than that specified may impair the protection provided by the device!

1.4 General Information

1.4.1 Protective Equipment

Safety shoes
When unpacking, carrying, and moving
Gloves
When unpacking, carrying, and moving
Hair net
For long-haired operators near ventilation slots

1.4.2 When Unpacking

Accessories

The accessories belonging to your electronic load, such as power cables, screws, etc., are listed in the separate file *TechDat_HES_dn*.PDF (*dn* = device number, see1.4.3 Product Identification) on a supplied USB flash drive. This depends on the model and built-in options. When unpacking, check that all specified parts are included in the delivery and, if necessary, inform the supplier of the device.

Mechanical inspection

After unpacking the device , immediately check it for mechanical damage and loose parts.

If any external defects are found, do not put the electronic load into operation!

If the damage was caused during transport, you must notify the carrier immediately, note this on the consignment note, and have the carrier countersign it. Please note that complaints made more than three days after receipt of the shipment are usually no longer accepted by the carrier. Also inform the supplier of the electronic load immediately.

1.4.3 Product Identification

The type plate is located on the rear of the right-hand side of the device (as seen from the front).

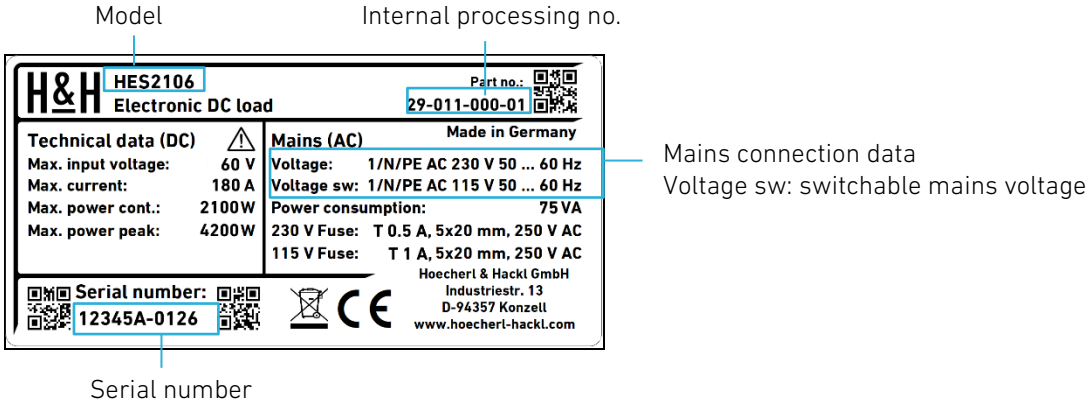


Figure 1.1: type plate

Serial number:

12345A-0126

Device number Series Date code (month, year)

1.4.4 Packaging

H&H recommends that you keep the original packaging and use it for transporting the devices.

Recycle materials marked with the adjacent symbol. Dispose of the packaging in accordance with applicable national regulations in the appropriate recycling container.

You can return the packaging to H&H for disposal. We only accept returns free of charge.

1.5 Requirements for the Operator

Personnel operating an electronic load are subject to the statutory provisions on occupational safety and must comply with the safety and accident prevention regulations applicable to the area of application in addition to the safety and warning instructions in the user manual.

Persons operating an electronic load

- must be qualified personnel who are familiar with the hazards associated with measuring electrical quantities and who have the appropriate training
- must not have their responsiveness impaired, e.g., by medication, alcohol, or drugs
- must be informed about the applicable occupational safety regulations
- must be informed about the responsibilities of maintenance and cleaning of the device
- must have read and understood the general safety instructions and the operating instructions in full before operating the device
- must use prescribed protective equipment.

Improper operation can result in personal injury and property damage. All activities may only be carried out by persons who have the necessary training, knowledge, and experience.
Qualified personnel are those who, based on their professional training, knowledge, and experience, as well as their knowledge of the relevant regulations, are able to perform the assigned tasks properly, independently recognize potential hazards, and avoid personal injury or property damage.

Any person operating an electronic load must check that the device is in perfect technical condition.

1.6 Obligations of the Owner

The owner is any natural or legal person who uses the device or allows third parties to use it and is responsible for the safety of the user, staff, or third parties during use.

The device is used in a commercial environment. The operator of the device is therefore subject to the legal obligations regarding occupational safety. In addition to the warnings and safety instructions in this manual, the safety, accident prevention, and environmental protection regulations applicable to the area of use of the device must be observed.

The owner must

- inform themselves about the applicable occupational safety regulations

- identify possible additional hazards resulting from the specific conditions of use at the location where the device is used by means of a risk assessment and minimize these by taking appropriate measures
- implement the necessary behavioral requirements for operating the device at the place of use in operating instructions
- regularly check throughout the entire period of use of the device whether the operating instructions he has drawn up comply with the current regulations
- adapt the operating instructions to new regulations, standards, and operating conditions, if necessary
- Clearly and unambiguously define responsibilities for the installation, operation, maintenance, and cleaning of the device
- Ensure that all employees who work with the device have read and understood the operating instructions and the general safety instructions
- Provide the personnel assigned to work on the device with the prescribed and recommended protective equipment.
- train personnel at regular intervals in the use of the device and inform them of the potential hazards.
- See also sections 1.10.1 Environment and Emissions.

The operator is responsible for ensuring that the electronic load is always in perfect technical condition.

1.7 General Safety Instructions

Only operate the electronic load under supervision!

Stop operating the electronic load immediately if it no longer functions properly. Do not attempt to repair the device yourself. Contact the manufacturer immediately.

In accordance with protection class 1, all accessible parts of the housing are connected to the protective earth. The devices may only be operated on properly functioning protective contact systems.

DO NOT disconnect the protective conductor connection on the power cord or inside the device!

Do not insert any objects into the ventilation slots!

If it can be assumed that safe operation is no longer possible, you must take the device out of service and secure it against unintentional switching on.

This may occur if:

- there is visible mechanical damage
- there are loose parts in the device
- smoke is visible
- the device has overheated
- liquids have entered the device
- the device is not working

If you unscrew the device feet, e.g. because you want to install the device in a cabinet, keep the feet together with the screws and only use the original feet and screws if you want to screw them back on later.
Do not screw the screws into the base plate without the corresponding foot!

If you want to open the housing, first disconnect the device from all power sources.

Checks with the housing open, repairs, or adjustment work may only be carried out by a qualified personnel who is familiar with the safety regulations.

The safety of a system in which the device is integrated is the responsibility of the system installer.

Also follow the safety instructions for connecting the test object in chapter 2.3.

1.8 Potential Hazards

When using the device, hazards may arise for persons and property.

1.8.1 Electric Shock

Warning of electric shock due to dangerous potentials, incorrect connection cables, or insufficiently covered input terminals!

Electric shock can cause serious injuries and even death: burns, muscle irritation such as muscle cramps, muscle paralysis, cardiac arrhythmia such as ventricular fibrillation, cardiac arrest, respiratory paralysis, neurological injuries, indirectly caused accidents such as falls.

- ➢ For potentially dangerous voltages, install H&H safety covers on load and sense inputs!
- ➢ Ensure that the load connection cables are of sufficient cross-section!

1.8.2 Burns

Warning of burns due to waste heat, unsuitable connection cables or poor connections, reverse polarity or overvoltage!

Electronic loads generate waste heat, which is dissipated through the rear panel. This can cause touchable parts on the device or parts exposed to the hot exhaust air stream to heat up and cause burns on contact. Highly flammable materials and liquids exposed to the hot air outlet may ignite. There is also a risk of burns if unsuitable cables are used to connect the test object or if the cable lugs or plugs used on the input terminals are not screwed on tightly enough. This can cause the connection terminals to heat up and cause burns if touched. Hand-held cables can cause burns. Loose connections can generate arcs that can ignite materials in the vicinity.
There is also a risk of burns if the test object is connected with reverse polarity or if there is overvoltage. Reverse polarity or overvoltage cause a short-circuit and thus uncontrolled current flow! The load circuit of the electronic load is not fused!

- Do not place any touchable parts or flammable materials in the hot exhaust air stream!
- Ensure that the cross-section of the load connection cables is sufficiently dimensioned!
- Screw cable lugs and plugs tightly!
- Ensure that the connected test object has the correct polarity!
- NEVER exceed the maximum input voltage!
- Connect an external fuse to the load circuit!

1.8.3 Mechanical Injuries

Warning of injuries due to falling, pinching, hair entanglement!

The electronic load can fall and cause injuries such as bruises, broken bones, and skin abrasions due to its weight. When carrying and setting down the device, fingers can become trapped in the handles or between the bottom of the housing and the surface on which it is set down. Long hair can be sucked into the rotating fans.

- When unpacking, transporting, carrying, and moving, follow the instructions at 1.11 Carrying and Moving!
- Wear safety shoes and gloves !
- Do not reach between the base of the device and the storage surface with your hands!
- Wear a hair net if necessary!

1.8.4 Injury Due to Noise

Warning of hearing damage caused by noise!

Powerful models generate high sound pressure levels (see technical data), which pose a risk to the operator.

- Wear hearing protection at levels above 80 dB(A)!
- See also 1.6 Obligations of the Owner!

1.8.5 Interference With Electro-Medical Devices

Warning of injury due to interference with electro-medical devices!

Electronic loads can operate at very high currents. High currents generate strong magnetic fields that can affect electro-medical devices such as pacemakers.

- People with electro-medical devices must not be in the vicinity of electronic loads that are in operation!

1.9 Measurement Category

The measurement categories refer to transients on the mains. Transients are short, very fast voltage and current changes that can occur periodically and non-periodically. The level of possible transients increases the shorter the distance to the source of the low-voltage installation.

The following applies to electronic DC loads:
The electronic DC load is intended for operating the load inputs on circuits that are either not connected to the mains at all or not directly connected to the mains.

No transient overvoltage may occur with DC loads. Direct operation (without galvanic isolation) on test objects of measurement categories II, III, or IV is not permitted!

The circuits of a test object are not directly connected to the mains if the test object is operated via an isolation transformer of protection class 2.

Measurement categories according to IEC 61010-2-30:

Category	Definition
O	Measurements on circuits that are not directly connected to the mains: *e.g., vehicle electrical systems in cars or aircraft, batteries*
CAT II	Measurements on electrical circuits that are directly connected to the low-voltage grid: *e.g., household appliances, portable tools*
CAT III	Measurements in building installations: *e.g., distribution boards, circuit breakers, fixed installation sockets*
CAT IV	Measurements at the source of the low-voltage installation: *e.g., meters, ripple control devices, primary overcurrent protection devices*

1.10 Operating Conditions and Installation of the Device

1.10.1 Environment and Emissions

The noise generated by the electronic loads depends on their design, power, and mode of operation. Taking into account other noise levels prevailing at the workplace, the owner must select a suitable location for the device that complies with the requirements of the Workplace Ordinance. The sound pressure must be measured both at the operator's location, where the operator is located during operation of the device, and at a point 1 m away from the housing. If an excessive noise level cannot be remedied by other measures, such as noise-reducing walls, the operator must be equipped with appropriate hearing protection.

Electronic loads generate heat and warm up the ambient air. When operating the device, take special measures to ensure compliance with the ambient conditions specified in the Workplace Ordinance.

1.10.2 Operating Conditions

The operating conditions are listed in the technical data *TechDat_HES_gn*.PDF (*gn* = device number, see 1.4.3 Product Identification) on the supplied USB flash drive.

Warning of voltage flashovers due to condensation!
If the device is operated despite condensation, malfunctions or total failure of the device may occur.

- If stored below the minimum operating temperature, the device must first be brought to the minimum operating temperature before it is switched on!
- Condensation must not occur!

The device is intended for use in clean, dry rooms. It must not be operated in environments with particularly high dust content in the air, where there is a risk of explosion, or where aggressive chemicals are present. The device may only be operated in an upright position. Position the device so that the mains voltage connection is easily accessible.

Keep the air inlet on the front panel and the air outlet on the rear panel clear to ensure adequate cooling.

When installing the device in a cabinet, ensure that the air outlet is not obstructed.

Never operate the device when the rear door closed without an air grille!
Do not operate the device unattended!

If the rear doors are closed with the air grille inserted, you must accept a reduction in the device's performance.

Take the power derating into account at elevated ambient temperatures (see technical data).

If the device is used in a manner not specified by the manufacturer, the protection provided by the device may be impaired.

1.10.3 Symbols Used on the Device


Direct current


Alternating current


Direct or alternating current


Ground terminal


Protective earth terminal


Warning of a hazardous location; read the user manual!


Warning of dangerous electrical voltage


Warning of hot surface

1.11 Carrying and Moving


If you want to move the electronic load, make sure that it is switched off and disconnected from all cables.


If the device has mounting kits with front panel handles, these must not be used for carrying!

Heavy devices have retractable carrying handles integrated into the top of the housing. These may only be used by carrying people!


Carrying handles may not be misused as crane eyes!

Very heavy devices that need to be lifted with a crane must be enclosed with appropriate heavy-duty straps and lifted using these.

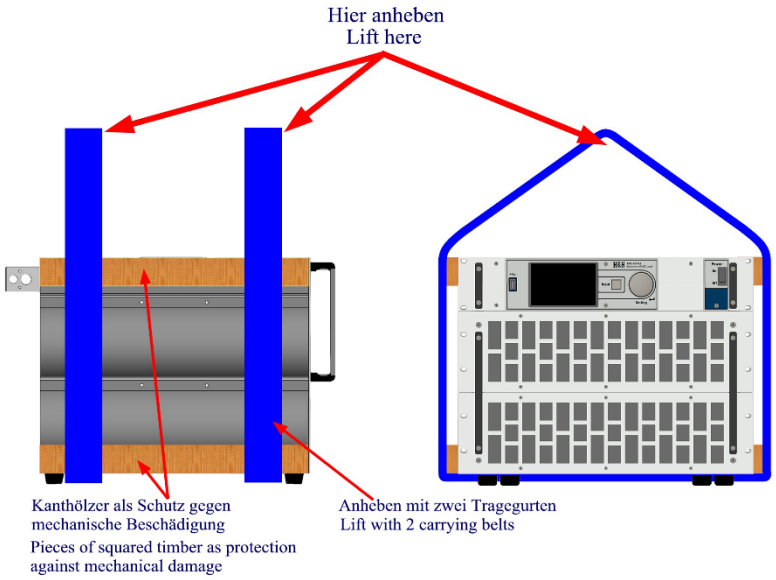


Figure 1.2: lifting with a crane

Take the operating instructions for the electronic load with you when moving it and keep them near the device or make the operating instructions available in electronic form.

1.12 Mains Connection

In accordance with protection class 1, all accessible parts of the housing are connected to the protective earth. The devices may only be operated on properly functioning protective contact systems that comply with regulations.

Do NOT disconnect the protective contact connection on the power cord or inside the device!

Only use a mains cable with a sufficient cross-section.
Detachable mains cables with power connectors in accordance with IEC 60320 must either meet the requirements of IEC 60799 or be rated for at least the current specified in the rating data of the power connector attached to the mains cable.

Devices with a three-phase mains connection must be protected with a circuit breaker as mains disconnect device in the building installation. The mains disconnect device must be marked as such, suitably located, and easily accessible to the operator.
RCDs and circuit breakers must also be provided in the building installation.

If 2 or more periods of mains voltage are missing, the device will restart if the mains voltage is stable again afterwards. Then, either the reset settings become active or the settings in memory location 0. See chapter 4.31 Saving and Loading Device Settings.

1.12.1 Mains Voltage Selector Switch

Before connecting the electronic load to the mains supply, make sure that the mains voltage set or required on the device matches the voltage of the mains supply.

On 2U and 3U devices, the mains voltage selector switch is located on the underside of the device; on devices with 5U or more, it is located on the rear. See the information in the technical data!

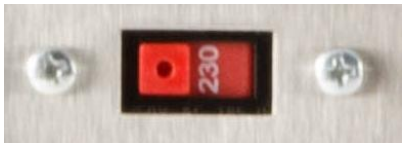


Figure 1.3: Mains voltage selector switch on the bottom or rear

When switching the mains voltage, you must also insert a corresponding fuse as specified on the device.

1.12.2 Replacing the Mains Fuse

Before replacing the mains fuse, take the device out of service. Disconnect all cables from the device.

1. Using a suitable screwdriver, apply slight pressure and pull the fuse holder B4 (see Figure 2.3) out of the housing in a counterclockwise direction.
2. Remove the fuse.
3. Insert a new fuse. Only use the fuses specified on the rear panel label!
4. Turn the fuse holder clockwise back into the housing using a screwdriver.

Short-circuiting the fuse holder or using repaired fuses is not permitted! Any damage resulting from this is not covered by warranty.

1.13 Cleaning and Maintenance

Cleaning cooling paths

For maintenance of the devices, it is important to clean the cooling paths regularly, as dust accumulates on the cooling rails and fans due to the strong forced ventilation. This is noticeable in that the device can no longer absorb its nominal power and overheating shutdowns occur more frequently (indicated by OTW or OTP).

You can clean the fans and output stages with ionized air. To do this, first take the device out of operation and disconnect it from all power sources. Blow through the rear panel onto the cooling rails, as dust accumulates there.

Cleaning the housing

For cleaning, switch off the device. Disconnect all connections from the device.

Clean the housing only with a cloth moistened with water. For stubborn dirt, you can use a glass cleaner. When cleaning, make sure that no liquid enters the device.

1.14 Calibration

Various important characteristics of the devices should be checked at regular intervals, such as the accuracy of the current setting and the accuracy of the displays.

If deviations outside the specified tolerance are detected, the device should be readjusted .

You can send the device to H&H, where it will be checked and calibrated at a fixed price. Every new series device is calibrated at H&H upon delivery.

Request an RMA number from H&H for calibration. See 1.16 Warranty and Repair.

For use under laboratory conditions, H&H recommends a calibration interval of 2 years. This is an empirical value that can be used as a guideline for the initial period of use. Depending on the intended use, duration of use, relevance of the application, and environmental conditions, the owner should adjust this interval accordingly.

1.15 Energy Efficiency

Electronic devices consume energy as soon as they are switched on, even when they are not in use. Therefore, switch off devices that are not in use by the power switch.

1.16 Warranty and Repair

H&H provides a 24-month functional warranty for new devices. This is subject to the condition that no modifications have been made to the device and that the fault occurred during normal use of the device.

Defects shall be remedied by repair or replacement if they are reported to H&H or a representative within 24 months of the date of the delivery note and are recognized by H&H.

As H&H is not aware of the exact application of the devices or the physical conditions of the equipment to be loaded, no guarantee can be given for the correct functioning of the devices in the customer's sense.

No warranty claims can be made in the event of damage to the device due to disregard of the technical data, including in particular exceeding the maximum permissible input voltage and the maximum permissible reverse polarity current (see section 2.7).

The warranty does not cover wear parts and consumables such as fuses, relays, contactors, and air filters.

Transport damage is also excluded from the warranty claim.

Packaged devices with a height of 2 U or more must be secured to a pallet! Do not send sensitive measuring devices by parcel service! We recommend using the original packaging for shipping by freight forwarder. If the original packaging is no longer available, you can request it from H&H at cost price. Please specify the exact device type.

The place of warranty is Konzell, Germany. The buyer is obliged to send the defective goods carriage paid, with a detailed description of the defects found. Please also provide a contact person and phone number for any queries. Unpaid shipments will not be accepted.

If warranty services are performed at the customer's location, the costs for travel to and from the location will be invoiced.

The following are excluded from the warranty:

- Destruction of the device due to voltages higher than 120 % of the nominal voltage range
- Destruction due to overcurrent in reverse polarity
- Input fuses in the load circuit
- Damage to the I/O port due to exceeding the specified limit values
- Modifications to the device by the customer
- Transport damage
- Damage due to improper handling (dropping, liquid ingress)
- Expenses for unjustified complaints

H&H service within the warranty period

Warranty at H&H:

- Materials and labor are not charged.

- Repairs are carried out at H&H.
- The shipping costs to H&H are to be borne by the customer.
- H&H will cover the costs of return shipping (but not express or scheduled deliveries!).

On-site warranty:

- Materials and labor incurred on site will not be charged.
- The costs for travel time to and from the site, distances traveled, and, if applicable, overnight accommodation will be invoiced.

After the warranty period has expired

Repairs at H&H:

- Materials and labor will be charged.
- Repairs are carried out at H&H.
- The shipping costs to H&H and the return shipping are to be borne by the customer.

Repairs on site:

- Materials and labor for the repair will be charged.
- The costs for travel time to and from the site, distances traveled, and, if applicable, overnight accommodation will be invoiced.

Requesting an RMA number

If you intend to return the device to H&H for repair, you shall request an RMA (Return Material Authorization) number from H&H.
You can do this by phone, by e-mail at support@hoecherl-hackl.com, or via the H&H website www.hoecherl-hackl.com.
Please indicate the RMA number on the return documents and on the outside of the packaging.

1.17 Disposal

Electrical appliances must not be disposed of with household waste. The end user is legally obliged to ensure that old appliances are disposed of properly. This can be done at municipal collection points or by returning them to the manufacturer, where they will be disposed free of charge. Appliances are marked accordingly with the crossed-out garbage can symbol.

1.18 Abbreviations in This Operating Manual

The following abbreviations are used in this manual :

AI	Analog interface
CC	Constant current
CP	Constant power
CR	Constant resistance
CV	Constant voltage
DI	Data interface
DUT	Device under test
GND	Ground
MSD	Mass storage device
OCP	Overcurrent protection
OPP	Overpower protection
OTW	Overtemperature Warning
OTP	Overtemperature protection

OV	Overvoltage
RV	Reverse voltage
UI	User interface
UUT	Unit under test
UVP	Undervoltage protection
UV	Undervoltage

2 Commissioning

2.1 Front Controls

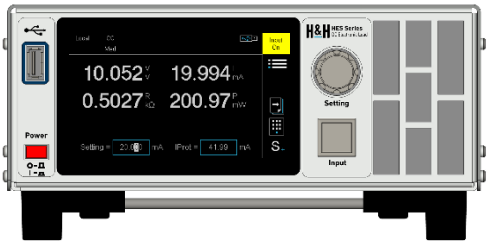


Figure 2.1: front view of model with ½ 19“, 2 U

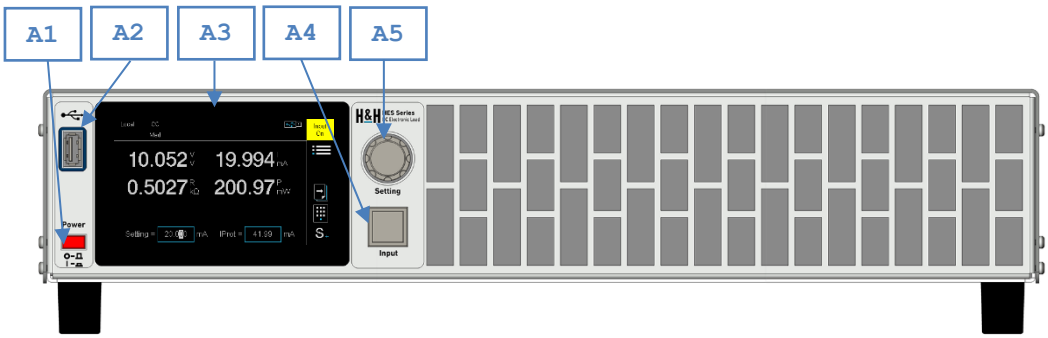


Figure 2.2: front view of model with 19“, 2 U

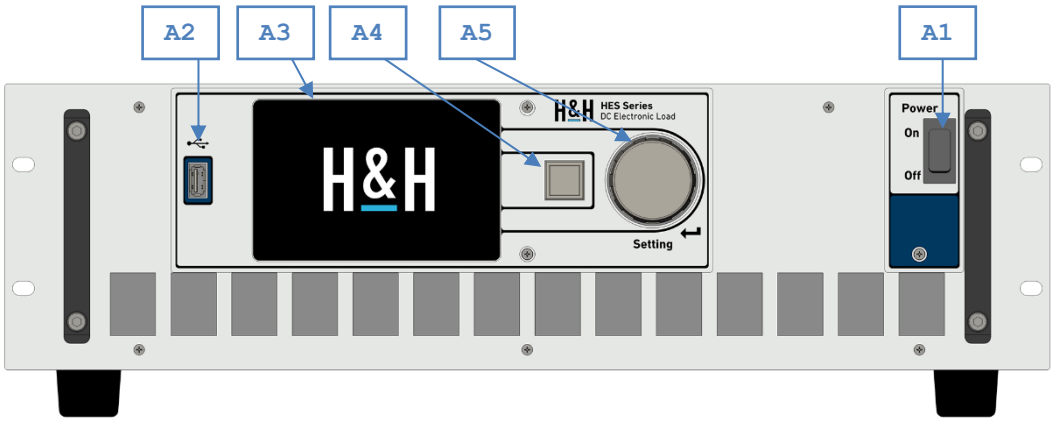


Figure 2.3: front view of model with 19“, 3 U

A1	Mains switch
A2	USB flash drive socket
A3	Touch display for operation and measurement value display
A4	Button for load input on/off
A5	Rotary encoder for settings

On models from 5 U upwards, the operating elements are arranged as on 3 U models.

2.2 Connections on Rear Panel

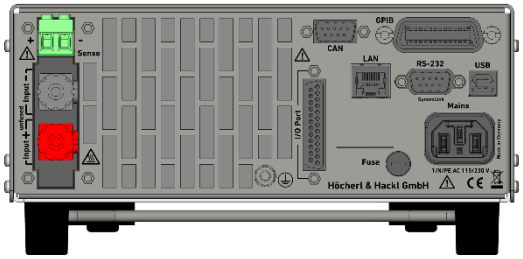


Figure 2.4: rear view of model with ½ 19", 2 U

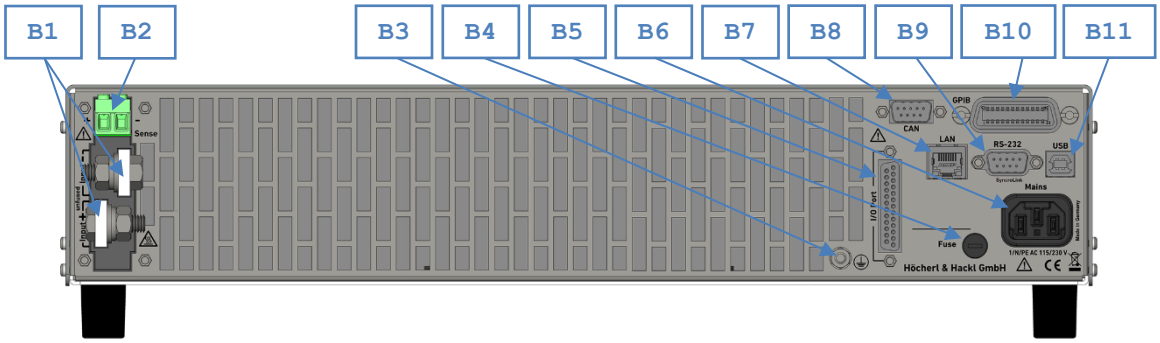


Figure 2.5: rear view of model with 19", 2 U

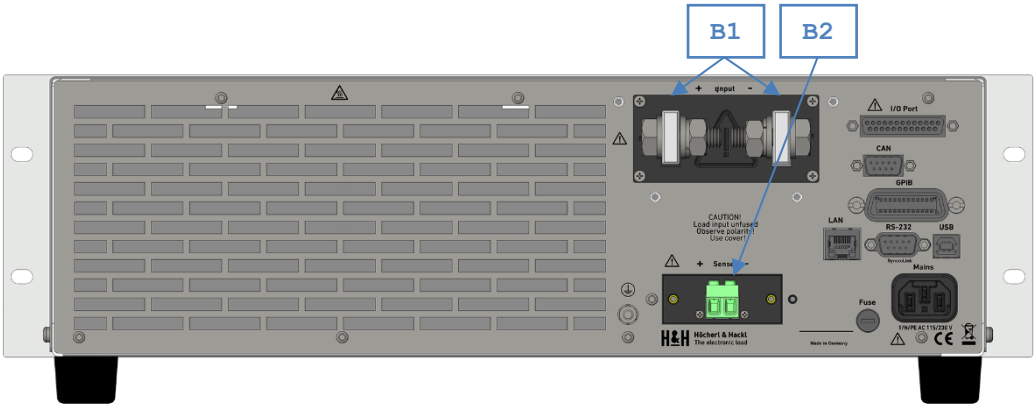


Figure 2.6: rear view of model with 3 U

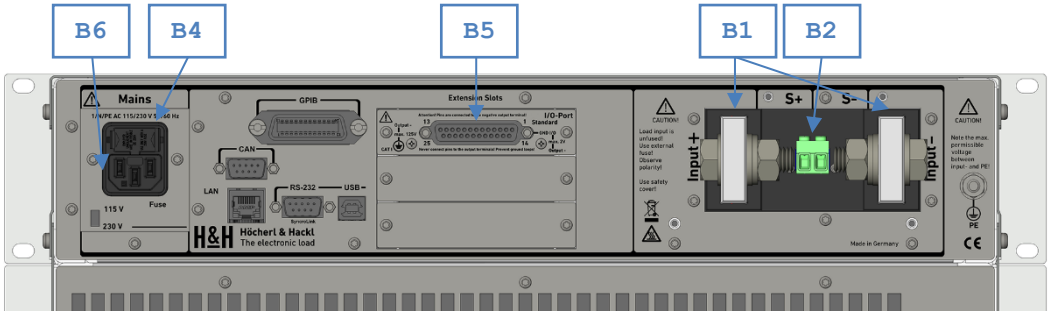


Figure 2.7: rear view of model with >= 5 U

B1 Load connections; 2 to 3 U: upper negative, lower positive; from 5 U: left positive, right negative

B2 Sense connection (shown with mating connector): left positive, right negative

B3 Protective earth connector

B4 Fuse holder

B5	I/O port socket
B6	Mains voltage terminal
B7	Ethernet socket
B8	CAN interface
B9	RS-232 interface
B10	GPIB socket (optional)
B11	USB socket

2.3 Connection of the Test Object

2.3.1 Safety Instructions for Connecting the Device Under Test

Attach the safety cover included in the delivery before putting the electronic load into operation. Safety covers can be reordered as accessories from H&H. The procedure for installation is described in chapter 2.4. You can also ensure touch protection by installing the device in other housings, cabinets, etc.

If the electronic load is used with voltages that pose a risk of contact, use a second measuring device to verify the level of the applied voltage.

The maximum permissible limits for touch protection are
for alternating voltage: 30 V_{rms} / 42.4 V_p
for direct voltage: 60 V

The load circuit of the electronic load has **NO fuse protection**! Connect a fuse that is suitable for your application between the device under test and Input+ of the electronic load!
If the potential at the input of the electronic load is increased relative to PE, also connect a fuse in the positive output branch of the source increasing the potential!

The permissible voltage between the negative load input and the housing can be found in the technical data.

Before connecting the voltage source to be loaded to the electronic load, switch on the load with the power switch A1 and switch off the load input A4!

Only connect and disconnect input and sense lines when not under voltage!

Position all cables so that they do not touch hot surfaces!

The maximum input voltage specified in the technical data must NOT be exceeded, even for a short time, neither at the load nor at the sense connections! **Overvoltage causes a short-circuit without any current limitation!**

Ensure correct polarity when connecting the test object to the load inputs! **Reverse polarity causes a short-circuit without any current limitation!**

The rear protective conductor connection B3 must always be connected to the protective earth of the overall system. Use a connection cable of at least 4 mm^2 for devices <= 3 U and at least 10 mm^2 for devices >= 5 U.

The negative load input (Input -) and the GND of the I/O port are galvanically connected to each other. This can result in dangerous voltages at the I/O port if the potential at the load input is raised.

A series connection of several electronic loads to increase the permissible input voltage is NOT permitted!

Only use cables with sufficient cross-section and sufficient voltage resistance for connection. Be aware of possible increased currents that may occur in the event of a fault in the device or test object!

2.3.2 Load and Sense Lines

The device under test is connected via the load clamps or copper bars on the rear of the device.

The terminals labeled "Input " are the current-carrying inputs. The terminals labeled s " are purely measuring inputs for voltage measurement.

For devices with copper bars as load input, observe the screw and washer arrangement in Figure 2.11!

The sense connections are internally connected to the corresponding load inputs via a PTC resistor and are protected against reverse polarity. If the sense connections are not connected, the load automatically measures the voltage at the input terminals.

However, accuracies for voltage measurement specified in the technical data only apply when sense lines are connected.

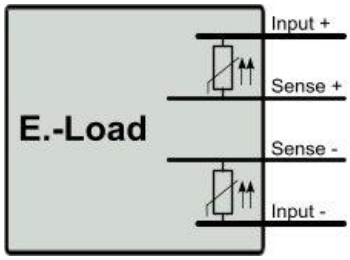


Figure 2.8: internal wiring of the sense inputs

Twist the load lines together to minimize the inductance of the supply lines. Also twist the sense lines together separately from the load lines to avoid coupling through the load lines.

The cables should not exceed 3 m in length.

2.3.3 Connection Examples

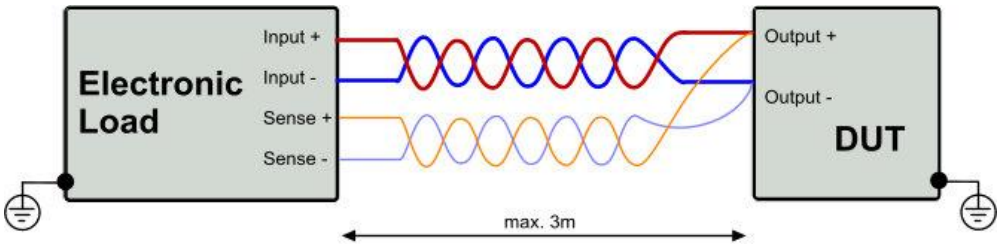


Figure 2.9: connection example for a single voltage

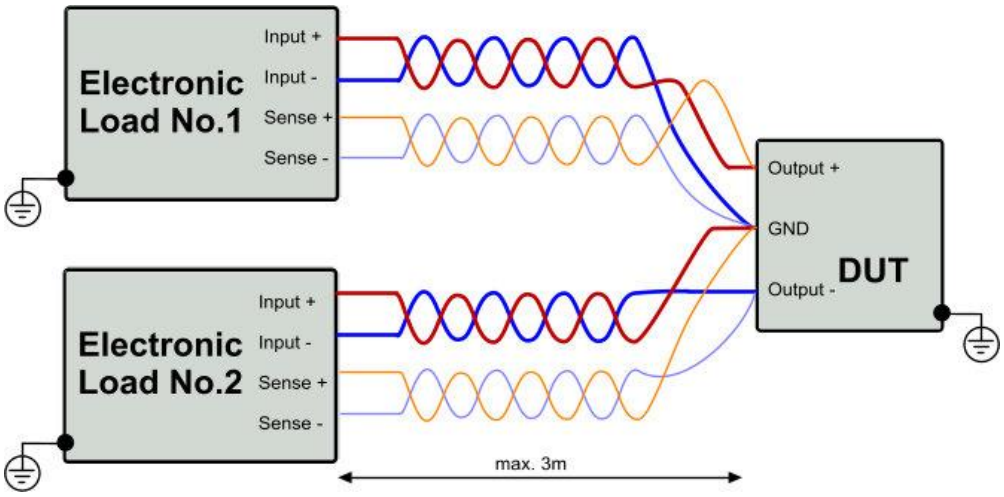


Figure 2.10: connection example for a bipolar output voltage

2.4 Installing Safety Cover

To protect against contact, the safety covers supplied must be fitted before the electronic load is put into operation..
All safety covers can be reordered from H&H.

For models with copper bars, the arrangement of screws and washers shown in Figure 2.11 applies. For high currents, two load cables should be installed per bar, see Figure 2.11 on the right.

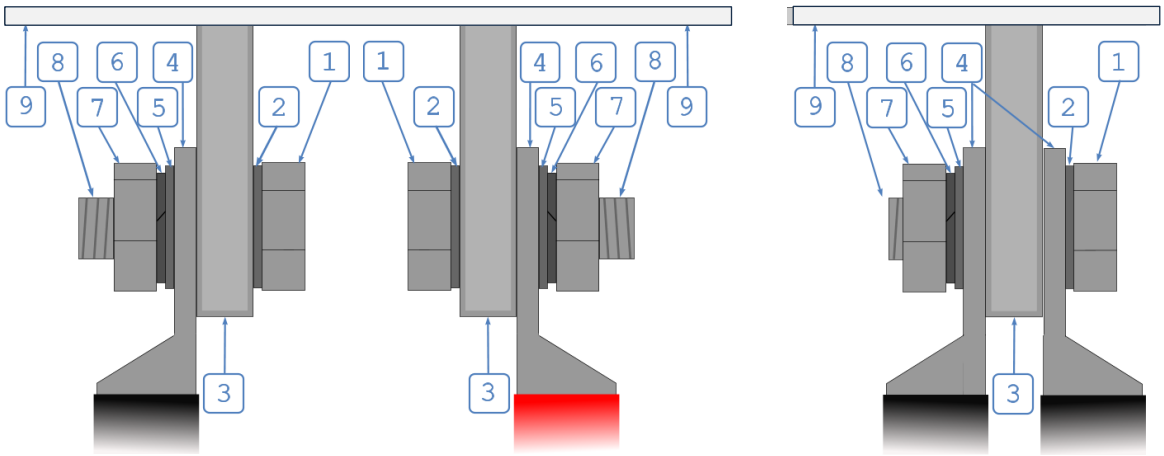


Figure 2.11: Screw and washer arrangement on copper bars

1 Screw head
2 Washer
3 Copper bar
4 Cable lug
5 Washer
6 Spring washer
7 Nut
8 Screw thread
9 Rear panel

2.4.1 Devices With 2 U

For devices with 2 U, there are different covers depending on the load connection:

SAB-HES-2CU	for copper bars
SAB-HES-2PK	for pole terminals
SAB-HES-2SB	for safety sockets

2.4.1.1 Cover for Copper Bars SAB-HES-2CU

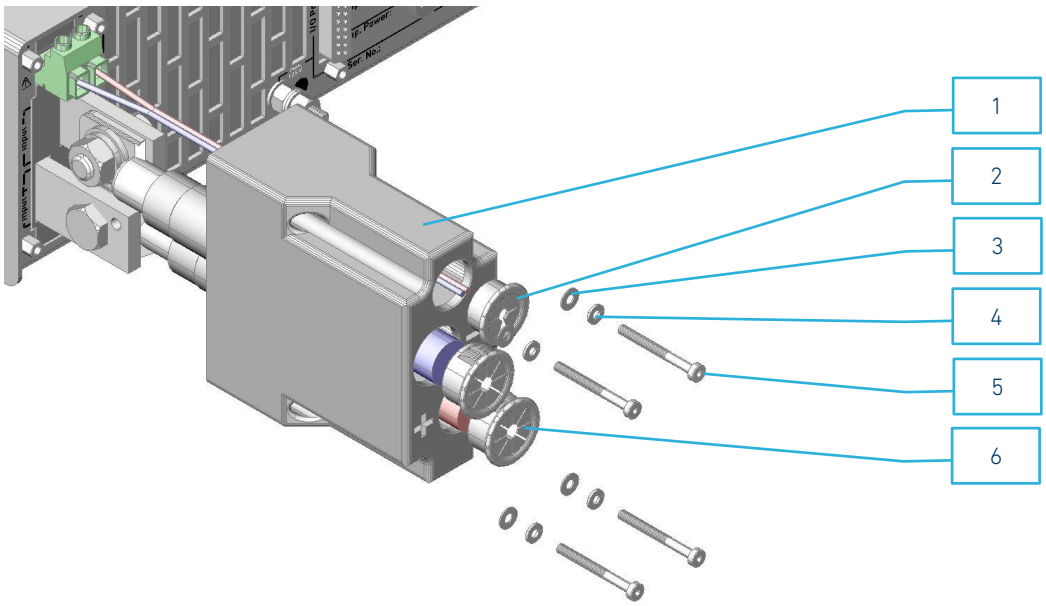


Figure 2.12: components and assembly of SAB-HES-2CU safety cover

1	1 pc. housing
2	1 pc. cable grommet sense
3	4 pc. washer
4	4 pc. spring washers
5	4 pc. torx screws M3x30
6	2 pc. cable grommet load

The following **numbers** refer to Figure 2.12.

1. Disconnect load and sense cables from all voltage sources!
   Disconnect the electronic load from all supply lines!

2. Connect the load cables to the copper bars as shown in Figure 2.12 using the screws and washers supplied, so that they run straight away from the bars.

Follow the screw and washer arrangement shown in Figure 2.12 to ensure the appropriate safety distances!

3. Use a knife or side cutters to cut the cable bushings 6 open far enough for the load cables to fit through. For thick load cables, omit the cable bushings if necessary, provided there is a maximum of 2 mm clearance between the cable and the cover! Proceed in the same way with the cable bushings for the sense cables 2.

4. Insert the loose ends of the load cables as shown in Figure 2.12 first through the corresponding openings in the housing 1 and then through the cable grommets 6. Ensure correct polarity!

5. Connect the sense cables to the sense terminals. Insert the loose ends through the upper opening in housing 1 and then through cable gland 2. Screw the housing to the rear panel using the screws and washers 3 4 5. Slide the cable glands over the cables and press them into the housing openings.

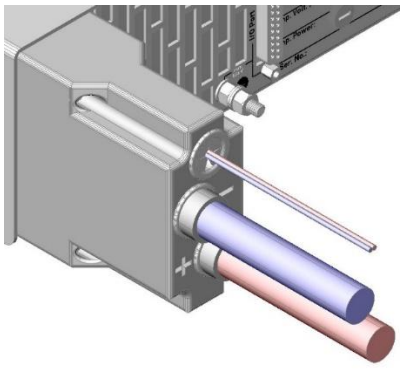


Figure 2.13: fully assembled safety cover SAB-HES-2CU

2.4.1.2 Cover for Pole Terminals SAB-HES-2PK, SAB-HES-2SB

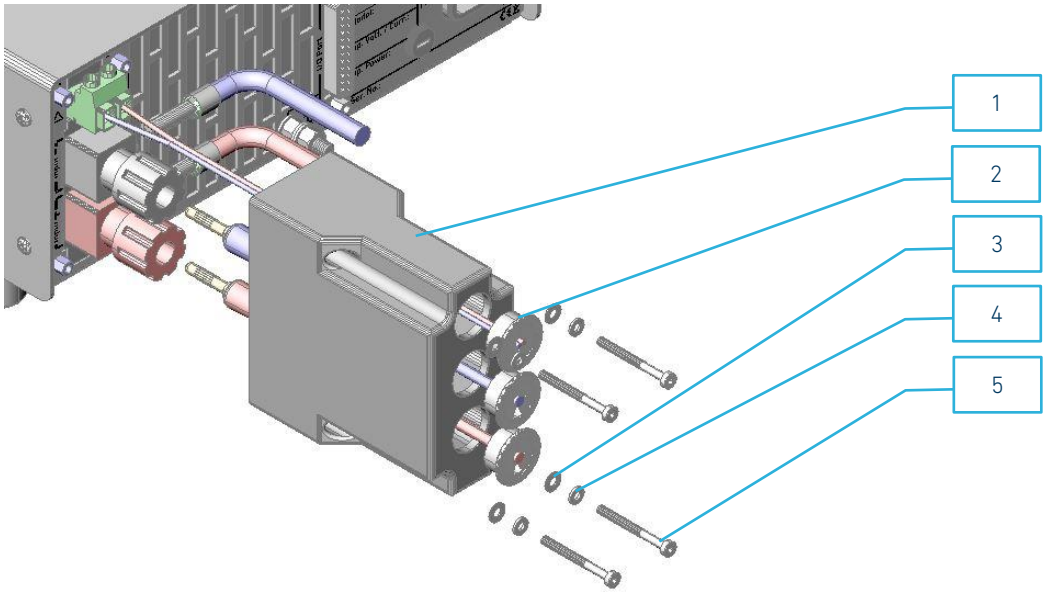


Figure 2.14: components and assembly of the SAB-HES-2PK/SB safety cover

1 1 pc. housing
2 3 pc. cable grommet
3 4 pc. washer
4 4 pc. spring washer
5 4 pc. torx screw M3x30

The following **numbers** refer to Figure 2.14.

1. Disconnect the load and sense cables from all voltage sources!
   Disconnect the electronic load from all supply lines!

2. Connect the load cables to the load input as shown in Figure 2.14. You can use 4 mm banana plugs or side-mounted, screwed, stripped cables with ferrules, or both.

3. Use a knife or side cutters to cut the cable bushings 2 far enough to allow the sense or load cables to pass through. For thick load cables, omit the cable bushings if necessary, provided there is a maximum of 2 mm clearance between the cable and the cover! If load cables are inserted and screwed in from the side, carefully break out the predetermined breaking points on the right side of the cover with a suitable tool.

4. Insert the loose ends of the plugged load cables through the corresponding openings in the housing 1 and then through the cable bushings 3, as shown in Figure 2.14.

5. Screw housing 1 to the rear wall using the screws and washers 3 4 5. Press the cable glands 2 over the cables into the housing openings.

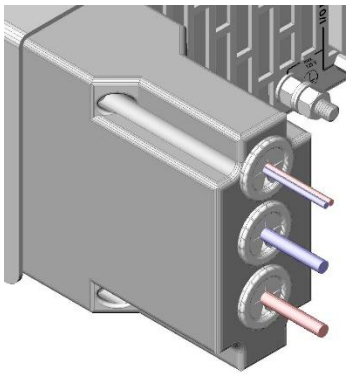


Figure 2.15: fully assembled safety cover SAB-HES-2PK/SB

2.4.2 Devices With 3 U

For devices with 3 U, the SAB-HES-3 safety cover is available to cover the load connections and the SAB-HES-3S cover for the sense connections.

