MARWAY
POWER SOLUTIONS

mPower™ DC Power Supplies
311 Series 2U, 3U, 4U

Operating Guide and Programming Reference
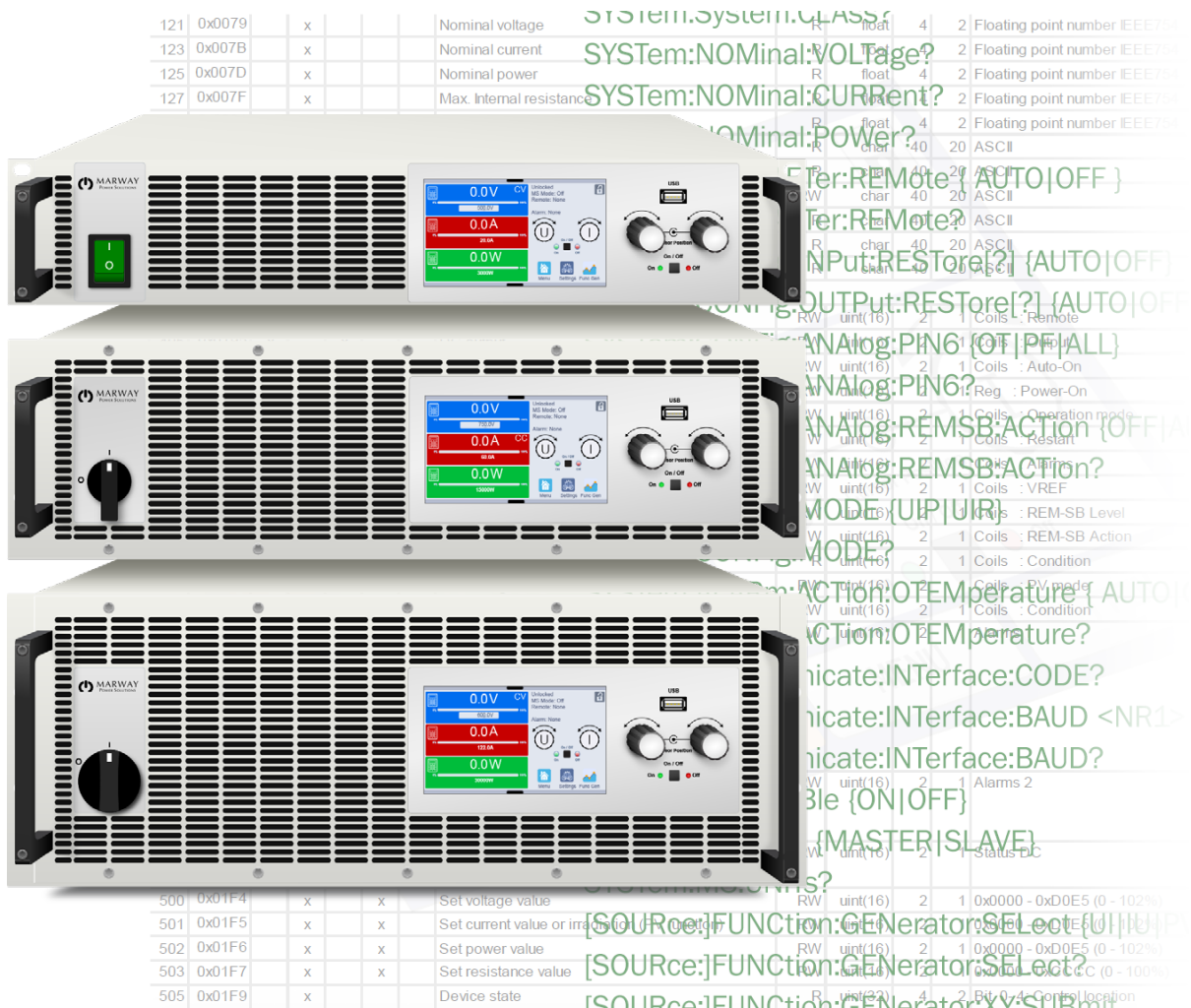
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There may be updates to this documentation and the software it describes at:
http://www.marway.com/mpower-dc-power-supply