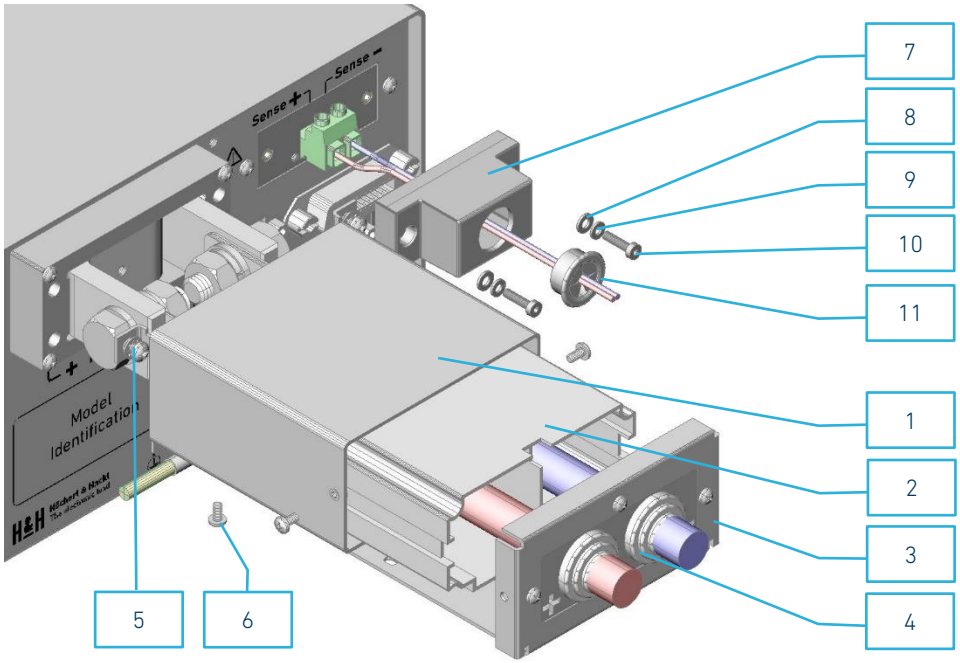


Figure 2.16: components and assembly of the SAB-HES-3 and SAB-HES-3S safety covers

Safety cover for load input SAB-HES-3

1 1 pc. base housing
2 1 pc. insulation sleeve
3 1 pc. cover
4 2 pc. cable grommet
5 4 pc. torx screw M4x8 with contact washer (included)
6 4 pc. torx screw M3x5

Safety cover for sense connections SAB-HES-3S

7	1 pc. housing
8	2 pc. washer M3
9	2 pc. M3 spring washer
10	2 pc. torx screw M3x12
11	1 pc. cable grommet

The following **numbers** refer to Figure 2.16.

1. Disconnect the load and sense cables from all power sources!
   Disconnect the electronic load from all supply lines!

2. Connect the load cables to the copper bars as shown in Figure 2.11 using the screws and washers supplied, so that they run straight away from the bars.

Follow the screw and washer arrangement shown in Figure 2.11 to ensure the appropriate safety distances!

3. Loosen the 4 screws 6 (2 on the side, 2 from below) that hold the base housing 1 and cover 3 together.

4. Screw the base housing 1 to the rear wall using the 4 screws 5 supplied.

5. Use a knife or side cutters to cut the cable grommets 4 open far enough to allow the load cables to pass through. If the load cables are thick, omit the cable grommets if necessary, provided that there is a maximum of 2 mm space between the cable and the cover!

6. Push the insulation sleeve 2 over the loose ends of the load cables into the base housing 1.

7. Insert the loose ends of the load cables through the cable grommets 4. Ensure correct polarity! Push the cover elements together as shown in Figure 2.16 and screw them back together using the screws 6 that were loosened previously.

8. Connect the sense cables to the sense terminals. Insert the loose ends through the housing 7 and the cable gland 11. Screw the housing to the rear panel using the screws and washers **8 9 10**. Press the cable grommet into the housing.

Mount the sense cover even if no sense cables are used!

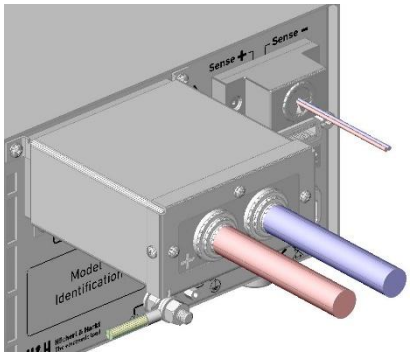


Figure 2.17: fully assembled SAB-HES-3/3S safety cover

2.4.3 Devices from 5 U

For devices from 5 U, the safety cover SAB-HES-5 is available .

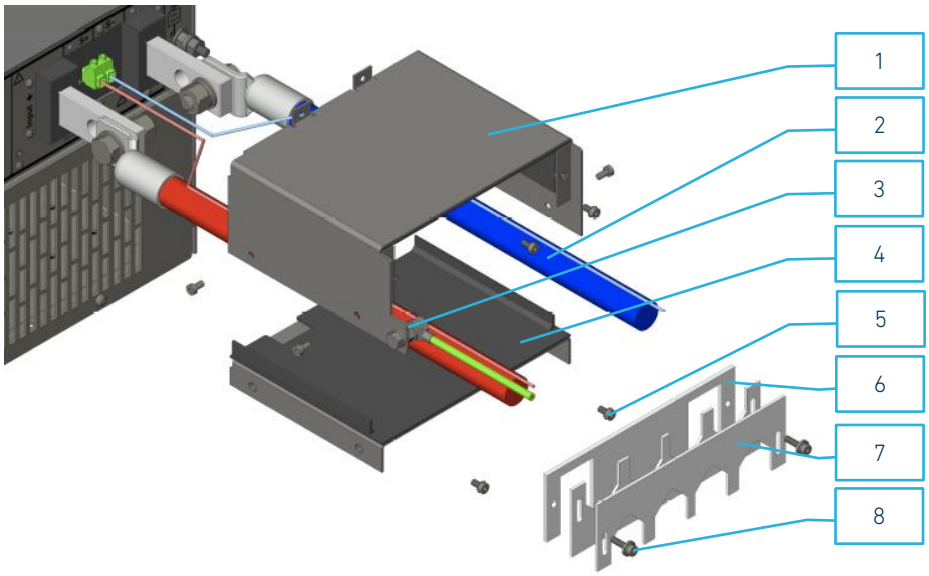


Figure 2.18: installing the SAB-HES-5 safety cover

1 1 pc. cover
2 2 pc. load cable with cable lug (not included in standard delivery)
3 terminal for protective conductor
4 1 pc. base plate
5 4 pc. torx screw M4x8 with contact washer (included)
6 1 pc. cover panel
7 2 pc. cover slider
8 2 pc. torx screw M4x16 with spring washer and washer

The following **numbers** refer to Figure 2.18.

1. Remove cover slider 7 from the pre-assembled box.

2. Disconnect the load cable from all power sources!
   Disconnect the electronic load from all supply lines!

3. If there are screws at the markings in Figure 2.18, remove them from the rear panel and dispose of them.

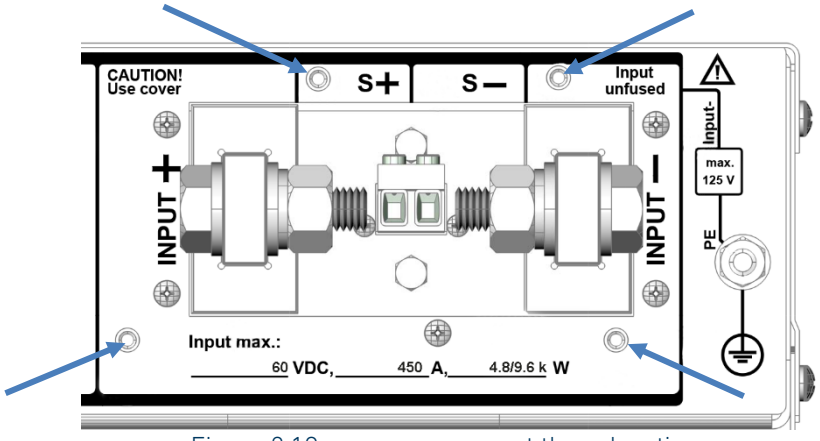


Figure 2.19: remove screws at these locations

4. Connect the load cables to the copper bars as shown in Figure 2.11and Figure 2.18 using the screws and washers supplied.

Follow the screw and washer arrangement in Figure 2.11 to ensure the appropriate safety distances!

5. Place the demounted cover over the load cables and the connection block from behind. Screw the cover to the rear panel using the screws 5 supplied.

6. Mount the cover sliders on the rear of the cover as shown in Figure 2.20 so that they enclose the cables as tightly as possible.

7. Connect the housing to the protective earth of the entire system using the screw on the left side of the safety cover. Use a protective earth connection cable of at least 4 mm^2 for this purpose. For the arrangement of the washers and nuts, see Figure 2.21.

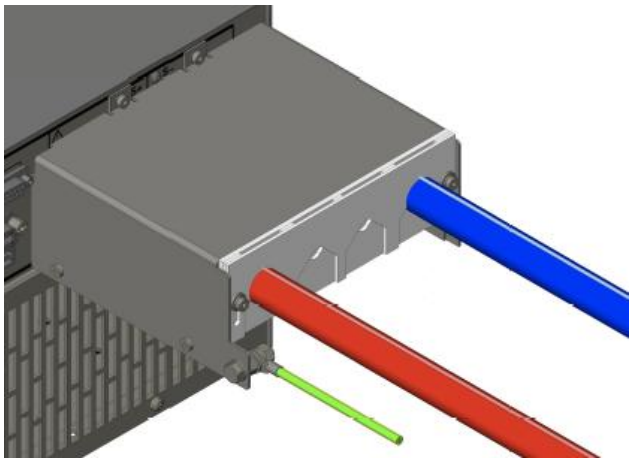


Figure 2.20 fully assembled SAB-HES-2PK/SB safety cover

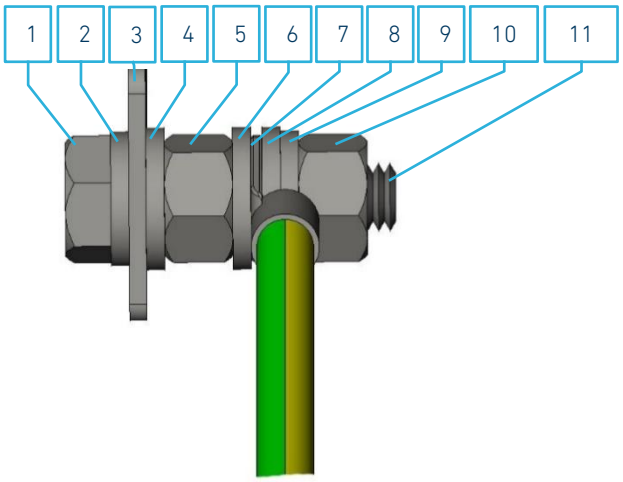


Figure 2.21: arrangement of nuts and washers on the protective conductor connection of the safety cover

1 Screw head
2 Spring washer
3 Side part of the cover
4 Spring washer
5 Nut
6 Washer
7 Cable lug
8 Washer
9 Spring washer
10 Nut
11 Screw thread

2.4.4 Removing Load Connections and Safety Cover

1. Disconnect load and sense cables from all power sources!
   Disconnect the electronic load from all supply lines!
2. Only then unscrew the safety cover from the electronic load and, if necessary, disconnect the load and/or sense cables from the device.

2.5 Permissible Potentials at the Device Connections

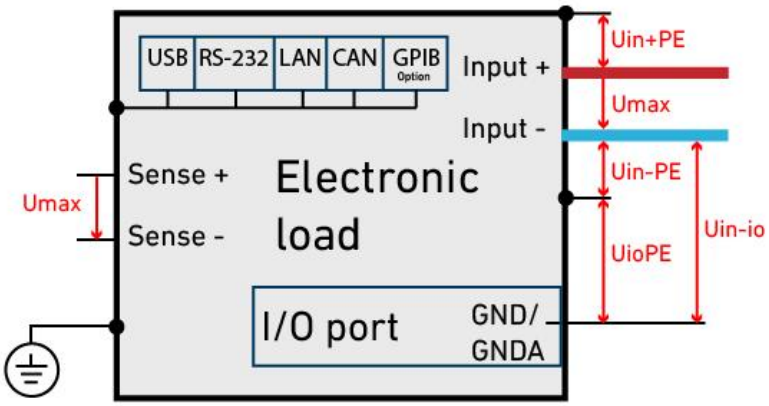


Figure 2.22: voltages at the device connections

The maximum permissible potentials/voltages are specified in the technical data. They must never be exceeded, even in the event of a fault!

With an isolated I/O port (option HES06), higher maximum voltages apply in some cases than with a standard I/O port. If you do not know whether your device has a standard or isolated I/O port, check the "Technical Data" menu: *Main Menu -> Technical data*

Potentials at the data interfaces
All data interfaces (USB, RS-232, LAN, CAN, and GPIB) are connected to the protective earth.

Protective earth connection
Always connect the rear protective earth connection B3 to the protective earth of the overall system!

2.6 Operating Range

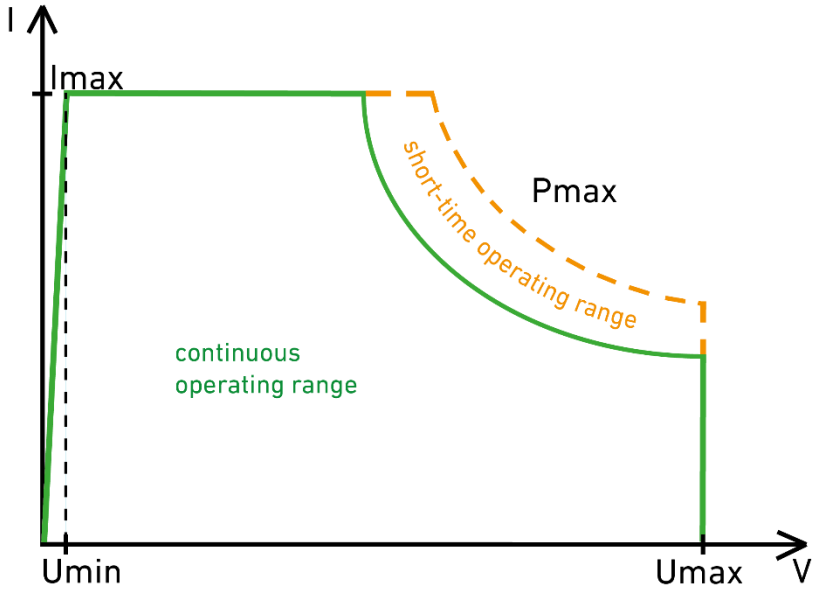


Figure 2.23: operating range

The operating range of the electronic load is determined by its minimum and maximum input voltage, maximum current, and maximum power consumption. The applicable limit values can be found in the technical data in the file *TechDat_HES_dn*.PDF (*dn* = device number, see 1.4.3 Product Identification) on a supplied USB flash drive.

With reduced load current, voltages below the minimum input voltage can still be loaded.

2.7 Protection Functions and Messages

Overcurrent protection OCP
In the voltage, power, and resistance operating modes, an overcurrent protection can be activated. The function of the adjustable current limit is described in 4.3.1 Overcurrent .

Overvoltage indication OV
If an input voltage higher than 105 % of the nominal voltage is applied to the load input, this is indicated by the "OV" status.

Overvoltage causes a short-circuit without any current limitation!

- ➢ The maximum input voltage specified in the technical data must never be exceeded, even for a short time!

The load circuit of the electronic load has no fuse protection!

- ➢ Connect a fuse that is suitable for your application between the test object and Input+ of the electronic load, as shown in Figure 2.24.
- ➢ Follow the instructions in 2.3.1 Safety Instructions for Connecting the Device Under Test!

Undervoltage indication UV
If the input voltage is too low, so that the electronic load is no longer able to maintain the set current, the electronic load reports a "UV" error.

Undervoltage protection UVP
In the current, power, and resistance operating modes, an undervoltage protection can be activated. The function of the adjustable undervoltage protection is described in 4.3.2 Undervoltage Protection.

Reverse polarity indicator RV (not with HES ZV!)
When the input voltage falls below -0.5 V, the electronic load displays "RV" .

Reverse polarity causes a short-circuit without any current limitation! This can destroy the electronic load.
Damage to the electronic load caused by reverse polarity is not covered by the warranty!

- Ensure correct polarity when connecting the test object to the load inputs!
- As shown in Figure 2.24 , we recommend additionally looping a reverse polarity diode into the load circuit externally to protect the test object and the device.
- Follow the instructions in 2.3.1 Safety Instructions for Connecting the Device Under Test.

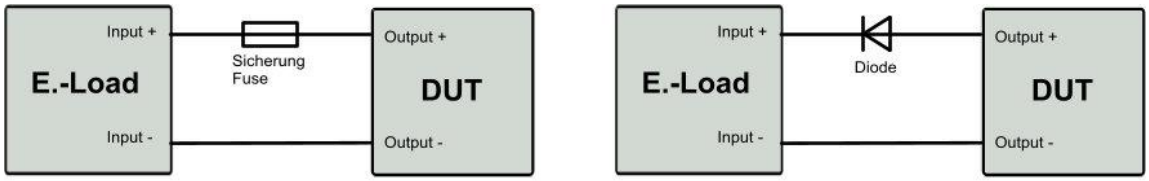


Figure 2.24: Reverse polarity protection by fuse (left) or diode (right)

Overpower protection OPP

To protect the built-in power stage, the overpower protection monitors the power consumption and limits the load current so that approx. 110 % of the permissible power is reached.

When overpower protection is active, the electronic load reports an "OPP" error.

When overpower protection is active, the device only resumes control of the setting when the power consumption is within the permissible temperature-dependent range.

Depending on the device type, the power protection allows increased short-term power when the power stage is cold.
The possible duration and level of overload depend on the temperature of the power stage and thus on the previous load. Maximum overload capacity is available when the electronic load is cold.
If the electronic load was previously subjected to rated power, so that the power stage has reached its maximum temperature, then no overload capacity is possible. The output stage needs a certain amount of time to cool down.
The currently possible short-term power can be queried with the command `POWer:PEAK?`, see 5.11.11 POWer Subsystem
The maximum short-term power of your electronic load is specified in the technical data.

Overtemperature protection OTP

To protect the built-in power transistors, there is a temperature sensor on the power stage that continuously measures the temperature. If the temperature exceeds the permissible maximum value, the current flow is interrupted.
Once the power stage has cooled down, the load input is automatically reconnected.

In the event of overtemperature, the electronic load displays "OTP".

Overtemperature warning (OTW)

When the power stage temperature approaches the shutdown point, the overtemperature warning is activated without shutting down the load input.

In the event of an overtemperature warning, the electronic load displays “OTW”.

2.8 Turning the Device On

Once the device has been set up correctly, connected to protective earth at **B3**, and connected to the required power supply, you can switch it on using **A1**.

After switching on, the device runs through the initialization function. This takes approx. 5 seconds and does not allow any entries to be made. The electronic load is then ready for operation.

The settings after switching on are identical to the settings after a reset, provided that no user-specific settings from a memory position are loaded after switching on (see 4.31 Saving and Loading Device Settings).

During commissioning, check the date and time of the electronic load and, if necessary, set both in the following dialog:
Menu *Main Menu -> Configuration -> Time and Date*

3 Basics of Local Operation

3.1 Control Elements

3.1.1 Mains Switch

Use the Mains switch A1 to switch the electronic load on and off. When pressed (|), the device is switched on. When not pressed (0), the device is switched off.

3.1.2 USB Port

3.1.2.1 USB Flash Drive

FAT16 and FAT32 formatted USB flash drives (mass storage devices) can be connected to the USB port A2 (USB embedded host interface). A connected and fully enumerated USB flash drive is indicated by a USB icon in the status bar (see 3.2 Touchscreen Layout).

The USB interface is used for the following functions:

- Measurement data recording
- Import of settings for executing a load profile
- Export of measurement data from internal memory
- Export/import of device settings
- Export/import of the user manual from/to internal memory
- Updating the firmware

The following USB flash drives have been tested:

- Intenso Alu Line USB2.0 4 GB
- Intenso Alu Line USB2.0 32 GB
- Intenso Speed Line USB3.0 8 GB
- Intenso Ultra Line USB3.0 32 GB
- Sandisk Ultra USB 3.0 64 GB
- Transcend Jetflash 700 USB 3.1 64 GB
- Verbatim Onestripe USB 3.0 128 GB

Only FAT16 and FAT32 formatted USB flash drives can be used. exFat and NTFS formatted USB flash drives are not compatible. MS Windows only offers the option of formatting NTFS and exFAT for USB flash drives larger than 64 GB. Therefore, please use a suitable formatting tool.

In principle, other USB flash drives should also be compatible, but H&H cannot guarantee this.

3.1.2.2 USB Mouse

For easier operation of the load in laboratory use, a wired standard mouse can be connected to the USB socket A2 (USB embedded host interface). Pressing the left mouse button corresponds to a normal touch event. If an edit widget (see 3.5.3) is focused, the selected decimal place can be changed using the mouse wheel. Pressing the mouse wheel moves the flashing cursor one place to the left. The mouse wheel thus has the same function as the "Setting" Rotary Encoder (see 3.1.5).

When using a mouse, a USB flash drive can no longer be connected. The USB interface does not support a USB hub.

3.1.3 Touchscreen

The A3 graphic touchscreen is the core element of the user interface and is used for easy operation of the device. It is used to display measured and set values, for menu navigation, and for configuring the device and its functions. See 3.2 Touchscreen Layout .

3.1.4 "Input" Button

The "Input" button A4 is used to switch the load input on or off. Each time the button is pressed, the activation status for the load input toggles between "on" (ON) and "off" (OFF).

3.1.5 "Setting" Rotary Encoder

The rotary encoder A5 is used to change numerical values in edit widgets. Turning clockwise increments the decimal place marked with a flashing cursor. Turning counterclockwise decrements the decimal place. Pressing the rotary encoder moves the flashing cursor one decimal place to the left.

3.1.6 Buzzer

The buzzer is used for acoustic signaling

- of an error event (a short beep is generated for each event)
- an alarm in critical system states (partially adjustable)
- a rotary encoder input (adjustable)

3.2 Touchscreen Layout

The touchscreen is used for user interaction with the device and is divided into 4 areas.

Figure 3.1: structure of the touchscreen

1. Main section
2. Right sidebar
3. Status bar
4. Left sidebar – only for HES MR

In addition, pop-up windows appear on the touchscreen during specific events to provide the user with additional information. See 3.6 Pop-Up Windows .

3.2.1 Main Section

The main section displays the various main, menu, and dialog windows.

3.2.1.1 Main Window

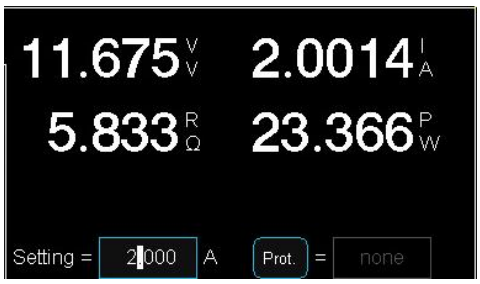


Figure 3.2: main window

Depending on the selected view, the main window displays different measured values and allows important settings to be changed, which take effect immediately.

The main window is displayed after switching on the electronic load and can be called up in a menu or dialog window by pressing the following button:

3.2.1.2 Menu Window

Figure 3.3: menu window

A menu window allows you to open another menu or dialog window. Each menu window contains menu entries in the form of symbols that can be selected by touching the screen. If there are more than 8 menu entries, the menu can be scrolled using vertical swipe gestures.

Pressing the "Esc" button closes the current menu window and switches to the previous menu or main window.

An overview of the individual menu entries can be found in the chapter 3.7 Menu Structure.

3.2.1.3 Dialog Window

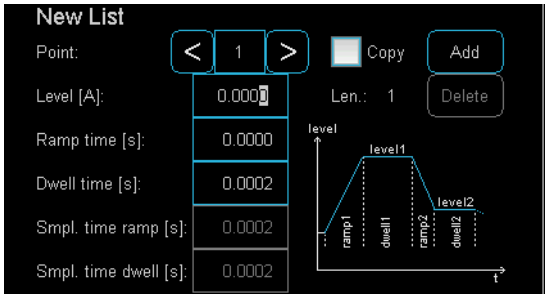


Figure 3.4: dialog window

Dialog boxes allow you to view and adjust settings for functions using various graphical controls.

Use the "OK" or "Esc" buttons to exit the dialog box. "OK" applies the changes, while "Esc" discards them.

Description of the graphical user interface elements: see 3.5 Graphical Control Elements for Input and Output.

3.2.2 Right Sidebar

Figure 3.5: right sidebar

This bar displays important buttons for navigation and quick operation (e.g. menu, virtual keyboard, etc.).

Icons in the right sidebar: see 3.4 Graphical Controls for Navigation.

3.2.3 Status Bar

Figure 3.6: status bar

The status bar displays operating states and status signals independently of menu and dialog windows. Examples:

- Control source (Local, RS-232, USB, CAN, LAN, GPIB)
- Activation status of the load input (On, Off)

- Control mode (CC, CV, CR, CP)
- Activation status of the external control via the I/O port (external)
- Operation, Questionable, Function, and Service Status
- Status of the error memory (ERR)
- Control of a function via the user interface ( )
- Key lock activated (or)
- Enumerated USB flash drive ( )

Detailed description of the status signals displayed: see 5.11.17 STATus Subsystem.

Tapping the status bar opens the status window, which lists all active status signals in a table (see 3.6.7 Status Overview).

3.2.4 Left Sidebar

Figure 3.7: left sidebar

For HES MR multi-range devices, the left sidebar offers up to 4 buttons for quickly switching the setting range. The active range is displayed at the top.

3.3 Main Views

The main views are usually displayed while a device under test is being loaded. They provide an overview of important measured values and their progression and allow settings to be entered.

3.3.1 Main View With Numerical Measured Values

Figure 3.8: main view

The following measured values are displayed in this main view:

- Input voltage (in volts)
- Input current (in amperes)
- Input resistance (in ohms)

- Input power (in watts)

In addition, the setting for control and the current or voltage limit during loading can be changed here. Changes to these values are applied immediately.

3.3.2 Main View Yt Graph

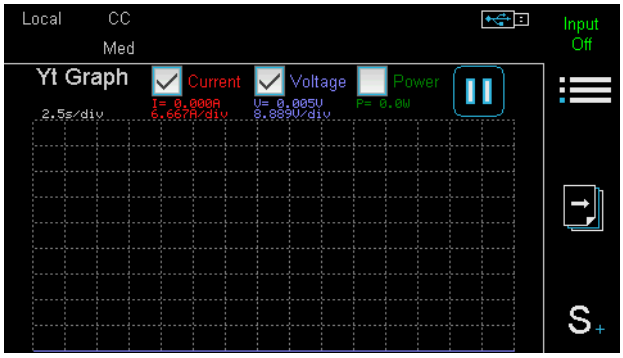


Figure 3.9: Yt graph

This main view shows the temporal progression of measured current, voltage, and power signals. The properties of the graphs displayed can be adjusted in a pop-up window by tapping on the gear icon. The pause button in the upper right corner pauses the updating of this display. Pressing this button again continues the measurement recording without interruption.

3.3.3 Function-Specific Main Views

For important functions, there are function-specific main views that display important measurement and status values when the function is activated and allow important settings to be changed. Changes to these values are applied immediately.

Depending on the function, it can be started with the shortcut combination S+ -> Start and ended with S+ -> Stop (see 3.4.7 Shortcut Selection Icon).

3.4 Graphical Controls for Navigation

Graphical navigation controls are displayed in the right sidebar depending on the window displayed in the main section. They allow you to navigate between main, menu, and dialog windows.

3.4.1 Main Menu Icon

This icon is displayed when main windows are active and allows you to open the main menu.

3.4.2 Main Window Icon

This icon is displayed with most menu and dialog windows. It allows you to switch directly to the main window. Changes made in dialog windows are discarded.

3.4.3 Main View Icon

This scroll icon is displayed when different views are available in the main window and it is possible to switch between them (see 3.3 Main Views).

3.4.4 Virtual Keyboard Icon

This icon is always displayed when an edit widget is in edit mode. It allows direct entry of a numeric decimal or floating point value.

3.4.5 OK Icon

This icon is mainly displayed in dialog boxes where changes to settings can be made. After pressing this icon, the changes are applied and the previous window is displayed.

3.4.6 Esc Icon

This symbol is mainly displayed with menu and dialog windows and is used to exit the window. Changes made in dialog windows are discarded.

3.4.7 Shortcut Selection Icon

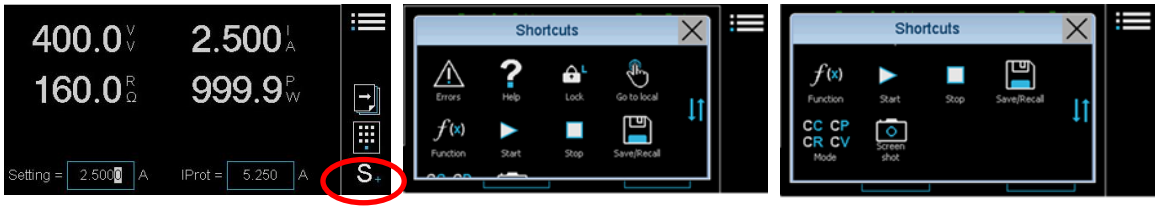


Figure 3.10: shortcut icon (left) and shortcut list

The shortcut icon is displayed with main, menu, and dialog windows. It opens a window that allows you to quickly select important functions and dialog windows.

- Displaying entries in the error memory
- Displaying help for the current dialog or menu window
- Key lock for local operation
- Exiting remote control mode and switching to local operation
- Starting a preset function
- Stopping a running function
- Activating the load input
- Deactivating the load input
- Calling up the Function menu
- Calling up the "Save/Recall" dialog box
- Calling up the "Mode" menu window
- Creating a screenshot on a connected USB flash drive

3.5 Graphical Control Elements for Input and Output

Graphical controls for input and output appear in the main and dialog windows and are used to interact with the device. They are identified by blue borders, blue areas in the icon, or blue shades.

3.5.1 Measurement Widget

The measurement widget shows a formatted measured value. In most cases, the corresponding formula symbol (top) and unit (bottom) are displayed after the value.

3.5.2 Graph Display

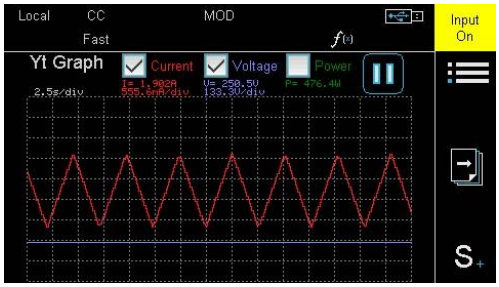
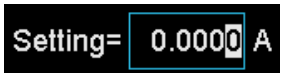


Figure 3.11: graph display

The graph display is used for the visual representation of a Yt or XY diagram. It is used, for example, to display the temporal progression of a measurement signal.

3.5.3 Edit Widget



This element is used to enter or change numerical values. It is represented by a square blue frame with a numerical value. The edit widget can be operated in two different ways.

Rotary encoder:
An edit widget can be set to edit mode by touching it. Edit mode is indicated by a flashing cursor at the decimal place touched. This decimal place can now be changed by turning the rotary encoder. In the event of an overflow or underflow, the adjacent decimal place is incremented or decremented. Pressing the rotary encoder moves the cursor one decimal place to the left. The value of this place can now be changed, and so on.

Figure 3.12: keypad symbol and virtual keypad

Virtual keypad:
When an edit widget is in edit mode, a keypad icon is displayed in the right-hand bar. Touching this icon opens the virtual keyboard. This keyboard allows you to enter a numerical value directly. The "AC" button deletes the entire entry. "OK" accepts the entry, "Esc" discards the entry.

The virtual keypad can also be opened by repeatedly tapping the corresponding edit widget quickly.

3.5.4 Button

A button is operated by touch. It is identified by a rounded blue frame with text. After releasing the button, the corresponding action is performed.

3.5.5 Checkbox

The checkbox is operated by touch. This causes the check mark that represents the status of the checkbox to be displayed or hidden.

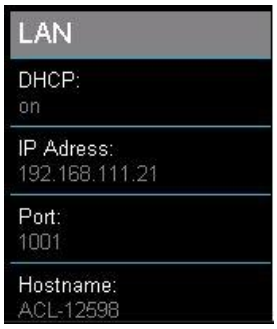
3.5.6 Dropdown Widget

The dropdown widget is operated by touch. It is identified by a rounded blue frame with a small triangle. After touching the dropdown widget, a selection list with predefined entries opens. If there are many entries in the selection list, the list can be scrolled using a swipe gesture. The selected list entry has blue text and is marked with a blue rectangle. Pressing an entry accepts it and closes the selection list.

3.5.7 Slider

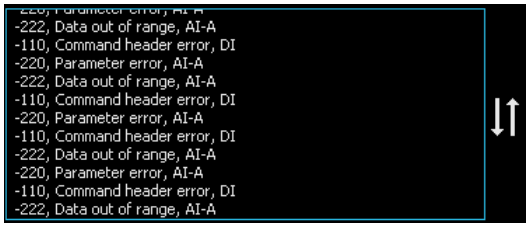
The slider can be operated with a swipe gesture.

3.5.8 Swipelist Widget



The swipelist widget is used to display read-only information. It can be scrolled vertically with a swipe gesture.

3.5.9 Simplified Swipelist Widget



The simplified swipelist widget is used to display read-only information. If there are many list entries, two arrows are displayed to the right of the simplified swipelist widget, indicating that the list can be scrolled vertically with a swipe gesture.

3.5.10 Progress Bar

The progress bar is used to visually display the progress of a time-limited action. In addition, the percentage of progress is displayed as a decimal number on the progress bar.

3.6 Pop-Up Windows

Pop-up windows are displayed over the currently displayed main, menu, or dialog window. They are used to display information to the user (e.g. about errors) or to have the user confirm an action.

3.6.1 Error Window

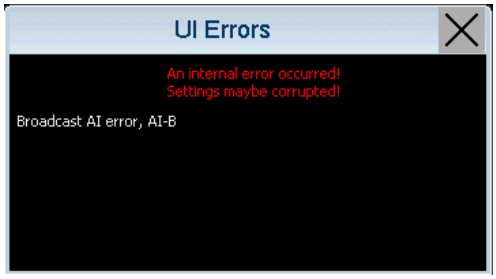


Figure 3.13: error window

This window is displayed when an unexpected error or a fault occurs during local operation. The errors are displayed in plain text.

This window can be closed by pressing the "X" or "Esc" buttons.

3.6.2 Notification Window

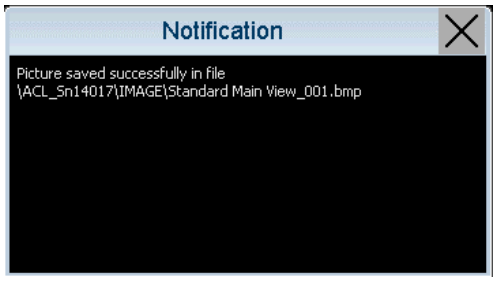


Figure 3.14: notification window

This window is displayed to inform the user about events, e.g. when a USB flash drive has been detected.

The window disappears after a short display time or can be closed earlier by pressing the "X" or "Esc" buttons.

3.6.3 Notification Window in Remote Control Mode

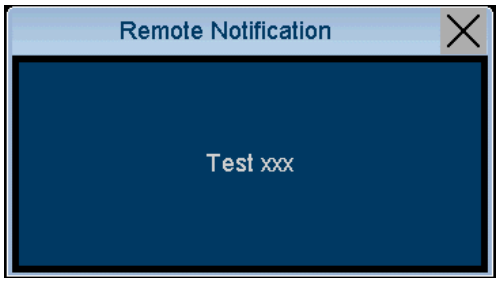


Figure 3.15: notification window in remote control mode

This window is displayed when text has been sent to the device via one of the digital data interfaces using the SCPI command `DISP:TEXT`.

The window remains displayed until it is closed by pressing the "X" button, redrawing the displayed screen, or using the SCPI command `DISP:TEXT ""` (empty text).

3.6.4 Warning Window

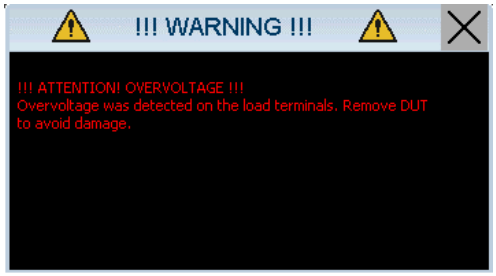


Figure 3.16: warning window

This window is displayed to inform the user of dangerous system conditions that could destroy the load and injure people (e.g. impermissible overvoltage at the load input).

The window is displayed continuously as long as the dangerous system condition exists. This warning cannot be hidden during this time. After the dangerous system condition no longer exists, the warning is still displayed until the user actively acknowledges it with the "Esc" key.

3.6.5 Help Window

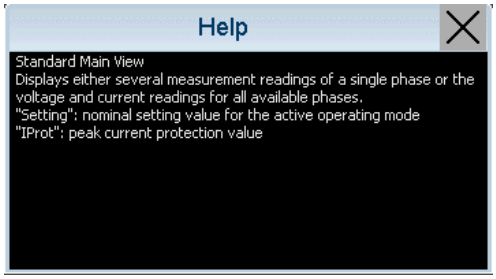


Figure 3.17: help window

This window is displayed after selecting S+ -> Help. It contains a brief explanation of the menu or dialog window displayed.

3.6.6 Confirmation Window

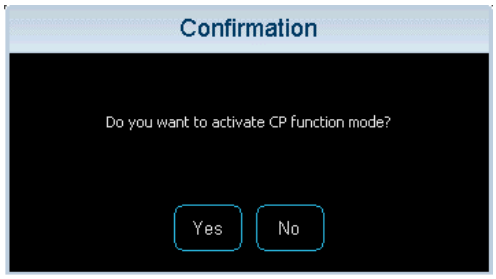


Figure 3.18: confirmation window

This window is displayed to ask the user whether a subsequent action should be performed.

3.6.7 Status Overview

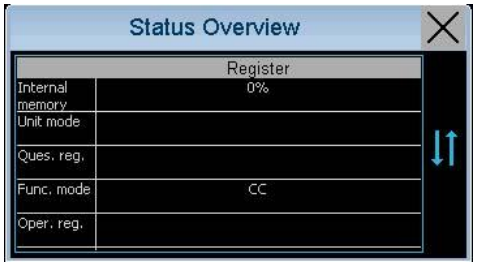


Figure 3.19: status overview

This window appears when you touch the status bar. It contains information about the current level of the internal measurement data memory and an overview of all active status signals.

A detailed description of the status signals displayed can be found in 5.11.17 STATus Subsystem.

3.7 Menu Structure

	Main Menu (Level 1)	Menu (Level 2)	Menu (Level 3)	Menu (Level 4)
Main Menu	Settings menu	Basic settings menu	Range	
			Mode menu	CC (Constant Current)
				CP (Constant Power)
				CR (Constant Resistance)
				CV (Constant Voltage)
			External control	
			Protection	
			Cooling	
			Speed	
			Zero voltage	
		Function menu	Rectangular	New rectangular
				Edit rectangular
			List	New list
				Edit list
				Import list from USB
				List settings
			Discharge	Initialize
			Ri measurement	
			Modulator	
			MPPT	Graph
		Trigger		
		Acquisition		
		Save/Recall	Import from USB flash drive	
		Reset		
	Data menu	Export		
		Graphical data viewer		
		USB data logging		
	Errors			
	Configuration menu	Power on		
		Master/Slave		
		Communication menu	RS-232	
			USB	
			LAN	LAN Configuration
				LAN Status
			CAN	
			GPIB[1)]	
		User interface menu	Display	
			Help language	
			Tips and tricks	
		Alarms		
		Buzzer		
		Time and date		
		Factory settings		
	Service menu	Firmware update		
		User manual export		
		Calibration	Calibration	
			Calibration signal name	
		Parameter menu	View parameter	
			Edit user parameter	
			Edit calibration parameter	
		Power stage temperature		
		H&H Service		
	Technical data			
	Contact			

1) "GPIB" is only displayed if the optional GPIB interface is installed.

3.8 Help for Dialog and Menu Windows

An internal help system is available to explain the individual dialog and menu windows (see 3.6.5 Help Window).

4 Functions

This chapter describes the functions of the electronic load. After each function description, reference is made to the various options for implementing the corresponding function in different control modes:

- Local operation
- Digital remote control
- Analog remote control

Local operation
Local operation is performed via the user interface on the front of the device (see 3 Basics of Local Operation).
Special functions are grouped together in the "Function" $f(x)$ menu on the user interface. These functions are each defined in a separate dialog box. Starting and stopping is done using the shortcut S+ -> Start or S+ -> Stop. If a special function has been defined, this will terminate any other function that may already be running.

Digital remote control
Digital remote control is carried out via one of the data interfaces on the rear of the device (see 5 Digital remote control). After switching on the device, local operation is automatically active. After receiving a SCPI command via one of the data interfaces, the device automatically switches to digital remote control (Remote).

External control
External control is carried out via the optional I/O port on the rear of the device (see 6 External Control via I/O Port). External control is independent of local operation and digital remote control and is configured via the *Main Menu -> Settings -> Basic settings -> Ext. control* dialog or using SCPI commands. This allows specific settings (e.g. setting for the output state) to be specified via analog and digital input signals.

4.1 Selecting the Control Source

The electronic load can be operated from various control sources.

- User interface (manually via the front panel)
- Data interface
- I/O port

The electronic load automatically switches to the "Remote" remote control mode when it receives a command via one of the available data interfaces. The settings made via the respective control source are not deleted when the control source is changed.

Local operation:
Main Menu -> Settings -> Basic Settings -> Ext. control

Digital remote control:
See 5.11.16 SETTing Subsystem

4.2 Basic Operating Modes and Settings

The electronic load offers four basic operating modes:

- Current mode CC
- Voltage mode CV

- Resistance mode CR
- Power mode CP

The active operating mode of the control is specified by the basic operating mode or an active function (e.g. list function). If the load input is switched on without any functions activated or if a function is deactivated while the input is switched on, the basic operating mode is used.

When the operating mode is changed, the previous setting is reset to the value for the selected operating mode. The load input is not deactivated when the operating mode is changed, not even temporarily.

Warning of undefined states during operating mode change! Changing the operating mode can result in dangerous states for the test object, which can lead to damage or destruction.

➢ Switch off the load input before changing the operating mode and only switch it back on after setting the new operating mode.

4.2.1 Constant Current Mode (CC)

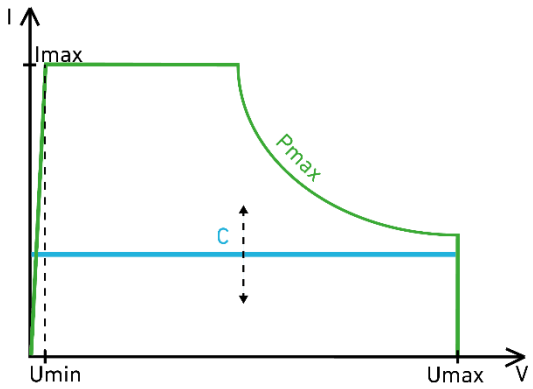


Figure 4.1: current mode (CC)

The set current is independent of the input voltage. Current control ensures that changes in the input voltage have no effect on the load current.

Sources with regulated output current cannot be loaded in current mode. Physical quantity can only be regulated once, either on the source or sink side.

Local operation:
Main Menu -> Settings -> Basic Settings -> Mode -> Constant current
"Setting" edit widget: Enter the setting for the input current.
Confirm with "OK".

Digital remote control:
See 5.11.2 CURRent Subsystem, 5.11.6 FUNCtion Subsystem

External control:
See 6 External Control via I/O Port

4.2.2 Constant Power Mode (CP)

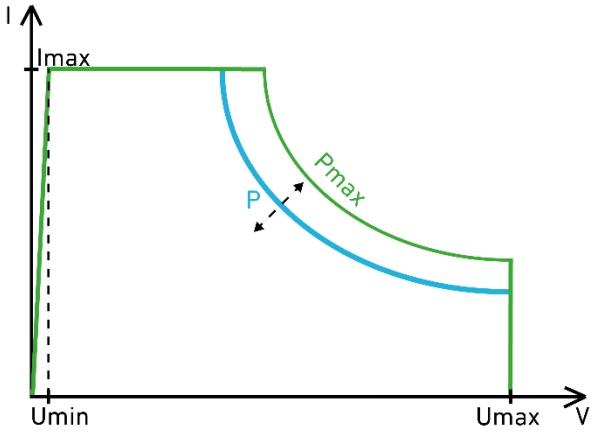


Figure 4.2: power mode (CP)

In power mode, the electronic load regulates the set power via software by adjusting the calculated current as a function of the input voltage using a PI controller.

The controller parameters are stored as non-volatile service parameters and can be adjusted manually or via a data interface. There is one parameter pair each for slow, medium, and fast control modes.

Parameter numbers: see 9.2 Device Parameters.

Controller parameter Kp
This parameter determines the control constant for the proportional component of the PI controller. This parameter has a default value of 0, which deactivates the proportional component of the software-based PI controller. If this value is increased to accelerate control, ensure that control remains stable in all operating situations.