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1 General

1.1 Documentation Symbols

Warning and safety notices as well as general notices in this document are shown in a box with a symbol as follows:

⚠	Symbol for a life threatening danger
⚠	Symbol for general safety notices (instructions and damage protection bans) or important information for operation
❗	Symbol for general notices

1.2 Product Key

The mPower DC 311 model number uses the following pattern, using an example:

MPW 311 - 5 4 - 0000 - 0000 - 004

mPower power supplies

Series:
311 = Gen 2, DC auto-ranging
      with function generator

Configurations:
-004 = USB, Analog, Ethernet, Anybus

Max. Output DC Amps (3 or 4 digits)
Max. Output DC Volts (3 or 4 digits)

Input Power:
0 = 1-phase, 100-240 Vac
1 = 1-phase, 220-240 Vac
2 = 1-phase, 208 Vac
3 = 1-phase, 380–480 Vac
4 = 3-phase, 208 Vac
5 = 3-phase, 380–480 Vac
6 = 1-phase, 208–240 Vac

Enclosure Type:
2 = Rackmount 2U
3 = Rackmount 3U
4 = Rackmount 4U

1.3 Intended Product Usage

The equipment is intended to be used as a general purpose power supply only as a variable voltage and current source.

1.4 Safety Notices

Mortal danger - Hazardous voltage

- This is electrical equipment with some parts operating with dangerous voltage. All exposed components which can have live voltage must be covered.
- All work on connections must be carried out under zero voltage (output disconnect), and may only be performed by qualified and informed persons. Improper actions can cause fatal injury as well as serious material damage.
- Never touch cables or connectors directly after unplugging from mains supply as the danger of electric shock remains. Verify there is zero voltage with a handheld meter.
- Never touch the contacts on DC output terminal directly after switching off the DC output, because there still can dangerous voltage present, sinking more or less slowly depending on the load. There also can be dangerous potential between negative DC output to GND or positive DC output to GND due to charged capacitors. Verify there is zero voltage with a handheld meter.
- Always follow 5 safety rules when working with electric devices:
  - Disconnect completely.
  - Secure against reconnection.
  - Verify that the system has zero voltage.
  - Carry out earthing and short-circuiting.
  - Provide protection from adjacent live parts.

- The equipment must only be used as intended.
- The equipment is only approved for use within the connection limits stated on the product label.
- Do not insert any object, particularly metallic, through the ventilator slots
- Avoid any use of liquids near the equipment. Protect the unit from wet, damp and condensation.
- Do not connect loads, particularly low resistance, to power supplies under power; sparking may occur which can cause burns as well as damage to the equipment and to the user.
- ESD regulations must be applied when plugging interface cards or modules into the relative slot
- Interface cards or modules may only be attached or removed after the unit is switched off. It's not necessary to open the unit.
- Do not connect external power sources with reversed polarity to DC input or outputs. The equipment will be damaged.
- Avoid where possible connecting external power sources to the DC output, and never those that can generate a higher voltage than the nominal voltage of the unit.
- Never insert a cable which is connected to Ethernet into the Master/Slave socket on the back of the unit.
- Always configure the various protecting features against overvoltage etc. for sensitive loads to what the target application requires.

2 Physical Overview

Installation details are in a separate *mPower 311 Series Installation and Wiring Guide*.

2.1 311 Series 4U Views

This Operating Guide covers mPower 311 Series 4U models with input power of 380–480 Vac.
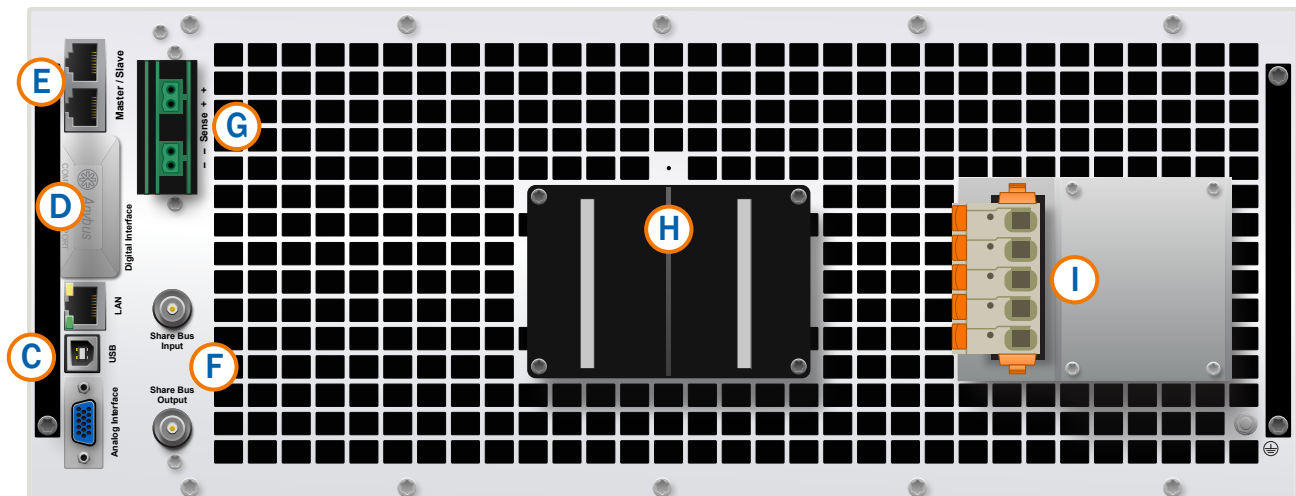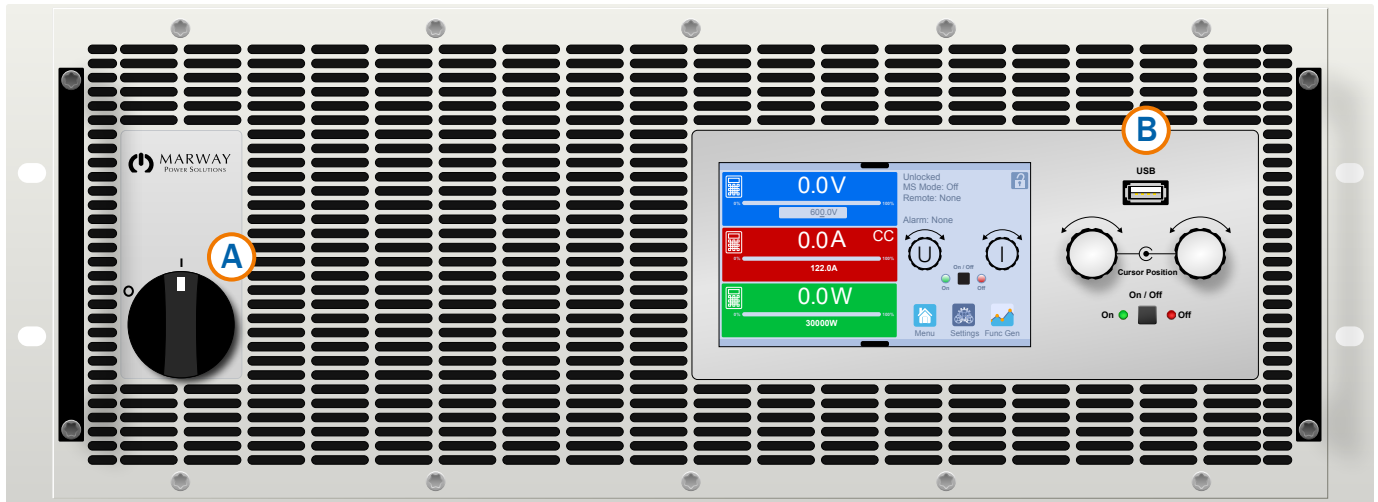
A - Power switch