Controller parameter Ki
This parameter determines the control constant for the integral component of the PI controller. This parameter depends on the internal resistance of the source. If this constant is increased to accelerate the control, ensure that the control remains stable over the entire voltage and current range.

Sources with regulated output current (e.g. due to current limiting) cannot be loaded in power mode if the required current exceeds that of the source.

Local operation:
Main Menu -> Settings -> Basic Settings -> Mode -> Constant power
"Setting" edit widget: Enter the setting for the input power.
Confirm with "OK".

Digital remote control:
See 5.11.6 FUNCtion Subsystem, 5.11.11 POWer Subsystem, 5.11.15 SERVice Subsystem

External control:
See 6 External Control via I/O Port

4.2.3 Constant Resistance Mode (CR)

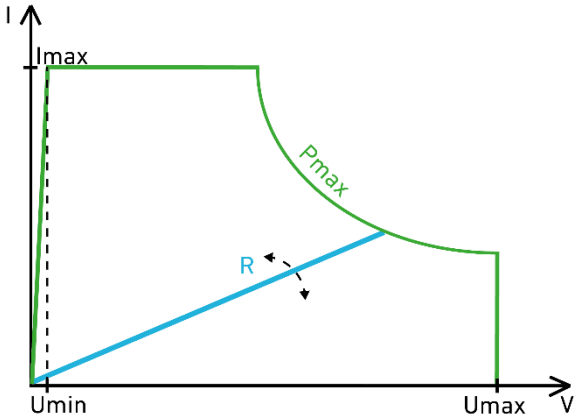


Figure 4.3: resistance mode (CR)

In resistance mode, the electronic load regulates the set resistance via software by adjusting the calculated current as a function of the input voltage using a PI controller. The current behaves according to Ohm's law and changes linearly with the input voltage.

In contrast to a real ohmic resistance, the current in an electronic load can only follow the input voltage at its limited control speed.

The controller parameters are stored as non-volatile service parameters in the electronic load and can be adjusted. There is one parameter pair for slow control mode and one for fast control mode.

Parameter no. 14: Kp_Resistance_Fast
Parameter no. 15: Ki_Resistance_Fast
Parameter no. 16: Kp_Resistance_Slow
Parameter no. 17: Ki_Resistance_Slow

Controller parameter Kp
This parameter determines the control constant for the proportional component of the PI controller. This parameter has a default value of 0, which deactivates the proportional component of the software-based PI controller. If this value is increased to accelerate control, care must be taken to ensure that control remains stable in all operating situations.

Controller parameter Ki
This parameter determines the control constant for the integral component of the PI controller. This parameter depends on the internal resistance of the source. If this constant is increased to accelerate the control, care must be taken to ensure that the control remains stable over the entire voltage and current range.

See also 9.2 Device Parameters.

Sources with regulated output current (e.g., due to current limiting) cannot be loaded in resistive mode if the required current exceeds that of the source.

Local operation:
Main Menu -> Settings -> Basic Settings -> Mode -> Constant resistance
"Setting" edit widget: Enter the setting for the input resistance. Confirm with "OK."

Digital remote control:
See 5.11.6 FUNCtion Subsystem, 5.11.14 RESistance Subsystem, 5.11.15 SERVice Subsystem.

External control:
See 6 External Control via I/O Port.

4.2.4 Constant Voltage Mode (CV)

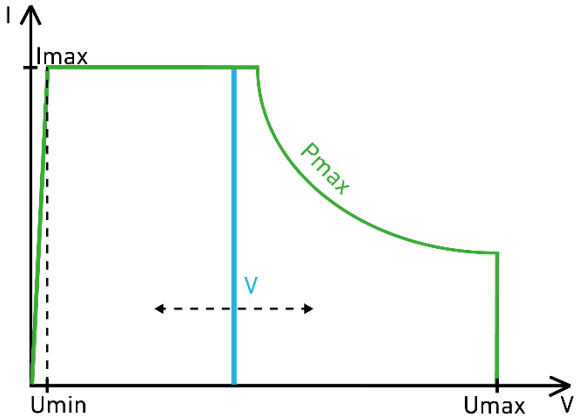


Figure 4.4: voltage mode (CV)

In voltage mode, the electronic load draws as much current as necessary until the desired voltage is reached due to the internal resistance or current limitation of the test object.

In the case of dynamic loads in voltage mode, high current peaks can occur at the output of the device under test if capacitance is present, which the device can no longer regulate.
This can cause the current limitation to take effect, and the generated waveform then deviates from the specified waveform.

Since an electronic load can only absorb current and not supply it, it can only regulate the falling edges in voltage mode under dynamic loads. The rising edges depend on the characteristics of the source to be loaded.

For stability reasons, the minimum load current in voltage mode should not be less than 10% of the current range of the device. If control oscillations occur, the system can possibly be stabilized by switching the control speed (see 4.5 Control Speed).

In voltage mode, the undervoltage protection (see 4.3.2 Undervoltage Protection) is deactivated.

Local operation:
Main Menu -> Settings -> Basic Settings -> Mode -> Constant voltage
"Setting" edit widget: Enter the setting for the input voltage. Confirm with "OK."

Digital remote control:
See 5.11.6 FUNCtion Subsystem, 5.11.20 VOLTage Subsystem.

External control:
See 6 External Control via I/O Port.

4.2.5 Immediate Settings

For each basic operating mode, the corresponding setting, which is set immediately, can be specified. When the operating mode is changed, the corresponding setting that was last programmed in this operating mode is set automatically. If a setting is specified for an operating mode that is not currently active, the setting is saved and set the next time this operating mode is selected.

If no setting has been specified for an operating mode, the load sets a default value. Default values are always selected so that they cause as little current flow as possible.

Local operation:
Main Menu -> Settings -> Basic Settings -> Mode -> <mode>
"Setting" edit widget: Enter the setting to be adjusted. Confirm with "OK".

Digital remote control:
See 5.11.2 CURRent Subsystem, 5.11.11 POWer Subsystem, 5.11.14 RESistance Subsystem, 5.11.20 VOLTage Subsystem.

External control:
See 6 External Control via I/O Port.

4.2.6 Triggered Settings

In addition to the immediate setting, there is a triggered setting for each operating mode, which is set once when a trigger occurs. The triggered setting of the current operating mode becomes active immediately when a trigger occurs. In operating modes that are currently inactive, the triggered setting overwrites the immediate value and becomes active when the respective operating mode becomes active. Once a setting has been triggered, further triggers have no effect on the setting signal until another triggered setting is programmed.

After a reset, after receiving an ABORt command, or after the value has been triggered, triggered settings follow the immediate setting until a triggered setting is explicitly programmed.

Local operation:
Main Menu -> Settings -> Basic Settings -> Mode -> <mode>
Activate the "Triggered setting" checkbox.
Enter the setting to be adjusted when triggered below. Confirm with "OK".

Digital remote control:
See 5.11.2 CURRent Subsystem, 5.11.11 POWer Subsystem, 5.11.14 RESistance Subsystem, 5.11.20 VOLTage Subsystem.

4.2.7 Setting Toggling

To make switching between two settings as easy as possible, the electronic load offers "Toggle settings" in each of the four basic operating modes when operated locally. If setting switching is activated, the setting can be switched in the main view with just one keystroke. Setting switching facilitates the recording of step responses, for example.

Temporary changes to the two settings in the main view are not considered when the "last setting" power-on configuration is activated.

Local operation:
Main Menu -> Settings -> Basic Settings -> Mode -> <mode>
Activate the "Toggle settings" checkbox.
Edit widgets "Setting A" and "Setting B": Enter settings.
Confirm with "OK."
In the main view, press "Set A" or "Set B" to switch. The settings can also be changed in the main view.

4.3 Protections and Combined Operating Modes

An adjustable overcurrent protection and an adjustable undervoltage protection ensure that, in addition to the basic operating modes, so-called combined operating modes are possible:
CC+CV, CR+CC+CV, CP+CC+CV, CV+CC.

Since overcurrent and undervoltage protection are permanently enabled in all basic operating modes, the combined operating modes are not available for selection in the operating mode selection. Only the basic operating mode is always displayed in the status bar.

4.3.1 Overcurrent Protection

The adjustable overcurrent protection is effective in all operating modes and does not allow any current higher than the set protection value. When overcurrent protection is active, "OCP" is displayed in the status bar of the user interface.

After switching on the device, the overcurrent limitation is set to the maximum value, which allows unrestricted operation. The overcurrent limitation cannot be disabled, but only set to the maximum value.

Local operation:
Main Menu -> Settings -> Basic Settings -> Protection
Enter the setting for the current limit in the "Current protection" edit widget. Confirm with "OK."

Digital remote control:
See 5.11.2 CURRent Subsystem.

External control:
See 6 External Control via I/O Port.

4.3.2 Undervoltage Protection

The electronic load has an adjustable undervoltage protection . This is effective in all operating modes except voltage mode and only allows current to flow when the input voltage is higher than the set protection value. When undervoltage protection is active, the “UVP“ status is set in the Questionable Status Register and displayed in the status bar of the user interface.

You can deactivate the undervoltage protection by setting the value to 0.0 V.

The undervoltage protection can be operated in two modes:

- regulating
- switching

Regulating mode
The regulating mode reduces the input current when the load input voltage drops to the setting for the undervoltage protection and is used, for example, to prevent deep discharge when discharging a battery.
The regulating mode is designed as a PI controller and cannot prevent the voltage from falling below the setting in the event of a sudden drop in voltage.

Switching mode
Switching mode switches the input current off/on when the load input voltage falls below/exceeds the setting for undervoltage protection and is used, for example, to achieve the shortest possible dead time until the load current flows when the input voltage is applied (see4.26 Voltage Connection and PWM Operation).
The switching mode is implemented as a comparator function. If the voltage falls below the setting, the current is switched off abruptly. This can cause the voltage to rise above the setting again due to the relief of the voltage source, and the current is switched on again. This can lead to unstable behavior around the switching point.

The factory setting for the undervoltage protection after switching on is a defined value, see 4.32 Reset Device Settings. When voltage mode is active, the undervoltage protection is automatically set to 0.0 V.

Local operation:
Main Menu -> Settings -> Basic Settings -> Protection
Adjust the setting for the undervoltage protection in the "Voltage protection" edit widget.
"Voltage protection mode" dropdown widget: select regulating or switching mode.
Confirm with "OK".

Digital remote control:
See 5.11.20 VOLTage Subsystem.

External control:
See 6 External Control via I/O Port.

4.4 Setting and measurement ranges (HES MR)

Models of the MR variant (HESxxxMR2, MR3, and MR4) have 2, 3, or 4 current ranges and thus the same number of resistance ranges and power ranges for setting adjustment and measurement. Only one range is available for voltage setting and measurement.

The active range is displayed in the status bar and in the left sidebar for multi-range devices : R1, R2, R3, or R4. The range can be switched via the left sidebar without having to switch to the range dialog.

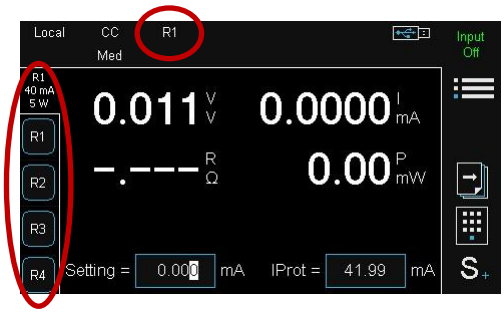


Figure 4.5: range indication at MR models

The current and power ranges are arranged in ascending order (R1 is the smallest CC or CP range), while the resistance ranges are arranged in descending order (R1 is the largest CR range). In CP and CR mode, the maximum current of the corresponding current range is possible in the respective range. The active range is always valid for CC, CP, and CR mode.

Example HES530MR3:

	CC range	CP range	CR range	Max. current
R1	0.16 A	50 W	20 kΩ	0.16 A
R2	1.6 A	300 W	2 kΩ	1.6 A
R3	16 A	750 W	200 Ω	16 A

If no range has been specified, the device sets the default range R1.

Requirements for range change:

- No function (e.g., list execution, discharge function) and no data acquisition may be active.
- All settings for current, power, and resistance operation must be within the new range. The settings also include the triggered and function-specific settings as well as the setting for current limiting.

If functions are active or if the settings in the new range are outside their end values, a "Settings Conflict" error is generated and the range is not changed.

To avoid current peaks, the input is deactivated for approx. 20 ms during the range change. This resets hardware- and software-based controllers.

Detailed information on range switching can be found in Application Note No. 20 on the H&H website: www.hoecherl-hackl.com/download/10560/

Local operation:
Main Menu -> Settings -> Basic Settings -> Range
Select the range in the "Range" dropdown widget. Confirm with "OK."
Or via the left sidebar.

Digital remote control:
See 5.11.12 RANGe Subsystem.

4.5 Control Speed

For certain devices under test or very long connection cables, it may be necessary to adjust the control time constant of the electronic load to achieve stable control. The control speed can be adjusted in three stages for this purpose.

The control speeds (, rise time, and fall time) are specified in the technical data.

"Medium" control speed is suitable for most applications. "Fast" should only be used if the supply lines are very short and twisted or if special low-induction cables are used. "Slow" is used for long connection cables or for DUTs with control characteristics that are incompatible with the load.

In the software-controlled operating modes CP and CR, the controller parameters Kp and Ki can be adapted to the characteristics of the test object, see 4.2.2 Constant Power Mode (CP).

Local operation:
Main Menu -> Settings -> Basic Settings -> Speed
Dropdown widget "Regulation speed": Select the control speed.
Confirm with "OK".

Digital remote control:
See 5.11.6 FUNCtion Subsystem .

4.6 Load Input

4.6.1 Setting for Load Input State

The load input is switched on and off using the A4 button. When the input is switched on, "Input On" is shown on the display and the connected test object is subjected to the load. When the input is switched off, the display shows "Input Off". The input resistance of the device is specified in the technical data.

In voltage mode, the load is switched on with a "soft start." It may take several milliseconds for the preset value to be reached.

Local operation:
Button A4

Digital remote control:
See 5.11.7 INPut Subsystem

External control:
See 6 External Control via I/O Port

4.6.2 Triggered Setting for Load Input State

In addition to the setting value for the activation status of the load input, which is set immediately, there is a triggered setting value in digital remote control mode, which overwrites the setting value to be set immediately when a trigger event occurs. The triggered setting value then becomes active immediately.

Once a setting has been triggered, further triggers have no effect on the setting to be set immediately until another triggered setting is programmed.

After a reset, after receiving an ABORt command, or after the value has been triggered, triggered settings follow the immediate setting until a triggered setting is programmed (see also 4.24 Trigger Model).

Digital remote control:
See 5.11.7 INPut Subsystem

4.7 Rectangular Function

The rectangular (square wave) function is used to load a test object with a square wave signal, in which the settings for high and low levels and the associated dwell times can be changed during the execution of the function.

The technically feasible range for the dwell times may be limited by the control speed or by the rise/fall time of the respective model (see technical data).

Possible conflicts:
The rectangulat function cannot be activated when one of the following functions is already active:

- internal resistance measurement
- discharge function
- modulator function
- MPPT function
- externally controlled operating mode or setting

Local operation:
Main Menu -> Settings -> Function -> Rectangular/PWM
Checkbox "PWM Mode": deactivate.
Press the "Edit" button.
"Mode" dropdown widget: Select operating mode.
Edit widgets "Level A" and "Level B," "Time A" and "Time B": Define settings for levels and dwell times.
Confirm with "OK".
Confirm the "Rectangular/PWM" window with "OK".
Start function with S+ -> Start.

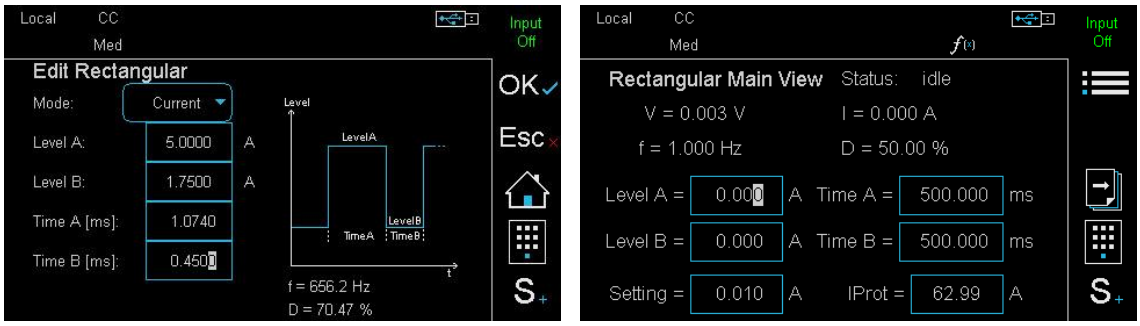


Figure 4.6: main view of rectangular function

Digital remote control:
See 5.11.13 RECTangle Subsystem

4.8 PWM Function

The PWM function is used to load a test object with a pulse width modulated signal, in which the settings for level, frequency, and duty cycle can be changed during execution of the function.

The technically feasible range for the frequency and duty cycle may be limited by the control speed or by the rise and fall times of the respective model (see technical data).

Local operation:
Main Menu -> Settings -> Function -> Rectangular/PWM
Check the "PWM Mode" box.
Press the "Edit" button.
"Mode" dropdown widget: Select operating mode.
Edit widgets "Level A," "Level B," "f," and "Duty cycle": Define settings for level, frequency, and duty cycle.
Confirm with "OK".
Confirm the "Rectangular/PWM" window with "OK".
Start function with S+ -> Start.

-

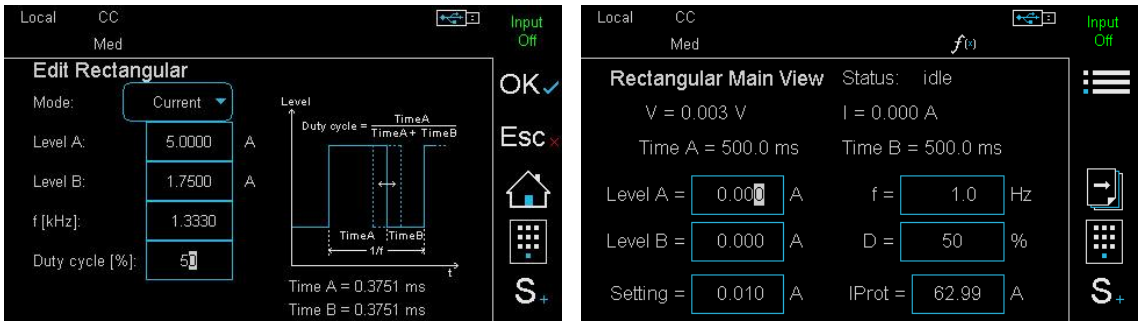


Figure 4.7: main view of PWM function

4.9 Modulator

In CC or CV operating modes, the modulator function superimposes a sinusoidal, square, or triangular signal on the constant base load. Amplitude and frequency can be set with high resolution. See also advanced function 4.10 Frequency Sweep.

The amplitude and frequency of the modulator are not calibrated. The technically feasible range for the frequency may be limited by the control speed or by the rise and fall times of the respective model (see technical data).

Possible conflicts:
The modulator function cannot be activated when one of the following functions is already active:

- internal resistance measurement
- discharge function
- list function
- rectangular function
- MPPT function
- externally controlled operating mode or setting

Local operation:
Main Menu -> Settings -> Function -> Modulator
"Type" dropdown widget: Select waveform.
"Mode" dropdown widget: Select the control mode.
"Level (DC)" edit widget: Enter the base load level.
"Frequency" edit widget: Enter frequency.
Edit widget "Amplitude": Enter the amplitude.
Confirm with "OK".
Start function with S+ -> Start.

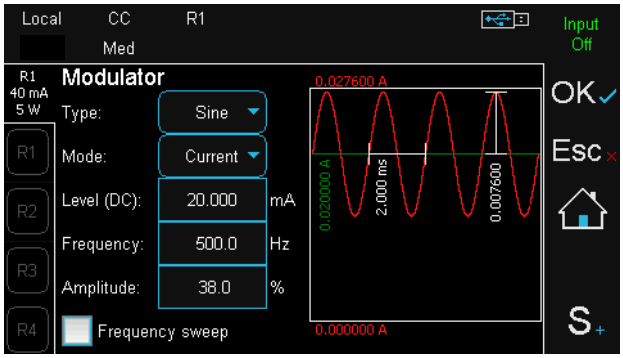


Figure 4.8: dialog window of modulator function

Digital remote control:
See 5.11.6 FUNCtion Subsystem (FUNCtion:MODulate).

4.10 Frequency Sweep

An advanced feature of the modulator is the modulator sweep. This function corresponds to a frequency sweep using the waveform set in the modulator function (see 4.9 Modulator).
By specifying the start, end, and step frequencies, as well as a defined dwell time for each frequency step, the frequency of the superimposed modulation is varied.

Local operation:
Main Menu -> Settings -> Function -> Modulator
Define modulator base function, see 4.9 Modulator.
„Edit" button: go to „Modulator Frequency Sweep" dialog.
Edit widget „Start frequency": enter start frequency.
Edit widget „End frequency": enter end frequency.
Edit widget „Step frequency": enter frequency step.
Edit widget „Step dwell": enter step duration.
Set „Continuous execution" or number of cycles by „Count".
Confirm with "OK".
Start function with S+ -> Start.

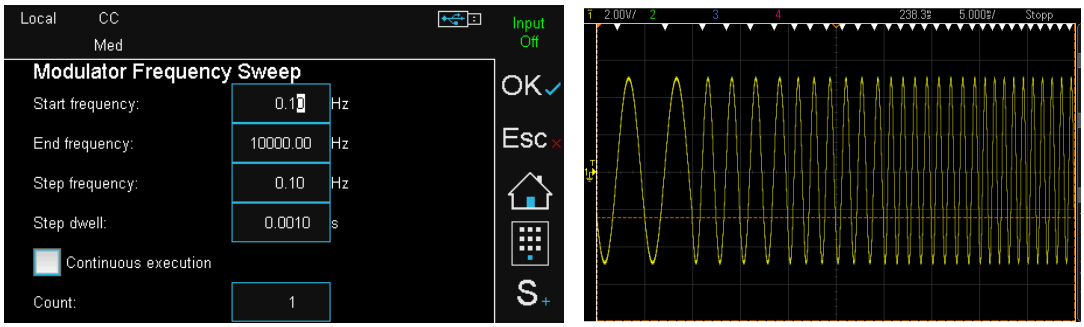


Figure 4.9: dialog window of frequency sweep (l), frequency sweep oscillogram

Digital remote control:
See 5.11.6 FUNCtion Subsystem (FUNCtion:MODulate:SWEep).

4.11 List Function

The electronic load can simulate load profiles in so-called LIST mode, both in local operation and when remotely controlled via a data interface. This is possible in all operating modes.

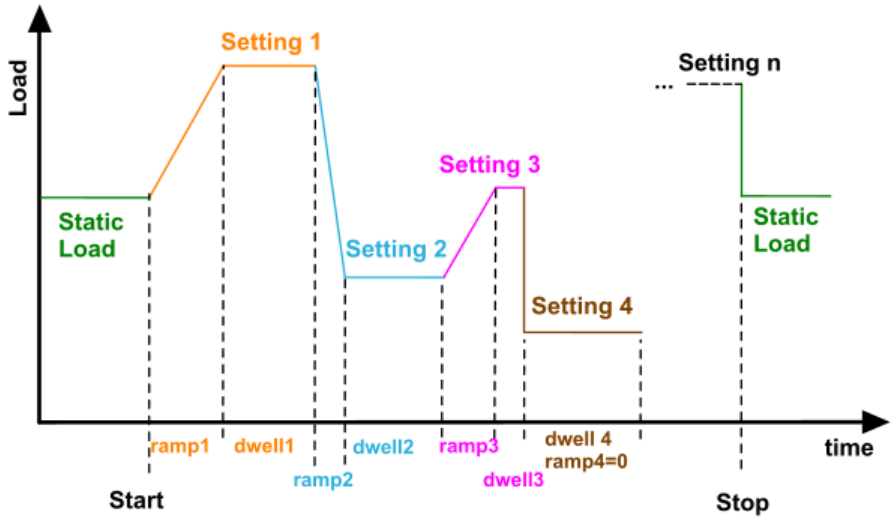


Figure 4.10: load profile with n LIST elements

4.11.1 Terminology

Load profile
A load profile consists of a series of straight lines that form a continuous function for the setting to be controlled (current, power, resistance, voltage).

Setting list
The setting list is used to define a load profile and contains the settings for the corresponding operating mode. A value in the list represents the setting that is controlled in LIST mode during the dwell time (see below).
A reset sets the list length to 0.

List mode
The list mode defines the operating mode (Current, Power, Resistance, Voltage) in which the list is to be executed. The list mode selects the corresponding setting list.
A reset sets the list mode to Current.

List of ramp times

This list is used to define a load profile. A value in the list represents the time duration for the rise/fall to the corresponding next setting.
A reset sets the list length to 0.

List of dwell times
This list is used to define a load profile. A value in the list represents the time duration for which the corresponding setting is set.
A reset sets the list length to 0.

List of sampling times in the ramps
This list is used to define measurement intervals for the corresponding ramps of a load profile. The list for sampling times does not need to be defined if measurement data acquisition is not activated.
A reset sets the list length to 0.

List of sampling times in the dwell times
This list is used to define measurement intervals for the corresponding dwell times of a load profile. The list for sampling times does not need to be defined if measurement data acquisition is not activated. A reset sets the list length to 0.

List set
A list set consists of the lists for the load profile (settings, ramp times, dwell times). The elements with identical indexes in the individual lists (of a list set) define a single section of the load profile.
In a valid list set, the lengths of all lists are > 0 and identical, i.e., all lists contain the same number of elements.
A reset sets the length of all lists in a list set to 0. The list set is then invalid and the list cannot be executed.

List count
The number of passes determines how often the complete list set is executed after startup.
A reset sets the number of passes to 1.

Measurement data set/measurement data point
A measurement data point is a set of three measured values consisting of a timestamp, voltage value, and current value. When reading a measurement data record, these three values are separated from each other by a comma followed by a space.

4.11.2 List Set Definition

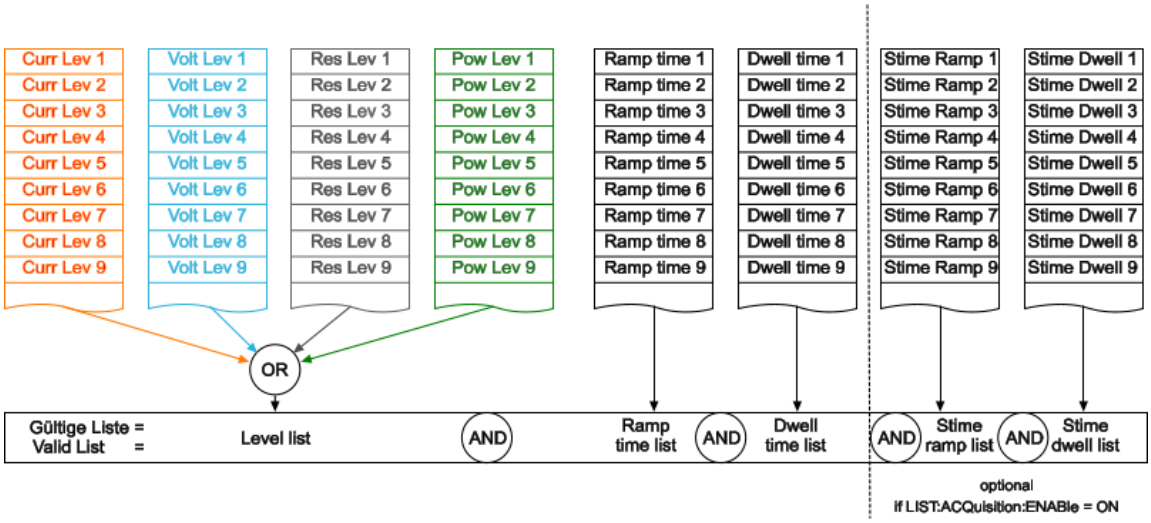


Figure 4.11: list memory usage

Figure 4.11 shows the internal memory usage of the lists in the electronic load. A valid "list set" consists of three lists of equal length. The "Level list" setting list is selected depending on the list mode. The lists for the ramp times and dwell times are used for all operating modes. As a result,

when changing the operating mode, the user may have to update the lists for the ramp time and dwell time of the new list mode.

When measurement data acquisition is active during list execution, the two lists for the sampling times ("Stim ramp list" and "Stim dwell list") behave in the same way as the lists for the ramp time and dwell time.

Local operation:
Main Menu -> Settings -> Function -> List
"New" button: Switch to the "Initialize New List" dialog box.
"List mode" dropdown widget: Select list mode.
If voltage and current are to be recorded synchronously during list execution, activate the "Data acquisition" checkbox.
Confirm with "OK".
In the following "New List" dialog box, define the settings for level, ramp time, dwell time, and, if necessary, sample times for the first list section.
Increment the value for "Point" and repeat the process for all list sections.
Individual list points can be inserted after the currently displayed list point using the "Add" button.
The "Delete" button removes the displayed list point.
Confirm with "OK".

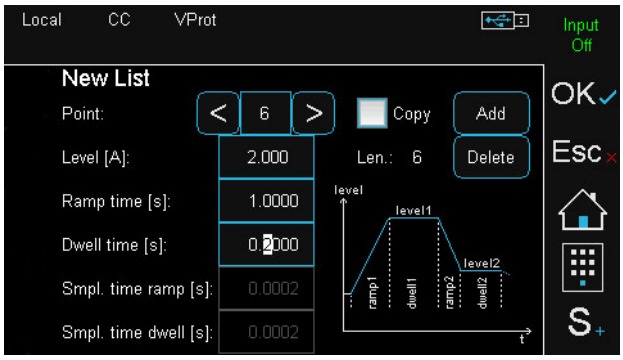


Figure 4.12: dialog window for defining a load profile

In the "List" dialog box, use the "Enter" button to edit additional settings for the list function as needed.

Once a valid list has been defined, the list is activated (but not yet started) and the function symbol $f(x)$ is displayed in the status bar.

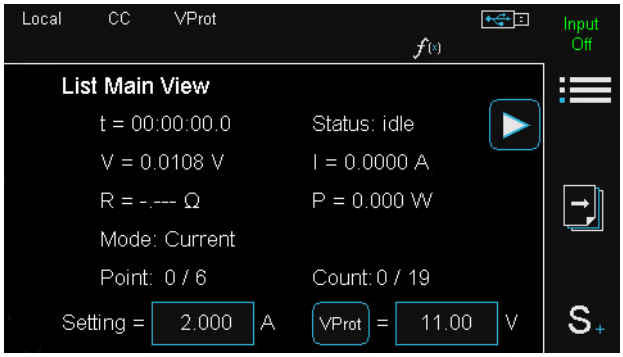


Figure 4.13: main view of the list function

Digital remote control:
See 5.11.8 LIST Subsystem

4.11.3 Importing a List File

As an alternative to manually creating or programming the list function using SCPI commands, there is an import function for list files. The required file can be created on a PC using the Load Control Tool and transferred to a USB flash drive. The list files with the extension *.lst must be located in the "LIST" subdirectory of the root directory of the USB flash drive. The prepared file can then be imported into the electronic load via the "Import list from USB" dialog.
Structure of a valid list file:

```
[LIST_MODE]\n
VOLT\n
\n
[LIST_COUNT]\n
6\n
\n
[LIST_ACQ]\n
ON\n
\n
;comment
[LIST_VALUES]\n
1,234, 2,566, 2,854, 0.001,
0.01;comment\n
2,168, 3,987, 3.1, 0.02, 0.003\n
;comment\n
5.78, 6.77, 9.6, 0.01, 0.1\n
\n
```

A valid list file must contain the following elements:

- Tag "[LIST_MODE]"
- Operating mode after the tag "[LIST_MODE]"
- Tag "[LIST_COUNT]"
- Number of list repetitions after tag "[LIST_COUNT]"
- Tag "[LIST_ACQ]"
- Activation status of synchronous data acquisition after tag "[LIST_ACQ]"
- Tag "[LIST_VALUES]"
- List values after day "[LIST_VALUES]"

Each line must be terminated with a line feed ('LF' or '0x0A' or '\n'). The data section is terminated with an additional blank line.

LIST_MODE:
Operating mode in which the list function is executed. Valid identifiers for the operating mode are: CURR, CURRENT, VOLT, VOLTAGE, POW, POWER, RES, and RESISTANCE (upper/lower case is ignored).

LIST_COUNT:
The value for the number of list repetitions must be a positive value between 1 and 4E9. An infinite list execution can be achieved with the value 9.9E37.

LIST_ACQ:
Measurement data acquisition by the list function can be activated with "1" or "ON" and deactivated with "0" or "OFF". If measurement data acquisition is activated, there must be 5 setting values per list point: setting, ramp time, dwell time, sampling time for the ramp time, and sampling time for the dwell time. If measurement data acquisition is deactivated, only the setting values for the setting, ramp time, and dwell time are required.

LIST_VALUES:
The list values of the individual reference points are arranged according to the following scheme:

Setting in A, V, W, or Ω, ramp time in s, dwell time in s[, sampling time ramp in s, sampling time dwell time in s]
e.g. 1.234, 2.566, 2.854, 0.001, 0.0002

The list values must be entered in a valid format for floating point numbers in accordance with IEEE 754 in the respective base unit (A, V, Ω, s). The values may also be specified in exponential form. A comma is used as the separator between the individual values of a data point. The list entries must be followed by a blank line.

A semicolon indicates a comment. Comments can be on a separate line or at the end of a line. The characters between the semicolon and the next line feed are not evaluated.

Possible messages after loading the list file:

List imported successfully (x steps)	The list (x list items) was loaded successfully.
Line x; Invalid char. or separator missing	There is an invalid character in line x or the separator is missing.
Line x; Blank line missing	A blank line is missing in line x.
LIST_MODE tag not found	Tag "[LIST_MODE]" not found.
LIST_MODE value not found	No valid operating mode found for LIST_MODE.
LIST_COUNT tag not found	Tag "[LIST_COUNT]" not found.
LIST_COUNT value not found	No valid value found for the number of list repetitions.
LIST_ACQ tag not found	Tag "[LIST_ACQ]" not found.
LIST_ACQ state not found	No valid value found for the status of the measurement data acquisition.
LIST_VALUES tag not found	Tag "[LIST_VALUES]" not found.
LIST_VALUES data not found	No valid values found for LIST_VALUES.
Line x; LIST_VALUES data missing	At least one required setting value for the list item in line x is missing.
Line x; Value out of range	List value in line x outside the valid range.
SBP data error	An error occurred when querying the minimum and maximum setting values.
Sample time values missing	The sample times for the ramp time and dwell time are missing (only displayed if LIST_ACQ is enabled).
Line x; Too long data string, end missing	The length of line x is greater than 70 characters.
List exceeds max. length	The maximum list length has been exceeded (see technical data for max. list length).
Could not open file	Could not open list file.
Could not close file	Could not close list file.
Could not open directory	Could not open directory LIST.
USB flash drive not found	The USB flash drive could not be found.

Local operation:
Main Menu -> Settings -> Function -> List
"Import" button: Switch to the "Choose File" dialog box (only if a USB flash drive is plugged into A2). Select file from list. Confirm with "OK." Press the "Import" button in the "Import List" dialog box.

4.11.4 List Execution

To execute the list function , a valid list set must be stored in the device (see 3.3.2 Structure of a valid list set). The list function can be started with the corresponding SCPI command, with the key sequence "Shortcut" -> "Start" or with a trigger event. The device automatically switches to the operating mode in which the list function is to be executed. While the list is running, the FUNC bit in the Operation Status Register is set.

If the load input is switched off during list execution, list execution is paused and resumed when the load input is switched back on. After a list has been completed or aborted, the device switches back to the previously set static operating mode with the corresponding setting. The load input remains switched on after list execution.

Local operation:
Shortcut S+ -> Start
The list starts as soon as the key sequence is executed. The device automatically switches to list mode . While the list is running, the FUNC bit in the operation status register is set and LIST is displayed in the status bar.

Shortcut S+ -> Stop
The list execution is stopped. The load input is switched off. After a list has been completed or canceled, the device switches back to the previously set basic operating mode with the corresponding setting .

Digital remote control:
See 5.11.8 LIST Subsystem

4.11.5 List Execution by Trigger

If list execution is to be started or stopped by a trigger event, the processing of trigger events must be activated by the list function.

Local operation:
Main Menu -> Settings -> Function -> List
"List settings": Press Enter.
Activate the "Trigger controlled" checkbox.

Digital remote control:
See 5.11.8 LIST Subsystem, 5.11.19 TRIGger Subsystem, ABORt Subsystem, INITiate Subsystem

4.11.6 Data Acquisition by List Function

Synchronous to the execution of a list, measurement data sets with defined sampling rates can be stored in the electronic load. A corresponding sampling rate is specified for each list section. When data recording is activated, voltage and current are measured synchronously and stored with the corresponding relative time stamp.

This function uses the fast ADC. For details, see 5.11.9 MEASure Subsystem and technical data.

Data recording during execution of the list function must be explicitly activated. A reset deactivates data recording.

A data record consists of a relative timestamp, voltage value, and current value. When the available data memory is full, the oldest data is overwritten with the new data according to the ring buffer principle. This is signaled by setting the MEM status in the Questionable Status Register and displaying it in the status bar of the user interface. This status remains until either a data record is read, all data records are deleted, or the list function is restarted.

To avoid overflowing the measurement data memory, measurement data records should be continuously removed from the memory during long measurements. The stored data records can be read out from the electronic load individually or in blocks of up to 100 data records per retrieval.

Local operation:
See 4.11.2 List Set, 4.14 Reading Data from Internal Memory.

Digital remote control:
See 5.11.3 DATA Subsystem, 5.11.8 LIST Subsystem

4.11.7 List Example with Data Acquisition

Programming example: Load profile with two current values (50 A, 20 A) and activated measurement data acquisition:

```
CURR 10;INP ON
LIST:MODE CURR
LIST:CURR 60,20
LIST:RTIM .025,.005
LIST:DWEL .01,.02
LIST:STIM:RTIM .005,.0025
LIST:STIM:DWEL .001,.01
LIST:COUN 10
LIST:ACQ ON
LIST:STAT ON
```

This example generates a load current curve according to Figure 4.14. The green markers are measurement points.

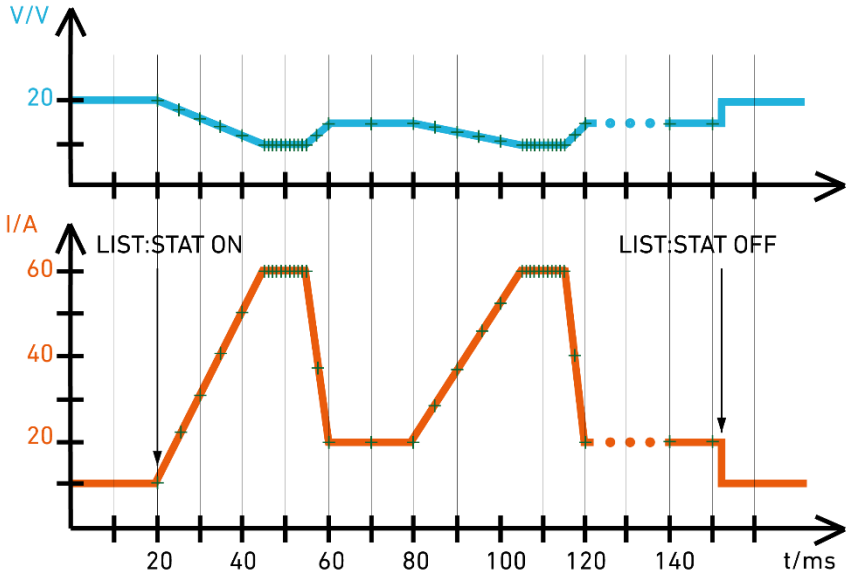


Figure 4.14: example of a list with synchronous data acquisition

4.11.8 General Information About the LIST Function

The usable time settings may be limited by the rise and fall times of the respective model (see technical data).

There is a separate setting list for each list mode. The lists for the ramp and dwell times are used for all list modes.

Possible conflicts:
The LIST function cannot be activated when one of the following functions is already active:

- internal data acquisition
- internal resistance measurement
- rectangular function

- MPPT function
- externally controlled operating mode or setting

The list mode cannot be changed while a list is running. When attempting to change list modes, or if any other specified conflict occurs while a list is running, the load generates a Settings Conflict Error. (see 9.1 Error Codes).

4.12 Measurement Data Acquisition

4.12.1 Internal Measurement Data Acquisition (ACQ)

For applications with a high sampling rate and high temporal accuracy, measurement data acquisition with a definable sampling rate can periodically acquire measured values for voltage and current and buffer them with a time stamp in the internal device memory. The measured values are acquired synchronously in time.

This function uses the fast ADC. For details, see 5.11.9 MEASure Subsystem and technical data.

A data record consists of a relative time stamp, voltage value, and current value. When the end of the available data memory is reached, the oldest data is overwritten with the new data according to the ring buffer principle. This is signaled by displaying MEM in the status bar on the user interface and setting the MEM bit in the Questionable Status Register. This state remains until either a data set is read or the measurement data acquisition is restarted.

If measurement data acquisition is to be started or stopped by a trigger event, the evaluation of trigger events must be activated by measurement data acquisition (see also 4.24 Trigger Model).

Internal measurement data acquisition cannot be performed while a list function or sweep function is running.

Local operation:
Main Menu -> Settings -> Acquisition
Checkbox "Enable state": Activate measurement data acquisition.
"Sample rate [s]" edit widget: Enter the measurement rate.
When you exit the window with "OK," data acquisition is activated and starts when the load input is switched on.

Digital remote control:
See 5.11.1 ACQuisition Subsystem, 5.11.3 DATA Subsystem

4.12.2 Data Logging on USB Flash Drive

For long measurements with a low sampling rate and low temporal accuracy, the electronic load can save measured data (for voltage and current) displayed during local operation directly to an external USB flash drive. To do this, a USB flash drive must be connected to the USB port A2.

This function uses the slow ADC. For details, see 5.11.9 MEASure Subsystem and technical data.

The measured values for time, voltage, and current are logged at an adjustable storage interval and immediately saved to the USB flash drive in the "Logging" directory.

Local operation:
Main Menu -> Data -> USB Logging
Edit widget "Sample time [s]": Enter the sampling interval.

Edit widget "DUT directory": The number entered here corresponds to the directory name on the USB flash drive (see4.15 Folder Structure on USB Flash Drive).
"Start" button: Start storing measured values.
See also 4.15 Folder Structure on USB Flash Drive .

4.13 Data Transfer According to IEEE 488.2 – Binary Block Data

Data transfer according to the IEEE 488.2 standard enables the transfer of measurement data in a defined binary block format. This method ensures more efficient and faster transfer of large amounts of data.

Binary block data transfer is used exclusively for reading measurement data. Using the SCPI command `DATA:REM?`, measured values can be retrieved in a compact binary format, which significantly reduces the transfer time compared to ASCII data.

1	2	3	4	5
'#'	number of elements that follow (ASCII) <nonzero digit>	number of bytes that follow (ASCII) <digit(s)>	binary data (non-ASCII) <8 bit data bytes>	termination character

Example:
#3144<data>NL
Start character
3 Number of subsequent digits
144 Number of data bytes to be transmitted
<data> Binary block data in IEEE 754 format
NL End character

The SCPI command `FORM:DATA REAL,32` is used to activate binary block data transfer. This configures data transfer in IEEE 754 format, which stands for precise and fast transfer of floating point numbers.

The byte order can be switched between little endian and big endian using the command `FORM:BORD NORM|SWAP`.

Binary block data transfer according to IEEE 488.2 can only be used via the RS-232, USB, and LAN communication interfaces. Use via GPIB and CAN is not possible.

Digital remote control:
See 5.11.3 DATA Subsystem, 5.11.5 FORMat subsystem

4.14 Reading Data from Internal Memory

The measured values buffered in the internal device memory (see4.11.6 Data Acquisition by List Function or4.12 Measurement Data Acquisition) are read out as follows.

Local operation:
Main Menu -> Data -> Export
Edit widget "DUT directory": A directory with the specified number is created on the USB flash drive, in which the read data is stored.
"Export" button: Start reading the data.

Digital remote control:
See 5.11.3 DATA Subsystem

4.15 Folder Structure on USB Flash Drive

Certain functions of the electronic load can save measurement data or measurement results to a connected USB flash drive (e.g., measurement data acquisition). The generated files are stored with the following directory structure:

Export/import device settings:
The electronic load can export the current device settings to a USB flash drive or import them from a USB flash drive. These "Settings" files must be located in the "SETTINGS" subdirectory in the root directory.

Exporting measurement data and measurement results:
The load creates a folder in the root directory of the USB flash drive, whose name is composed of the device series and the device number. To be able to assign the exported files to a test object, the user has the option of specifying a test object number in the respective dialog windows of the functions. This test item number is used to create the folder "DUTxx" (xx = test item number). In the DUT folder, subfolders are created based on the function performed, in which the measurement data and results are then stored.

4.16 Voltage Sweep Function

The voltage sweep function, which can only be operated via the user interface, is used to determine the U/I characteristic curve of test objects.

To do this, a voltage ramp is defined using the start and end voltage and the corresponding duration of the sweep process. The ramp can be ascending or descending.

This function uses the fast ADC. For details, see 5.11.9 MEASure Subsystem and technical data.