B - Control panel

C - Built-in remote interfaces
     Ethernet, USB, Analog

D - Anybus expansion port

E - Master/Slave ports

F - Share bus connectors

G - Remote voltage sense connectors

H - DC output terminals

I - AC input connector

311 Series 4U Dimension Views (380–480 AC)

1.7" 26.3" ≈3.4"
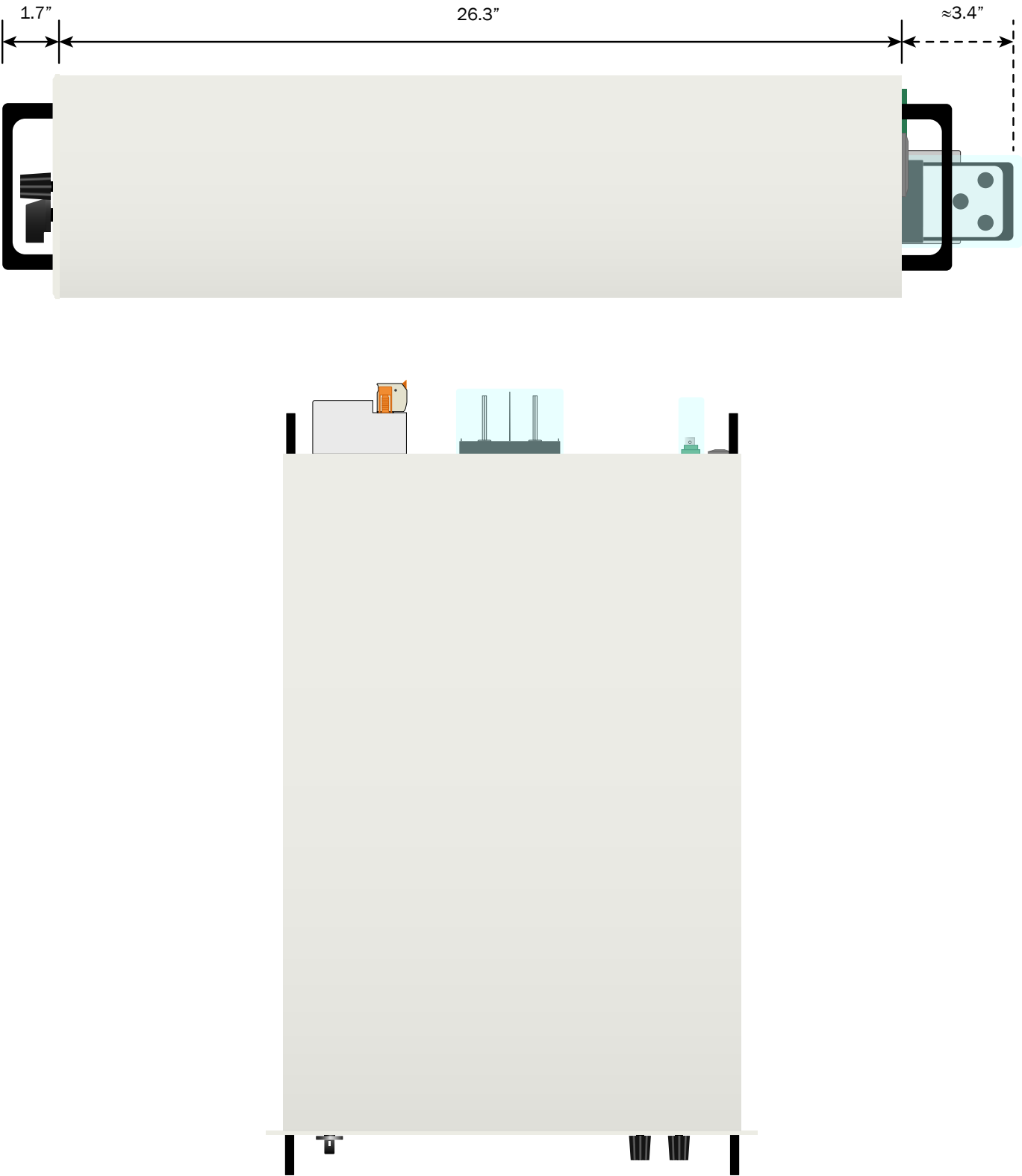
2.2 311 Series 3U Views