After starting the voltage sweep function, the electronic load sets the value of the start voltage. The sweep process begins after a delay of one second. The load continuously changes the voltage value until the end voltage is reached. This is followed by another one-second pause. During the sweep process, the measurement data is recorded using the internal ACQ function. The electronic load sets the sampling time so that a maximum of 360 measurement points are recorded.

After the function has been executed, the recorded measurement data can be viewed in the graphical "Data Viewer" or exported to a connected USB flash drive.

The usable time settings may be limited by the rise and fall times of the respective model (see technical data).

The voltage sweep function cannot be executed during ongoing internal measurement data acquisition.

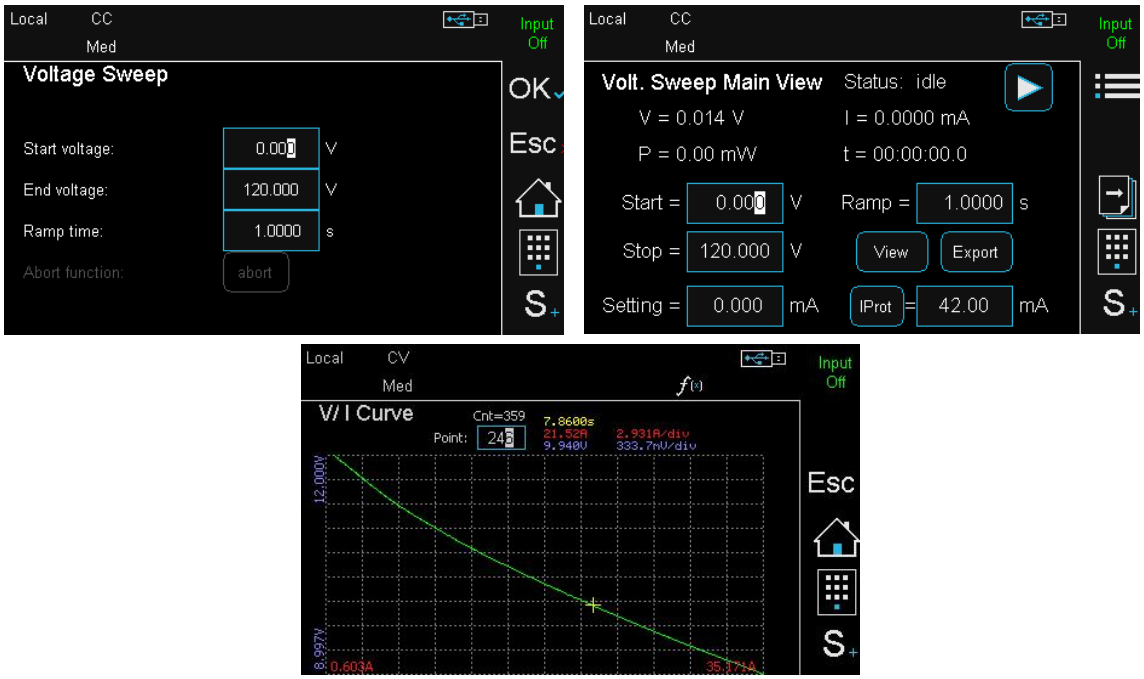


Figure 4.15: configuration, main view, and resulting curve of the voltage sweep function

Local operation:
Main Menu -> Settings -> Function -> Voltage Sweep
Edit widgets "Start voltage" and "End voltage": Enter values for start and end voltages.
"Ramp time" edit widget: Enter the duration of the sweep process.
Confirm with "OK."
In the function-specific main view "Voltage Sweep Main View," adjust the current limit in the "IProt" edit widget if necessary.
"Setting" edit widget: Adjust the setting of the still active static operating mode if necessary.
Start the sweep with the shortcut S+ -> Start and wait for it to finish.
"View" button: Display the recorded curve in the Graphical Data Viewer.
"Export" button: Export recorded data to a USB flash drive. See also 4.15 Folder Structure on USB Flash Drive

4.17 Discharge Function

To test energy storage devices such as batteries, ultracaps, and capacitors, the electronic load can discharge a connected test object in a controlled manner and provide the values for the charge and energy consumed.

During local operation, the user is guided through the menu so that the device requests some important settings, such as current and voltage limitation.

You start the discharge by switching on the load input with the discharge function activated and the load preselected. To do this, you must have at least one stop condition activated for local operation.

During ongoing discharge, the load accumulates the charge taken from the test object in Ah and the energy in Wh every second. These are displayed on the user interface along with the current measured values for voltage and current and the elapsed discharge time.

The test object connected to the load input is subjected to the selected load until one of the activated stop conditions is fulfilled.

Operating mode for discharge

The discharge function is possible in principle in every operating mode. The following operating modes are available for local operation:

- Current mode
- Power mode
- Resistance mode
- Dynamic discharge in list mode

Enter the setting for the selected operating mode directly in the "Level" window. You can also change this later during static discharge.

Dynamic discharge

4.18 The discharge function offers the option of discharging a DUT in a controlled manner using a dynamic load profile. For this application, a valid load profile must first be created using the list function (see 4.10 Frequency Sweep

An advanced feature of the modulator is the modulator sweep. This function corresponds to a frequency sweep using the waveform set in the modulator function (see 4.9 Modulator).
By specifying the start, end, and step frequencies, as well as a defined dwell time for each fre step, the frequency of the superimposed modulation is varied.

Local operation:
Main Menu -> Settings -> Function -> Modulator
Define modulator base function, see 4.9 Modulator.
„Edit“ button: go to „Modulator Frequency Sweep“ dialog.
Edit widget „Start frequency“: enter start frequency.
Edit widget „End frequency“: enter end frequency.
Edit widget „Step frequency“: enter frequency step.
Edit widget „Step dwell“: enter step duration.
Set „Continuous execution“ or number of cycles by „Count“.
Confirm with "OK".
Start function with S+ -> Start.

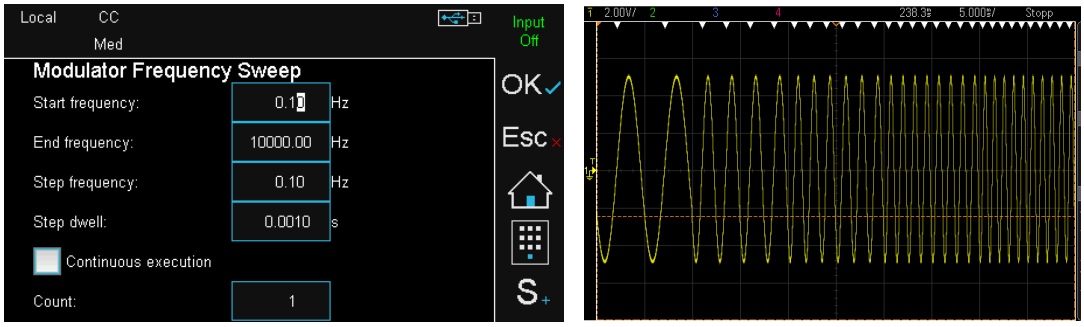


Figure 4.9: dialog window of frequency sweep (l), frequency sweep oscillogram

Digital remote control:
See 5.11.6 FUNCtion Subsystem (FUNCtion:MODulate:SWEep).

List Function).
Then, the "List" entry can be selected in the "Discharge Mode" dialog box. After starting the discharge function with the key sequence Shortcut -> Start, the list and discharge functions are executed together.

In digital remote control mode, the list and discharge functions must be started separately.

IUa discharge, CC+CV discharge

A special type of discharge is CC+CV or IUa discharge. In this case, the test object is first discharged with constant current up to a defined minimum voltage (setting of the undervoltage protection). When this voltage is reached, the electronic load implicitly switches to voltage mode, i.e., the specified voltage is kept constant until the measured current has fallen below the value of the current stop condition (see below). Only then does the load switch off the load input and the test is completed.

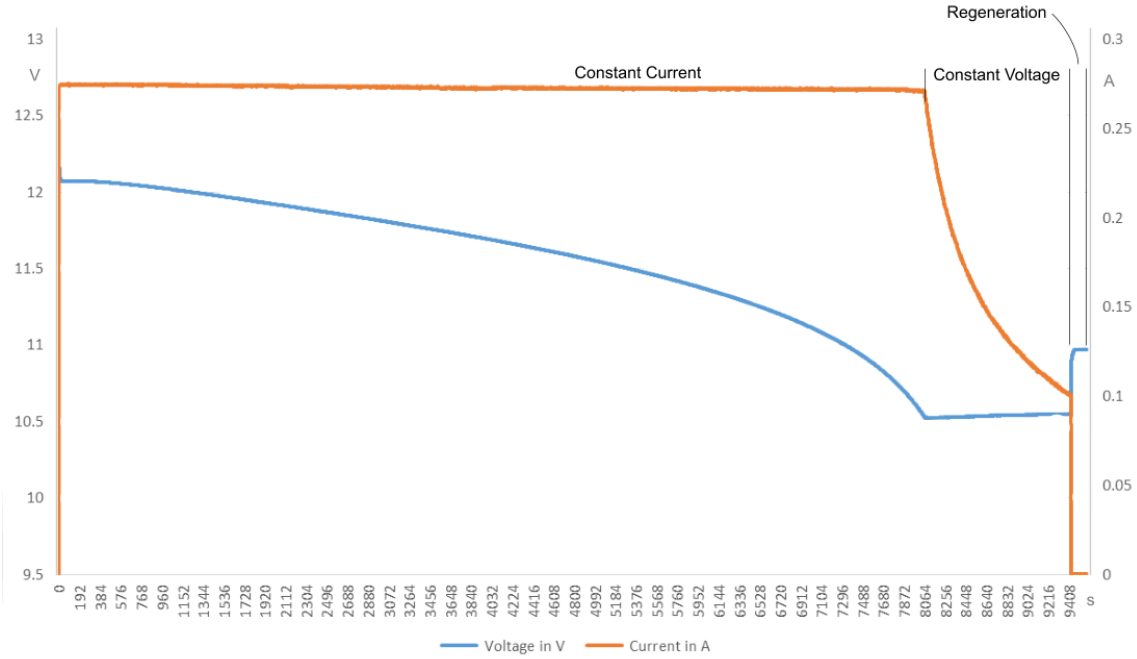


Figure 4.16: IUa discharge with 0.27 A and 10.5 V voltage protection. Switch-off condition: current with 0.1 A

You can implement an IUa discharge by specifying the value of the minimum voltage to be regulated as the setting for the undervoltage protection and activating and defining the current stop condition.

Stop conditions

The following stop conditions can be activated independently of each other:

- Charge
- Energy
- Time
- Current
- Voltage

With digital remote control, the stop conditions can also be changed during ongoing discharge.

The stop conditions charge, energy, and time are checked for exceeding the specified values, while the stop conditions current and voltage are checked for falling below the specified values. This means that discharging stops, for example, when the cumulative charge is greater than or equal to the specified stop value or when the measured voltage is less than or equal to the specified stop value.

If one of the activated stop conditions is reached, the electronic load switches off the load input and deactivates the discharge function.

Static measurement data acquisition

Static measurement data acquisition can be activated for digital remote control to store measurement data (see 4.12 Measurement Data Acquisition).

Measurement data acquisition with follow-up time to USB memory

When operating locally, the electronic load can record the measured values on a USB flash drive (see 4.12.2 Data Logging on USB Flash Drive).

The special feature of the discharge function is that you can define a follow-up time for data logging in order to document the recovery phase of the test object after shutdown (see section "Regeneration" in Figure 4.16).

Possible conflicts:
The discharge function cannot be activated when one of the following functions is already active:

- internal resistance measurement
- rectangular function
- MPPT function
- externally controlled load input activation state

Local operation:
Main Menu -> Settings -> Function -> Discharge
"Initialize function": Press "Enter."
In the following dialog box "Discharge Stop Conditions," activate and define at least one shutdown condition. Confirm with "OK."
In the following dialog box "Discharge Mode and Protection," adjust the settings for operating mode, level, and protection functions. Confirm with "OK."
In the following "Discharge" dialog box, complete the configuration of the function by pressing "OK".
In the function-specific main view "Discharge Main View," start the discharge function with the shortcut S+ -> Start.

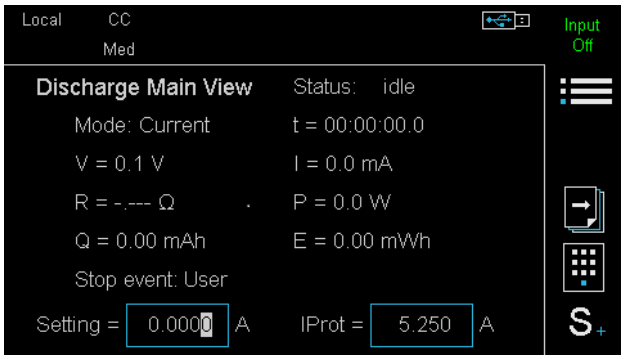


Figure 4.17: main view of the discharge function

Digital remote control:
See 5.11.6 FUNCtion Subsystem: commands `FUNCtion:DISCharge`

4.19 Internal Resistance Measurement

The electronic load can measure the DC internal resistance of the connected device under test.

This function uses the fast ADC. For details, see 5.11.9 MEASure Subsystem and technical data.

The determination of the internal resistance is based on the principle specified in various standards for batteries and accumulators, e.g., DIN EN 61951, DIN EN 61960: the terminal voltage of the test object is measured at two defined load levels at intervals of a few seconds.

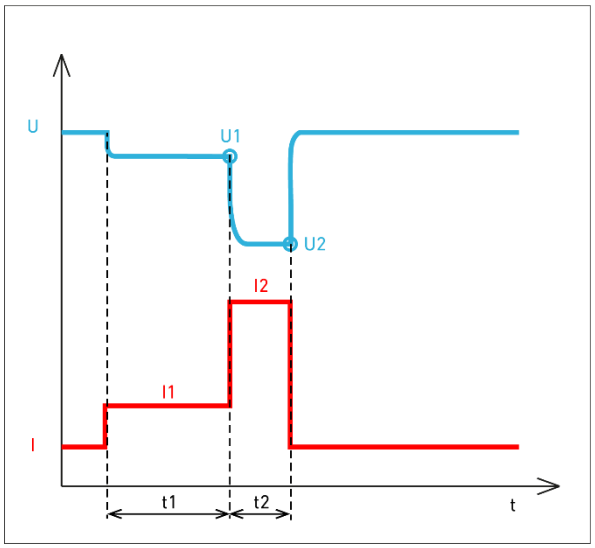


Figure 4.18: principle of internal resistance measurement

At the end of the first load level I1, the voltage U1 is measured on the test object. Then the second, higher load level is immediately set, at the end of which the voltage U2 is measured. The load then calculates the internal resistance from the quotient of the measured voltage and current difference:

Ri = (U1-U2)/(I2-I1)

The load levels I1 and I2 as well as the dwell times t1 (for I1) and t2 (for I2) are adjustable. The second load level I2 must be higher than I1, otherwise the electronic load will generate a settings conflict error when starting the measurement function.

When operated locally, the electronic load can save the parameters and the measurement result to a connected USB flash drive.

To measure internal resistance, connect the sense terminals to the test object, otherwise the voltage drop on the load lines will distort the measurement result.

Possible conflicts:
Internal resistance measurement cannot be activated when one of the following functions is already active:

- discharge function
- list function
- rectangular function
- MPPT function
- externally controlled operating mode or setting

Local operation:
Main Menu -> Settings -> Function -> Ri Measurement
Define the settings for current level and time in the "Current/Time 1" and "Current/Time 2" edit widgets. Confirm with "OK."
Start the measurement function in the function-specific main view "Ri Main View" with the shortcut S+ -> Start.

4.20 MPP Tracking

The Maximum Power Point Tracking function (MPPT function) enables solar or photovoltaic modules to be tested by the electronic load regulating the maximum power point of the connected test object by varying the voltage setting in voltage mode.

This function uses the fast ADC. For details, see 5.11.9 MEASure Subsystem and technical data.

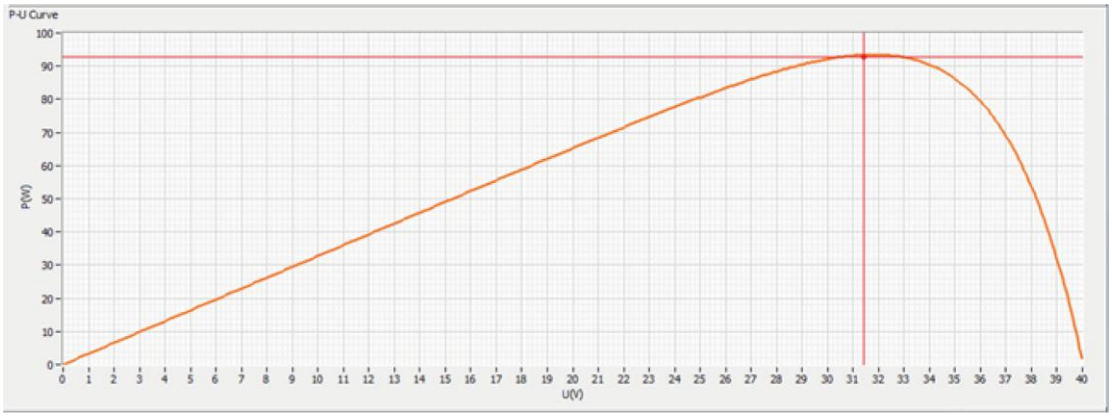


Figure 4.19: power-voltage characteristic with MPP

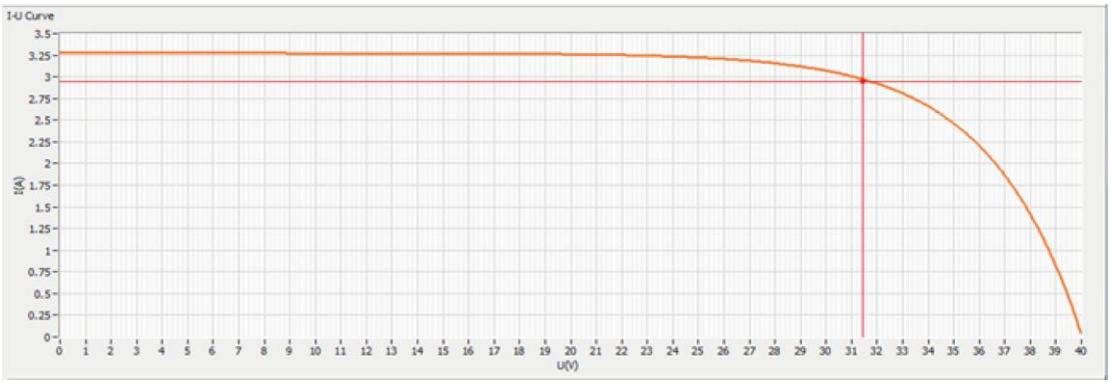


Figure 4.20: current-voltage characteristic with MPP

4.20.1 Terminology

MPP
The MPP (Maximum Power Point) is the operating point at which the test object (solar/PV module) delivers the most power. The last MPP found/regulated is displayed on the user interface and can be queried via a data interface.

Sweep
The MPPT sweep function measures the open-circuit voltage Uoc of the test object, measures the U/I characteristic curve, and determines the global MPP on this basis.

Sweep duration
The sweep duration determines how long a single sweep lasts. It is set via the user interface or via a data interface.

Sweep period
The sweep period determines the interval at which a sweep is performed. It is set via the user interface or via a data interface.

Sweep direction
The sweep direction determines whether the voltage is reduced from the open-circuit voltage Uoc of the device under test to 0 volts (down direction) or whether the voltage is increased from 0 volts to the open-circuit voltage Uoc (up direction). The sweep direction can be specified via the user interface or a data interface.

Sweep measurement data
The measured sweep measurement data represents the U/I characteristic curve of the device under test with 100 points. It is composed as follows:
<Volt_0>,<Curr_0>,<Volt_1>,<Curr_1>,...,<Volt_99>,<Curr_99>
The sweep measurement data can be queried via a data interface. The number of measurement points of the last sweep can also be queried via a data interface. If the number is 0, no sweep has taken place yet.

Cumulative energy
Energy in Wh that has been drawn from the test object since the MPPT function was activated. When the MPPT function is activated, the energy in Wh is accumulated starting at 0 until the function is deactivated. If the load input is switched off while MPPT is running, the accumulation is paused until the input is switched on again. The value is retained even after the function is deactivated until the MPPT function is restarted.
The energy value is displayed on the user interface in the main view and can be queried via a data interface.

Control accuracy ΔP
The control accuracy determines the accuracy with which the MPP is readjusted. Starting at the MPP of the last sweep, the voltage is varied in the same direction until the power has decreased by ΔP · MPP. Then the direction of the voltage variation is reversed until a maximum power is found again, which then decreases by ΔP · MPP, and so on.
The MPP control accuracy is stored as a non-volatile device parameter (see 9.2 Device Parameters). This parameter is set to the default value when the device is reset to factory settings (Factory Reset or SYSTem:PRESet).

Minimum voltage
The minimum voltage determines the open-circuit voltage of the test object at which sweep and tracking are performed.
The minimum voltage is stored as a non-volatile device parameter (see 9.2 Device Parameters). This parameter is set to the default value when the device is reset to factory settings (Factory Reset or SYSTem:PRESet).

4.20.2 MPPT Function

The function consists of two sub-functions, sweeping and tracking, which alternate continuously at an adjustable interval (sweep period duration). A sweep can also be forced via a data interface, provided that the electronic load is not already performing a sweep at that moment.

To start MPP control, the MPPT function must be activated and the load input switched on. If the measured open-circuit voltage is greater than the minimum voltage, the electronic load performs a sweep and then adjusts to the MPP found during the sweep.

The U/I characteristic curve is displayed together with the U/P characteristic curve in the function graph of the user interface.

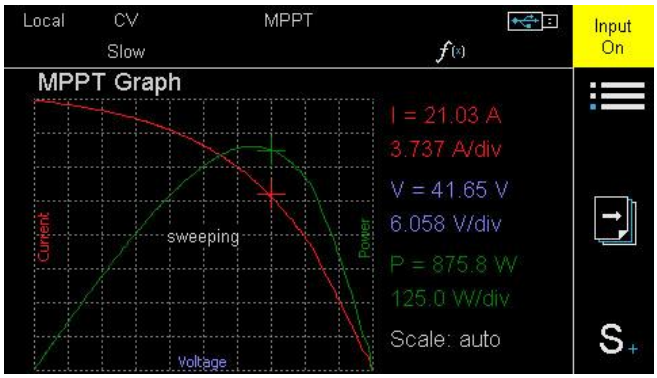


Figure 4.21: U/I and U/P characteristic curves

Possible conflicts:
The MPPT function cannot be activated when one of the following functions is already active:

- internal resistance measurement
- discharge function
- list function
- rectangular function
- externally controlled operating mode or setting

Local operation:
Main Menu -> Settings -> Functions-> MPPT
Define settings for sweep duration, sweep period, and sweep direction. Confirm with "OK."

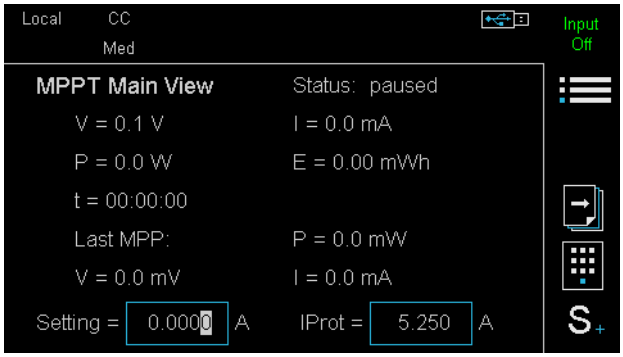


Figure 4.22: main view of MPPT function

Digital remote control:
See 5.11.6 FUNCtion Subsystem .

4.21 Master-Slave Operation in System Connection

4.21.1 Functions and Terms

To increase power or current, electronic loads of the same type can be operated in parallel as a single system in master-slave mode.

The master unit regulates the entire input current of the system. It also displays the measured values of the system on the user interface and returns them when queried via one of the data interfaces (except CAN). The voltage measured at the master unit is the basis for the regulated settings in voltage, power, and resistance mode.

System unit
An electronic load is a system unit . It operates in one of the system operating modes: single, master, or slave. The factory setting for the system operating mode is single. The system operating mode is not changed during a reset or when switching off and on.

connection
A system connection consists of at least two system units: exactly one master device and up to four slave devices.

Single mode
In single mode, the electronic load is not connected to any other units via the CAN interface or the I/O port. All device functionality and all data interfaces are available without restriction.

Master operation
In master mode, the system unit controls one or more system units in slave mode via the CAN interface and the I/O port.

Slave mode
In slave mode , the system unit is controlled by the master unit via the CAN interface and the I/O port. With the exception of a few diagnostic functions, it cannot be operated otherwise.

4.21.2 Requirements for a System Connection

- All system units must be of the same series and type.
- The firmware version (major and minor version) of all system units must be identical.
- When switching on the master unit, all slave units must already be switched on, or all units must be switched on simultaneously.

4.21.3 Restrictions in Master-Slave mode

Restrictions in the system network:

- Functions for measured value acquisition and management (ACQuisition, DATA, and LIST:ACQuisition subsystems) are not available.
- Functions for discharging/battery testing (DISCharge) are not available.
- Functions for internal resistance measurement are not available (MEASure:IRESistance).
- Functions for maximum power point tracking (MPPT) are not available.
- Calibration functions (Subsystem SERVice:CALibration) are not available.
- Functions for setting and reading device parameters are only available to a limited extent (Subsystem SERVice:PARameter).

Master device limitations:

- Firmware updates cannot be performed.
- The external CAN interface is not available for communication with a control computer.
- When using the K-MS-HES master-slave cable, the I/O port is only available with SubD25 Doppler (optional accessory).
- Individual functions, menu entries in the user interface, and SCPI commands are not available or are only available to a limited extent.

Slave device restrictions:

- Communication via the data interfaces is not possible.
- The menu structure of the user interface is reduced to a few diagnostic functions.

- When using the K-MS-HES master-slave cable, the I/O port is only available with SubD25 Doppler (optional accessory).

4.21.4 Establishing a System Connection

1. Switch on all system units. Leave load inputs switched off.
2. Set the electronic load that controls the other units and is to display the total measured values to master mode.

   Local operation:
   Main Menu -> Configuration -> Master/Slave
   Dropdown widget "Unit mode": Select "Master". Confirm with "OK". Close the following notification window.

   Digital remote control:
   See 5.11.18 SYSTem Subsystem
3. In the same way, set slave mode with slave address 2 on the first electronic load to be controlled by the master unit.
4. If necessary, set up to three additional electronic loads in slave mode. Set slave addresses 3 to 5.

Each address may only exist once in the system! If multiple addresses are used, the system will malfunction and calculate incorrect measured values.

5. Connect the load inputs of all system units to the test object as shown in Figure 4.23 twisted. Run the cables of all system units to the test object; do not connect them to the system units!

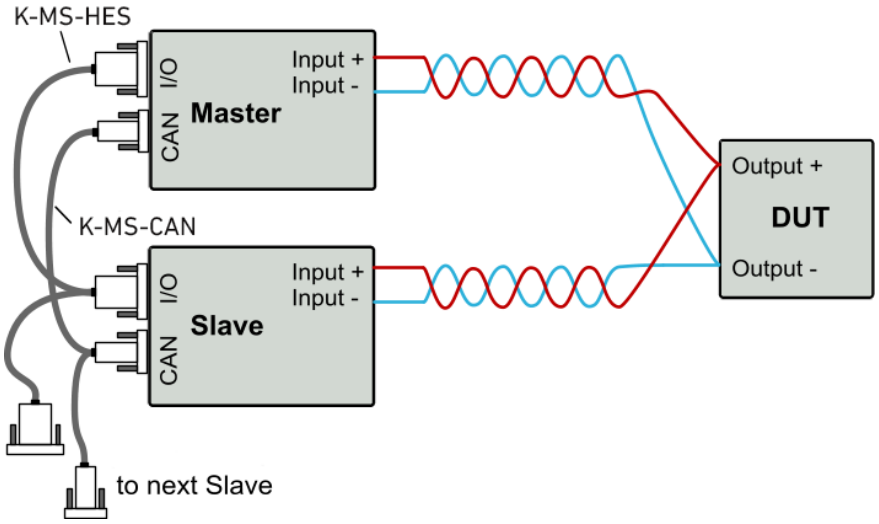


Figure 4.23: wiring in master-slave mode

Series connection of the load inputs to increase the input voltage is NOT permitted!

6. Switch off all system units.
7. Connect the CAN interfaces of all system units with K-MS-CAN cables. Connect the I/O ports of all system units with K-MS-HES cables.
8. Switch on all slave units.
9. Switch on the master unit.

   Each system unit now displays the active system operating mode ("Master" or "Slave") and the address of the system unit in the status bar.

The system network is now configured and can be controlled via the master unit. The master unit determines the current consumption and input status of the slave units and displays measurement and status values for the entire system network.

4.21.5 Dissolving the System Connection

1. Switch off the load inputs on all system units.
2. Set all system units to single mode.

   Local operation:
   Main Menu -> Configuration -> Master/Slave
   Select "Single" in the "Unit mode" dropdown widget. Confirm with "OK." Close the following notification window.

   Digital remote control:
   See 5.11.18 SYSTem Subsystem.
3. Switch off all system units.
4. Disconnect all K-MS-HES cables from the I/O ports and all K-MS-CAN cables from the CAN interfaces.
5. Switch on all system units.

4.21.6 Pin Assignment of the K-MS-HES Cable

There is a 25-pin D-sub connector at both ends of the cable.

Pin assignment:

Master			Slave*	
Pin	Signal		Pin	Signal
24	GND	←→	24	GND
5	/STAT-ON	←→	9	/INP-ON
1	GNDA	←→	3	LEVEL10V-
15	IMON	←→	16	LEVEL10V+

* and additional slaves

The K-MS-HES cable is used to connect two system units. It also provides a coupling for connecting an additional slave unit.

A K-MS-HES cable is required for each additional slave unit.

4.21.7 Pin Assignment of the K-MS-CAN Cable

There is a 9-pin D-sub socket at both ends of the cable.

Connector pin assignment:

Master			Slave*	
Pin	Signal		Pin	Signal
2	CAN_L	←→	2	CAN_L
3	GND	←→	3	GND
6	GND	←→	6	GND
7	CAN_H	←→	7	CAN_H

* and additional slaves

The K-MS-CAN cable is used to connect two system units. It provides a coupling for connecting an additional slave unit.

A K-MS-CAN cable is required for each additional slave unit.

4.22 Measurement Data Display

There are various types of measured value and measurement data display in local operation.

In addition to displaying measured values in numerical format, the Yt graph shows the temporal progression of voltage, current, and/or power. The Yt graph is displayed by touching the scroll icon in the main view.

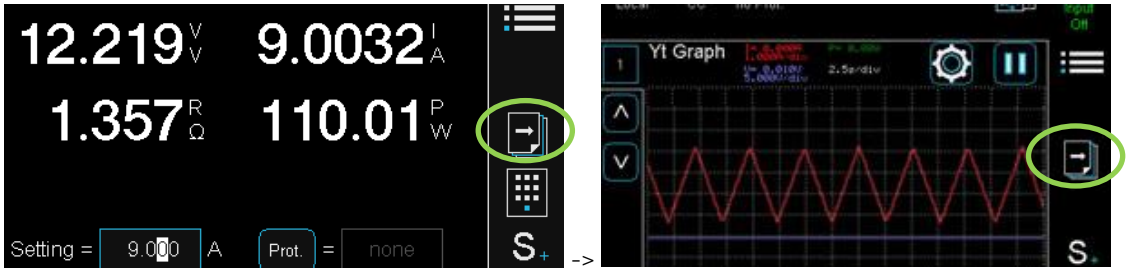


Figure 4.24: main views of measured values/data

Local operation:
Main view -> Scroll icon

4.23 Fan Control

The devices feature automatic fan control . The fan speed is switched between two levels depending on the temperature of the power stage.

In some applications, it is advantageous to keep the temperature of the power stage as low as possible. To do this, the fan control can be set from "Automatic" to "Full" so that the fans run at maximum cooling capacity.

Local operation:
Main Menu -> Settings -> Basic settings -> Cooling

Digital remote control:
See 5.11.18 SYSTem Subsystem

4.24 Zero-Volt Function

In order to operate load models with minimum input voltages higher than 0 V up to short-circuit, an external auxiliary voltage can be connected to compensate for the internal losses of the device, see Figure 4.25. This makes the electronic load suitable for recording current limiting characteristics up to short-circuit.

To use this auxiliary voltage, activate the zero-volt function in the Basic Configuration menu or send the corresponding command to the load in remote control mode.

If a load current greater than the test object can supply is set in current mode, the voltage of the test object collapses to 0 V and the short-circuit current flows.

In voltage mode, the load voltage can be set to 0 V.

In resistance mode, the resistance range is extended to 0 ohms. If the Sense terminals are connected, the short-circuit is regulated to the point where the Sense terminals are connected to the output terminals of the device under test.

This means that the resistance of the load cables is also taken into account and compensated for during regulation. To do this, the load terminals can even become slightly negative in order to compensate for the voltage loss on the load cables. This allows a near-short-circuit to be set despite the resistance of the cable on the device under test.

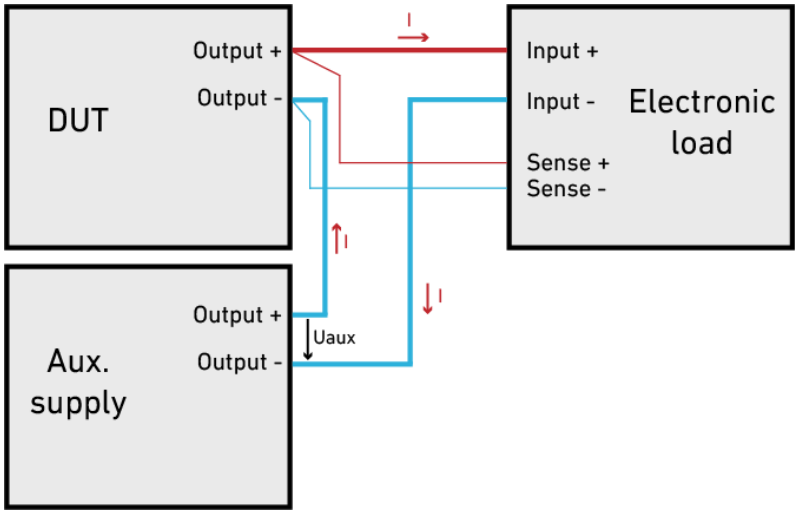


Figure 4.25: connection of an auxiliary voltage with the zero-volt function activated

Power reduction due to external auxiliary voltage

The power limitation of the electronic load is calculated from the voltage measured at the sense inputs. However, when using an auxiliary voltage as shown in Figure 4.25 , the power measured by the load is lower than the actual power.

The remaining power Pmax for the test depends on the load current and is calculated using the following formula:

$$P_{max} = P_{cont} - (I \cdot U_{aux})$$

Pmax: Remaining maximum test power for electronic load
Pcont: Continuous power of the electronic load (see technical data)
I: Load current
Uaux: Auxiliary voltage

A power higher than Pmax can destroy the electronic load. The maximum power Pmax must therefore not be exceeded!

The auxiliary voltage should be as low as possible.
We recommend 3.5 V. It must not exceed 5 V.
It must be able to supply the maximum current that occurs.

During fast control processes in the range around 0 volts, transient voltage reversal up to the level of the applied auxiliary voltage Uaux may occur at the test object due to transient processes.

- ➢ Ensure that the device under test is not damaged by short-term voltage reversal!
- ➢ If necessary, connect a reverse-polarity diode to the load circuit!

The quality of the auxiliary voltage is also decisive for the quality of the input variable to be controlled. Interference on the auxiliary voltage may affect the controlled variable.

To enable loads up to 0 volts, the undervoltage protection must be set to 0.0 volts and operated in control mode when the zero-volt function is activated (see 4.3.2 Undervoltage Protection).

Local operation:

Main Menu -> Settings -> Basic settings -> Zero voltage
Activate the "Enable zero voltage" checkbox. Confirm with "OK."

Digital remote control:
See 5.11.6 FUNCtion Subsystem

4.25 Trigger Model

Various trigger actions can be triggered in digital remote control mode by a trigger event :

- Set triggered settings for all operating modes
- Set activation status of load input, list function, and measurement data acquisition

4.25.1 States in the Trigger Model

A system-specific trigger model (see Figure 4.26) is integrated in the electronic load.
Possible states:

- IDLE: The trigger model is in idle mode. The electronic load is not waiting for a trigger. Trigger events in IDLE mode cause an error. The IDLE mode is entered after the ABORt command or after a reset.
- INITIATED: In the INITIATED state, the device is waiting for a trigger event.
- ACTION: The trigger actions are executed. Afterwards, the IDLE state is resumed if continuous initialization is deactivated. Otherwise, the INITIATED state is resumed.

4.25.2 Trigger Delay and Holdoff Time

A delay time (trigger delay) can be defined for the state transition from INITIATED to ACTION, after which the triggered actions are executed.

Similarly, a holdoff time can be defined for the state transition from ACTION to IDLE or INITIATED to prevent unintentional repeated triggering, e.g., in the event of bouncing of the external trigger signal.

The latency time (delay time) from the arrival of a trigger command (*TRG) to the execution of the trigger action can be found in the technical data.

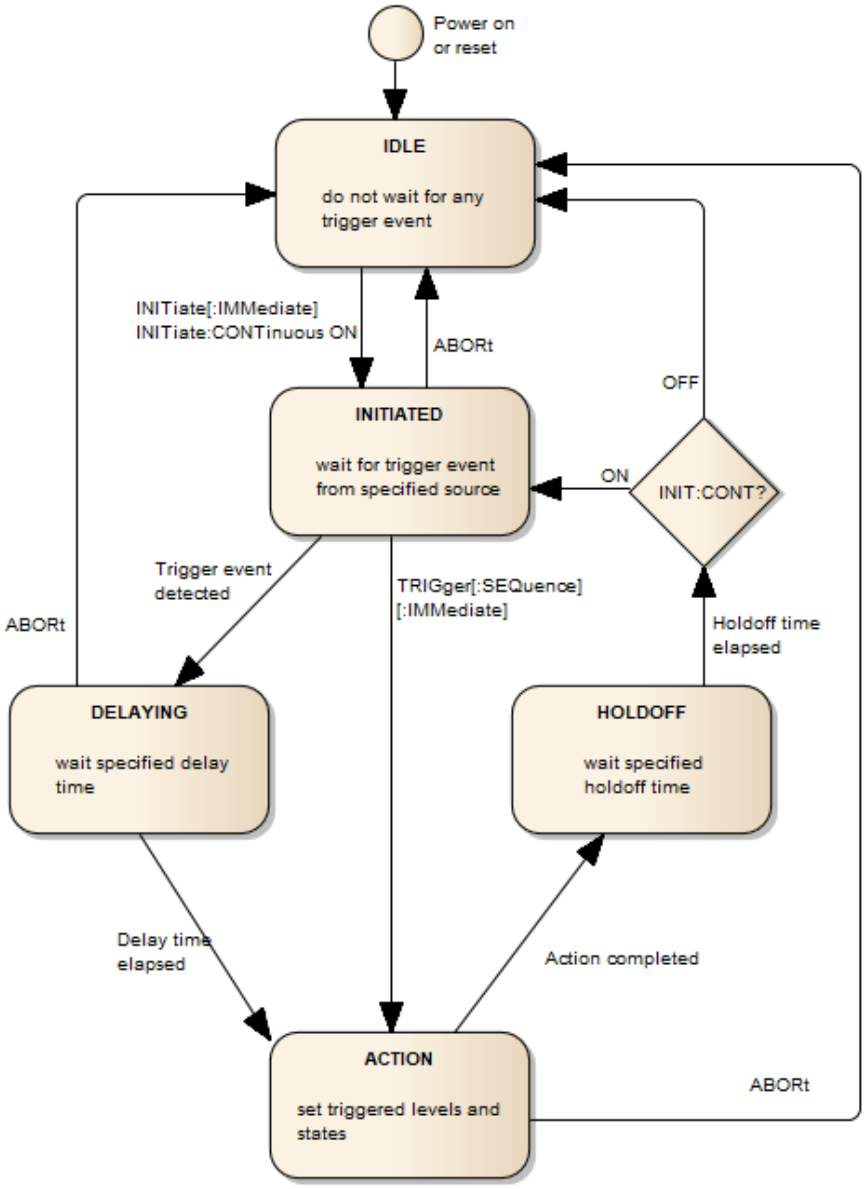


Figure 4.26: trigger model

4.25.3 Trigger Sources

A trigger event is only accepted by the selected trigger source . One of the following sources can be selected:

- BUS: Trigger command on a communication interface
- EXTernal: Trigger input signal at the I/O port
- HOLD: Detection of a trigger event is deactivated
- MANual: Shortcut combination S+ -> Manual Trigger
- VOLTage: Level of the input voltage
- CURRent: Level of the input current

If a trigger event occurs whose source is not selected, the load generates a trigger ignored error, e.g. if the trigger button is pressed in the INITIATED state but BUS is active as the trigger source.

For the trigger input signal at the I/O port (trigger source EXTernal), for the input current (trigger source CURRent), and for the input voltage (trigger source VOLTage), the edge (SLOPe) that generates a trigger event can also be specified:
- Rising edge only (POSitive)
- Falling edge only (NEGative)
- Rising or falling edge (EITHer)

Trigger voltage

In some applications, it is advantageous to start a specific action, e.g, a defined load curve, by applying a specific input voltage. To do this, the trigger source can be set to Voltage and a trigger voltage can be defined.

The set trigger edge ( ) also applies to this trigger source, i.e., with a rising edge, a trigger event is generated when the measured input voltage exceeds the value of the programmed trigger voltage. Conversely, a trigger event is generated on a falling edge when the measured input voltage falls below the programmed trigger voltage value.

Trigger current

Similar to the trigger source voltage, an action can be started by the level of a certain load current. To do this, the trigger source can be set to current and a trigger current can be defined.

The set trigger edge also applies to this trigger source, i.e, on a rising edge, a trigger event is generated when the measured input current exceeds the programmed trigger current value. Conversely, a trigger event is generated on a falling edge when the measured input current falls below the value of the programmed trigger current.

Local operation:
Main Menu -> Settings -> Trigger
Edit widget "Delay time": Define trigger delay.
"Hold off time" edit widget: Define trigger hold-off time.
"Source" dropdown widget: Select source for trigger events. If "External" is selected, the trigger edge that generates trigger events must be specified in the "Slope" dropdown widget. If "Current" or "Voltage" is selected, the current or voltage level that generates a trigger event must also be defined in the "Level" edit widget.
"State" dropdown widget: Activate the trigger system with "Single" or "Cont.".
Confirm with "OK".

Digital remote control:
See 5.10.12 *TRG , 5.11.19 TRIGger Subsystem, ABORt Subsystem, INITiate Subsystem

4.26 SyncroLink

4.26.1 Function

The SyncroLink function enables the synchronization of multiple electronic loads (across series) using a trigger signal to ensure simultaneous operation of the devices. It offers precise synchronization and deterministic behavior, making it ideal for applications where multiple loads need to be controlled synchronously.

SyncroLink uses the physical RS-232 interface to transmit the synchronization signal.
One device acts as the SyncroLink master, which generates the synchronization signal, while the other devices act as SyncroLink slaves and receive the signal. Which device is the SyncroLink master or slave is determined by a special SyncroLink cable that is connected via the RS-232 ports of all devices. See Figure 4.27 and Figure 4.28.

All devices in the SyncroLink network must initially be configured via another data interface (e.g., LAN or USB).

Configuration example for activating the load input:
Configure RS-232 interface:
Local operation:
Main Menu -> Configuration -> Communication -> RS-232 Configuration
Select "Mode": Select "SyncroLink". Confirm with "OK".

Digital remote control:
`SYST:COMM:SER:MODE SLIN`
This setting becomes active after a restart and remains permanently stored.

Activate SyncroLink:
Digital remote control: `SYST:SLIN ON`
Activate triggered load input: `INP:TRIG ON`
Initialize trigger system continuously: `INIT:CONT ON`
Generate synchronization signal, only on SyncroLink master: `*TRG`

The synchronization signal is then distributed by the master device to all connected slave devices via the SyncroLink cable.