This Operating Guide covers mPower 311 Series 3U models with input power of 380–480 Vac.

A - Power switch

B - Control panel

C - Built-in remote interfaces
       Ethernet, USB, Analog

D - Anybus expansion port

E - Master/Slave ports

F - Share bus connectors

G - Remote voltage sense connectors

H - DC output terminals

I - AC input connector

311 Series 3U Dimension Views (380–480 AC)

1.8" 26.3" ≈2.8"
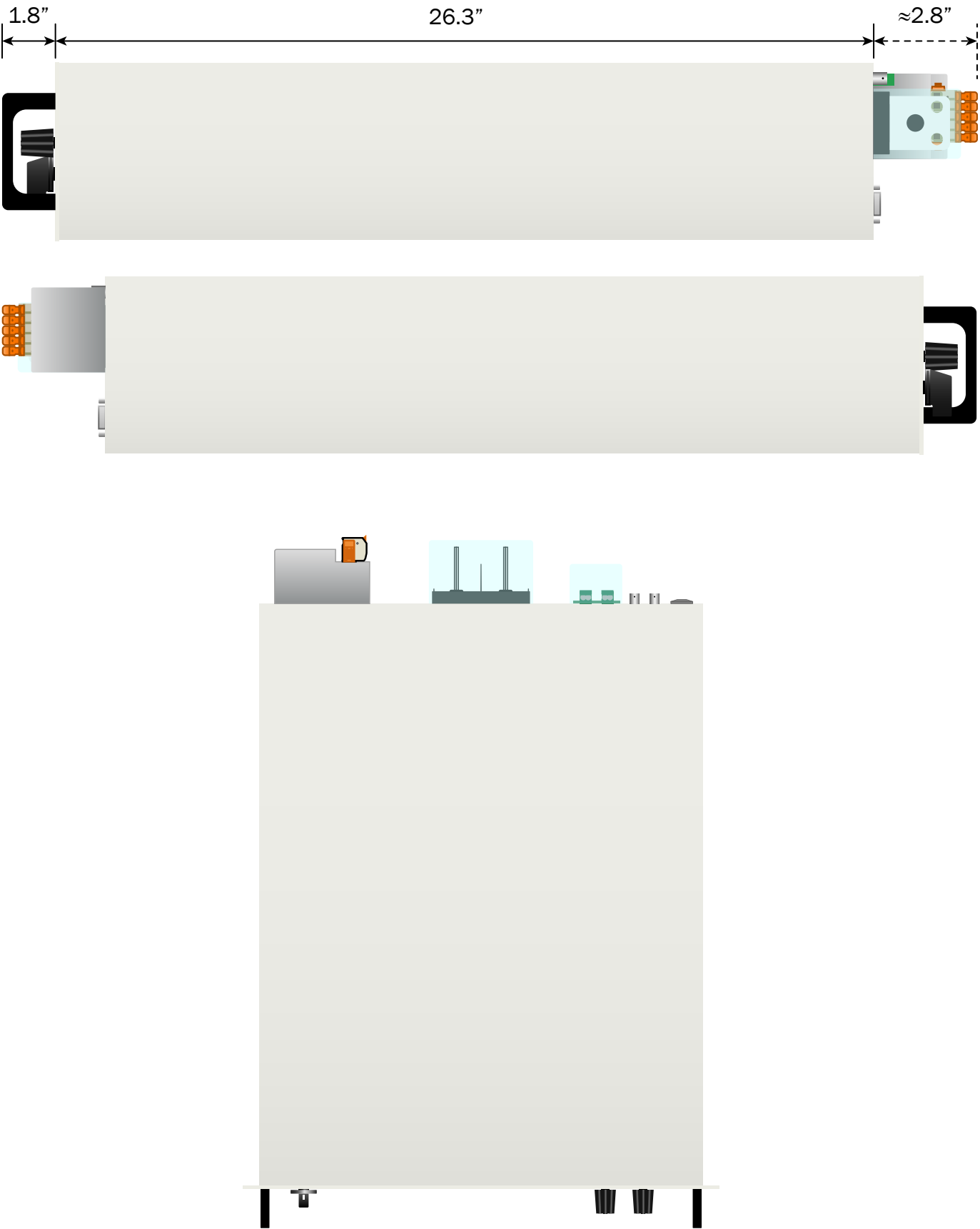
2.3 311 Series 2U Views

This Operating Guide covers mPower 311 Series 2U models with input power of 380–480 Vac.
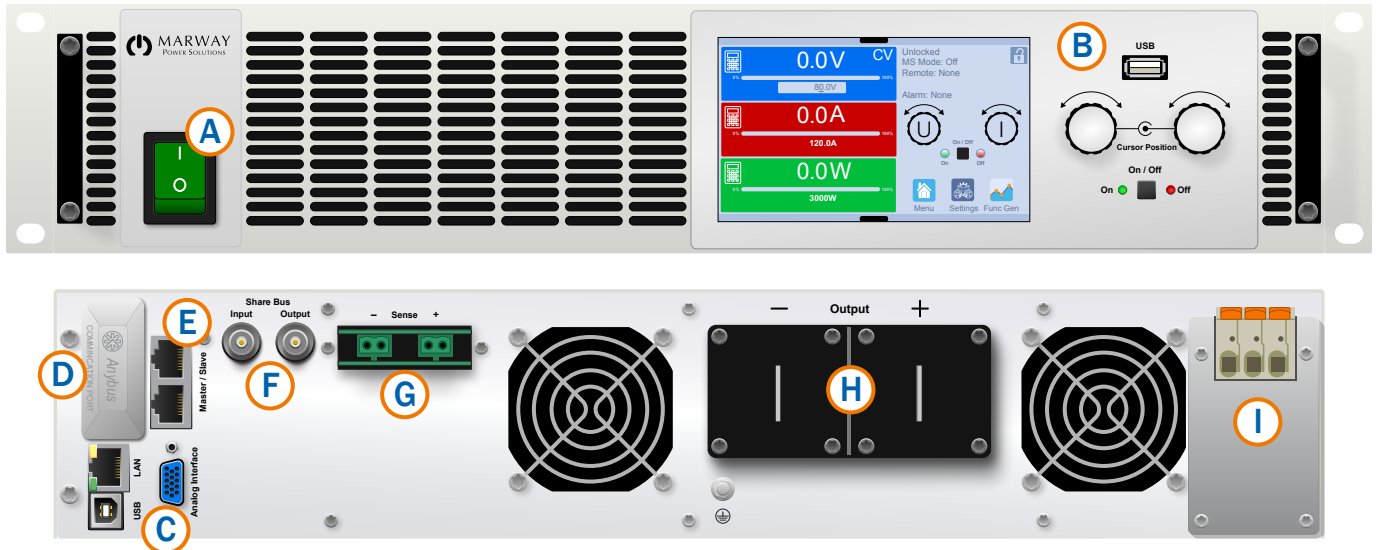
A - Power switch