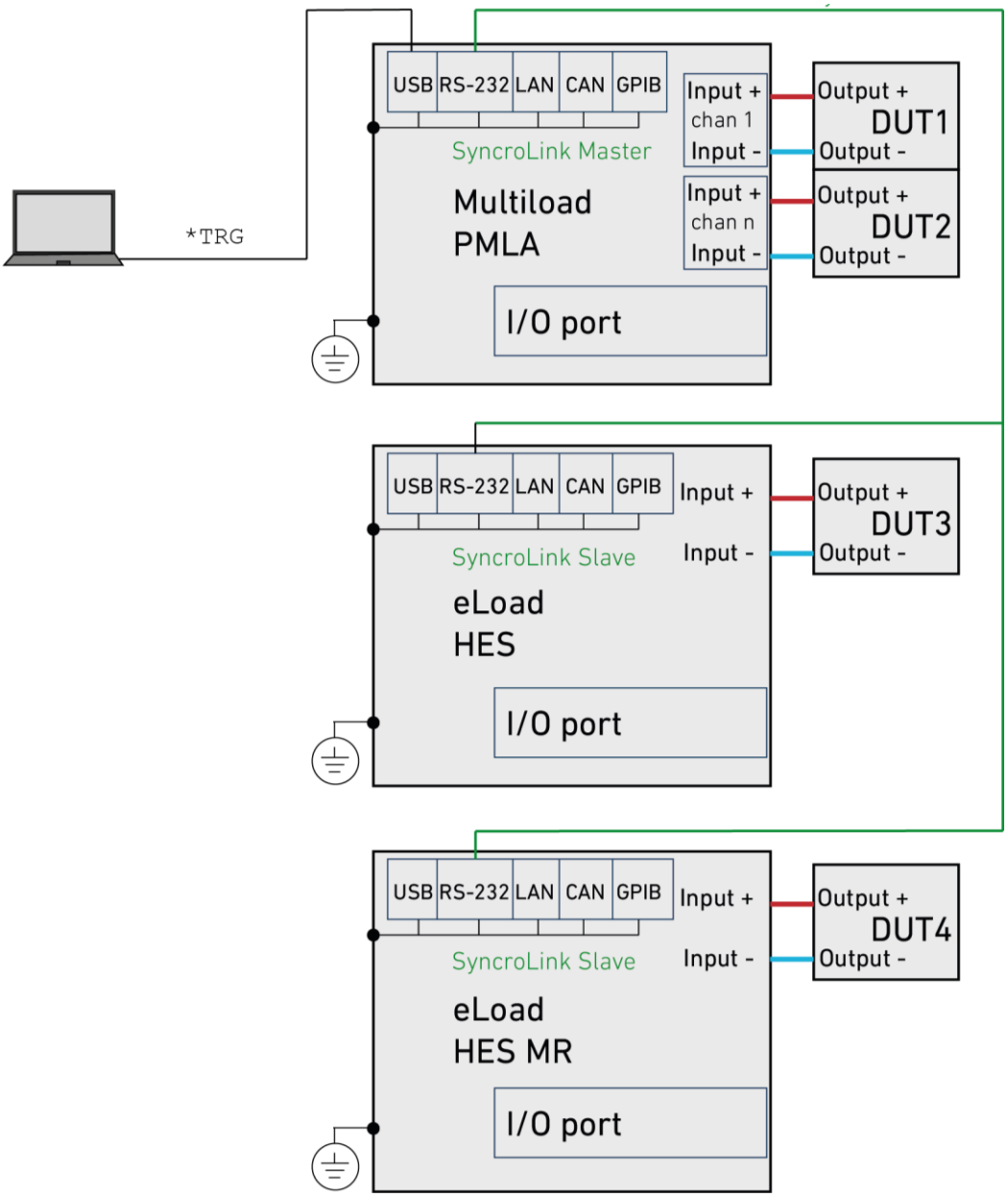


Figure 4.27: interconnection of multiple devices with SyncroLink

Advantages

- High synchronism: The SyncroLink function offers synchronization with a delay of typically less than 300 µs.
- Deterministic behavior: The load input is executed within a predictable time frame.
- No I/O port required: The RS-232 interface is used as the physical medium; the I/O port is not required.
- Galvanic isolation of the devices

4.26.2 Pin Assignment SyncroLink Cable

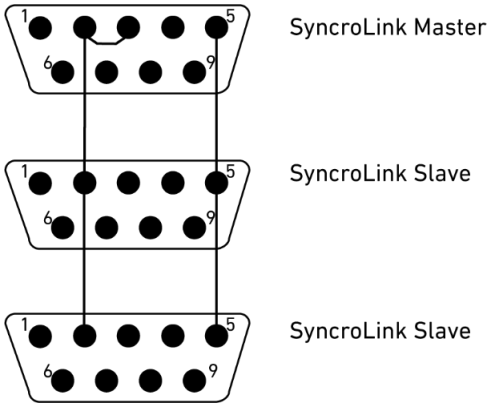


Figure 4.28: SyncroLink cable wiring

Detailed information on this can be found in Application Note No. 21 on the H&H website:
www.hoecherl-hackl.com/download/10805/

4.27 Voltage Connection and PWM Operation

Electronic loads from H&H are suitable for voltage application and operation at PWM voltages.

To avoid inrush current peaks when applying the input voltage or during the rising edge of the PWM voltage, the setting for the undervoltage protection of the electronic load should be adjusted to the value of the input voltage. This means: set the setting for the undervoltage protection to a value greater than 0 V and less than the input voltage.

To achieve the shortest possible dead time until the load current flows, set the fast control (see 4.3.2 Undervoltage Protection).

Detailed information on this can be found in Application Note No. 7 on the H&H website:
www.hoecherl-hackl.com/download/1259/

4.28 Watchdog

The electronic load has a watchdog function that switches off the load input if the previously programmed watchdog delay time expires without the watchdog being reset.

The watchdog delay time is set to a defined time in seconds via SCPI command. Another command activates the watchdog. When the watchdog is active, a control program must ensure that the command to reset the watchdog is sent to the electronic load cyclically before the delay time expires.

When the watchdog is reset, the time starts counting down again from the programmed delay time. If the time expires without a watchdog reset command, the load switches off the load input and sets the WDP status. In this case, the watchdog must be switched off to reactivate the load input.

The watchdog does not change the setting for the input state.

Digital remote control:
See 5.11.7 INPut Subsystem

4.29 Keylock

To prevent unintentional or unauthorized operation of the electronic load, the keylock can be activated.

The keylock can be activated and deactivated locally using the key sequence Shortcut -> Lock or remotely using the SCPI command SYSTem:KLOCk ON|OFF.

If the keylock is activated locally, a lock symbol with 'L' for "Local lock" is displayed in the main menu. The locally activated keylock can be deactivated manually (repeat Shortcut Lock) or remotely.

If the keylock is activated remotely via one of the data interfaces, a lock symbol with "R" for "Remote Lock" is displayed in the main menu. Remote activation of the keylock can only be deactivated remotely. The remote attribute overrides the local attribute.

Local operation:
Shortcut S+ -> Lock
Shortcut S+ -> Unlock

Digital remote control:
See 5.11.18 SYSTem Subsystem

4.30 Remote Notification

To alert the operator to a specific situation, a control unit can emit acoustic and/or optical signals on the device via one of the data interfaces.

4.30.1 Beeper

The `SYSTem:BEEP` command causes the beeper to emit an acoustic signal of a specified duration.

Digital remote control:
See 5.11.18 SYSTem Subsystem

4.30.2 Notification Window

The `DISPlay:TEXT` command displays a specific message in a notification window on the user interface display.

If an empty string ("") is passed, the notification window is closed again. The operator can also acknowledge and close the notification window.

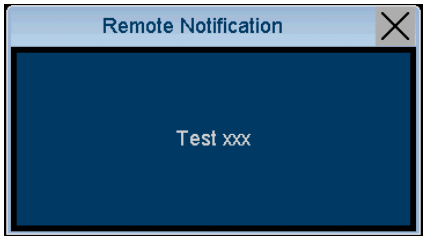


Figure 4.29: information text on user interface

Digital remote control:
See 5.11.4 DISPlay Subsystem

4.31 Configuring Alarm

Figure 4.30: alarm configuration

When critical conditions occur, the electronic load emits audible and visual signals.

An acoustic signal can be activated in the event of overtemperature and overpower (inactive by default). In the event of overvoltage or reverse polarity input voltage, a notification window is displayed in addition to the acoustic alarm signal, which the user must actively confirm (active by default).

For special applications in which the electronic load is to be operated specifically at the threshold of a critical condition, the OV, RV , and OTP/OPP (overtemperature protection/overpower protection) alarms can be activated or deactivated separately.

The "OTP, OPP (only acoustic)" setting activates the acoustic alarm signal for temperature and power limitation. No notification window is displayed for the device states OTP and OPP.

Overvoltage or reverse polarity cause a short-circuit without any current limitation! This can destroy the electronic load and the device under test!

- Use a fuse in the load circuit to ensure that the load current in the test setup is limited!
- Reactivate the messages as soon as the application with deactivated messages is finished!

Local operation:
Main Menu -> Configuration -> Alarms
Checkbox "OV (Overvoltage)": When checked, audible and visual warnings are active in case of overvoltage at the load input.
"RV (Reverse Voltage)" checkbox: When checked, audible and visual warnings are activated in the event of reverse polarity at the load input.
"OTP, OPP" check box: When checked, the acoustic warning is active in the event of overtemperature or power limitation.

4.32 Saving and Loading Device Settings

4.32.1 Internal Memory

The active settings can be stored non-volatile in the device so that they can be reloaded at a later time. To save the active settings, the user can choose from 9 available memory locations: memory locations 0 to 9.

Memory location 0 always automatically stores the last settings before the electronic load is switched off. Memory 0 is reserved for this purpose only and cannot be selected by the user to store settings. However, memory 0 can be selected for loading in the same way as memory locations 1 to 9.

In local operation, various settings to be loaded can be selected when switching on.

The following settings are saved when the memory function is executed and set when loading:

- Activation status of the load input
- Triggered activation status of the load input
- Basic operating mode for control
- Settings for all basic operating modes
- Limit values for current and voltage
- Operating mode for undervoltage protection
- Control speed
- Activation status for measurement data acquisition
- Measurement interval for measurement data acquisition
- Activation status for trigger evaluation by measurement data acquisition
- Activation status of external control
- Activation states of the individual external control signals
- Settings of all lists
- Operating mode for list execution
- Number of passes for the list set
- Activation status for list execution
- Activation status for measurement data acquisition during list execution
- Activation status for trigger evaluation by the list function
- Activation status for the unloading function
- Activation status of all stop conditions for the unloading function
- Values of the stop conditions of the unload function
- Activation status of the internal resistance measurement
- Current level and dwell times of the internal resistance measurement
- Activation status of the square wave function
- Operating mode of the square wave function
- Levels and dwell times for the square wave function
- Activation status of the modulation function
- Operating mode of the modulation function
- Relative amplitude, frequency, and signal shape for the modulation
- Activation status of the zero-volt function
- Activation status of the MPPT function
- Sweep direction of the MPPT function
- Sweep duration of the MPPT function
- Sweep period of the MPPT function
- Activation status for continuous trigger initialization
- Trigger source
- Trigger edge
- Trigger delay
- Trigger hold time
- Trigger current level
- Trigger voltage level
- SyncroLink activation status
- Activation status of the digital output on the I/O port
- Activation status of the local key lock

If a memory number is specified for loading in which no settings have been saved before, the load generates a "Memory use Error".

Local operation:
Main Menu -> Settings -> Save-Recall
Select memory location for loading settings when switching on:
Main Menu -> Configuration -> Power-on

Digital remote control:
See 5.10.7 *RCL, 5.10.9 *SAV

4.32.2 USB Memory

The settings active in the electronic load can also be exported to and imported from a connected USB flash drive. This allows settings for different test tasks to be saved and managed, for example. In addition, exporting the settings can facilitate support in the event of a support case.

To export the settings, the user can choose from 100 memory numbers. The settings are saved in the "Settings" directory of the connected USB flash drive. A corresponding subfolder is created for each memory number, which contains the settings file for the electronic load.

Naming scheme for the subfolder of the memory number:
HES_xx (xx = memory number)

To import settings, you can choose from the existing subfolders of the memory numbers in the "Settings" folder.

Structure of a valid settings file:

```
HES3206, 1.0, 2026-02-15 10:00:09
Unit mode: SINGLE
;Device number: 55418
;FW versions: AI1.0.1, DI1.0.0, UI1.0.3

[ACQ]
[:STAT]
1
[:STIM]
0.00215
[END_ACQ]

[CURR]
[:LEV:IMM]
2.158
[:PROT:LEV]
10
…
[END_CURR]

[FUNC]
[:MODE]
CURR
...
[END_FUNC]

[LIST]
[:CURR]
3.2588, 6.2411, 3.58712, 4.547212, …
...
[END_LIST]

[END_FILE]
```

A valid settings file must contain the following elements:

- Header with model name and version number of the settings file
- Subsystem start tags (e.g., [ACQ])
- Subsystem end tags (e.g., [END_ACQ])
- Command tags (e.g., [:TRIG:ENAB])
- Setting values after the command tags
- File end tag

In addition, each line must be terminated with a line feed ('LF' or '0x0A' or '\n').

Blank lines may be inserted (exception**:** in lists (e.g., LIST:CURR:LEV), a blank line means that no list is available).

A semicolon indicates a comment. Comments can be on a separate line or at the end of a line. The characters between the semicolon and the next line feed are not evaluated.

The following messages are possible after loading the settings file:

- Settings imported successfully: The system settings were loaded successfully.
- Could not open file: The settings file could not be opened.
- Could not close file: The settings file could not be closed.
- USB flash drive not found: The USB flash drive could not be found.
- Device mismatch error: The settings file and the target device do not match.
- Document version error: The major version number of the settings file does not match the firmware version of the user interface.
- Document version warning: The minor version number of the settings file does not match the firmware version -> Not all settings from the settings file may have been applied.
- Unknown tag error: An unknown tag was read.
- Read line error: An error occurred while reading a line from the settings file.
- Value error: A setting value is outside its valid range.
- Reset error: Error during device reset at the start of the import function.
- Error detected: An unspecified error has occurred.

Local operation:
Main Menu -> Settings -> Save-Recall

4.33 Reset Device Settings

When resetting " ," the electronic load is set to a defined device state.

Local operation:
Main Menu -> Settings -> Reset

Digital remote control:
See 5.10.8 *RST

4.34 Set Factory Settings (Preset)

When the factory settings are reset, all non-volatile device and interface settings are reset to their default values.

This function can be triggered using the `SYSTem:PRESet` command via one of the data interfaces.

Power-on
Power-on setting: Reset
Quick boot: OFF
RS-232
Mode: SCPI
Baud rate: 115200
Parity bit: None
Number of stop bits: 1
LAN
DHCP: On
Port: 1001
IP address: 192.168.0.1
Subnet mask: 255.255.255.0

Gateway: 192.168.0.254
DNS server: 192.168.0.253
GPIB
GPIB address: 7
CAN
Address: 1
Baud rate: 1000000
Termination: Off
User Interface
Display backlight intensity: 50%
Auto dimming: On
Time to dim: 30s
Help language: English
Alarms
OV: ON
RV: ON
OTP, OPP: OFF
Buzzer
Encoder sound: OFF
Settings memory
All deleted

The reset interface settings will only take effect after the device is turned off and on again.

Local operation:
Main Menu -> Configuration -> Factory Settings

Digital remote control:
See 5.11.18 SYSTem Subsystem

4.35 Firmware and User Manual Update

The firmware of all microcontroller-controlled components can be updated. This is done in cooperation with H&H, as only the manufacturer can assess the compatibility of the hardware and firmware as well as the components with each other.

To perform a firmware update, you need a FAT16 or FAT32 formatted USB mass storage device. Copy the hex file(s) and the corresponding operating instructions in PDF format, which you will receive from H&H Support, onto this device.

There is a corresponding hex file for each of the following three assemblies, which recognizes the electronic load based on the file name:

Module	File name
Analog Interface AI	*HES_AI_xx_yy_zz*.hex
Data Interface DI	*HES_DI_xx_yy_zz*.hex
User interface UI	*HES_UI_xx_yy_zz*.hex

xx_yy_zz stands for the firmware version number.

The files required for the update must be located directly in the root directory of the USB flash drive. In addition, there must be only ONE hex file per assembly in the root directory of the memory, otherwise the error message "multiple files" will appear. If the load does not find a file with the required file name for an assembly, "n.a." will appear in the relevant line.
The device cannot be operated during the firmware update.

Local operation:
Main Menu -> Service -> Firmware/User manual update

Insert the USB flash drive into the USB port A2 on the front of the device. Once the load has recognized the storage medium, use the corresponding checkboxes to select the assembly or assemblies whose firmware is to be updated. Proceed in the same way with the operating instructions (manual). Press "OK" to start the update of all selected components. The selected components will now be updated one after the other.

After you have updated all components, you must switch the load off and then back on again after 5 seconds.

4.36 User Manual Download

The operating instructions are stored in the device's internal memory and can be exported to a connected USB flash drive.

Local operation:
Main Menu -> Service -> User Manual
Insert the USB flash drive into the USB port A2 on the front of the device. Once the load has recognized the storage medium, press the Export button. The progress of the export is displayed graphically with a progress bar. The manual is copied as a PDF file to the root directory of the USB flash drive.

5 Digital remote control

The following data interfaces are available as standard for the electronic load:

- LAN (Ethernet)
- RS-232
- USB
- CAN

Optional extras:

- GPIB (option HES02)

Most device functions can be operated remotely in addition to manual operation. Only the CAN interface has a reduced command range compared to the other interfaces.

Standard settings
The standard interface settings are listed in chapter 4.34 Set Factory Settings (Preset).

5.1 Standards

The GPIB, LAN, RS-232, and USB bus interfaces implement the following standards for the transmitted commands and queries :
IEEE 488.1-1987
IEEE 488.2 -1992
SCPI Specification 1999.0
IEEE Std 1174-2000 for Performance Class 1
Universal Serial Bus Specification 2.0, Full Speed

5.2 Selecting and Deselecting Interfaces

An interface is automatically selected upon receipt of a valid command. Upon receipt of a query that triggers a response from the load, the response is sent back to the same interface from which the query originated.

As soon as the electronic load receives a valid command via one of the data interfaces, the load switches to the Remote state. The word "Local" at the top left of the user interface is replaced by the name of the active data interface (e.g., RS-232). A "Notification" window briefly appears on the user interface.

An interface is deselected by receiving a valid command via another communication interface if no query is open, i.e., if the response to a received query has been sent back.

Pressing a key (except "Shortcut" -> "Local") or the rotary encoder on the front panel is ignored in remote- mode. This is indicated by a "Notification" window appearing on the user interface for a few seconds when you press a key.

You can switch back to manual mode by pressing the key sequence "Shortcut" -> "Local" or using the SCPI command `SYSTem:LOCal`.

Simultaneous communication via different interfaces is not permitted, i.e., commands must not be sent to the device via different interfaces at the same time. However, different interfaces can be used one after the other.
If this restriction is not observed, commands sent to the device may be lost.

5.3 CAN Interface

The CAN interface supports the CAN 2.0A standard with 11-bit identifiers.

Only the most important functions of the electronic load that are relevant for automated testing can be controlled via the CAN interface:

- Saving, loading, and resetting device settings
- Setting and querying the target and triggered value for the current in current mode
- Setting and querying the setting and triggered value for the resistance in resistance mode
- Setting and querying the setting and triggered value for the power in power mode
- Setting and querying the setting and triggered value for the voltage in voltage mode
- Setting and querying the limit value for the current in all operating modes
- Setting and querying the limit value for the voltage in all operating modes
- Setting and querying the operating mode
- Setting and querying the load input status
- Setting and querying the triggered load input status
- Common commands for reset, trigger, status, and settings memory
- Querying current measured values
- Querying status values
- Querying the current value for peak power
- Setting and querying the operating mode for cooling
- Querying the number of errors in the error queue
- Querying the last error in the error queue

5.3.1 CAN Connector

The master device must be connected to a CAN communication network via the 9-pin D-sub connector on the rear of the device.
Pin assignment:

Pin 1	Not assigned
Pin	CAN_L
Pin 3	GND
Pin 4	Not assigned
Pin 5	Not assigned
Pin 6	GND
Pin 7	CAN_H
Pin 8	Not assigned
Pin 9	Not assigned

5.3.2 Termination

A CAN communication bus (ISO 11898-2) must be terminated with 120 Ω at both ends for correct operation. Without termination, disruptive signal reflections occur on the communication bus.
The CAN interface of the electronic load contains a switchable internal termination resistor with 120 Ω, which can be activated with the SCPI command
`SYSTem:COMMunicate:CAN:TERMination[:STATe]`
making a termination resistor in the D-sub connector unnecessary.

A reset has no effect on the activation status of the termination resistor. The factory setting for the termination resistor is OFF.

5.3.3 CAN Cable

The maximum length of a CAN communication bus and thus the cable length for a point-to-point connection depends primarily on the transmission rate.
The following table shows the theoretically maximum possible cable length at different transmission rates:

Transmission rate	Cable length
1 Mbit/s	40 m
500 Kbit/s	110 m
250 Kbit/s	240 m
125 Kbit/s	500 m

5.3.4 Transmission Rate

The transmission rate for the CAN interface can be set using the SCPI command
`SYSTem:COMMunicate:CAN:BAUD`

The same transmission rate must be configured for all devices connected to a common CAN communication bus!
After changing the value for the transmission rate, the electronic load must be switched off and on again to apply the new value.

5.3.5 CAN Address

The device-specific CAN address can be configured using the SCPI command
`SYSTem:COMMunicate:CAN:ADDRess`

The identifiers of the two CAN messages used by the electronic load for communication via the CAN interface are derived from this address:
0x100 + CAN address: ID of the request message
0x300 + CAN address: ID of the response message

A unique address must be configured for all devices connected to a common CAN communication bus. After changing the address value, the electronic load must be switched off and on again to apply the new value.

5.3.6 CAN Messages

Request message:
This message is used for requests to the electronic load to execute a function. It contains a 16-bit multiplexer value for the command or query to be executed with the corresponding parameter values.

Response message:
This message is used for responses from the electronic load after a function has been executed. It contains the 16-bit multiplexer value of the request, the value for the execution status, and the value requested by the electronic load in the case of a query.

Each request message is answered with a response message from the electronic load.
The detailed structure of the messages can be found in a CAN symbol file (data exchange format from PEAK-System, file extension .sym) or a CAN database file (data exchange format from Vector Informatik, file extension .dbc). With the help of these files, it is possible to control the electronic load via the CAN interface using the PCAN-Explorer software tool from PEAK-System or CANoe from Vector Informatik. Both files are available from H&H on request.

5.4 LAN Interface

The integrated LAN interface supports the exchange of SCPI commands and queries for configuring and controlling the electronic load via a TCP/IP socket connection in the local area network (LAN). To commission the LAN interface, its configuration values can be adjusted via the user interface or another SCPI-compatible device interface (GPIB, RS-232, USB) using the commands and queries described below.

Detailed information on configuring the LAN interface can be found in Application Note No. 19 on the H&H websiteC
www.hoecherl-hackl.com/download/9118/

5.4.1 Ethernet

The Ethernet interface complies with the Ethernet standard IEEE 802.3 (100BASE-TX, 10BASE-T).

5.4.2 Ethernet connector

The electronic load must be connected to the LAN via the RJ-45 socket (8P8C modular socket) on the rear of the device.
Socket assignment:

Pin 1	Tx
Pin	Tx-
Pin 3	Rx+
Pin 4	Not assigned
Pin 5	Not assigned
Pin 6	Rx-
Pin 7	Not assigned
Pin 8	Not assigned

The RJ-45 socket uses two LEDs to indicate the status of the Ethernet connection:

Left green LED:
This LED lights up continuously when a connection is established and flashes when data is being transmitted (sending or receiving).
Right yellow LED:
Depending on the device type, this LED indicates either the connection speed or data activity.

5.4.3 Ethernet Cable

Shielded or unshielded twisted pair cables of category 3 or 5 must be used to connect the electronic load to the LAN. Regardless of the shielding, the cable length must not exceed 100 m.

5.4.4 Transmission Rate

The transmission rate for Ethernet is 10 Mbit/s or 100 Mbit/s and cannot be configured by the user. It is automatically configured by the corresponding switch or router in the LAN to which the electronic load is connected.

5.4.5 Identification

The electronic load can be identified in the network segment by its globally unique Ethernet address (MAC address). This can be determined using the SCPI command
`SYSTem:COMMunicate:LAN:MAC[:ADDRess]?`
. The Ethernet address cannot be changed by the user.

5.4.6 TCP/IP

For communication in the LAN, the electronic load requires a valid configuration in the form of an IP address and subnet mask. This configuration can be carried out automatically by a DHCP server in the LAN using the DHCP protocol (Dynamic Host Configuration Protocol, DHCP).

The dynamic configuration values assigned by a DHCP server, particularly the IP address, may change over time. If the electronic load is therefore controlled automatically via the LAN interface over a longer period, a configuration with static configuration values should be carried out. In this case, ask your network administrator for static configuration values for TCP/IP communication.

Automatic configuration of network parameters

To automatically configure the network parameters via a DHCP server in the LAN, the DHCP functionality of the electronic load must be activated using the SCPI command
`SYSTem:COMMunicate:LAN:DHCP[:STATe] ON`

After activating the DHCP client functionality, the electronic load must be switched off and on again to apply the new value for the activation status.

The DHCP server configures the IP address of the electronic load, the subnet mask of the network, and the IP addresses of the DNS and gateway servers. The current configuration values can be queried using the SCPI commands
`SYSTem:COMMunicate:LAN:DNS[:ADDRess]?`
`SYSTem:COMMunicate:LAN:GATeway[:ADDRess]?`
`SYSTem:COMMunicate:LAN:IP[:ADDRess]?`
`SYSTem:COMMunicate:LAN:SUBNet[:MASK]?`
.
If the queried values for the address or mask are "0:0:0:0", no configuration has been performed by the DHCP server.

If the DHCP server does not configure the LAN parameters within 60 seconds, contact your network administrator.

Manual configuration of the network parameters

To manually configure the network parameters, the DHCP client functionality of the electronic load must be disabled using the SCPI command
`SYSTem:COMMunicate:LAN:DHCP[:STATe] OFF`

After deactivating the DHCP client functionality, the electronic load must be switched off and on again to apply the new value for the activation status.

The static configuration values for the IP address of the electronic load, the subnet mask of the network, and the IP addresses of the DNS and gateway servers can be set using the SCPI commands
`SYSTem:COMMunicate:LAN:IP[:ADDRess]`
`SYSTem:COMMunicate:LAN:SUBNet[:MASK]`
`SYSTem:COMMunicate:LAN:DNS[:ADDRess]`
`SYSTem:COMMunicate:LAN:GATeway[:ADDRess]`

Check the configuration values for the network parameters with your network administrator. Invalid configuration values can disrupt the network!

After changing a value for a communication parameter, the electronic load must be switched off and on again to apply the new value or values.

Identification

The electronic load can be identified in the LAN by its host name. This can be determined using the SCPI command
`SYSTem:COMMunicate:LAN:HOSTname?`
The host name cannot be changed.

5.4.7 TCP Socket

To exchange SCPI commands and queries, a TCP connection must be established to the integrated TCP socket of the electronic load. A terminal program or a customer/application-specific program can be used for this purpose.
The port number of the socket can be queried using the SCPI command
`SYSTem:COMMunicate:LAN:PORT?`
It is configured to the value 1001 by default.

5.5 RS-232 Interface

The RS-232 interface allows the electronic load to be programmed in the standard programming language SCPI (Standard Commands for Programmable Instruments).
It meets the requirements of the IEEE Std 1174-2000 standard for Performance Class 1.

The RS-232 interface of the electronic load is a 9-pin standard Sub-D connector.

5.5.1 RS-232 Cable

A standard null modem cable with RTS-CTS handshake or a cable manufactured according to the following wiring diagram (sockets in wiring view) must be used as an RS-232 cable:

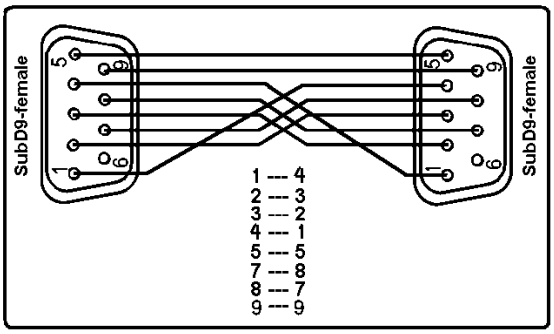


Figure 5.1: wiring diagram for RS-232 cable

The RxD and TxD lines (pins 2 and 3) are crossed, i.e., pin 2 of the left socket is connected to pin 3 of the right socket, and pin 3 of the left socket is connected to pin 2 of the right socket.
The RTS and CTS lines (pins 7 and 8) and the DCD and DTR lines (pins 1 and 4) are also cross-wired.
Pins 5 and 9 are wired through.

When using the H&H SyncroLink, the RS-232 communication interface is not available.

5.5.2 RS-232 Interface Parameters

The RS-232 interface parameters can be set using the SCPI commands
`SYSTEM:COMMUNICATE:SERIAL:BAUD`
`SYSTem:COMMunicate:SERial:PARity`
`SYSTem:COMMunicate:SERial:SBITs`
can be configured.

After one or more parameters have been changed, you must switch the device off and on again to apply the new settings.

5.5.3 Data Format for RS-232 Communication

The RS-232 interface of the electronic load expects the character <LineFeed> (10 dec.) as the termination character (end identifier).

The load also sends <LineFeed> (10 dec.) as the termination character when sending data.

5.6 USB Interface

The USB interface is compatible with the following standards:
Universal Serial Bus Specification 2.0, Full Speed.
The USB interface implements a Virtual COM Port (VCP) and allows the electronic load to be programmed in the standard programming language SCPI (Standard Commands for Programmable Instruments).
It implements the requirements of the IEEE Std 1174-2000 standard for Performance Class 1.

After connecting the electronic load to a control computer via a USB cable, the load can be addressed via a virtual serial port (equivalent to RS-232).

Data flow control is handled by the USB protocol.

5.6.1 USB Cable

A standard USB 2.0 type A/B cable must be used to control the electronic load via USB. This is not included in the scope of delivery.

5.6.2 Driver and Data Format

Starting with Windows 10, the driver is installed automatically after connecting the device to the PC. For older operating systems, ST provides a corresponding driver.

The VCP settings (baud rate, data bits, stop bits, parity) do not need to be configured, as the microcontroller's integrated USB peripheral is used.

The USB interface of the electronic load expects the character <LineFeed> (10 dec.) as the termination character (end marker). When sending data, the load also sends <LineFeed> (10 dec.) as the termination character.

5.7 GPIB Interface (Option HES02)

The optional GPIB interface allows the electronic load to be programmed in the standard programming language SCPI (Standard Commands for Programmable Instruments).
It is based on the requirements of the IEEE 488.2 standard .

The GPIB interface implements the following standardized functions:

Source handshake SH1
Acceptor handshake AH1
Talker T6
Listener L4
Service request SR1
Remote local RL1
Device clear DC1
Device trigger DT1
Electrical interface E1

The following functions are not supported:
Parallel poll PP0
Controller C0

5.7.1 GPIB Cable

H&H recommends the use of double-shielded standard cables. These are not included in the scope of delivery, but can be obtained from various measuring device manufacturers.

If a system contains multiple GPIB devices, the total length of all cables must not exceed 2 m times the number of GPIB devices, but must not exceed a total of 20 m.

No more than 15 devices may be connected to the GPIB bus. At least two-thirds of the connected devices must be switched on.

5.7.2 GPIB address

The GPIB address is set using the command
`SYSTem:COMMunicate:GPIB:ADDRess`

When an electronic load is delivered by H&H, the GPIB address 7 is set as standard.

After changing the GPIB address, you must switch the electronic load off and on again to apply the new setting.

5.7.3 Data Format for GPIB Communication

When receiving data, the GPIB interface of the electronic load expects the character <LineFeed> (10 dec.) or EOI with the last data byte or EOI with <LineFeed> as the termination character (end identifier).

When sending data via the GPIB bus, the load sends <LineFeed> with EOI as the termination character.

The output buffer for SCPI responses is 15,000 bytes for the GPIB interface.

5.8 SCPI Command Syntax

The SCPI (Standard Commands for Programmable Instruments) standard describes a uniform set of commands for programming devices, regardless of device type and manufacturer. The aim is to standardize device-specific commands.

There are basically two groups of SCPI commands:

- Common Commands
- Device-specific commands

Common commands are device-independent commands defined in the IEEE 488.2 standard. They consist of an asterisk (*) and three letters, possibly followed by a parameter.
Query commands are formed by appending a question mark.

Device-specific commands are subject to a certain syntax, which is described below.

5.8.1 Header Construction

The structure of device-specific commands is hierarchical. A command consists of a so-called header and possibly one or more parameters following it, separated from the header by a "white space" (see below).

The header consists of one or more keywords, which in turn are separated from each other by a colon (:).

5.8.2 Indentations

The different levels of the command hierarchy are shown in the overview by indenting to the right. The deeper the level, the further it is indented to the right.

Example: CURRent command system:

```
CURRent
  [:LEVel]
     [:IMMediate] <num>
     [:IMMediate]?
      :TRIGgered <num>
      :TRIGgered?
   :PROT
     [:LEVel] <num>
     [:LEVel]?
```

5.8.3 Selection

Some commands have a selection of possible parameters. These keywords are listed in the command overview on the same line, separated by a vertical bar (|).
Only one of the alternative keywords may be specified in the command string.

Example: Command system FUNCtion:

```
FUNCtion
  [:SPEed] FAST|MEDium|SLOW
  [:SPEed]?
```

5.8.4 White Space

White space includes all characters with ASCII codes from 0 to 9 and from 11 to 32 decimal. The LineFeed character (10 dec.) is therefore excluded from white space. This is used for termination.

White space is used to separate parameters from the header. Multiple white spaces may follow one another.

5.8.5 Long and Short Forms, Upper and Lower Case

Keywords have a short and a long form (provided the word consists of more than four characters). Only the short form or the complete long form of a keyword may be specified. Other abbreviations are not permitted and cause a syntax error.

For differentiation purposes, the short form is written in uppercase letters in this manual. The remaining string, which together with the short form results in the long form, is appended to the short form in lowercase letters.

The device itself does not distinguish between upper and lower case letters.

For example, there are the following options for programming a current limit value of 5A:
`CURRENT:PROT 5`
`curr:protection 5`
`Curr:PRot 5`
but not: `CURR:PROTECT 5`

The short form should be used to ensure the shortest possible transmission times.

5.8.6 Optional Keywords

In some command systems, for reasons of SCPI conformity, it is possible to optionally insert or omit certain keywords in the header. In this description, such words are indicated by square brackets.

Note that omitting the optional keywords can significantly shorten the command string.

Example: Load current 10 A
`CURRent[:LEVel][:IMMediate] 10`
can be shortened to:
`CURR 10`

5.8.7 Parameters

For most commands, a parameter must be appended to the header (separated by white space, see above). Depending on the recognized header, the device expects a specific parameter type. This type can be:
Numeric value, Boolean, Text

If a command requires multiple parameters, these are separated by a comma (,).

Example:
`LIST:CURR 5.5,44,83.2`

5.8.8 Numeric Values

Numeric values can generally be sent to the electronic load in any decimal form defined in the IEEE488.2 standard (Section 7.7.2).

<NR1> Decimal integer (e.g., 132)

Floating point number (e.g., 132.0)

<NR3> Number in exponential format (e.g., +1.320000E+02)

<NRf> Flexible numerical representation
|<NR2>|<NR3>

The decimal separator is a period (.), not a comma! The command overview uses <NRf> (flexible numeric representation) as a placeholder for numerical values received from the load.

Example (resistance 0.558 ohms):
```
RESistance 55.8E-2
RES .558
```

5.8.9 Units and Multipliers

The unit (suffix) can be specified after most numerical values. In addition, a multiplier can be placed before the unit.

Common multipliers for electronic loads are:

Mnemonic	Definition	Multiplier
M	Milli	0.001
K	Kilo	1000

Regarding physical size, the following units are generally permitted for electronic loads:

Quantity	Unit	Description
Current	A	Ampere
	MA	Milliampere
	KA	kiloampere
Resistance	OHM	Ohm
	KOHM	Kiloohm
Power	W	Watt
	MW	Milliwatt
	KW	Kilowatt
Voltage	V	Volt
	MV	Millivolt
Time	S	Second
	MS	Millisecond

Example (load current 520 mA):
```
CURRENT 520MA
CURR:IMM 0.52
CURR 520E-3
```

5.8.10 Numerical and Extreme Values <NRf>|MIN|MAX

For most commands that have a numerical value as a parameter, the text parameters MIN and MAX can also be specified. MIN refers to the smallest possible value that a parameter can take (usually 0). MAX refers to the largest possible value of a parameter.

Example: Setting the maximum current
`CURR MAX`

No suffix may be added to MIN and MAX.

The minimum and maximum values of a numerical parameter can be determined by querying. To do this, a white space and MIN or MAX are appended after the question mark.

Example: Determining the maximum load current:
`CURR? MAX` could return:
`+3.000000E+01`

5.8.11 Boolean Parameters <boolean>

Some commands require a Boolean parameter, e.g., the command for switching the device input:
`INPut ON`

Boolean parameters have two logical states. The logical state "FALSE" is represented by the parameter OFF or the numerical value 0. Similarly, the parameter ON or 1 represents the state "TRUE."

When programming a Boolean parameter, it does not matter whether the numerical or text form is selected. Numbers are always rounded by the electronic load. If the number is greater than zero after rounding, this logically means TRUE.

For example, the command
`INPut ON` has the same effect as
`INPut 1` or
`INPut 34.8`

When querying Boolean states, the Boolean numerical value 0 or 1 is always returned.

Example:
`INPut?` (Answer: `1`)

5.8.12 Text Parameters

Text parameters follow the syntactic rules for keywords, meaning they have a long form and a short form. As with all parameters, they are separated from the header by a white space.

Example:
`FUNC:MODE VOLT`

When text parameters are queried, the short form is returned.

Example:
`FUNC:MODE?` Response: `VOLT`

5.8.13 Using the Semicolon

There are various ways to combine multiple commands in a single command string.

A semicolon (;) at the end of the first command returns to the last colon (:) and another command of the same hierarchical level of a command system can be added.

Example:
The two individual statements
`CURR:IMM 10` and
`CURR:PROT 15`
can be combined into a single string:
`CURR:IMM 10;PROT 15`

The highest hierarchy level is reached by appending a colon directly to the semicolon (;:).

Example:
`CURR:LEV:IMM 10;PROT 15;:INP ON`

If the first command has only one hierarchy level, the colon after the semicolon can be omitted, as the highest hierarchy level is reached again after the semicolon anyway.

Example:
`CURR 15;:INP ON` produces the same result as
`CURR 15;INP ON`

However, with
`FUNC:MODE RES;:INP ON`
the sequence ;: must be specified.

When the end of a character string is reached, the SCPI parser automatically returns to the highest hierarchy level.
The end of a character string is marked by the LineFeed character (10 dec.).

5.8.14 Query Commands

Most commands have a corresponding query command that returns the current setting. To do this, a question mark (?) is appended to the header.

Example: Determining the current setting for the load current
`CURRent?`
Response, e.g., `+1.000000E+01`

The number sent by the device appears in exponential format with a sign, one digit before the decimal point, six decimal places, an exponent, a sign, and two exponent digits. The device does not send units after numerical values.

To determine the minimum or maximum permissible setting value for the corresponding command, append a white space and MIN or MAX to the question mark. You will receive the numerical value without units as a response.

Example: Determining the maximum current
`CURRent? MAX`
Response, e.g.: `+1.200000E+02`

5.9 Error Queue

If the electronic load receives an invalid command or a command triggers a conflict with the current status, the load enters an error in the error queue. A short beep sounds.

See command SYSTem:ERRor in 5.11.18 SYSTem Subsystem and 9.1 Error Codes.

5.10 Command Description Common Commands

Common commands are defined in the IEEE488.2 standard. They begin with an * and contain three characters for a command or three characters and a question mark ('?') for a query.

5.10.1 *CLS

Clears the contents of the following status registers:

- Questionable Status Event Register
- Operation Status Event Register
- Standard Event Status Register
- Status Byte Register
- Error Queue

5.10.2 *ESE <NRf>, *ESE?

Sets the value of the Standard Event Status Enable Register.

Parameter: 0 ... 255
The numeric parameter specifies the new value of the register and is implicitly rounded to the nearest integer.

Query: *ESE?
Queries the value of the standard event status enable register as a decimal integer.

See also 5.11.17 STATus Subsystem.

5.10.3 *ESR?

Queries the value of the Standard Event Status Register as a decimal integer. This query clears the register value, i.e., resets it to 0.

See also 5.11.17 STATus Subsystem.

5.10.4 *IDN?

Queries the identification data of the electronic load.

The returned ID string consists of the following information:
Manufacturer, model name, serial number, firmware version.

5.10.5 *OPC, *OPC?

Sets the Operation Complete Bit (Bit 0) in the Standard Event Status Register when all previous commands have been processed.

Query: *OPC?
Queries the execution status of all previous commands. If all previous commands have been processed, the numeric value 1 is returned as a decimal integer.

5.10.6 *OPT?

Queries the options currently installed and activated in the device.

A string consisting of concatenated sub-strings separated by commas is returned.

Position 0: "ISO" (isolated I/O port)
Position 1: "GPIB"
Position 2: reserved
Position 3: ZV (Zero Volt Module)
Position 4: reserved
Position 5: Reserved
Position 6: Reserved
Position 7: reserved

If an option is activated in the electronic load, the corresponding substring is set to the designated position in the response. If the option is not activated, the character '0' appears at the corresponding position in the response string.

Example
*OPT?
Response string if GPIB option is available:
0,GPIB

5.10.7 *RCL <NRf>

Loads the settings for the electronic load from a specific settings memory and activates them.

Parameter: 0 ... 9

The numerical parameter is implicitly rounded to the nearest integer and specifies the memory number.
See 4.32 Saving and Loading Device Settings.

5.10.8 *RST

Performs a reset of the electronic load. The following settings are set during a reset:

ABORT
ACQuisition OFF
ACQuisition:TRIGger OFF
ACQuisition:STIMe MIN
CURRent MIN
CURRent:PROTection MAX
CURRent:TRIGgered MIN
Format:Border Norm

Format:DATA ASCII,7
Format:SREGister ASCii
FUNCTION:DISCharge OFF
FUNCTION:DISCharge:STOP:CHARge 0
FUNCTION:DISCharge:STOP:CURRent 0
FUNCTION:DISCharge:STOP:ENERgy 0
FUNCTION:DISCharge:STOP:TIME 1
FUNCTION:DISCharge:STOP:VOLTAGE 0
FUNCTION:DISCharge:STOP:ENABLE CHARGE,OFF
FUNCTION:DISCharge:STOP:ENABLE CURRent,OFF
FUNCTION:DISCharge:STOP:ENABLE ENERGY,OFF
FUNCTION:DISCharge:STOP:ENABLE TIME,OFF
FUNCTION:DISCharge:STOP:ENABLE VOLTAGE OFF
FUNCTION:MEASURE:IRRESISTANCE OFF
FUNCTION:MEASURE:IRRESISTANCE:CURRENT 0.0
FUNCTION:MEASURE:IRRESISTANCE:DWELL 10.1
FUNCTION:MODE CURRENT
FUNCTION:MODULATE OFF
FUNCTION:MODULATE:MODE CURR
FUNCTION:MODULATE:WAVEFORM:AMPLITUDE 0.0
FUNCTION:MODULATE:WAVEFORM:FREQUENCY 1.0
FUNCTION:MODULATE:WAVEFORM:TYPE SINE FUNCTION:MODE CURRENT
FUNCTION:MPPT OFF
FUNCTION:MPPT:SWEEP:DIRECTION DOWN
FUNCTION:MPPT:SWEEP:TIME 1.0
FUNCTION:MPPT:SWEEP:PERIOD MIN
FUNCTION:SPEED MEDIUM
FUNCTION:ZVOLTAGE OFF
INITiate:CONTinuous OFF
INPUT OFF
INPUT:TRIGgered OFF
LIST OFF
LIST:ACQuisition OFF
LIST:COUNT MIN
LIST:CURRent <undefined>
LIST:DWELL <undefined>
LIST:MODE CURRent
LIST:POWER <undefined>
LIST:RESistance <undefined>
LIST:RTIMe <undefined>
LIST:STIMe:RTIMe <undefined>
LIST:STIMe:VOLTage <undefined>
LIST:TRIGgered OFF
LIST:VOLTage <undefined>
POWer MIN
POWER:TRIGGERED MIN
RANGE MIN (only with HES MR)
RECT OFF
RECT:CURR MIN,MIN
RECT:DWEL 0.5,0.5
RECT:MODE CURR
RECT:RES MAX,MAX
RECT:VOLT MAX,MAX
RESistance MAX
RESistance:TRIGgered MAX
SETTing:EXTernal OFF
SETTing:EXTernal:ENABle INPut, OFF
SETTing:EXTernal:ENABle MODE, OFF

Setting: External: Enable Level, OFF
Setting: External: Enable Level, OFF
SYSTEM:COOLING AUTO
SYSTEM:CLOCK OFF
SYSTEM:SLINK OFF
TRIGger:DELay 0
TRIGger:HOLDoff 0
TRIGger:LEVel:CURRent MAX
TRIGger:LEVel:VOLTage <default>
TRIGger:SLOPe POSitive
TRIGger:SOURce BUS
VOLTage MAX
VOLTage:PROTection <default>
VOLTage:PROTection:REGulation OFF
VOLTage:TRIGgered MAX

5.10.9 *SAV

Saves the active settings to a specific settings memory.

Parameter: 0 ... 9

The numerical parameter is implicitly rounded to the nearest integer and specifies the memory number.
See 4.32 Saving and Loading Device Settings

5.10.10 *SRE <NRf>, *SRE?

Sets the value of the Service Request Enable register.

Parameter: 0 ... 255
The numeric parameter specifies the new value of the register and is implicitly rounded to the nearest integer.

Query: *SRE?
Queries the value of the Service Request Enable Register as a decimal integer.

See also 5.11.17 STATus Subsystem .

5.10.11 *STB?

Queries the value of the status byte register as a decimal integer.

See also 5.11.17 STATus Subsystem.

5.10.12 *TRG

Generates a trigger event to execute trigger actions when the trigger source BUS is selected.

5.10.13 *TST?

Starts the self-test of the electronic load and returns the test result.
If the returned numerical value is 0, no errors occurred during the self-test. Otherwise, an error code defined by SCPI is returned.

5.10.14 *WAI

Blocks the processing of subsequent commands until all previous commands have been executed.

5.11 Command Description Device-Specific Commands

This chapter describes the device-specific SCPI commands of the electronic load. You should be familiar with the basic SCPI syntax description in chapter5.8 .

The commands are described with the following information:

Syntax
Syntax definitions are always listed in long form with optional keywords.

Parameters
Most commands require one or more parameters. For some commands, the valid range of the associated parameters depends on the model type (i.e., the current, voltage, resistance, or power range) of the electronic load. The actual minimum and maximum parameter values can be queried by appending MIN or MAX, e.g., `CURR? MAX`

Unit
If a unit is permitted after the parameter, it is specified with the valid multiplier, if applicable, e.g. A|MA

**RST value*
For commands whose setting changes due to a reset, the *RST value is specified. This also corresponds to the value after switching on.

Examples
Examples are always given in short form, without optional keywords.

Query syntax
Most commands have an associated query command that returns the corresponding setting.

Return value
The parameter type of the query is specified in the description.

All commands are listed in alphabetical order in the chapters5.12 and0 .

5.11.1 ACQuisition Subsystem

ACQuisition

This command sets the activation status of measurement data acquisition.

The parameter OFF or 0 deactivates measurement data acquisition, the parameter ON or 1 activates it.

Syntax	ACQuisition[:STATe] <boolean>
Parameter	0|OFF|1|ON
**RST value*	OFF

Example	ACQ ON
Query syntax	ACQuisition[:STATe]?
Return value	0|1

ACQuisition:TRIGger

This command sets the trigger state for measurement data acquisition.

The parameter OFF or 0 deactivates measurement data acquisition when a trigger event occurs, while the parameter ON or 1 activates measurement data acquisition when a trigger event occurs.

Syntax	ACQuisition[:STATe]:TRIGger <boolean>
Parameter	0|OFF|1|ON
**RST value*	OFF
Example	ACQ:TRIG ON
Query syntax	ACQuisition[:STATe]:TRIGger?
Return value	0|1

ACQuisition:STIMe

This command sets the sampling interval for measurement data acquisition.

The numeric parameter specifies the sampling interval in the base unit of seconds.

Syntax	ACQuisition:STIMe <NRf>
Parameter	1E-03 ... 100|MIN|MAX
Unit	S|MS
**RST value*	0.001
Example	ACQ:STIM 0.5
Query syntax	ACQuisition:STIM? [MIN|MAX]
Return value	

5.11.2 CURRent Subsystem

CURRent

This command sets the setting value for the regulated input current in current mode.

The numeric parameter specifies the current in the base unit Ampere. The MIN parameter sets the minimum permissible value for the current, the MAX parameter sets the maximum permissible value for the current.

The <max> value corresponds to the current range and can be found in the technical data.

Syntax	CURRent[:LEVel][:IMMediate] <NRf>|MIN|MAX
Parameter	0 ... <max>|MIN|MAX
Unit	A|MA
**RST value*	0
Example	CURR 12.5
Query syntax	CURRent[:LEVel][:IMMediate]? [MIN|MAX]
Return value	<NR3>

CURRent:PROTection

This command sets the user-specific upper limit for the input current, regardless of the operating mode.

The numeric parameter specifies the current in the base unit of amperes. The MIN parameter sets the minimum allowable value for the current, and the MAX parameter sets the maximum allowable value for the current.

The <max> value corresponds to the current range and can be found in the technical data.

Syntax	CURRent:PROTection[:LEVel] <NRf>|MIN|MAX
Parameter	0 ... <max>|MIN|MAX
Unit	A|MA
**RST value*	MAX
Example	CURR:PROT 6.5
Query syntax	CURRent[:PROTection][:LEVel]? [MIN|MAX]
Return value	<NR3>

CURRent:PROTection:RANGe

This command queries the maximum value for the current limit for the specified range. It is only available for multi-range devices (HES MR).

The numeric parameter specifies the number of the range. If the parameter MIN is passed, the maximum current for range 1 is queried; if the parameter MAX is passed, the maximum current for the largest range is queried.

Query syntax	CURRent:PROTection:RANGe? [NRf|MIN|MAX]
Return value	<NR3>

CURRent:RANGe?

This command queries the maximum current for the specified range. It is only available for multi-range devices (HES MR).

The numeric parameter specifies the number of the range. If the parameter MIN is passed, the maximum current for range 1 is queried; if the parameter MAX is passed, the maximum current for the largest range is queried.

Query syntax	CURRent[:LEVel]:RANGe? [NRf|MIN|MAX]
Return value	<NR3>

CURRent:TRIGgered

This command sets the triggered value for the input current in current mode.

The numeric parameter specifies the current in the base unit of amperes. The MIN parameter sets the smallest permissible value for the current, the MAX parameter sets the largest permissible value for the current.

The <max> value corresponds to the current range and can be found in the technical data.

Syntax	CURRent[:LEVel]:TRIGgered <NRf>|MIN|MAX
Parameter	0 ... <max>|MIN|MAX
Unit	A|MA
**RST value*	0
Example	CURR:TRIG 18.5
Query syntax	CURRent[:LEVel]:TRIGgered? [MIN|MAX]
Return value	<NR3>

5.11.3 DATA Subsystem

The DATA subsystem is available for reading out measurement data records stored in the electronic load.

A measurement data point consists of a sequence of <NRf> values in the order timestamp_x, voltage_x, current_x. The retrieved measurement data sets are strung together in the following manner:
Timestamp_1, Voltage_1, Current_1, Timestamp_2, Voltage_2, Current_2, ... Timestamp_n, Voltage_n, Current_n.

All values are separated from each other in ASCII format by a comma followed by a space. In REAL format, the data is returned in IEEE 754 format.
See 5.11.5 FORMat subsystem , 4.13Data Transfer According to IEEE 488.2 – Binary Block Data .

DATA:DELete

This command deletes all measurement data records buffered in the electronic load.
This command has no query form.

Syntax	DATA:DELete
Parameter	None
Example	DATA:DEL

DATA:LAST?

This command queries the last measurement data record stored in the electronic load.

Query syntax	DATA:LAST?
Return value	<NR3>,<NR3>,<NR3>

DATA:POINTS?

This command queries the number of measurement records stored in the electronic load.

Query syntax	DATA:POINts? [VMEM]
Return value	<NR1>

DATA:REMove?

This command queries the number of measurement records stored in the electronic load specified by the parameter.

Only a limited number of measurement data records can be read in a query. If more data records are available than can be read in a single read operation, the existing data records must be divided into several queries.

The parameter of the query command must not be greater than the number of stored data records.

No measurement data records can be read out during measurement data acquisition.

Query syntax	DATA:REMove? <NRf>
Parameter	1 ... 100
Return value	{,<NR3>}
Example	DATA:POIN? *// Response: 324* DATA:REM? 100 DATA:REM? 100 DATA:REM? 100 DATA:REM? 24

5.11.4 DISPlay Subsystem

DISPlay:TEXT

This command displays the specified string in a notification window on the user interface or queries it.

The parameter specifies the character string with a maximum length of 32 characters. If the character string is empty (""), the notification window is closed.

The notification window with the message text can be confirmed and closed by the operator. The query `DISPlay:TEXT?` can be used to determine whether the notification window with the message text is still visible. The query returns either the displayed text or an empty string ("") if no notification window is displayed.

Syntax	DISPlay:TEXT[:DATA] <string>
Parameter	<string>
Example	DISP:TEXT "Function canceled"
Query syntax	DISPlay:TEXT[:DATA]?
Return value	<string>

5.11.5 FORMat subsystem

FORMat

This command sets the data format for decimal numeric values queried by SCPI commands.

The first parameter, ASCii, returns the values in the form of ASCII characters. The parameter REAL returns the values in IEEE 754 format. See4.13 Data Transfer According to IEEE 488.2 – Binary Block Data .
The second parameter determines the number of significant digits of a queried value.

The data format and the number of significant digits are volatile, i.e., they are reset to their default values after the device is turned off and on again.

Syntax	FORMat[:DATA] <format>,<NRf>
Parameter1	ASCii|REAL
Parameter2	1 ... 7|32
**RST value*	7
Example	FORM REAL,32
Query syntax	FORMat[:DATA]?
Return value	ASC|REAL,<NR1>

FORMat:BORDer

This command sets the byte order for queried measurement data in REAL format.

If the parameter NORM is transferred, the measurement data is transferred in little endian format (LSBF).

If the parameter SWAP is transferred, the measurement data is transferred in big-endian format (MSBF).

Syntax	FORMat:BORDer <order>
Parameter	NORMal|SWAPped
Default value	NORMal
Example	FORM:BORD NORM
Query syntax	FORMat:BORDer?
Return value	NORM|SWAP

FORMat:SREGister

This command sets the data format for queried SCPI status register values.

When the ASCii parameter is passed, a queried register value is transferred as an ASCII string in decimal format to base 10 in accordance with the IEEE 488.2 standard.

When the HEXadecimal parameter is passed, a queried register value is transferred as an ASCII character in hexadecimal format to base 16 in accordance with the IEEE 488.2 standard. The electronic load then precedes each requested register value with the character string "#H".

When the OCTal parameter is transferred, a queried register value is transmitted as an ASCII character in octal format to base 8 in accordance with the IEEE 488.2 standard. The electronic load then precedes each requested register value with the character string "#Q".

Syntax	FORMat:SREGister <format>
Parameters	ASCii|HEXadecimal|OCTal

**RST value*	ASCii
Example	FORM:SREG ASC
Query syntax	FORMat:SREGister?
Return value	ASC|HEX|OCT

5.11.6 FUNCtion Subsystem

FUNCtion:DISCharge

The FUNCtion:DISCharge command group configures and operates the discharge function of the electronic load.
The command `FUNCtion:DISCharge[:STATe]` sets the activation status for the discharge function.

The parameter OFF or 0 deactivates the discharge function, the parameter ON or 1 activates the discharge function.

Syntax	FUNCtion:DISCharge[:STATe] <boolean>
Parameter	0|OFF|1|ON
**RST value*	OFF
Example	FUNC:DISC ON
Query syntax	FUNCtion:DISCharge[:STATe]?
Return value	0|1

FUNCtion:DISCharge:CHARge?

This command queries the charge quantity in Ah that has been removed from the test object since the discharge function was activated.

Query syntax	FUNCtion:DISCharge:CHARge?
Return value	<NR3>

FUNCtion:DISCharge:ENERgy?

This command queries the amount of energy in Wh that has been drawn from the device under test since the discharge function was activated.

Query syntax	FUNCtion:DISCharge:ENERgy?
Return value	<NR3>

FUNCtion:DISCharge:STOP:CHARge

This command sets the value for the charge amount at which the discharge function is deactivated and the load input is switched off. The stop condition is enabled with the command `FUNCtion:DISCharge:STOP:ENABle`.

The numeric parameter specifies the charge amount in ampere hours. The MIN parameter sets the minimum permissible value for the charge amount, and the MAX parameter sets the maximum permissible value for the charge amount.

Syntax	FUNCtion:DISCharge:STOP:CHARge <NRf>
Parameter	0 ... 999999.9|MIN|MAX
Unit	AH|MAH|KAH
**RST value*	0
Example	FUNC:DISC:STOP:CHAR 1.2
Query syntax	FUNCtion:DISCharge:STOP:CHARge? [MIN|MAX]
Return value	

FUNCtion:DISCharge:STOP:CURRent

This command sets the value for the minimum current at which the discharge function is deactivated and the load input is switched off. The stop condition is enabled with the command `FUNCtion:DISCharge:STOP:ENABle`.

The numeric parameter specifies the current in amperes. The MIN parameter sets the minimum permissible value for the current, while the MAX parameter sets the maximum permissible value for the current.

The <max> value can be found in the technical data.

Syntax	FUNCtion:DISCharge:STOP:CURRent[:LEVel] <NRf>
Parameter	0 ... <max>|MIN|MAX
Unit	A|MA|KA
**RST value*	0
Example	FUNC:DISC:STOP:CURR 1.2
Query syntax	FUNCtion:DISCharge:STOP:CURRent[:LEVel]? [MIN|MAX]
Return value	<NR3>

FUNCtion:DISCharge:STOP:ENABle

This command sets the activation status for a condition for terminating the discharge function (stop condition).

The first parameter specifies the stop condition:
CHARge: Stop when defined charge amount is accumulated
CURRent: Stop when defined minimum current is reached
ENERgy: Stop when defined amount of energy accumulated
TIME: Stop when defined discharge time has elapsed
VOLTage: Stop when defined minimum voltage is reached

The second parameter specifies the activation status for the stop condition:
0|OFF: The condition cannot terminate the discharge.
1|ON: The condition can terminate the discharge.

Syntax	FUNCtion:DISCharge:STOP:ENABle <signal>,<boolean>
Parameter1	CHARge|CURRent|ENERgy|TIME|VOLTage
Parameter2	0|OFF|1|ON
**RST value*	All OFF
Example	FUNC:DISC:STOP:ENAB CHAR,ON
Query syntax	FUNCtion:DISCharge:STOP:ENABle? <signal>
Return value	0|1

FUNCtion:DISCharge:STOP:ENERgy

This command sets the value for the amount of energy at which the discharge function is deactivated and the load input is switched off. The stop condition is activated with the command `FUNCtion:DISCharge:STOP:ENABle`.

The numeric parameter specifies the amount of energy in watt-hours. The MIN parameter sets the minimum permissible value for the amount of energy, and the MAX parameter sets the maximum permissible value for the amount of energy.

Syntax	FUNCtion:DISCharge:STOP:ENERgy <NRf>
Parameter	0 ... 999999.9|MIN|MAX
Unit	WH|MWH|KWH
**RST value*	0
Example	FUNC:DISC:STOP:ENER 10.56
Query syntax	FUNCtion:DISCharge:STOP:ENERgy? [MIN|MAX]
Return value	<NR3>

FUNCtion:DISCharge:STOP:EVENt?

This query command queries the event that last terminated the discharge function.

The return value can be one of the following values:
NONE: no event occurred
CHAR: defined charge amount accumulated
CURR: defined minimum current reached
ENER: defined amount of energy accumulated
TIME: defined discharge time elapsed
VOLT: defined minimum voltage reached

Query syntax	FUNCtion:DISCharge:STOP:EVENt?
Return value	NONE|CHAR|CURR|ENER|TIME|VOLT

FUNCtion:DISCharge:STOP:TIME

This command sets the value for the time period after which the discharge function is deactivated and the load input is switched off. The stop condition is activated with the command `FUNCtion:DISCharge:STOP:ENABle`.

The numeric parameter specifies the time in seconds. The MIN parameter sets the minimum permissible value for the time, while the MAX parameter sets the maximum permissible value for the time.

Syntax	FUNCtion:DISCharge:STOP:TIME <NRf>
Parameter	1 ... 999999|MIN|MAX
Unit	S|MS
**RST value*	
Example	FUNC:DISC:STOP:TIME 18000
Query syntax	FUNCtion:DISCharge:STOP:TIME? [MIN|MAX]
Return value	<NR3>

FUNCtion:DISCharge:STOP:VOLTage

This command sets the value for the minimum voltage at which the discharge function is deactivated and the load input is switched off. The stop condition is activated with the command `FUNCtion:DISCharge:STOP:ENABle`.

The numerical parameter specifies the voltage in volts. The MIN parameter sets the minimum permissible value for the voltage, while the MAX parameter sets the maximum permissible value for the voltage.

The <max> value can be found in the technical data.

Syntax	FUNCtion:DISCharge:STOP:VOLTage [:LEVel] <NRf>
Parameter	0 ... <max>|MIN|MAX
Unit	V|MV
**RST value*	0
Example	FUNC:DISC:STOP:VOLT 1.253
Query syntax	FUNCtion:DISCharge:STOP:VOLTage [:LEVel]? [MIN|MAX]
Return value	<NR3>

FUNCtion:DISCharge:TIME?

This command queries the time in seconds that has elapsed since the discharge function was activated.

Query syntax	FUNCtion:DISCharge:TIME?
Return value	

FUNCtion:MEASure:IRESistance

This command sets the activation status for the function to measure the internal resistance of a connected device under test.

The parameter OFF or 0 deactivates the function, the parameter ON or 1 activates the function.

Syntax	FUNCtion:MEASure:IRESistance [:STATe] <boolean>
Parameter	0|OFF|1|ON
Example	FUNC:MEAS:IRES ON
Query syntax	FUNCtion:MEASure:IRESistance[:STATe]?
Return value	0|1
**RST value*	OFF

FUNCtion:MEASure:IRESistance:CURRent

This command sets the two load currents for determining the internal resistance. The second current must be greater than the first.

The numerical parameters specify the current strengths in the base unit of amperes. They are specified as two parameters separated by a comma.

The <max> value corresponds to the current range and can be found in the technical data.

Syntax	FUNCTION:MEASURE:IRRESISTANCE:CURRENT [:LEVEL] <NRf>,<NRf>
Parameter 1	0 ... <max>
Parameter 2	0 ... <max>
Unit	A
Example	FUNC:MEAS:IRES:CURR 0.5, 4.5
Query syntax	FUNCtion:MEASure:IRESistance:CURRent [:LEVel]?
Return value	<NR3>,<NR3>
**RST Values*	0, 0

FUNCtion:MEASure:IRESistance:DWELl

This command sets the two dwell times of the respective load currents to determine the internal resistance.

The numerical parameters specify the dwell times in the base unit of seconds. They are specified as two parameters separated by a comma.

Syntax	FUNCtion:MEASure:IRESistance:DWELl <NRf>,<NRf>
Parameter 1	0.1 ... 100
Parameter 2	0.1 ... 100
Unit	S
Example	FUNC:MEAS:IRES:DWEL 1.5,12
Query syntax	FUNCtion:MEASure:IRESistance:DWELl?
Return value	<NR3>,<NR3>
**RST Values*	10, 1

FUNCtion:MEASure:IRESistance:RESistance?

This command queries the internal resistance of the connected device under test, which was last determined by the electronic load.

If the electronic load has not yet determined a value for the internal resistance, it returns the value 0.

Query syntax	FUNCtion:MEASure:IRESistance :RESistance?
Return value	<NR3>

FUNCtion:MEASure:IRESistance:TIME?

This command queries the time in seconds that has elapsed since the internal resistance measurement function was activated.

The value is reset to 0 when the function is started.

Query syntax	FUNCtion:MEASure:IRESistance:TIME?
Return value	<NR3>

FUNCtion:MODE

This command sets the operating mode to " " for the control.

The CURRent parameter activates current control.
The RESistance parameter activates resistance control.
The VOLTage parameter activates voltage control.
The POWer parameter activates power control.

Syntax	FUNCtion:MODE <mode>
Parameters	CURRent|RESistance|VOLTage|POWer
**RST value*	CURRent
Example	FUNC:MODE VOLT
Query syntax	FUNCtion:MODE?
Return value	CURR|RES|VOLT|POW

FUNCtion:MODulate

This command sets the activation status of the modulation.

The parameter ON or 1 activates this function, the parameter OFF or 0 deactivates this function.

Syntax	FUNCtion:MODulate[:STATe] <boolean>
Parameter	0|OFF|1|ON
Example	FUNC:MOD ON
Query syntax	FUNCtion:MODulate[:STATe]?
Return value	0|1
**RST value*	OFF

FUNCtion:MODulate:MODE

This command sets the operating mode of the control for modulation.

The CURRent parameter activates current control.
The VOLTage parameter activates voltage control.

Syntax	FUNCtion:MODulate:MODe <mode>
Parameters	CURRent|VOLTage
Example	FUNC:MOD VOLT
Query syntax	FUNCtion:MODulate:MODe?
Return value	CURR|VOLT
**RST value*	CURRent

FUNCtion:MODulate:SWEep

This command sets the activation state oft he modulator sweep function.

The parameter ON or 1 activates this function, the parameter OFF or 0 deactivates this function.

Syntax	FUNCtion:MODulate:SWEep[:STATe] <boolean>
Parameter	0|OFF|1|ON
Example	FUNC:MOD:SWE ON
Query syntax	FUNCtion:MODulate:SWEep[:STATe]?
Return value	0|1
**RST value*	OFF

FUNCtion:MODulate:SWEep:COUNt

This command sets the number of sweep iterations.

The numeric parameter value specifies the number of iterations and is implicitly rounded to the nearest integer. The MIN parameter sets the minimum allowed value, and the MAX parameter sets the maximum allowed value. A value higher than the MAX value or the numerical value for infinity (9.9E37) causes the sweep to run continuously until it is terminated with FUNCtion:MODulate:SWEep OFF.

Syntax	FUNCtion:MODulate:SWEep:COUNt <NRf>|MIN|MAX
Parameter	<NRf>|MIN|MAX
Example	FUNC:MOD:SWE:COUN 10
Query syntax	FUNCtion:MODulate:SWEep:COUNt? [MIN|MAX]
Return value	<NRf>
**RST value*	1

FUNCtion:MODulate:SWEep:COUNt:ACTual?

This command queries the number of completed sweep iterations.

Syntax	FUNCtion:MODulate:SWEep:COUNt:ACTual?
Example	FUNC:MOD:SWE:COUN:ACT?
Return value	<NRf>

FUNCtion:MODulate:SWEep:DWELl

This command sets the dwell time for each frequency step in s.

Syntax	FUNCtion:MODulate:SWEep:DWELl <NRf>|MIN|MAX
Parameter	<NRf>|MIN|MAX
Example	FUNC:MOD:SWE:DWEL 0.1
Query syntax	FUNCtion:MODulate:SWEep:DWELl? [MIN|MAX]
Return value	<NRf>
**RST value*	0.1

FUNCtion:MODulate:SWEep:FREQuency:STARt

This command sets the start frequency in Hz.

Syntax	FUNCtion:MODulate:SWEep:FREQency:STARt <NRf>|MIN|MAX
Parameter	<NRf>|MIN|MAX
Example	FUNC:MOD:SWE:FREQ:STAR 1E3
Query syntax	FUNCtion:MODulate:SWEep:FREQency:STARt? [MIN|MAX]
Return value	<NRf>
**RST value*	MIN

FUNCtion:MODulate:SWEep:FREQuency:STEP

This command sets the frequency step size in Hz.

Syntax	FUNCtion:MODulate:SWEep:FREQency:STEP <NRf>|MIN|MAX
Parameter	<NRf>|MIN|MAX
Example	FUNC:MOD:SWE:FREQ:STEP 100
Query syntax	FUNCtion:MODulate:SWEep:FREQency:STEP? [MIN|MAX]
Return value	<NRf>
**RST value*	100

FUNCtion:MODulate:SWEep:FREQuency:STOP

This command sets the end frequency in Hz.

Syntax	FUNCtion:MODulate:SWEep:FREQency:STOP <NRf>|MIN|MAX
Parameter	<NRf>|MIN|MAX
Example	FUNC:MOD:SWE:FREQ:STOP 10E3
Query syntax	FUNCtion:MODulate:SWEep:FREQency:STOP? [MIN|MAX]
Return value	<NRf>
**RST value*	MAX

FUNCtion:MODulate:SWEep:FREQuency?

This command queries the current sweep frequency in Hz.

Syntax	FUNCtion:MODulate:SWEep:FREQuency?
Example	FUNC:MOD:SWE:FREQ?
Return value	<NRf>

FUNCtion:MODulate:SWEep:TIME?

This command queries the elapsed time in s since activation of the sweep function.

Syntax	FUNCtion:MODulate:SWEep:TIME?
Example	FUNC:MOD:SWE:TIME?
Return value	<NRf>

FUNCtion:MODulate:WAVeform:AMPLitude

This command sets the amplitude for modulation.

The numeric parameter value specifies the target value for the amplitude in the normalized range from 0 to 1. The MIN parameter sets the smallest permissible value 0 for the amplitude, the MAX parameter sets the largest permissible value 1 for the amplitude.

Syntax	FUNCtion:MODulate:WAVeform:AMPLitude <NRf>|MIN|MAX
Parameter	0 ... 1|MIN|MAX
Example	FUNC:MOD:WAV:AMPL 0.27
Query syntax	FUNCtion:MODulate:WAVeform:AMPLitude?
Return value	
**RST value*	0.0

FUNCtion:MODulate:WAVeform:FREQuency

This command sets the frequency for modulation.

The numeric parameter value specifies the target value for the frequency in hertz. The MIN parameter sets the smallest permissible value for the frequency, and the MAX parameter sets the largest permissible value for the frequency.

Syntax	FUNCtion:MODulate:WAVeform:FREQuency <NRf>|MIN|MAX
Parameter	0.1 ... 10000|MIN|MAX
Unit	HZ
Example	FUNC:MOD:WAV:FREQ 50.0
Query syntax	FUNCtion:MODulate:WAVeform:FREQuency?
Return value	<NR3>
**RST value*	1.0

FUNCtion:MODulate:WAVeform:TYPE

This command sets the waveform for modulation.

The parameter SINE activates sinusoidal modulation.
The SQUare parameter activates square wave modulation.
The TRIangle parameter activates triangular modulation.

Syntax	FUNCtion:MODulate:WAVeform:TYPE <type>
Parameter	SINE|SQUare|TRIangle
Example	FUNC:MOD:WAV:TYPE TRI
Query syntax	FUNCtion:MODulate:WAVeform:TYPE?
Return value	SINE|SQU|TRI
**RST Value*	SINE

FUNCtion:MPPT

This command sets the activation status for the MPP tracking function.

The parameter OFF or 0 deactivates the MPPT function, while the parameter ON or 1 activates the MPPT function.

Syntax	FUNCtion:MPPT[:STATe] <boolean>
Parameter	0|OFF|1|ON
**RST value*	OFF
Example	FUNC:MPPT ON
Query syntax	FUNCtion:MPPT[:STATe]?
Return value	0|1

FUNCtion:MPPT:ENERgy?

This command queries the cumulative energy in Wh for an MPP tracking function.

Query syntax	FUNCtion:MPPT:ENERgy?
Return value	

FUNCtion:MPPT:MPP?

This command queries the last found and regulated MPP.
The return value is a tuple consisting of the following values:
Umpp, Impp, Pmpp

Query syntax	FUNCtion:MPPT:MPP?
Return value	<NR3>,<NR3>,<NR3>

FUNCtion:MPPT:SWEep

This command triggers an immediate sweep, unless a sweep is already in progress.

Syntax	FUNCtion:MPPT:SWEep[:IMMediate]
Example	FUNC:MPPT:SWE

FUNCtion:MPPT:SWEep:DATA?

This command queries the recorded measurement data from the last sweep.

The retrieved measurement data consists of 100 voltage-current value pairs and is composed as follows:
<Volt_0>,<Curr_0>,....,<Volt_99>,<Curr_99>

Query syntax	FUNCtion:MPPT:SWEep:DATA?
Return value	{,<NR3>}

FUNCtion:MPPT:SWEep:DATA:POINts?

This command queries the number of measurement data points from the last sweep.

If no sweep has been performed yet, the number of measurement data points is 0, otherwise it is always 100.

Query syntax	FUNCtion:MPPT:SWEep:DATA:POINts?
Return value	<NR3>

FUNCtion:MPPT:SWEep:DIRection

This command sets the sweep direction of the MPP tracking function.

The text parameter specifies the sweep direction:
DOWN: from Uoc towards 0 V
UP: from 0 V towards Uoc

Syntax	FUNCtion:MPPT:SWEep:DIRection DOWN|UP
Param	DOWN|UP
**RST value*	DOWN
Example	FUNC:MPPT:SWE:DIR UP
Query syntax	FUNCtion:MPPT:SWEep:DIRection?
Return value	<NR3>

FUNCtion:MPPT:SWEep:PERiod

This command sets the sweep period of the MPP tracking function.

The numeric parameter specifies the sweep period in seconds. The MIN parameter sets the smallest permissible value for the time, the MAX parameter sets the largest permissible value for the time.

Syntax	FUNCtion:MPPT:SWEep:PERiod <NRf>
Parameter	10 ... 3600
**RST value*	10
Example	FUNC:MPPT:SWE:PER 60
Query syntax	FUNCtion:MPPT:SWEep:PERiod? [MIN|MAX]
Return value	<NR3>

FUNCtion:MPPT:SWEep:TIME

This command sets the sweep duration of the MPP tracking function.

The numeric parameter specifies the sweep duration in seconds. The MIN parameter sets the smallest permissible value for the time, the MAX parameter sets the largest permissible value for the time.

Syntax	FUNCtion:MPPT:SWEep:TIME <NRf>
Parameter	0.1
**RST value*	1
Example	FUNC:MPPT:SWE:TIME 60
Query syntax	FUNCtion:MPPT:SWEep:TIME? [MIN|MAX]
Return value	<NR3>

FUNCtion:MPPT:TIME?

This command queries the time that has elapsed since the MPPT function was activated.

The returned value is in seconds.

Query syntax	FUNCtion:MPPT:TIME?
Example	FUNC:MPPT:TIME?
Return value	

FUNCtion:SPEed

This command sets the control speed for hardware-based control.

The parameter can take one of the following values:
SLOW: low control speed
FAST: high control speed

Syntax	FUNCtion:SPEed <speed>
Parameter	SLOW|FAST
**RST value*	FAST
Example	FUNC:SPE SLOW
Query syntax	FUNCtion:SPEed?
Return value	SLOW|FAST

FUNCtion:ZVOLtage

This command sets the activation status of the zero-volt function.

The parameter ON or 1 activates the zero-volt function, the parameter OFF or 0 deactivates the zero-volt function.

Syntax	FUNCtion:ZVOLtage[:ENABle] <boolean>
Parameter	0|OFF|1|ON
**RST value*	OFF
Example	FUNC:ZVOL ON
Query syntax	FUNCtion:ZVOLtage[:ENABle]?
Return value	0|1

5.11.7 INPut Subsystem

INPut

This command sets the state of the load input.

The parameter OFF or 0 deactivates the input, the parameter ON or 1 activates the input.

The query command always returns the target state. This means that if the command INPut ON is received by the electronic load, it returns 1 when queried, even if, for example, the load input is actually switched off due to overtemperature protection. The actual activation state of the load input is returned by querying the Operation Status Register.

Syntax	INPut[:STATe] <boolean>
Parameters	0|OFF|1|ON
**RST value*	OFF
Example	INP ON
Query syntax	INPut[:STATe]?
Return value	0|1

INPut:TRIGgered

This command sets the trigger state of the load input.

The parameter OFF or 0 deactivates the load input when a trigger event occurs, while the parameter ON or 1 activates the load input when a trigger event occurs.

Syntax	INPut[:STATe]:TRIGgered <boolean>
Parameter	0|OFF|1|ON
**RST value*	OFF
Example	INP:TRIG ON
Query syntax	INPut[:STATe]:TRIGgered?
Return value	0|1

INPut:WDOG

This command sets the activation status of the watchdog.

The parameter OFF or 0 deactivates the watchdog, the parameter ON or 1 activates the watchdog.

The watchdog is deactivated after the electronic load is switched on. A device reset does not change the activation status.

Syntax	INPut:WDOG[:STATe] <boolean>
Parameter	0|OFF|1|ON
Example	INP:WDOG ON
Query syntax	INPUT:WDOG[:STATe]?
Return value	0|1

INPut:WDOG:DELay

This command sets the delay time for the watchdog.

The numeric parameter value specifies the delay time in seconds. The numeric value is implicitly rounded to the nearest integer. The MIN parameter sets the smallest permissible value, the MAX parameter sets the largest permissible value.

The delay time is 60 s after the electronic load is switched on. A device reset does not change the delay time.

INPut:WDOG:RESet

This command resets the watchdog.

This command has no query form.

Syntax	INPut:WDOG:RESet
Example	INP:WDOG:RES

5.11.8 LIST Subsystem

LIST

This command sets the activation status for executing a list .

The parameter ON or 1 activates the execution of a list, the parameter OFF or 0 deactivates the execution of a list.

Syntax	LIST[:STATe] <boolean>
Parameter	0|OFF|1|ON
**RST Value*	OFF
Example	LIST ON
Query syntax	LIST[:STATe]?
Return value	0|1

LIST:ACQuisition

This command sets the activation status for synchronous data acquisition when executing a list.

The parameter ON or 1 activates data acquisition, the parameter OFF or 0 deactivates it.

Syntax	LIST:ACQuisition[:ENABle] <boolean>
Parameter	0|OFF|1|ON
Example	LIST:ACQ ON
Query syntax	LIST:ACQuisition[:ENABle]?
Return value	0|1
Reset value	OFF

LIST:COUNT

This command sets the number of times a list is processed after activation.

The numeric parameter value specifies the number of passes and is implicitly rounded to the nearest integer. The MIN parameter sets the smallest permissible value, the MAX parameter sets the largest permissible value. A value greater than the MAX value or the numerical value for infinity (9.9E37) causes the list to be executed continuously until it is terminated with LIST:STATe OFF.

Syntax	LIST:COUNt <NRf>
Parameter	1 ... 999999|MIN|MAX
**RST value*	1
Example	LIST:COUN 23
Query syntax	LIST:COUNt? [MIN|MAX]
Return value	<NR3>

LIST:CURRent

This command sets the individual settings in the list for the input current.

A numeric parameter specifies the current strength in the basic unit of amperes. The maximum number of parameter values is 100.

Syntax	LIST:CURRent[:LEVel] <NRf>{,<NRf>}
Param	{,<NRf>}
Unit	A|MA
**RST Value*	Invalid list
Example	LIST:CURR 12.75,56.2,0
Query syntax	LIST:CURRent[:LEVel]?
Return value	{,<NR3>}

LIST:CURRent:POINts?

This command queries the current number of specified settings for the input current in the list.

If the optional parameter MIN is passed, the smallest permissible value for the number is queried; if the optional parameter MAX is passed, the largest permissible value for the number is queried.

Query syntax	LIST:CURR[:LEVel]:POINts? [MIN|MAX]
Return value	

LIST:DWELl

This command sets the individual target values in the list for dwell times.

A numeric parameter specifies the dwell time in the base unit of seconds. The maximum number of parameter values is 100.

Syntax	LIST:DWELl <NRf>{,<NRf>}
Parameter	0.0002 ... 1000.0{,0.0002 ... 1000.0}
Unit	S|MS
**RST value*	Invalid list

Example	LIST:DWEL 5.5E-3,0.01,1.02
Query syntax	LIST:DWELl?
Return value	<NR3>{,<NR3>}

LIST:DWELl:POINts?

This command queries the current number of specified dwell times in the list.

If the optional parameter MIN is passed, the smallest permissible value for the number is queried; if the optional parameter MAX is passed, the largest permissible value for the number is queried.

Query syntax	LIST:DWELl:POINts? [MIN|MAX]
Return value	

LIST:MODE

This command sets the operating mode valid for the LIST function. It selects the corresponding setting list.

Syntax	LIST:MODE <mode>
Parameter	CURRent|POWer|RESistance|VOLTage
**RST value*	CURRent
Example	LIST:MODE VOLT
Query syntax	LIST:MODE?
Return value	CURR|POW|RES|VOLT

LIST:POINts?

This command queries the number of list points executed since the list was activated.

Query syntax	LIST:POINts?
Return value	

LIST:POWer

This command sets the individual settings for a power list.

A numeric parameter specifies the power in the base unit of watts. The maximum number of parameter values is 100.

Syntax	LIST:POWer[:LEVel] <NRf>{,<NRf>}
Parameter	<NRf>{,<NRf>}
Unit	W|MW|KW
**RST value*	Invalid list
Example	LIST:POW 50,8.5,26.8
Query syntax	LIST:POWer[:LEVel]?
Return value	{,<NR3>}

LIST:POWer:POINts?

This command queries the current number of specified target values for power in the list.

If the optional parameter MIN is passed, the smallest permissible value for the number is queried; if the optional parameter MAX is passed, the largest permissible value for the number is queried.

Query syntax	LIST:POWer[:LEVel]:POINts? [MIN|MAX]
Return value	<NR1>

LIST:RESistance

This command sets the individual settings for a resistance list.

A numeric parameter specifies the input resistance in the base unit ohms. The maximum number of parameter values is 100.

Syntax	LIST:RESistance[:LEVel] <NRf>{,<NRf>}
Parameter	{,<NRf>}

Unit	OHM|KOHM
**RST value*	Invalid list
Example	LIST:RES 5.0,0.85,2.667E-2
Query syntax	LIST:RESistance[:LEVel]?
Return value	{,

LIST:RESistance:POINts?

This command queries the current number of specified target values for the input resistance in the list.

If the optional parameter MIN is passed, the smallest permissible value for the number is queried; if the optional parameter MAX is passed, the largest permissible value for the number is queried.

Query syntax	LIST:RESistance[:LEVel]:POINts? [MIN|MAX]
Return	<NR1>

LIST:RTIMe

This command sets the individual settings in the list for the ramp times.

A numeric parameter specifies the ramp time in the base unit of seconds. The maximum number of parameter values is 100.

Syntax	LIST:RTIMe <NRf>{,<NRf>}
Parameter	0.0 ... 1000.0{,0.0 ... 1000.0}
Unit	S|MS
**RST value*	Invalid list
Example	LIST:RTIMe 5.5E-3,0.01,1.02
Query syntax	LIST:RTIMe?
Return value	{,

LIST:RTIMe:POINts?

This command queries the current number of specified ramp times in the list.

If the optional parameter MIN is passed, the smallest permissible value for the number is queried; if the optional parameter MAX is passed, the largest permissible value for the number is queried.

Query syntax	LIST:RTIMe:POINts? [MIN|MAX]
Return value	

LIST:STIMe:DWELl

This command sets the target values in the list for sampling times during dwell times.

A numeric parameter specifies the sampling time in the base unit of seconds. The maximum number of parameter values is 300.

Syntax	LIST:STIMe:DWELl <NRf>{,<NRf>}
Parameter	2E-04 ... 1E+03{,2E-04 ... 1E+03}
Unit	S
Example	LIST:STIM:DWEL 1E-3,0.01,0.05
Query syntax	LIST:STIMe:DWELl?
Return value	{,<NR3>}
Reset value	Empty list

LIST:STIMe:DWELl:POINts?

This command queries the current number of settings in the list for sampling times during dwell times.

If the optional parameter MIN is passed, the smallest permissible value for the number is queried; if the optional parameter MAX is passed, the largest permissible value for the number is queried.

Query syntax	LIST:STIMe:DWELl:POINts? [MIN|MAX]

Return value <NR1>

LIST:STIMe:RTIMe

This command sets the target values in the list for sampling times during ramp times.

A numeric parameter specifies the sampling time in the base unit of seconds. The maximum number of parameter values is 300.

Syntax LIST:STIMe:RTIMe <NRf>{,<NRf>}
Parameter 2E-04 ... 1E+03{,2E-04 ... 1E+03}
Unit S
Example LIST:STIM:RTIM 1E-3,0.01,0.05
Query syntax LIST:STIMe:RTIMe?
Return value {,<NR3>}
Reset value Empty list

LIST:STIMe:RTIMe:POINts?

This command queries the current number of target values in the list for sampling times during ramp times.

If the optional parameter MIN is passed, the smallest permissible value for the number is queried; if the optional parameter MAX is passed, the largest permissible value for the number is queried.

Query syntax LIST:STIMe:RTIMe:POINts? [MIN|MAX]
Return value <NR1>

LIST:TIME?

This command queries the time that has elapsed since the list was activated.

The returned value is in seconds.

Query syntax LIST:TIME?
Return value <NR3>

LIST:TRIGger

This command sets the activation status for trigger evaluation to start or stop a list.

The parameter ON or 1 activates trigger evaluation, the parameter OFF or 0 deactivates trigger evaluation.

Syntax LIST:TRIGger[:ENABle] <boolean>
Parameter 0|OFF|1|ON
**RST value* OFF
Example LIST:TRIG ON
Query syntax LIST:TRIGger[:ENABle]?
Return value 0|1

LIST:VOLTage

This command sets the specified settings in the list for the input voltage.

A numeric parameter specifies the input voltage in volts. The maximum number of parameter values is 100.

Syntax LIST:VOLTage[:LEVel] <NRf>{,<NRf>}
Parameter <NRf>{,<NRf>}
Unit V|MV
**RST value* Invalid list
Example LIST:VOLT 12.75,56.2,0
Query syntax LIST:VOLTage[:LEVel]?
Return value {,<NR3>}

LIST:VOLTages:POINts?

This command queries the current number of specified voltage settings in the list.

If the optional parameter MIN is passed, the smallest permissible value for the number is queried; if the optional parameter MAX is passed, the largest permissible value for the number is queried.

Query syntax	LIST:VOLTages[:LEVel]:POINts? [MIN|MAX]
Return value	MEASure

5.11.9 MEASure Subsystem

The electronic load provides measured values for the load current, input voltage, power consumption, input resistance, and output stage temperature.

When a measurement query is received, the load sends the value determined using the fast, low-resolution A/D converter by default. However, you also have the option of querying the value of the slow, high-resolution A/D converter by appending the optional parameter SLOW (not with `MEASure:TEMPerature?, MEASure:VOLTage:EXTernal?, MEASure:VOLTage:FET?`). If the optional parameter FAST or no parameter is appended to the query command, the load sends the value of the fast ADC.

MEASure:CURRent?

This command queries the current measured value for the load current.

The returned value for the current is in amperes.

Query syntax	MEASure:CURRent? [FAST|SLOW]
Return value	<NR3>

MEASure:POWer?

This command queries the current value for the input power, calculated from voltage and current.

The returned value for the power is in watts.

Query syntax	MEASure:POWer? [FAST|SLOW]
Return value	<NR3>

MEASure:RESistance?

This command queries the current value for the input resistance, calculated from voltage and current.

The returned value for the resistance is in ohms.

Query syntax	MEASure:RESistance? [FAST|SLOW]
Return value	<NR3>

MEASure:TEMPerature?

This command queries the current measured value for the output stage temperature if the parameter PSTage or no parameter is appended.

Optionally, the parameter CPU can be appended to measure the CPU temperature.

The returned value for the temperature is in degrees Celsius.

Query syntax	MEASure:TEMPerature? [PSTage|CPU]
Return value	<NR3>

MEASure:VOLTage?

This command queries the current measured value for the input voltage.

The returned value for the voltage is in volts.

Query syntax	MEASure:VOLTage? [FAST|SLOW]
Return value	<NR3>

MEASure:VOLTage:EXTernal?

This command queries the current measured value for the voltage at the analog control input LEVEL+ against LEVEL- at the I/O port.

The returned value for the voltage is in volts.

Query syntax	MEASure:VOLTage:EXTernal?
Return value	<NR3>

MEASure:VOLTage:FET?

This command queries the current measured value for the voltage at the power semiconductor of the output stage.

The returned value for the voltage is in volts.

Query syntax	MEASure:VOLTage:FET?
Return value	<NR3>

5.11.10 PORT Subsystem

PORT:IO:IPIN?

This command queries the logical state of the digital logic input on the I/O port.

The numeric parameter value is 0 because there is only one queryable logic input on the I/O port.
If the value 0 is returned, the pin is logically low; if the value 1 is returned, the pin is logically high.

See also6.3 I/O Port Pin Assignment .

Query syntax	PORT:IO:IPIN? <NRf>
Parameter	0
Example	PORT:IO:IPIN? 0
Return value	0|1

POWer:IO:OPIN

This command sets the logical state for the programmable logic output on the I/O port.

The first numeric parameter value is 0, as there is only one programmable logic output on the I/O port.
The second numeric parameter value sets the state of the pin: ON or 1 sets the pin to logical high, OFF or 0 sets the pin to logical low.

See also6.3 I/O Port Pin Assignment .

Syntax	PORT:IO:OPIN <NRf>,<boolean>
Parameter 1	0
Parameter 2	0|OFF|1|ON
**RST value*	OFF
Example	PORT:IO:OPIN 0,ON
Query syntax	PORT:IO:OPIN? <NRf>
Return value	0|1

5.11.11 POWer Subsystem

POWer

This command sets the setting for the regulated power in power mode.

The numerical parameter specifies the power in the base unit of watts. The MIN parameter sets the smallest permissible value for the power, the MAX parameter sets the largest permissible value for the power.

The <max> or MAX value corresponds to the maximum short-term power and can be found in the technical data.

Syntax	POWer[:LEVel][:IMMediate] <NRf>|MIN|MAX
Parameter	0 ... <max>|MIN|MAX
Unit	W|KW|MW
**RST value*	0
Example	POW 57.88
Query syntax	POWer[:LEVel][:IMMediate]? [MIN|MAX]
Return value	<NR3>

POWer:TRIGgered

This command sets the triggered setting for the regulated power in power mode.

The numeric parameter specifies the power in the base unit of watts. The MIN parameter sets the smallest permissible value for the power, the MAX parameter sets the largest permissible value for the power.

The <max> or MAX value corresponds to the maximum short-term power and can be found in the technical data.

Syntax	POWer[:LEVel]:TRIGgered <NRf>|MIN|MAX
Parameter	0 ... <max>|MIN|MAX
Unit	W|KW|MW
**RST value*	0
Example	POW:TRIG 2.3E3
Query syntax	POWer[:LEVel]:TRIGgered? [MIN|MAX]
Return value	<NR3>

POWer:PEAK?

This command queries the currently possible peak power, which depends on the output stage temperature ( ).

The returned value for the peak power is in watts.

Query syntax	POWer:PEAK?
Return value	<NR3>

POWer:RANGe?

This command queries the maximum power for the specified range. It is only available for multi-range devices (HES MR).

The numeric parameter specifies the number of the range. If the parameter MIN is passed, the maximum power for range 1 is queried; if the parameter MAX is passed, the maximum power for range 3 (3-range device) or 4 (4-range device) is queried.

Query syntax	POWer:RANGe? [NRf|MIN|MAX]
Return value	<NR3>

5.11.12 RANGe Subsystem

RANGe

This command sets the setting for range selection in current, power, and resistance mode. It is only available for HES MR multi-range devices.

The numeric parameter specifies the number of the range to be selected. The MIN parameter sets the smallest permissible number (1), the MAX parameter sets the largest permissible number, depending on the number of available ranges.

By appending the optional parameter 1, the settings are automatically corrected when the new range is set. Without the optional parameter, the settings are not corrected.

Note the dependencies in the chapter "4.4Setting and measurement ranges (HES MR) !

Syntax	RANGe <NRf>|MIN|MAX[,1}
Parameter	1 ... 4|MIN|MAX
**RST Value*	1
Example	RANK 3
Query syntax	RANK? [MIN|MAX]
Return value	<NR1>

5.11.13 RECTangle Subsystem

RECTangle

This command sets the activation status for executing the rectangle function.

The parameter ON or 1 activates the execution of the function, the parameter OFF or 0 deactivates the execution of the function.

Syntax	RECTangle[:STATe] <boolean>
Parameter	0|OFF|1|ON
Example	RECT ON
Query syntax	RECTangle[:STATe]?
Return value	0|1
Reset value	OFF

RECTangle:CURRent

This command sets the two settings for the load current during the dwell times of the rectangle function.

The <max> value corresponds to the maximum current and can be found in the technical data.

The numerical parameters specify the current in the basic unit of amperes.

Syntax	RECTangle:CURRent[:LEVEL] <NRf>,<NRf>
Parameter 1	0 ... <max>
Parameter 2	0 ... <max>
Unit	A
Example	RECT:CURR 4.33,0
Query syntax	RECTangle:CURRent[:LEVel]?
Return value	<NR3>
Reset value	0.0,0.0

RECTangle:DWELl

This command sets the two settings for the dwell times of the square wave function.

The numerical parameters specify the dwell times in the base unit of seconds.

Syntax	RECTangle:DWELl <NRf>,<NRf>
Parameter 1	0.000001 ... 9.999999
Parameter 2	0.000001 ... 9.999999
Unit	A
Example	RECT:DWELl 5.67E-3,1.1E-3
Query syntax	RECTangle:DWELl?
Return value	<NRf>,<NRf>
Reset value	0.5,0.5

RECTangle:MODE

This command sets the control mode for executing the rectangle function.

The CURRent parameter activates current control.
The RESistance parameter activates resistance control.
The VOLTage parameter activates voltage control.

Syntax	RECTangle:MODE <mode>
Parameter	CURRent|RESistance|VOLTage
Example	RECT:MODE VOLT
Query syntax	RECTangle:MODE?
Return value	CURR|RES|VOLT
Reset value	CURRent

RECTangle:RESistance

This command sets the two settings for the resistance during the dwell times of the rectangle function.

The <max> value corresponds to the maximum resistance and can be found in the technical data.

The numerical parameters specify the resistance in the base unit ohms.

Syntax	RECTangle:RESistance[:LEVEL] <NRf>,<NRf>
Parameter 1	0 ... <max>
Parameter 2	0 ... <max>
Unit	OHM
Example	RECT:RES 800.0,80.0
Query syntax	RECTangle:RESistance[:LEVel]?
Return value	<NR3>
Reset value	<max>,<max>

RECTangle:VOLTage

This command sets the two settings for the voltage during the dwell times of the square wave function.

The <max> value corresponds to the maximum voltage and can be found in the technical data.

The numerical parameters specify the voltages in the base unit volts.

Syntax	RECTangle:VOLTage[:LEVEL] <NRf>,<NRf>
Parameter 1	0 ... <max>
Parameter 2	0 ... <max>
Unit	VOLT
Example	RECT:VOLT 22.4,5.5
Query syntax	RECTangle:VOLTage[:LEVel]?
Return value	<NR3>
Reset value	<max>,<max>

5.11.14 RESistance Subsystem

RESistance

This command sets the setting for the controlled input resistance in resistance mode.

The numerical parameter specifies the resistance in the base unit ohms. The MIN parameter sets the smallest permissible value for the resistance, the MAX parameter sets the largest permissible value for the resistance.

<min> and MIN values are the smallest possible settings, <max> and MAX values are the largest possible settings. They can be found in the technical data.

Syntax	RESistance[:LEVel][:IMMediate] <NRf>|MIN|MAX
Parameter	<min> ... <max>|MIN|MAX
Unit	OHM|KOHM
**RST value*	MAX
Example	RES 3.77
Query syntax	RESistance[:LEVel][:IMMediate]? [MIN|MAX]
Return value	<NR3>

RESistance:TRIGgered

This command sets the triggered setting for the controlled input resistance.

The numeric parameter specifies the resistance in the base unit ohms. The MIN parameter sets the smallest permissible value for the resistance, the MAX parameter sets the largest permissible value for the resistance.

The values for <min> and <max> or MIN and MAX can be found in the technical data.

Syntax	RESistance[:LEVel]:TRIGgered <NRf>|MIN|MAX
Parameter	<min> ... <max>|MIN|MAX
Unit	OHM|KOHM
**RST value*	MAX
Example	RES:TRIG 0.91
Query syntax	RESistance[:LEVel]:TRIGgered? [MIN|MAX]
Return value	RESistance:RANGe?

RESistance:RANGe?

This command queries the maximum resistance for the specified range. It is only available for multi-range devices (HES MR).

The numeric parameter specifies the number of the range. If the parameter MIN is passed, the maximum resistance for range 1 is queried; if the parameter MAX is passed, the maximum resistance for range 3 (3-range device) or 4 (4-range device) is queried.

Query syntax	RESistance:RANGe? [NRf|MIN|MAX]
Return value	SERVice Subsystem

5.11.15 SERVice Subsystem

SERVice:CALibration

This command sets the activation status for the calibration mode.

The first parameter specifies the state: the parameter ON or 1 activates the calibration mode, the parameter OFF or 0 deactivates the calibration mode. The second parameter specifies the password for activating the mode. It is not required for deactivation.

The query command only returns the activation status of the calibration mode. If the numerical value 0 is returned, the calibration mode is deactivated; if the value 1 is returned, the calibration mode is activated.

This command is only intended for trained personnel who are familiar with the calibration process for H&H electronic loads. It is therefore password-protected.
Misuse of this command can lead to malfunction of the electronic load and render it unusable!

Syntax	SERVice:CALibration[:STATe] <boolean>[,<code>]
Parameter1	0|OFF|1|ON
Parameter2	<code>
**RST value*	OFF
Example	SERV:CAL OFF
Query syntax	SERVice:CALibration[:STATe]?
Return value	0|1

SERVice:PRODuction

This command sets the activation status for production mode.

The first parameter value specifies the new state: the parameter ON or 1 activates production mode, the parameter OFF or 0 deactivates production mode. The second parameter value specifies the password for activating production mode. It is not required for deactivation.

The query command only returns the activation status of production mode. If the numeric value 0 is returned, production mode is deactivated; if the value 1 is returned, production mode is activated.

This command is only intended for trained specialists who are familiar with the production process of H&H electronic loads. It is therefore password-protected.
Misuse of this command can lead to malfunction of the electronic load and render it unusable!

Syntax	SERVice:PRODuction[:STATe] <boolean> [,<code>]
Parameter1	0|OFF|1|ON
Parameter2	<code>
**RST value*	OFF
Example	SERV:PROD OFF
Query syntax	SERVice:PRODuction[:STATe]?
Return value	0|1

SERVice:STRing

This command sets the specified parameter string with the specified character string in non-volatile memory.

The first numeric parameter specifies the number of the string. The second parameter specifies the character string to be set.

This command is intended only for trained personnel who are familiar with the production process of H&H electronic loads. It is therefore password-protected and only permitted in production mode.
Misuse of this command can cause the electronic load to malfunction and render it unusable!

Syntax	SERVice[:PARameter]:STRing <NRf>,<string>
Parameter1	0 ... 19
Parameter2	<string>
Example	SERV:STR 8,"Abc123"
Query syntax	SERVice[:PARameter]:STRing? <NRf>
Return value	<string>

SERVice:VALue

This command sets the specified system parameter to the specified value in non-volatile memory.

The first numeric parameter specifies the number of the system parameter. The second numeric parameter specifies the parameter value to be set.

With the exception of a small unprotected section, the system parameters are intended for use by trained specialists who are familiar with the production process of H&H electronic loads. A certain parameter range is therefore password-protected and can only be written to in production or calibration mode.
Misuse of this command can lead to malfunction of the electronic load and render it unusable!

See also 5.11.18 SYSTem Subsystem (command `SYSTem:PRESet`).

Syntax	SERVice[:PARameter]:VALue <NRf>,<NRf>
Parameter1	0 ... 2015
Parameter2	<NRf>
Example	SERV:VAL 7.0.8
Query syntax	SERVice[:PARameter]:VALue?
Return value	<NR3>

5.11.16 SETTing Subsystem

SETTing:EXTernal

This command sets the activation status for external control via the I/O port.

The parameter ON or 1 activates external control, the parameter OFF or 0 deactivates external control.

The desired externally controllable signals must be enabled with the SETTing:EXTernal:ENABle command.

Syntax	SETTing:EXTernal[:STATe] <boolean>
Parameter	0|OFF|1|ON
**RST value*	OFF
Example	SETT:EXT ON
Query syntax	SETTing:EXTernal[:STATe]?
Return value	0|1

SETTing:EXTernal:ENABle

This command sets the enable state of the corresponding external signal for control.

The first parameter specifies the external signal:
INPUT: Activation status of the load input
MODE: Basic operating mode
ILEVel: Setting for control (immediate level)
PLEVel: Current and voltage limitation (protection level)

The second parameter specifies the enable status:
0|OFF: The external signal is not enabled for control.
1|ON: The external signal is enabled for control.

Syntax	SETTing:EXTernal:ENABle <signal>,<boolean>
Parameter1	INPUT|MODE|ILEVEL|PLEVEL
Parameter2	0|OFF|1|ON
**RST value*	All OFF
Example	SETT:EXT:ENAB INP,ON
Query syntax	SETTing:EXTernal:ENABle? <signal>
Return value	0|1

5.11.17 STATus Subsystem

The STATus subsystem is used to determine the status of the electronic load and to configure the collective status in the status byte.
The content of a status register is represented by a decimal number composed of the values of the set bits:

Bit	Value	Bit	Value
0	1	8	256
1	2	9	512
2	4	10	1024
3	8	11	2048
4	16	12	4096
5	32	13	8192
6	64	14	16384
7	128	15	32768

After power-up, all bits of all status registers are FALSE – with the exception of bit 7 (PON) in the standard event register (see below).

The status model is divided into the following groups (see below):

- Questionable Status
- Operation Status
- Standard Event Status
- Status Byte

The Questionable, Condition, and Standard Event status groups are divided into

- Condition Register (Questionable and Operation Status only)
- Event Register
- Enable Register

Condition register
Represents the current status of conditions/functions and errors. The bit status of a condition register is not changed by reading. A condition/error is active when the corresponding bit is set. If the corresponding condition is no longer active, the respective bit in the corresponding condition register is also deleted.

Event Register
Stores information about events and errors that have occurred. Each bit of an event register corresponds to a bit in the condition register (for questionable status and operation status) or directly to specific events (standard event status).
A bit in the event register is set when the corresponding event has become active. The event remains set until the corresponding event register has been read. When read, all bits in the relevant event register are reset to 0.

Enable register
Determines which bits of the associated event register are logically ORed to form a sum bit. The enable register acts as a filter on the associated event register.
The bit state of an enable register is not changed by reading.

HES status model

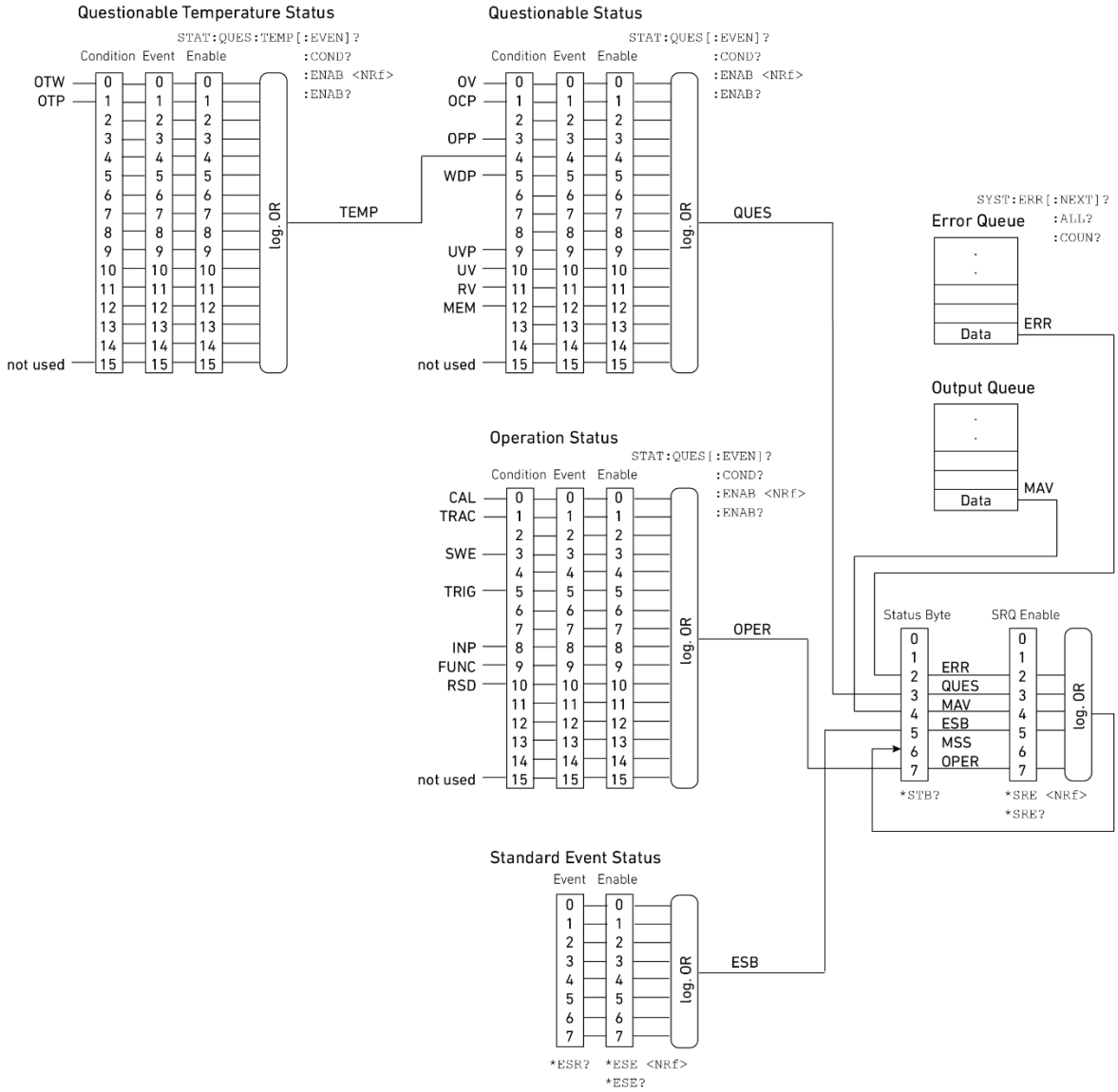


Figure 5.2: HES status model

Questionable Temperature Status

The Questionable Temperature Status registers contain important information about current and past questionable temperature conditions of the device. They have a width of 16 bits.

The contents of this register group are linked using an OR function and mapped via bit 4 (TEMP) in the Questionable Status Register.

Bit	Value	Meaning
0 OTW	1	Overtemperature warning active. OTW is displayed on the user interface.
1 OTP	2	Overtemperature protection active. OTP is displayed on the user interface.

Questionable Status

The Questionable Status registers provide information about certain error or overload conditions. They have a width of 16 bits.

See below for the commands for reading and writing the questionable status registers.

Bit	Value	Meaning
0 OV	1	Overvoltage active. OV is displayed on the user interface.
1 OCP	2	Overcurrent protection active. OCP is displayed on the user interface.
3 OPP	8	Overpower protection active. OPP is displayed on the user interface.
4 TEMP	16	Questionable temperature condition. OTW or OTP (Over Temperature Protection) is displayed on the user interface.
5 WDP	32	Watchdog triggered. WDP is displayed on the user interface.
9 UVP	512	Undervoltage protection active. UVP is displayed on the user interface.
10 UV	1024	Undervoltage active. UV is displayed on the user interface.
11 RV	2048	Reverse voltage active. RV is displayed on the user interface.
12 MEM	4096	Memory overflow. Set when the ring buffer for measurement data storage is full and the old data is overwritten.

Operation Status

The operation status registers provide information about the operating status of the electronic load. They have a width of 16 bits.

See below for the commands for reading and writing the operation status registers.

Bit	Value	Meaning
0 CAL	1	A calibration process is active.
1 TRAC	2	MPP tracking is active.
3 SWE	8	MPP Sweeping is active.
5 TRIG	3	The electronic load is waiting for a trigger.
8 INP	25	The load input is active.
9 FUNC	51	One of the functions ACQ, LIST, MOD, RECT, MPPT, DISC, MEAS_IRES is active.
10 RSD	10	Remote shutdown is active.

Standard Event Status

The system-specific standard event status register contains information about standard events defined in the IEEE 488.2 standard.
It has a width of 8 bits and is read with the common command `*ESR?` (see5.10.3).

The command `*ESE <NRf>` (see5.10.2) sets the bit combination specified by the decimal parameter in the Standard Event Status Enable Register. This determines which bits from the Standard Event Register are relevant for the ESB sum bit evaluation. The enable register can be read out with `*ESE?`.

Bit	Value	Meaning
0 OPC	1	Operation Complete. The device has executed all pending commands. Always TRUE for electronic loads, as the commands are not

		executed in overlapped mode, but always sequentially.
2 QYE	4	Query Error. Errors in the range from -400 to -499 can set this bit.
3 DDE	8	Device Dependent Error. Errors in the range from -399 to -300 can set this bit.
4 EXE	16	Execution Error. Errors in the range from -299 to -200 can set this bit.
5 CME	32	Command Error. Errors in the range from -199 to -100 can set this bit.
7 PON	12	Power On. Indicates that the electronic load has been switched off and on again since the last reading of the register value, or that a power failure has occurred.

Status Byte

The status events of all status registers and the sum bits for the system-specific QUES and OPER statuses are collected in the status byte register.
It has a width of 8 bits and is read with the common command `*STB?` (see5.10.11).

Bit	Value	Meaning
2 ERR	4	Error. An error entry is in the error queue.
3 QUES	8	Questionable. An enabled questionable event has occurred.
4 MAV	16	Message Available.
5 ESB	32	Event status bit. An enabled standard event has occurred.
6 MSS	64	Master Summary Status.
7 OPER	12	Operation. An enabled operation event has occurred.

STATus:OPERation?

This command queries the value of the operation status event register.

This query deletes the register value, i.e., resets it to 0.

Query syntax	STATus:OPERation[:EVENt]?
Return value	<NR1>

STATus:OPERation:CONDition?

This command queries the value of the operation status register.

Query syntax	STATus:OPERation:CONDition?
Return value	<NR1>

STATus:OPERation:ENABle

This command sets the bit combination specified by the decimal parameter of the Operation Status Enable register.

The numeric parameter specifies the new value for the register.
The register contents are retained after a reset (*RST).

Syntax	STATus:OPERation:ENABle <NRf>
Parameter	0 ... 32767
Example	STAT:OPER:ENAB 16
Query syntax	STATus:OPERation:ENABle?

Return value <NR1>

STATus:PRESet

This command sets all SCPI status enable registers to defined values.

Operation Status Enable Register: 0
Questionable Status Enable Register: 0
SRQ Enable Register: 0
Standard Event Status Enable Register: 0

This command has no query form.

Syntax STATus:PRESet
Example STAT:PRES

STATus:QUEStionable?

This command queries the value of the Questionable Status Event Register.

This query deletes the register value, i.e., resets it to 0.

Query syntax STATus:QUEStionable[:EVENt]?
Return value <NR1>

STATus:QUEStionable:CONDition?

This command queries the value of the Questionable Status Register.

Query syntax STATus:QUEStionable:CONDition?
Return value <NR1>

STATus:QUEStionable:ENABle

This command sets the value of the QUEStionable Status Enable register.

The numeric parameter specifies the new value for the register.
The register contents are retained after a reset (*RST).

Syntax STATus:QUEStionable:ENABle <NRf>
Parameter 0 ... 32767
Example STAT:QUES:ENAB 16
Query syntax STATus:QUEStionable:ENABle?
Return value <NR1>

STATus:QUEStionable:TEMPerature?

This command queries the value of the Questionable Temperature Status Event Register.

This query clears the register value, i.e., resets it to 0.

Query syntax STATus:QUEStionable:TEMPerature[:EVENt]?
Return value <NR1>

STATus:QUEStionable:TEMPerature:CONDition?

This command queries the value of the Questionable Temperature Status Register.

Query syntax STATus:QUEStionable:TEMPerature:CONDition?
Return value <NR1>

STATus:QUEStionable:TEMPerature:ENABle

This command sets the value of the QUEStionable Temperature Status Enable register.

The numeric parameter specifies the new value for the register.
The register contents are retained after a reset (*RST).

Syntax STATus:QUEStionable:TEMPerature:ENABle <NRf>

Parameter	0 ... 32767
Example	STAT:QUES:ENAB 16
Query syntax	STATus:QUEStionable:TEMPerature:ENABle?
Return value	<NR1>

5.11.18 SYSTem Subsystem

SYSTEM:BEEP

This command activates the electronic load's beeper for the specified duration.

The numeric parameter specifies the duration in seconds (value range from 0.1 to 2.0 s). The MIN parameter activates the beeper for the shortest possible duration, the MAX parameter activates the beeper for the longest possible duration.

Syntax	SYSTem:BEEP <NRf>|MIN|MAX
Parameter	0.1
Example	SYST:BEEP 0.8

SYSTem:COMMunicate:CAN:ADDRess

This command sets the address for the CAN interface.

The numeric parameter specifies the new address for the CAN interface. The MIN parameter sets the smallest permissible address, the MAX parameter sets the largest permissible address.

Syntax	SYSTem:COMMunicate:CAN:ADDRess <NRf>
Parameter	1 ... 127|MIN|MAX
Example	SYST:COMM:CAN:ADDR 4
Query syntax	SYSTem:COMMunicate:CAN:ADDRess? [MIN|MAX]
Return value	

SYSTem:COMMunicate:CAN:BAUD

This command sets the baud rate for the CAN interface.

The numeric parameter specifies the baud rate in bits per second. The MIN parameter sets the minimum permissible baud rate, while the MAX parameter sets the maximum permissible baud rate.

Syntax	SYSTem:COMMunicate:CAN:BAUD <NRf>
Parameter	125000|250000|500000|1000000|MIN|MAX
Unit	Bits/s
Example	SYST:COMM:CAN:BAUD 500000
Query syntax	SYSTem:COMMunicate:CAN:BAUD? [MIN|MAX]
Return value	

SYSTem:COMMunicate:CAN:TERMination

This command sets the activation status for the terminating resistor for bus termination.

The parameter OFF or 0 deactivates the termination resistor, the parameter ON or 1 activates the termination resistor.

Syntax	SYSTem:COMMunicate:CAN:TERMination[:STATe] <boolean>
Parameter	0|OFF|1|ON
Example	SYST:COMM:CAN:TERM ON
Query syntax	SYSTem:COMMunicate:CAN:TERMination[:STATe]?
Return value	0|1

SYSTem:COMMunicate:GPIB:ADDRess

This command sets the address for the GPIB interface.

The numeric parameter specifies the new address for the GPIB interface. The MIN parameter sets the smallest permissible address, the MAX parameter sets the largest permissible address.

Syntax	SYSTem:COMMunicate:GPIB:ADDRess <NRf>
Parameter	1 ... 30|MIN|MAX
Example	SYST:COMM:GPIB:ADDR 12
Query syntax	SYSTem:COMMunicate:GPIB:ADDRess? [MIN|MAX]
Return value	<NR1>

SYSTem:COMMunicate:LAN:DHCP

This command enables/disables the use of the Dynamic Host Configuration Protocol (DHCP).

The parameter OFF or 0 disables the use of DHCP, the parameter ON or 1 enables the use of DHCP.

Syntax	SYSTem:COMMunicate:LAN:DHCP[:STATe] <boolean>
Parameter	0|OFF|1|ON
Example	SYST:COMM:LAN:DHCP ON
Query syntax	SYSTem:COMMunication:LAN:DHCP[:STATe]?
Return value	0|1

SYSTem:COMMunicate:LAN:DNS

This command sets the static IP address of the server for the Domain Name System (DNS).

The parameter specifies the IP address in dotted notation ("XXX.XXX.XXX.XXX"). Values between 0 and 255 are permitted for XXX.

The query command reads the configured address by appending the keyword STATic. By appending the keyword ACTual or without appending a keyword, the DNS address actually used is read.

Syntax	SYSTem:COMMunicate:LAN:DNS[:ADDRess] <string>
Parameter	<string>
Example	SYST:COMM:LAN:DNS "192.168.0.253"
Query syntax	SYSTem:COMMunication:LAN:DNS[:ADDRess]? [ACTual|STATic]
Return value	<string>

SYSTem:COMMunicate:LAN:GATeway

This command sets the static IP address of the gateway.

The parameter specifies the IP address in dotted notation ("XXX.XXX.XXX.XXX"). Values between 0 and 255 are permitted for XXX.

The query command reads the configured gateway address by appending the keyword STATic. By appending the keyword ACTual or without appending a keyword, the actual gateway address used is read.

Syntax	SYSTem:COMMunicate:LAN:GATeway[:ADDRess] <string>
Parameter	<string>
Example	SYST:COMM:LAN:GAT "192.168.0.254"
Query syntax	SYSTem:COMMunicate:LAN:GATeway[:ADDRess]? [ACTual|STATic]
Return value	<string>

SYSTem:COMMunicate:LAN:HOSTname?

This command queries the host name for the electronic load.

The host name is returned in the form of a string.

Query syntax	SYSTem:COMMunicate:LAN:HOSTname?
Return value	<string>

SYSTem:COMMunicate:LAN:IP

This command sets the static IP address for the LAN interface.

The parameter specifies the IP address in dotted notation ("XXX.XXX.XXX.XXX"). Values between 0 and 255 are permitted for XXX.

The query command reads the configured IP address by appending the keyword STATic. By appending the keyword ACTual or without appending a keyword, the IP address actually used is read.

Syntax	SYSTem:COMMunicate:LAN:IP[:ADDRess] <string>
Parameter	<string>
Example	SYST:COMM:LAN:IP "192.168.0.1"
Query syntax	SYSTem:COMMunicate:LAN:IP[:ADDRess]? [ACTual|STATic]
Return value	<string>

SYSTem:COMMunicate:LAN:MAC?

This command queries the Media Access Control (MAC) address of the Ethernet interface.
This 48-bit address is globally unique and cannot be changed.

The MAC address is returned in the form "XX:XX:XX:XX:XX:XX", where XX is a hexadecimal value between 00 and FF.

Query syntax	SYSTem:COMMunicate:LAN:MAC[:ADDRess]?
Return value	<string>

SYSTem:COMMunicate:LAN:PORT

This command sets the TCP port number for the LAN interface.

Syntax	SYSTem:COMMunicate:LAN:PORT <NRf>
Parameter	0 ... 65535
Example	SYST:COMM:LAN:PORT 1001
Query syntax	SYSTem:COMMunicate:LAN:PORT?
Return value	<NR1>

SYSTem:COMMunicate:LAN:SUBNet

This command sets the subnet mask for the LAN interface.

The parameter specifies the network mask in dot notation ("XXX.XXX.XXX.XXX"). Values between 0 and 255 are permitted for XXX.

The query command reads the configured subnet mask by appending the keyword STATic. By appending the keyword ACTual or without appending a keyword, the subnet mask actually used is read.

Syntax	SYSTem:COMMunicate:LAN:SUBNet[:MASK] <string>
Parameter	<string>
Example	SYST:COMM:LAN:SUBN "255.255.255.0"
Query syntax	SYSTem:COMMunicate:LAN:SUBNet[:MASK]? [ACTual|STATic]
Return value	<string>

SYSTem:COMMunicate:SERial:BAUD

This command sets the baud rate for the RS-232 interface.

The numeric parameter specifies the baud rate in bits per second. The MIN parameter sets the minimum permissible baud rate, while the MAX parameter sets the maximum permissible baud rate.

Syntax	SYSTem:COMMunicate:SERial:BAUD <NRf>
Parameter	1200|2400|4800|9600|19200|38400|57600|115200|250000|MIN|MAX
Example	SYST:COMM:SER:BAUD 57600
Query syntax	SYSTem:COMMunicate:SERial:BAUD?[MIN|MAX]
Return value	<NR1>

SYSTem:COMMunicate:SERial:BITS?

This command queries the current number of data bits of a character transmitted via the RS-232 interface.

The optional parameter MIN queries the smallest permissible bit number, the optional parameter MAX queries the largest permissible bit number.

Query syntax	SYSTem:COMMunicate:SERial:BITS?[MIN|MAX]
Return value	<NR1>

SYSTem:COMMunicate:SERial:MODE

This command sets the communication mode of the RS-232 interface.

The parameter can have the following values:
SCPI: Use of the interface for communication with SCPI protocol
SLINk: Use the interface as SyncroLink to synchronize multiple devices

A reset has no effect on the configured mode.

Syntax	SYSTem:COMMunicate:SERial:MODE <NRf>
Parameter	[SCPI|SLINk]
Example	SYST:COMM:SER:MODE SLIN
Query syntax	SYSTem:COMMunicate:SERial:MODE?
Return value	SCPI|SLINk

SYSTem:COMMunicate:SERial:PARity

This command configures the parity of individual characters transmitted via the RS-232 interface.

The parameter can take the following values:
EVEN: The parity of a character is even.
NONE: Parity is not checked and not generated.
ODD: The parity of a character is odd.

Syntax	SYSTem:COMMunicate:SERial:PARity <parity>
Parameter	EVEN|NONE|ODD
Example	SYST:COMM:SER:PAR EVEN
Query syntax	SYSTem:COMMunicate:SERial:PARity?
Return value	EVEN|NONE|ODD

SYSTem:COMMunicate:SERial:SBITs

This command sets the number of stop bits for a character transmitted via the RS-232 interface.

The numeric parameter specifies the number of stop bits per data byte.

Syntax	SYSTem:COMMunicate:SERial:SBITs <NRf>
Parameter	1 ... 2|MIN|MAX
Example	SYST:COMM:SER:SBIT 2
Query syntax	SYSTem:COMMunicate:SERial:SBITs? [MIN|MAX]
Return value	1|2

SYSTem:COOLing

This command sets the cooling mode for the power output stage.

If the parameter AUTO is passed, the output stage is cooled by temperature control. If the parameter FULL is passed, the output stage is cooled at full fan power.

Syntax	SYSTem:COOLing[:MODE] <mode>
Parameter	AUTO|FULL
**RST value*	AUTO
Example	SYST:COOL FULL

Query syntax	SYSTem:COOLing[:MODE]?
Return value	AUTO|FULL

SYSTem:DATE

This command sets the date.

All parameter values must be numeric. The first parameter value specifies the year, the second value specifies the month, and the third value specifies the day.

Similarly, when querying, the first return value is the year, the second value is the month, and the third value is the day.

Syntax	SYSTem:DATE <NRf>,<NRf>,<NRf>
Parameter1	2000 ... 2099
Parameter2	1 ... 12
Parameter3	1 ... 31
Example	SYST:DATE 2016,10,28
Query syntax	SYSTem:DATE?
Return value	<NR1>,<NR1>,<NR1>

SYSTem:ERRor?

This command queries the next entry from the error queue (Error Queue) and then deletes this entry from the queue.

The error queue is a FIFO (first in, first out) buffer, which means that the oldest error messages are read out first. If more errors have accumulated than the error queue can hold, the last entry
-350,"Queue Overflow;DI"
is stored as the last entry.

The returned entry consists of the error/event number, a text describing the error/event, and information about the error source <source>.
If the error occurred in the data interface (CAN, GPIB, LAN, RS-232, USB), the character string DI is read as the third parameter. If the error occurred in the internal analog interface, the character string AI is read as the third parameter.

If the queue is empty, the response is:
0,"No error"

Query syntax	SYSTem:ERRor[:NEXT]?
Return value	<NR1>,<string>;<source>

A table with possible error codes can be found in Appendix9.1 Error Codes .

SYSTem:ERRor:ALL?

This command queries all unread entries from the error and event queue (Error Queue) and then deletes these entries.

The individual entries returned in the order in which they occurred (see SYSTem:ERRor[:NEXT]?) are separated by commas and consist of the error/event number, a text describing the error/event, and the error source <source>.

If the queue is empty, the response is:
0,"No error"

Query syntax	SYSTem:ERRor:ALL?
Return value	<NR1>,<string>;<source>{,<NR1>,<string>;<source>}

A table of possible error codes can be found in Appendix9.1 Error Codes .

SYSTem:ERRor:COUNt?

This command queries the number of unread entries in the error and event queue (Error Queue).

The returned numeric value specifies the number of unread entries in the queue.

Query syntax	SYSTem:ERRor:COUNt?
Return value	<NR1>

A table of possible error codes for electronic loads can be found in Appendix9.1 Error Codes .

SYSTem:HELP:HEADers?

This command queries all SCPI headers (complete command without parameters) from the electronic load. The headers are separated from each other by the line feed character (10 dec.).

At the end of the list of all SCPI headers, the electronic load therefore sends two Line Feed characters (10 dec.), one to terminate the last line and one to terminate the response.

In the first line, the electronic load sends a hash sign (#) followed by a multi-digit number. The first digit of this number indicates the number of remaining digits, which specifies the number of following characters including all line terminations.

If no query is available for a command, the string /nquery/ is appended to the returned header.

If only a query but no command is available for a header, the string /qonly/ is appended to the returned header.

Query syntax	SYSTem:HELP:HEADers?
Return value	#<NR1> <header 1><LF> {<header n><LF>}

SYSTem:KLOCk

This command sets the activation status for the keylock .

The parameter OFF or 0 deactivates the key lock, the parameter ON or 1 activates the key lock.

If the key lock has been activated remotely, it cannot be deactivated manually. This is indicated by the letter 'R' in the lock symbol on the user interface.

Syntax	SYSTem:KLOCk <boolean>
Parameter	0|OFF|1|ON
**RST value*	OFF
Example	SYST:CLOCK ON
Query syntax	SYSTem:KLOCk?
Return value	0|1

SYSTem:LOCal

This command activates manual control of the electronic load via the user interface.

Syntax	SYSTem:LOCal
Example	SYST:LOC

SYSTem:PRESet

This command resets all interface settings stored non-volatily in the electronic load to factory settings.

The relevant parameters are described in chapter4.34 Set Factory Settings .

Syntax	SYSTem:PRESet
Example	SYST:PRES

SYSTem:REMote

This command activates control of the electronic load via a data interface (e.g., RS-232, GPIB, LAN, USB).

Syntax	SYSTem:REMote
Example	SYST:REM

SYSTem:SLINk

This command sets the activation status for SyncroLink.

The parameter ON or 1 activates the SyncroLink, the parameter OFF or 0 deactivates the SyncroLink.

Syntax	SYSTem:SLINk[:STATe] <boolean>
Parameter	0|OFF|1|ON
**RST value*	OFF
Example	SYST:SLIN ON
Query syntax	SYSTem:SLINk[:STATe]?
Return value	0|1

SYSTem:TIME

This command sets the time.

All parameter values must be numeric. The first parameter value specifies the hour, the second parameter value specifies the minute, and the third parameter value specifies the second.

Similarly, when querying, the first return value read is the hour, the second value is the minute, and the third value is the second.

Syntax	SYSTem:TIME <NRf>,<NRf>,<NRf>
Parameter1	0 ... 23
Parameter2	0 ... 59
Parameter3	0 ... 59
Example	SYST:TIME 10,22,30
Query syntax	SYSTem:TIME?
Return value	<NR1>,<NR1>,<NR1>

SYSTem:UNIT:CATalog?

This command queries a list of all addresses of the system units (master and slave units) of a configured system network.

The returned addresses are separated by commas. If none of the units are configured as masters or slaves, an empty list, i.e., only a terminator character, is returned.

Query syntax	SYSTem:UNIT:CATalog?
Return value	{<address 1>,...,<address n>}

SYSTem:UNIT:COUNt?

This command queries the number of system units (master and slave units) in the configured system network.

Query syntax	SYSTem:UNIT:COUNt?
Return value	<NR1>

SYSTem:UNIT:MODE

This command sets the operating mode of the system unit.

The MASTer parameter sets the operating mode to master.
The parameter SLAVe sets the operating mode to Slave.
The parameter SINGle sets the operating mode to Single, i.e. the device is not integrated into a system network. The Single operating mode is the factory setting.

The operating mode of the system unit is not changed by a reset.

Syntax	SYSTem:UNIT:MODE <sysmode>
Parameter	MASTer|SLAVe|SINGle
Example	SYST:UNIT:MODE MAST
Query syntax	SYSTem:UNIT:MODE?
Return value	MAST|SLAV|SING
Factory setting	SINGle

SYSTem:UNIT:SLAVe:ADDRess

This command sets the slave address of the system unit (for slave mode).

The address of the master unit is always 1. It is used automatically when master mode is activated for a system unit.

The slave address is not changed during a reset.

Syntax	SYSTem:UNIT:SLAVe:ADDRess <address>
Parameter	2|3|4|5
Example	SYST:UNIT:SLAV:ADDR 2
Query syntax	SYSTem:UNIT:SLAVe:ADDRess?
Return value	2|3|4|5

SYSTem:VERSion?

This command queries the version number of the SCPI standard on which the SCPI command syntax and command semantics are based.

The returned value has the following format:
YYYY.V

YYYY: Release year of the SCPI standard
V: Revision number of the SCPI standard in the release year

Query syntax	SYSTem:VERSion?
Return value	<NR1>.<NR1>
Example	1999.

5.11.19 TRIGger Subsystem, ABORt Subsystem, INITiate Subsystem

ABORt

This command stops the trigger system, i.e., resets the trigger system to the IDLE state. The triggered values follow the immediate values. The INIT:CONT state is set to OFF.

Syntax	ABORt
Example	ABOR

INITiate

This command initializes the trigger system, i.e., sets the trigger system from the IDLE state to the INITiated state. In this state, the trigger system is ready to receive and evaluate trigger events.

This command has no query form.

Syntax	INITiate[:IMMediate]
Parameter	None
Example	INIT

INITiate:CONTinuous

This command activates/deactivates the continuous initialization of the trigger system after receiving and processing a trigger event.

The parameter OFF or 0 deactivates continuous starting of the trigger system, the parameter ON or 1 activates continuous starting.

Syntax	INITiate:CONTinuous <boolean>
Parameter	0|OFF|1|ON
**RST value*	OFF
Example	INIT:CONT ON
Query syntax	INITiate:CONTinuous?
Return value	0|1

TRIGger:DELay

This command sets the wait time between receiving a trigger and triggering an action.

The numeric parameter specifies the wait time in seconds. If the optional parameter MIN is passed, the smallest permissible value for the wait time is set; if the optional parameter MAX is passed, the largest permissible value for the wait time is set.

Syntax	TRIGger:DELay <NRf>|MIN|MAX
Parameter	<0 ... 10>|MIN|MAX
**RST value*	0
Example	TRIG:DEL 0.4
Query syntax	TRIGger:DELay?
Return value	<NR3>

TRIGger:HOLDoff

This command defines the trigger hold time in seconds, i.e., the length of time during which the trigger system does not accept any further trigger signals after receiving a trigger signal.

Syntax	TRIGger:HOLDoff <NRf>
Parameter	0 ... 1|MIN|MAX
**RST value*	0
Example	TRIG:HOLD 0.15
Query syntax	TRIGger:HOLDoff?
Return value	NR3

TRIGger:LEVel:CURRent

This command defines the value of the load current (trigger current) that must be exceeded or fallen below in order to generate a trigger action when the trigger source is set to LEVel:CURRent.

The numerical parameter specifies the current in the basic unit of amperes. The MIN parameter sets the smallest permissible value for the current, the MAX parameter sets the largest permissible value for the current.

The <max> or MAX value can be found in the technical data.

Whether the trigger is activated by exceeding or falling below the defined current is determined by the set trigger edge, which is programmed with the TRIGger:SLOPe command.

Syntax	TRIGger:LEVel:CURRent <NRf>
Parameter	0 ... <max>|MIN|MAX
Unit	A|MA
**RST value*	<max>
Example	TRIG:LEV:CURR 20
Query syntax	TRIGger:LEVel:CURRent?
Return value	<NR3>

TRIGger:LEVel:VOLTage

This command defines the value of the input voltage (trigger voltage) that must be exceeded or fallen below in order to generate a trigger action when the trigger source is set to LEVel:VOLTage.

The numerical parameter specifies the voltage in the base unit of volts. The MIN parameter sets the smallest permissible value for the voltage, while the MAX parameter sets the largest permissible value for the voltage.

The <max> or MAX value can be found in the technical data.

Whether the trigger is triggered by exceeding or falling below the defined voltage is determined by the set trigger edge, which is programmed with the TRIGger:SLOPe command.

Syntax	TRIGger:LEVel:VOLTage <NRf>
Parameter	0 ... <max>|MIN|MAX
Unit	V|MV
**RST value*	0.5 V
Example	TRIG:LEV:VOLT 20
Query syntax	TRIGger:LEVel:VOLTage?
Return value	

TRIGger:SLOPe

This command defines the type of edge that should generate a trigger action when the trigger source is set to EXTERNAL, LEVEL:CURRENT, or LEVEL:VOLTAGE.

The parameter can take one of the following values:
EITHer: A trigger event is generated on the falling or rising edge of the trigger signal.
NEGative: A trigger event is generated on the falling edge of the trigger signal.
POSitive: A trigger event is generated on the rising edge of the trigger signal.

Syntax	TRIGger:SLOPe <slope>
Parameter	EITHer|NEGative|POSitive
**RST value*	POSitive
Example	TRIG:SLOP NEG
Query syntax	TRIGger:SLOPe?
Return value	EITHer|NEGative|POSitive

TRIGger:SOURce

This command sets the source for trigger events.

The parameter can take one of the following values:
BUS: Trigger command on a communication interface
CURRent: Level of the load current
EXTernal: Trigger input signal at the I/O port
HOLD: Detection of a trigger event is disabled.
MANual: Trigger button on the control panel
VOLTage: Level of the input voltage

Syntax	TRIGger:SOURce <source>
Parameter	BUS|CURRent|EXTernal|HOLD|MANual|VOLTage
**RST value*	BUS
Example	TRIG:SOUR MAN
Query syntax	TRIGger:SOURce?
Return value	BUS|CURRent|EXTernal|HOLD|MANual|VOLTage

5.11.20 VOLTage Subsystem

VOLTage

This command sets the setting for the regulated input voltage in voltage mode.

The numerical parameter specifies the voltage in the base unit volts. The MIN parameter sets the smallest permissible value 0 for the voltage, the MAX parameter sets the largest permissible value for the voltage.

The <max> or MAX value can be found in the technical data.

Syntax	VOLTage[:LEVel][:IMMediate] <NRf>|MIN|MAX
Parameter	0 ... <max>|MIN|MAX
Unit	V|MV
**RST value*	MAX
Example	VOLT 45.6
Query syntax	VOLTage[:LEVel][:IMMediate]? [MIN|MAX]
Return value	<NR3>

VOLTage:TRIGgered

This command sets the triggered setting for the regulated input voltage in voltage mode.

The numeric parameter specifies the voltage in the base unit of volts. The MIN parameter sets the smallest permissible value 0 for the voltage, the MAX parameter sets the largest permissible value for the voltage.

The <max> or MAX value can be found in the technical data.

Syntax	VOLTage[:LEVel]:TRIGgered <NRf>
Parameter	0 ... <max>|MIN|MAX
Unit	V|MV
**RST value*	MAX
Example	VOLT:TRIG 1.08E1
Query syntax	VOLTage[:LEVel]:TRIGgered? [MIN|MAX]
Return value	<NR3>

VOLTage:PROTection

This command sets the user-specific lower limit for the input voltage regardless of the operating mode.

The numerical parameter specifies the voltage in the base unit of volts. The MIN parameter sets the minimum permissible value 0 for undervoltage protection, while the MAX parameter sets the maximum permissible value for undervoltage protection.

The <max> or MAX value can be found in the technical data.

Syntax	VOLTage:PROTection[:LEVel] <NRf>
Parameter	0 ... <max>|MIN|MAX
Unit	V|MV
**RST value*	0
Example	VOLT:PROT 1.65
Query syntax	VOLTage:PROTection[:LEVel]? [MIN|MAX]
Return value	<NR3>

VOLTage:PROTection:REGulation

This command sets the behavior of the electronic load when the undervoltage protection setting is reached or exceeded/not reached.

The parameter can take one of the following values:
ON: The electronic load regulates the input current to maintain the input voltage.
OFF: The electronic load switches the input current on when the limit value is exceeded and off when the limit value is undershot.

Syntax	VOLTage:PROTection:REGulation[:STATe] <boolean>
Parameter	0|OFF|1|ON
Example	VOLT:PROT:REG OFF
Query syntax	VOLTage:PROTection:REGulation[:STATe]?
Return	0|1
Reset value	ON

5.12 Command Overview Common Commands

Command	Parameter	Description
*CLS		Clear status
*ESE	<NRf>	Set value of standard event status enable register
*ESE?		Read value of standard event status enable register
*ESR?		Read value of standard event status register
*IDN?		Read identification data
*OPC		Set operation complete bit
*OPC?		Read operation complete bit
*OPT?		Read options
*RCL	<NRf>	Load device settings
*RST		Reset device settings
*SAV	<NRf>	Save device settings
*SRE	<NRf>	Set value of service request enable register
*SRE?		Read value of service request enable register
*STB?		Read status byte
*TRG		Generate trigger event
*TST?		Perform self-test
*WAI		Wait until all commands have been executed

5.13 Command Overview Device-Specific Commands

Command	Parameter	Unit	Description
ABORt			Reset trigger system to IDLE state
ACQuisition			
[:STATe]	<Boolean>		Set activation state for measurement data acquisition
[:STATe]?			Query activation status for measurement data acquisition
:TRIGgered	<Boolean>		Set trigger state for measurement data acquisition
:TRIGgered?			Set trigger state for measurement data acquisition
:CONTinuous	<Boolean>		Set activation state for continuous measurement data storage
:CONTinuous?			Query activation state for continuous measurement data storage
:STIMe	<NRf>|MIN|MAX	[S|MS]	Set sampling interval
:STIMe?	[MIN|MAX]		Query sampling interval
CURRent			
[:LEVel]			
[:IMMediate]	<NRf>|MIN|MAX	[A|MA]|KA	Set setting for load current
[:IMMediate]?	[MIN|MAX]		Query setting for load current
:TRIGgered	<NRf>|MIN|MAX	[A|MA]|KA	Set setting for triggered load current
:TRIGgered?	[MIN|MAX]		Query setting for triggered load current
:PROTection			
[:LEVel]	<NRf>|MIN|MAX		Set value for current limitation
[:LEVel]?	[MIN|MAX]		Query value for current limit
DATA			
:POINts?	[VMEM]		Query number of stored measurement data sets
:REMove?	<NRf>		Read out measurement data records
DISPlay			
:TEXT	<String>		Display string in notification window on user interface
:TEXT?			Query string in notification window on user interface
FORMat			
[:DATA]	ASCii|REAL,<NRf>		Set data format for queried <NRf> values
[:DATA]?			Query data format for queried <NRf> values
:BORDer	NORMal|SWAPped		Set byte order for queried measurement data in real format
:BORDer?			Query byte order for queried measurement data in real format
:SREGister	ASCii|HEXadecimal		Set data format for queried status register values
:SREGister?			Query data format for queried status register values
FUNCtion			
:DISCharge			

[:STATe]	<Boolean>		Set activation status for discharge function
:CHARge?			Query charge consumed
:ENERgy?			Query energy consumed
:STOP			
:CHARge	<NRf>|MIN|MAX		Set value for stop condition charge
:CHARge?	MIN|MAX		Query value for stop condition charge
:CURRent			
[:LEVel]	<NRf>|MIN|MAX	[A|MA|KA]	Set value for minimum current stop condition
[:LEVel]?	MIN|MAX		Query value for minimum current stop condition
:ENABle	CHARge|CURRent|ENERgy|TIME|VOLTage, <Boolean>		Set enable status for specified event to terminate discharge function
:ENABle?	CHARge|CURRent|ENERgy|TIME|VOLTage		Query enable status for the specified event to terminate the discharge function
:ENERgy	<NRf>|MIN|MAX		Set value for energy stop condition
:ENERgy?	MIN|MAX		Query value for energy stop condition
:EVENt?			Query stop event
:TIME	<NRf>|MIN|MAX	[S|MS]	Set value for stop condition unloading time
:TIME?	MIN|MAX		Query value for stop condition discharge time
:VOLTage			
[:LEVel]	<NRf>|MIN|MAX	[V|MV]	Set value for stop condition min. voltage
[:LEVel]?	MIN|MAX		Query value for stop condition min. voltage
:TIME?			Check elapsed unloading time
:MEASure			
:IRESistance			
[:STATe]	<Boolean>		Set activation status for internal resistance measurement
[:STATe]?			Query activation status for internal resistance measurement
:CURRent			
[:LEVel]	<NRf>,<NRf>	[A|MA]	Set load currents to determine internal resistance
[:LEVel]?			Query load currents to determine internal resistance
:DWELl	<NRf>,<NRf>	[S|MS]	Set dwell times to determine internal resistance
:DWELl?	<NRf>,<NRf>	[S|MS]	Query dwell times for determining internal resistance
:RESistance?			Query internal resistance
:TIME?			Query time since activation of internal resistance measurement function
:MODE	CURRent|POWer|		Set basic operating mode

	RESistance|VOLTage		
:MODE?			Query basic operating mode
:MODulate			
[:STATe]	<Boolean>		Set modulation activation status
[:STATe]?	<Boolean>		Query modulation activation status
:MODE	CURRent|VOLTage		Set the operating mode of the modulation control
:MODE?			Query the operating mode of the modulation control
:SWEep			
[:STATe]	<Boolean>		Set activation state of modulation sweep
[:STATe]?			Query activation state of modulation sweep
:COUNt	<NRf>|MIN|MAX		Set number of sweep iterations
:COUNt?	[MIN|MAX]		Query number of sweep iterations
:ACTual?			Query number of completed sweep iterations
:DWELl	<NRf>|MIN|MAX		Set dwell time of frequency steps
:DWELl?	[MIN|MAX]		Query dwell time of frequency steps
:FREQuency			
:STARt	<NRf>|MIN|MAX		Set start frequency
:STARt?	[MIN|MAX]		Query start frequency
:STEP	<NRf>|MIN|MAX		Set step frequency
:STEP?	[MIN|MAX]		Query step frequency
:STOP	<NRf>|MIN|MAX		Set end frequency
:STOP?	[MIN|MAX]		Query end frequency
:FREQuency?			Query current sweep frequency
:TIME?			Query elapsed time since start of modulation sweep
:WAVeform			
:AMPLitude	<NRf>|MIN|MAX		Set amplitude for modulation
:AMPLitude?	MIN|MAX		Query amplitude for modulation
:FREQuency	<NRf>|MIN|MAX	[Hz]	Set frequency for modulation
:FREQuency?	MIN|MAX		Query frequency for modulation
:TYPE	SINE|SQUARE|TRIANGLE		Set signal shape for modulation
:TYPE?			Query signal shape for modulation
:MPPT			
[:STATe]	<Boolean>		Set activation status for MPP tracking function
[:STATe]?			Query activation status for MPP tracking function
:ENERgy?			Query cumulative energy for MPPT
:MPP?			Query last MPP found
:SWEep			
[:IMMediate]			Execute sweep immediately
:DATA			
:POINTS?	MIN|MAX		Query number of measurement data pairs from last sweep
:DATA?			Read out the last recorded sweep curve
:DIRection			Set sweep direction
:DIRection?			Query sweep direction
:PERiod	<NRf>|MIN|MAX	[S|MS]	Set sweep period
:PERiod?			Query sweep period

:TIME	<NRf>|MIN|MAX	[S|MS]	Set sweep duration
:TIME?			Query sweep duration
:TIME?			Query time since MPPT function activation
:PROTection			
[:STATe]	<Boolean>		Set activation state for voltage or current limitation
[:STATe]?			Query activation status for voltage or current limitation
:MODE	CURRent|VOLTage		Set operating mode for limitation
:MODE?			Query operating mode for limitation
:SPEed	SLOW|FAST		Set control speed
:SPEed?			Query control speed
INITiate			
[:IMMediate]			Set trigger system to INIT state
:CONTinuous	<Boolean>		Set activation state for continuous initialization of the trigger system
:CONTinuous?			Query activation state for continuous initialization of the trigger system
INPut			
[:STATe]	<Boolean>		Set state of load input
[:STATe]?			Query state of load input
:TRIGgered	<Boolean>		Set trigger state of input
:TRIGgered?			Query trigger state of the input
:WDOG			
[:STATe]	<Boolean>		Set the activation state of the watchdog
[:STATe]?			Query activation status of watchdog
:DELay	<NRf>|MIN|MAX		Set the delay time of the watchdog
:DELay?	[MIN|MAX]		Query watchdog delay time
:RESet			Reset watchdog
LIST			
[:STATe]	<Boolean>		Set activation state for executing a list
[:STATe]?			Query activation status for executing a list
:TRIGgered	<Boolean>		Set trigger state for executing a list
:TRIGgered?			Set trigger state for executing a list
:ACQuisition			
[:ENABle]	<Boolean>		Set activation state for measurement data acquisition when executing a list
[:ENABle]?			Query activation status for measurement data acquisition when executing a list
:COUNt	<NRf>|MIN|MAX		Set number of list passes
:COUNt?			Query number of list passes
:CURRent			
[:LEVel]	<NRf>{,<NRf>}	[A|MA|KA]	Define current setting list
[:LEVel]?			Query current setting list
:POINts?	[MIN|MAX]		Query number of specified current settings in the list
:DWELl	<NRf>{,<NRf>}	[S|MS]	Define list with dwell times
:DWELl?			Query list with dwell times

:POINts?	[MIN|MAX]		Query number of specified dwell times in the list
:MODE	CURRent|RESistance| VOLTage		Set list mode
:MODE?			Query list mode
:POINts?			Query number of list points executed since list activation
:POWer			
[:LEVel]	<NRf>{,<NRf>}	[W|MW|KW]	Define performance target value list
[:LEVel]?			Query power setting list
:POINts?	[MIN|MAX]		Query the number of specified performance targets in the list
:RESistance			
[:LEVel]	<NRf>{,<NRf>}	[OHM|KOHM]	Define resistance setting list
[:LEVel]?			Query resistance setting list
:POINts?	[MIN|MAX]		Query number of specified resistance settings in list
:RTIMe	<NRf>{,<NRf>}	[S|MS]	Define list with ramp times
:RTIMe?			Query list of ramp times
:POINts?	[MIN|MAX]		Query number of specified ramp times in the list
:STIMe			
:DWELl	<NRf>{,<NRf>}		Set period times for sampling during dwell phases
:DWELl?			Query period times for sampling during dwell phases
:POINts?	[MIN|MAX]		Query number of specified values for sampling periods during dwell phases
:RTIMe	<NRf>{,<NRf>}		Set period times for sampling during ramp phases
:RTIMe?			Query period times for sampling during ramp phases
:POINts?	[MIN|MAX]		Query number of period times for sampling during ramp phases
:TIME?			Query time duration since list activation
:VOLTage			
[:LEVel]	<NRf>{,<NRf>}	[V|MV]	Define voltage setting list
[:LEVel]?			Query voltage setting list
:POINts?	[MIN|MAX]		Query number of specified voltage settings in the list
MEASure			
:CURRent?			Query current measurement value
:POWer?			Query power measurement
:RESistance?			Query resistance measurement
:TEMPerature?			Query temperature measurement value
:VOLTage?			Query voltage measurement value
:EXTernal?			Query external voltage measurement value
POWer			
[:LEVel]			
[:IMMediate]	<NRf>|MIN|MAX	[W|MW|KW]	Set target value for power
[:IMMediate]?	[MIN|MAX]		Query setting for power
:TRIGgered	<NRf>|MIN|MAX	[W|MW|KW]	Set triggered setting for power

:TRIGgered?	[MIN|MAX]		Query triggered setting for power
:PEAK?			Query current peak power
RECTangle			
[:STATe]	<Boolean>		Set activation status for executing the rectangle function
[:STATe]?			Query activation status for executing the rectangle function
:CURRent			
[:LEVel]	<NRf>,<NRf>	[A]	Set settings for the input current during the dwell times of the square wave function
[:LEVel]?			Query settings for the input current during the dwell times of the square wave function
:DWELl	<NRf>,<NRf>	[S]	Set settings for the dwell times of the square wave function
:DWELl?			Query settings for dwell times of the square wave function
:MODE	CURRent|RESistance|VOLTAGE		Set the operating mode of the control for executing the square wave function
:MODE?			Query the control mode for executing the square wave function
:RESistance			
[:LEVel]	<NRf>,<NRf>	[OHM]	Set settings for resistance during dwell times of the square wave function
[:LEVel]?			Query settings for resistance during dwell times of the square wave function
VOLTages			
[:LEVel]	<NRf>,<NRf>	[V]	Set settings for voltage during the dwell times of the square wave function
[:LEVel]?			Query settings for voltage during dwell times of square wave function
RESistance			
[:LEVel]			
[:IMMediate]	<NRf>|MIN|MAX	[OHM|KOHM]	Set resistance target value
[:IMMediate]?	[MIN|MAX]		Query setting for resistance
:TRIGgered	<NRf>|MIN|MAX	[OHM|KOHM]	Set triggered setting for resistance
:TRIGgered?	[MIN|MAX]		Query triggered setting for resistance
SERVice			
:CALibration			
[:STATe]	<Boolean>[,<Code>]		Set activation status for calibration
[:STATe]?			Query activation status for calibration
:EXTernal			
:HIGH	<NRf>		Set reference value for upper external measurement point
:LOW	<NRf>		Set reference value for lower external measurement point
:LEVel			
:HIGH			Set reference value for upper setting support point

:LOW			Set reference value of lower setting support point
:MEASure			
:HIGH			Set reference value of upper measured value support point
:LOW			Set reference value for lower measurement point
:PROTection			
:HIGH			Set reference value for upper protection support point
:LOW			Set reference value of lower protection support point
[:PARameter]			
:STRing	<NRf>,<string>		Write string to parameter
:STRing?	<NRf>		Read string from parameter
:VALue	<NRf>,<NRf>		Write value to parameter
:VALue?	<NRf>		Read value from parameter
:PRODuction			
[:STATe]	<Boolean>[,<Code>]		Set activation status for production
[:STATe]?			Query activation status for production
SETTing			
:EXTernal			
[:STATe]	<Boolean>		Set activation status for external control
[:STATe]?			Query activation status for external control
:ENABle	INPut|ILEVel, <Boolean>		Set enable status of an external signal for control
:ENABle?	INPut|ILEVel|		Query enable status of an external signal for control
STATus			
:CHANnel			
:OPERation			
[:EVENt]?			Query channel operation status event register
:CONDition?			Query channel operation status condition register
:ENABle	<NRf>		Set channel operation status enable register
ENABLE?			Query channel operation status enable register
:PRESet			Set status enable register to defined values
:QUEStionable			
[:EVENt]?			Query channel questionable status event register
:CONDition?			Query channel questionable status condition register
:ENABle	<NRf>		Set channel questionable status enable register
:ENABle?			Query Channel Questionable Status Enable Register
:OPERation			
[:EVENt]?			Query operation status event register

:CONDition?			Query operation status condition register
:PRESet			Set status enable register to defined values
:QUEStionable			
[:EVENt]?			Query Questionable Status Event Register
:CONDition?			Query questionable status condition register
SYSTem			
:BEEP	<NRf>|MIN|MAX	[S|MS]	Activate system beeper for the specified duration
:COMMunication			
:CAN			
:ADDRess	<NRf>|MIN|MAX		Set address of CAN interface
:ADDRess?	[MIN|MAX]		Query address of CAN interface
:BAUD	<NRf>|MIN|MAX		Set baud rate for the CAN interface
:BAUD?	[MIN|MAX]		Query baud rate for the CAN interface
:TERMination			
[:STATe]	<boolean>		Set activation status for CAN termination
[:STATe]?			Query activation status for CAN termination
:GPIB			
:ADDRess	<NRf>|MIN|MAX		Set address of GPIB interface
:ADDRess?	[MIN|MAX]		Query address of GPIB interface
:LAN			
:DHCP			
[:STATe]	<Boolean>		Set activation status for use of the DHCP protocol
[:STATe]?			Query activation status for use of the DHCP protocol
:DNS			
[:ADDRess]	<string>		Set static IP address of the DNS server
[:ADDRess]?	[ACTual|STATic]		Query IP address of DNS server
:GATEway			
[:ADDRess]	<string>		Set static IP address of the gateway
[:ADDRess]?	[ACTual|STATic]		Query IP address of the gateway
:HOSTname?			Query host name of electronic load
:IP			
[:ADDRess]	<string>		Set static IP address of LAN interface
[:ADDRess]?	[ACTual|STATic]		Query IP address of LAN interface
:MAC			
[:ADDRess]?			Query MAC address of LAN interface
:PORT	<NRf>		Set TCP port number of the LAN interface
:PORT?			Query TCP port number of LAN interface
:SUBNet			
[:MASK]	<string>		Set the subnet mask of the LAN interface

[:MASK]?	[ACTual|STATic]		Query the subnet mask of the LAN interface
:SERial			
:BAUD	<NRf>|MIN|MAX		Set baud rate for the RS-232 interface
:BAUD?	[MIN|MAX]		Query baud rate for the RS-232 interface
:BITS?	[MIN|MAX]		Query number of data bits for the RS-232 interface
:MODE	[SCPI|SLINk]		Set the communication mode of the RS-232 interface
:MODE?			Query communication mode of the RS-232 interface
:PARity	EVEN|NONE|ODD		Set parity for the RS-232 interface
:PARity?			Query parity for the RS-232 interface
:SBITs	<NRf>|MIN|MAX		Set the number of stop bits for the RS-232 interface
:SBITs?	[MIN|MAX]		Query the number of stop bits for the RS-232 interface
:COOLing			
[:MODE]	AUTO|FULL		Set cooling mode of the fans
[:MODE]?			Check fan cooling mode
:DATE	<year>,<month>, <day>		Set date
:DATE?			Query date
:ERROR			
[:NEXT]?			Read next entry from error queue
:ALL?			Read all entries from the error queue
:COUNt?			Query the number of entries in the error queue
:HELP			
:HEADers?			Query all SCPI command headers
:KLOCk	<Boolean>		Set key lock activation status
:LOCal			Activate manual control
:PRESet			Set factory settings
:REMote			Enable control via a data interface
:SLINk			
[:STATe]	<Boolean>		Set SyncroLink activation status
[:STATe]?			Query SyncroLink activation status
:DELay	<NRf>|MIN|MAX	[S|MS]	Set delay for SyncroLink
:DELay?	[MIN|MAX]		Read delay for SyncroLink
:TIME	<hour>,<minute>, <second>		Set time
:TIME?			Query time
:VERSion?			Query version of compatible SCPI standard
TRIGger			
:DELay	<NRf>|MIN|MAX	[S|MS]	Set setting for trigger delay
:DELay?			Query setting for trigger delay
VOLTage			
[:LEVel]			
[:IMMediate]	<NRf>|MIN|MAX	[V|MV]	Set voltage setting
[:IMMediate]?	[MIN|MAX]		Query setting for voltage
:TRIGgered	<NRf>|MIN|MAX	[V|MV]	Set triggered setting for voltage

:TRIGgered?	[MIN|MAX]		Query triggered setting for voltage
:PROTection			
[:LEVel]	<NRf>|MIN|MAX	[V|MV]	Set value for undervoltage protection
[:LEVel]?	[MIN|MAX]		Query value for undervoltage protection

6 External Control via I/O Port

Settings and measurements can be made via the I/O port which each HES load has included as standard.
This interface allows for the fastest possible type of control. The monitor signals are provided in real time.

The I/O port is designed as a 25-pin D-sub female connector. Two variants are available:

- Standard I/O port (non-isolated)
- Galvanically isolated I/O port (option HES06)

Both ports have the same range of functions and the same pin assignment.

The I/O port may only be connected and disconnected when the electronic load is switched off!

6.1 Standard I/O Port

With the standard I/O port, the negative load input (Input -) and the GND of the I/O port are galvanically connected to each other. This can result in dangerous voltages at the I/O port if the potential at the load input is raised!

An additional connection of any connection on the I/O port to the load input or sense input of the device creates short-circuits or ground loops and can lead to malfunctions, incorrect measurements, or even destruction of the device!

For applications in which voltage differences higher than ±2 V are to be expected between the GND of the I/O port and the negative load input, we recommend the galvanically isolated I/O port (option HES06). Dynamic voltage differences must also be taken into account.

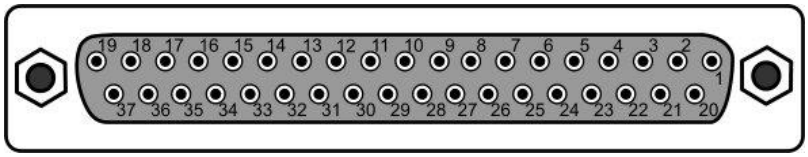
See 2.5 Permissible Potentials at the Device Connections and technical data.

6.2 Isolated I/O Port (Option HES06)

With the isolated I/O port, all inputs and outputs are galvanically isolated from the load input.
The permissible potentials at the isolated I/O port are defined in chapter 2.5 Permissible Potentials at the Device Connections and in the technical data.

The SCPI command *OPT? can be used to check whether an isolated I/O card is installed.
See 5.10.6 *OPT?

6.3 I/O Port Pin Assignment



Pin	Name[1)]	Description	Dir.[2)]	Level[3)]
1	GNDA	GND for analog signals		
2	n.u.	No function. Do not connect!		
3	10V_LEVEL-	Negative control input for setting adjustment 0 ... 10 V	I	10 V
4	5V_LEVEL-	Negative control input for setting adjustment 0 ... 5 V	I	5 V
5	/STAT_INP_ON	Activation status of the load input	O	Logic
6	PROT_C+	Positive control input for current limitation 0 ... 10 V	I	10 V
7	PROG_IN	Queryable logic input	I	Logic
8	MODE_CURR	Control input for the control mode	I	Logic
9	/INP_ON	Control input for load input	I	Logic
10	SPEED_FAST	Control input for setting speed	I	Logic
11	RSD	Remote Shut-Down	I	Logic
12	/TRIG_OUT	Trigger output	O	Logic
13	/STAT_OL	Status for overload	O	Logic
14	VMON	Monitor signal for voltage at load input	O	±10 V
15	IMON	Monitor signal for current through load input	O	±10 V
16	10V_LEVEL+	Positive control input for setting adjustment 0 ... 10 V	I	10 V
17	5V_LEVEL+	Positive control input for setting adjustment 0 ... 5 V	I	5 V
18	PROT_C-	Negative control input for current limitation 0 ... 10 V	I	10 V
19	PROT_V-	Negative control input for undervoltage protection 0 ... 10 V	I	10 V
20	n.u.	No function. Do not connect!		
21	PROT_V+	Pos. Control input for undervoltage protection 0 ... 10 V	I	10 V
22	/CTRL_EXT	Control input for activating external control	I	Logic
23	PROG_OUT	Programmable logic output	O	Logic
24	GND	GND for logic signals		
25	TRIG_IN	Trigger input	I	Logic

[1)] Low-active signals have a slash (/) before their name.
[2)] Signal direction: O: Output, I: Input
[3)] Signal level : Logic: see technical data
5 V: 0 ... 5 V DC
10 V: 0 ... 10 V DC

6.4 Controllable Functions

To use the control functions of the I/O port, you must

- activate the external control
  - by manual configuration on the user interface
  - or via SCPI command via data interface
  - or by bridging to GND on pin /CTRL_EXT on the I/O port

and

- enable individual control signals
  - by manual configuration at the user interface
- or via SCPI command via data interface

The following settings can be specified externally:

- Activation status for load input
- Control mode (CC or CV)
- Setting for the controlled input variable
- Setting for current limitation
- Setting for voltage limitation
- Control speed

External control can be activated via configuration (in the menu or via SCPI command) or via a jumper on the I/O port. The individual control signals can only be enabled via configuration (see Figure 6.1).

If the load input is controlled via the I/O port and the "Input" button on the front panel is pressed, this user input is ignored. This is signaled to the operator by a "Notification" window popping up on the user interface for a few seconds. If the setting input is activated via the I/O port and the user presses the rotary encoder, the user input is ignored and a "Notification" window is also displayed briefly.

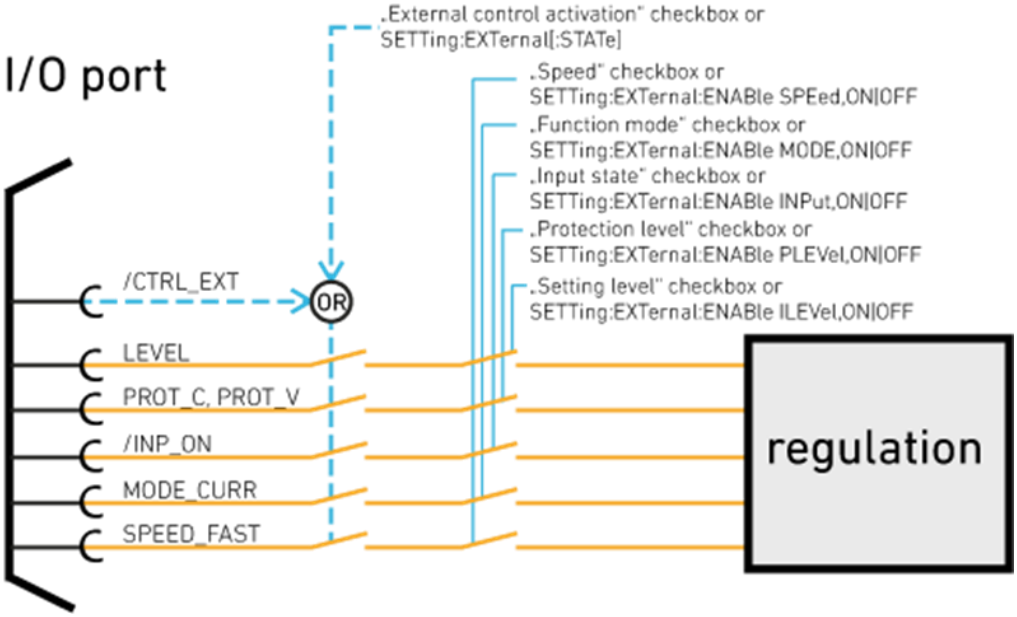


Figure 6.1: schematic diagram of the externally controllable functions

When switching off and on, the enable states of the individual signals are reset. If this is undesirable, you can save the device settings after configuration and set a corresponding power-on configuration via the user interface. See4.32 Saving and Loading Device Settings

Local operation:
Main Menu -> Settings -> Basic settings -> Ext. control
Checkbox "External control activation": Activate higher-level activation of externally controllable signals.
Activate individual checkboxes for externally controllable signals.

Digital remote control:
5.11.16 SETTing Subsystem

External control:
Bridge pin /CTRL_EXT to GND (port activation only; control signals can only be activated locally or via digital remote control).

6.5 Logic Level and Remote Shutdown

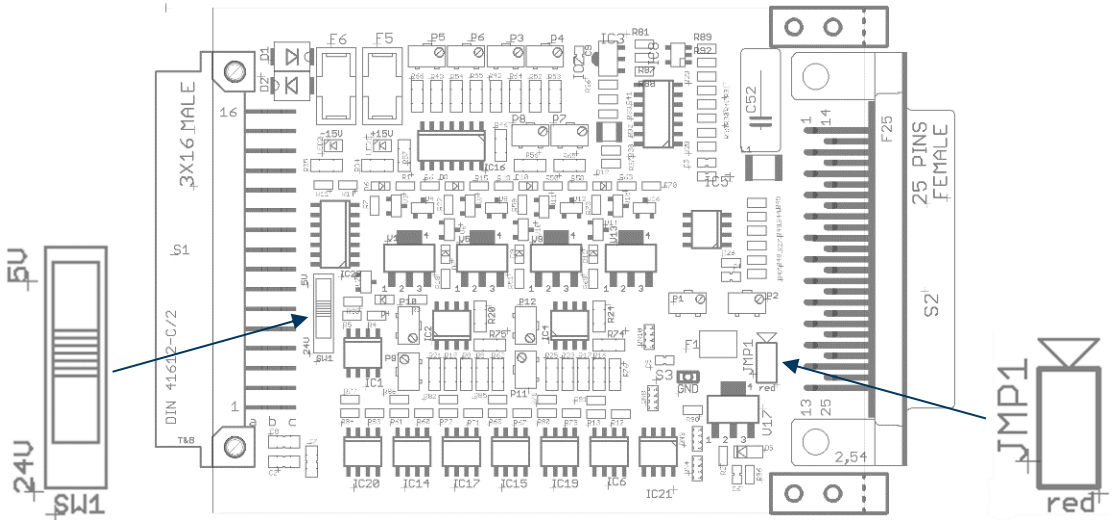


Figure 6.2: uninsulated I/O port board with SW1 and JMP1

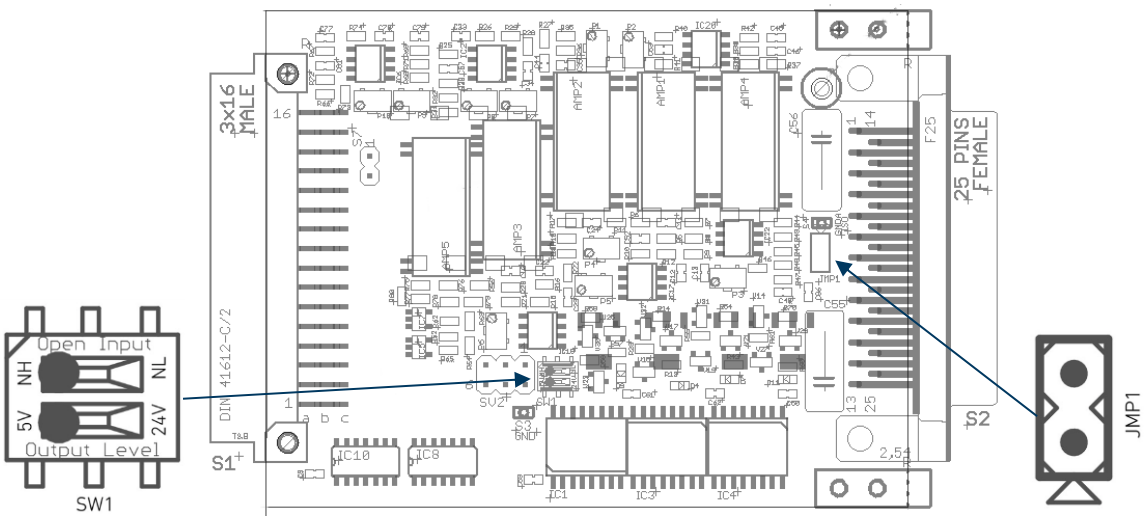


Figure 6.3: isolated I/O port board QL06 with SW1 and JMP1

Disconnect the electronic load from all power sources and take ESD precautions when removing and installing the circuit board!

SW1 (only for isolated I/O port): Logic level

"Output Level" switch for voltage level of logic outputs:

- Position 5V (TTL level, default setting)
- Position 24V

"Open Input" switch for logic level of unconnected inputs:

- Leave in position NH!

JMP1: Activation of the remote shutdown function

- Jumper JMP1 plugged in: Function deactivated (factory setting)
- Jumper JMP1 removed: Function activated

6.6 Logic Inputs and Outputs

6.6.1 Control Inputs

The control inputs are related to the digital GND and have a voltage level of 5 or 24 volts in the idle state. A control signal can be activated or deactivated by an external voltage (see technical data for level) or by connecting to GND (e.g. via a relay).

Note the level definitions for digital inputs in the technical data!

6.6.1.1 Safety Circuit (Remote Shutdown)

The load input can be safely deactivated by the input signal RSD. As part of the safety circuit, this signal takes precedence over all other control sources and is active at logic level high.

This function is deactivated when the device is delivered. To activate the function, the short-circuit bridge JMP1 must be removed on the I/O board (see6.5 Logic Level and Remote Shutdown). Now the output can only be activated when the RSD signal is inactive.

The status of the RSD signal can be queried via a communication interface using the command `STATus:OPERation:CONDition?` When the remote shutdown signal is active, RSD is displayed in the status bar of the display.

When using the safety circuit, jumper JMP1 must be removed! Otherwise, the applied voltage will be short-circuited and the I/O port may be damaged.

6.6.1.2 Switching the Load Input On and Off

The load input can be switched on and off using the input signal /INP_ON.

The input is low-active and can be controlled either via a corresponding logic level or by an external relay. The status of the /INP_ON signal cannot be queried explicitly.

RSD has higher priority than /INP_ON. This means that an active RSD line switches off the load input even if /INP_ON is active.

6.6.1.3 Selecting the Control Mode

The MODE_CURR signal can be used to select the operating mode for the control.

When unconnected or logically high, CC mode is selected; logically low selects CV mode.

The source sink can also be controlled externally in CR or CP mode. However, the operating mode must be specified via the user or data interface, not via the I/O port.

6.6.1.4 Select Control Speed

The control speed is selected using the SPEED_FAST signal.

When unconnected or logically high, the fast control speed is selected; logically low selects the slow control speed.

6.6.1.5 Trigger Input

The TRIG_IN signal generates an external trigger event. The active edge is adjustable (see 4.25 Trigger Model). After a reset, the positive edge is selected.

6.6.1.6 Digital Input

The input signal PROG_IN is not linked to any device function, but can be connected for any purpose.

External logic states can be read by the control PC via the electronic load.

See also:5.11.10 PORT Subsystem .

6.6.2 Status Outputs

Level of the status outputs
Standard I/O port: see technical data.
Isolated I/O port: Voltage level can be set with switch SW1 (see Figure 6.2).

Do not apply voltages to the status outputs! Applying voltages to the status outputs can damage the electronic load.

6.6.2.1 Status of the Load Input

The output signal /STAT_INP_ON shows the activation status of the load input (input).

The output is low-active, i.e. the load input is active when the status signal is low.

6.6.2.2 Overload Status

The output signal /STAT_OL indicates the overload status. The overload status is the result of an OR combination of the individual statuses OV, OCP, OPP, OTP.

The output /STAT_OL is low-active. If one of the statuses OV, OCP, OPP, OTP is active, the status output /STAT_OL is low.

6.6.2.3 Trigger Output

A 200 µs low pulse is output at the trigger output /TRIG_OUT when the device has detected a trigger event from the configured trigger source.

6.6.2.4 Programmable Output

The output signal PROG_OUT is not linked to any device function, but can be used for any purpose.

You can use the output to control external functions via the electronic load with the PC.

See also 5.11.10 PORT Subsystem.

6.7 Analog Inputs and Outputs

The electronic loads have one analog control input for the control setting, one analog control input each for the setting of overcurrent limitation and undervoltage protection, and two monitor outputs.

6.7.1 Analog Inputs

6.7.1.1 Setting for Control

The setting for the control can be defined by analog control signals. <max> corresponds to the maximum value of the control range depending on the active operating mode of the control.

- 5V_LEVEL: Setting 0 ... 5 V for 0 ... <max>
- 10V_LEVEL: Setting 0 ... 10 V for 0 ... <max>

A + input (5V_LEVEL+/10V_LEVEL+) and a - input (5V_LEVEL-/10V_LEVEL-) are available for each control voltage. The control input 5V_LEVEL+ or 10V_LEVEL+ must be connected to the positive output of the control source, and the control input 5V_LEVEL– or 10V_LEVEL- must be connected to the negative output of the control source.

The input resistance is greater than 10 kΩ when controlled via 5V_LEVEL and greater than 20 kΩ when controlled via 10V_LEVEL.

Do not apply voltages higher than the specified end values (5 V/10 V) to the control inputs! Voltages higher than 20 V will destroy the input amplifier.

6.7.1.2 Settings for Limits

The settings for overcurrent limitation and undervoltage protection can be defined by analog control signals.

- PROT_C: Setting 0 ... 10 V for 0 ... Imax
- PROT_V: Setting 0 ... 10 V for 0 ... Umax

A + input (PROT_C+/PROT_V+) and a - input (PROT_C-/PROT_V-) are available for each control voltage. The control input PROT_C+ or PROT_V+ must be connected to the positive output of the control source, and the control input PROT_C- or PROT_V- must be connected to the negative output of the control source.

The input resistance is greater than 20 kΩ.

Do not apply voltages higher than 10 V to the control inputs! Voltages greater than 20 V will destroy the input amplifier.

6.7.2 Analog Outputs

The following analog outputs are available:
VMON: Monitor signal for voltage at load input
IMON: Monitor signal for current through load input

The monitor signals with an output voltage of 0 to 10 V correspond to 0 to 100% of the respective measuring range and are referenced to the analog ground GNDA.
VMON: 0 to 10 V for 0 to Umax
IMON: 0 ... 10 V for 0 ... Imax

Maximum load on the measurement outputs: see technical data.

7 Options

7.1 GPIB Data Interface (Option HES02)

See 5.7 GPIB Interface (Option HES02).

7.2 Isolated I/O Port (Option HES06)

See 6 External Control via I/O Port .

8 Troubleshooting

8.1 Oscillations

The cabling is often the cause of control oscillations.
Long cables (in extreme cases, untwisted) have high self-inductance, which influences the control behavior of the electronic load.

As a first measure, check the cabling. See also 2.3 Connection of the Test Object, 2.3.2 Load and Sense Lines .

When using the "FAST" control speed, only use very short twisted load cables! Otherwise, there is a risk of oscillations!

When testing power supplies or other circuits that stabilize an output variable via a control loop, two controllers are connected to each other when the electronic load is connected. Under certain conditions, namely when a phase shift greater than 180° occurs in the overall system and the gain is greater than 1, the oscillation condition is met and the system begins to oscillate.

This condition is not a defect in the electronic load, but a possible physical condition that is undesirable for testing. You can avoid this condition by eliminating the oscillation condition.

See also 4.5 Control Speed.

In practice, an MKT capacitor of approx. 1 µF connected in parallel to the load input with a series resistance of approx. 1.5 Ω (5 W) often helps to stabilize the system.

8.2 Electromagnetic Coupling

Particularly in resistive mode, there is a risk that the sense lines will cause the current-carrying load cables to be coupled into the voltage measurement of the device.

Since in resistive mode the exact measurement of the voltage at the device under test is used as the control variable for the current, magnetic coupling into the sense lines can cause feedback coupling, which makes the system unstable.

The first measure to be taken is to reduce the coupling.

This means:

Lay the sense cables as far away as possible from the live load cables (and, of course, away from all other live cables, power cables, etc.). It is best to twist the sense cables together, as this cancels out the magnetically induced voltage.

See also 2.3.2 Load and Sense Lines.

It is best to twist the live wires together or at least lay them parallel to each other so that the magnetic fields compensate each other at least partially.
Never twist the sense lines with the live lines!
Keep all cables as short as possible!

If none of this improves the situation, a capacitor can be connected between the sense lines.

8.3 Distorted Current Rise in Dynamic Operation

8.3.1 Causes

Certain conditions must be met in order to achieve the best possible current rise in dynamic operation:

- The dynamic internal resistance of the voltage source must be very low. A drop in voltage at the load input during current rise due to the control behavior of the voltage source or due to inductive supply lines counteracts a rapid current rise.
- The impedance of the supply lines must be very low.
- The supply lines must be low-inductance. Inductive supply lines (every cable has an inductive component) together with the ohmic resistance limit the maximum possible current rise rate. The load cannot achieve a rapid current rise if the connection cables limit the rate. In addition, the supply lines act as energy storage devices (self-induction) and return current to the load and test object when the load is relieved.

8.3.2 Measuring the Current Rise Time

The current rise time may only be measured with a current clamp of sufficient speed (e.g. Tektronix Current Measurement).

Current measurement using measuring shunts usually produces incorrect results, as most measuring shunts are not induction-free. Such measurements inevitably result in slower rise times with considerable overshoot.

8.4 Distorted Monitor Signals

Particularly when testing switched-mode power supplies, the measurement signals at the I/O port for voltage, current, etc. (IMON, VMON) may be distorted. The cause of this can be found in the design of the measurement circuit.

Switched-mode power supplies have filters in the output circuit, including so-called Y capacitors, which are connected from the output to the protective earth of the device.

The electronic load and other measuring devices also have filters installed for EMC reasons.

Due to the common mode interference voltage (voltage that both output terminals of the power supply have relative to the protective earth), a fault current flows back to the load output via the interference suppression capacitor through the electronic load or connected measuring devices.

This interference current usually generates high-frequency interference in the measurement signals.

Particularly high interference voltages are generated during dynamic tests.
This can be remedied by supplying the electronic load and/or other connected measuring devices via isolating transformers with low coupling capacity. This interrupts the interference current circuit and improves the quality of the measurement signals.

8.5 Effects of Input Capacitance

Every electronic load has a certain input capacity (see technical data). This has little to no effect on clean DC input voltages.

However, if the voltage at the load input contains an AC component, the load current will also contain an AC component depending on the amplitude and frequency of the AC voltage. This is not a steady-state oscillation of the electronic load.

If the amplitude component or frequency of the AC voltage component is high, the input capacity may be overloaded!

The accuracies specified in the technical data apply to clean DC voltages at the load input.

9 Appendix

9.1 Error Codes

9.1.1 Command Errors

An error code in the range [-199 ... -100] indicates that a syntax error has been detected in a command to the electronic load. If an error of this class occurs, the Command Error bit (Bit 5) is set in the Event Status.

Error code		Description
-100	Command error	General syntax error.
-101	Invalid character	A syntactic element contains an invalid character.
-104	Data type error	The parser has detected an invalid data element.
-108	Parameter not allowed	Too many parameters were received for the corresponding header.
-109	Missing parameter	Too few parameters were received for the corresponding header.
-110	Command header error	An error was detected in the header.
-120	Numeric data error	A numeric data element is incorrect.
-130	Suffix error	General suffix error.
-138	Suffix not allowed	A suffix was detected in a data element without a permitted suffix.
-140	Character data error	Character error
-150	String data error	String error
-160	Block data error	Block data error
-170	Expression error	Expression error
-180	Macro error	Macro error

9.1.2 Execution Errors

An error code in the range [-299 ... -200] indicates that an error was detected during the execution of a command. If an error of this class occurs, the Execution Error bit (Bit 4) is set in the Event Status.

Error code		Description
-200	Execution error	General execution error
-210	Trigger error	A trigger error has occurred.
-211	Trigger ignored	A trigger event was detected but ignored.
-213	Init ignored	A trigger initiation was ignored.
-220	Parameter error	A parameter error was detected.
-221	Settings conflict	A valid command was detected, but could not be executed due to the current device status.
-222	Data out of range	A parameter was detected that is outside the permissible value range of the electronic load.
-224	Illegal parameter value	An exact value from a list of possible parameters was expected.
-226	Lists not same length	The start of the LIST function was aborted due to different list lengths.
-230	Data corrupt or stale	Invalid data has been encountered.
-240	Hardware error	A valid command was recognized but could not be executed due to a hardware error.
-250	Mass storage error	A mass storage error has occurred.
-280	Program error	A program-related execution error has occurred.
-290	Memory use error	A user request has directly or indirectly caused a memory-related error.

9.1.3 Device-Specific Errors

An error code in the range [-399 ... -300] indicates a device-specific error, which is therefore neither a command error, a query error (see below), nor an execution error; some device functions may have failed as a result of an abnormal hardware or firmware condition.
When an error of this class occurs, the Device-Dependent Error bit (Bit 3) is set in the Event Status.

Error code		Description
-300	Device-specific error	General device-specific error
-310	System error	A device-specific system error has occurred.
-315	Configuration memory lost	Non-volatile configuration data stored in the electronic load has been lost.
-320	Storage fault	The firmware has detected an error when using the data storage.
-330	Self-test failed	Self-test failed.
-340	Calibration failed	Calibration failed.
-350	Queue overflow	The error queue is full, and the error that caused it was not logged.
-360	Communication error	General communication error, such as a parity error or framing error in data that arrived via a serial interface.

9.1.4 Query Errors

An error code in the range [-499 ... -400] indicates that the output queue control of the electronic load has detected a problem with the message exchange protocol. The occurrence of an error of this class causes the Query Error bit (bit 2) to be set in the event status register.

Error code		Description
-400	Query error	General query error.
-410	Query interrupted	A query has been interrupted.
-420	Query terminated	A query was not terminated.
-430	Query deadlocked	A query has stalled (input and output buffers of the electronic load are full).

9.1.5 Non-Standard Errors

Error codes with positive error numbers are those that are not specified in the SCPI standard, but by the manufacturer of the electronic load.

Errors with positive error numbers should not occur in a fault-free device, or only in exceptional cases.

The following error codes may occur during the firmware update process.

Error code	Description
1000	General update error
1002	USB flash drive not recognized
1003	Update file not found
1004	Multiple update files available for the target hardware
1005	Error in the update file
1006	The bootloader detected an error.
1008	The update file and the target hardware are not compatible

All other errors may result from malfunction or damage to the load. For more detailed information about the errors, contact H&H Support.

9.2 Device Parameters

The following is a list of user-relevant device parameters and their functions.

Reserved parameters must not be written to!

Par. No.	Function	Value on delivery	Access
0 9	*Reserved*		-
10	Control constant Kp for operating mode CP with control speed FAST	0	read, write
11	Control constant Ki for operating mode CP with control speed FAST	0.1	read, write
12	Control constant Kp for operating mode CP with control speed MEDium	0	read, write
13	Control constant Ki for operating mode CP with control speed MEDium	0.05	read, write
14	Control constant Kp for operating mode CP with control speed SLOW	0	read, write
15	Control constant Ki for operating mode CP with control speed SLOW	0.02	read, write
16 19	*reserved*		-
20	MPPT accuracy	0.001	read, write
21	MPPT minimum voltage	10	read, write
22 ... 100	*reserved*		-
101 ...	Production and calibration parameters		read

9.3 Information on Special Designs

Information on special designs can be found in the file *TechDat_HES_dn*.pdf (*dn* = device number) on a USB flash drive supplied with the device.

9.4 Supplied Accessories

The supplied accessories are listed in the file *TechDat_HES_dn*.pdf (*dn* = device number) on a supplied USB flash drive.

9.5 Technical Data

The technical data for your electronic load can be found in the file *TechDat_HES_dn*.pdf (*dn* = device number) on a USB flash drive supplied with the device.

9.6 Declaration of Conformity

The declaration of conformity for your electronic load can be found in the file *TechDat_HES_dn*.pdf (*dn* = device number) on a USB flash drive supplied with the device.

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