B - Control panel

C - Built-in remote interfaces
Ethernet, USB, Analog

D - Anybus expansion port

E - Master/Slave ports

F - Share bus connectors

G - Remote voltage sense connectors

H - DC output terminals

I - AC input connector

311 Series 2U Dimension Views (380–480 AC)

1.6" 18.2" ≈1.8"
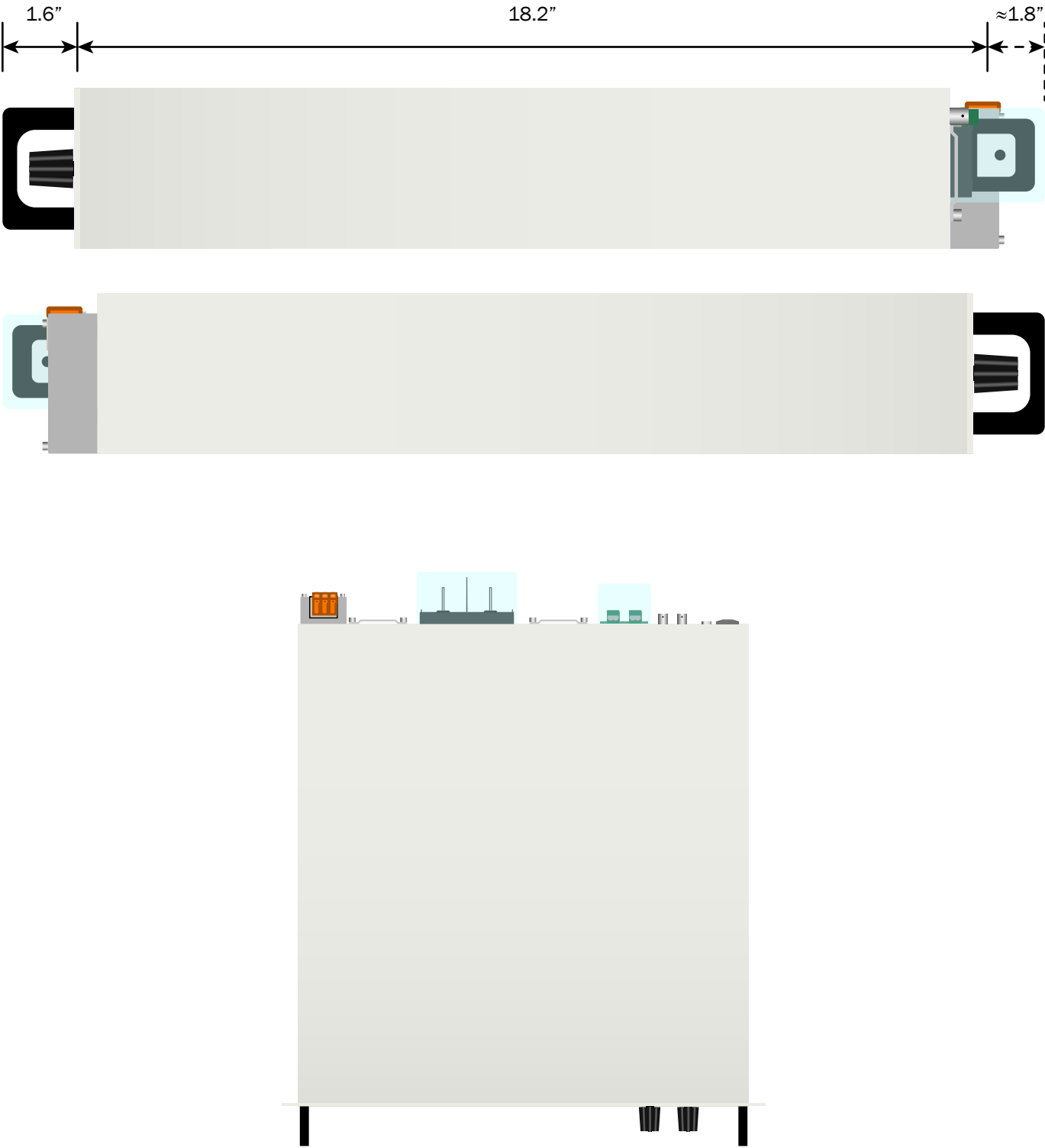
3 Features Overview

3.1 General Description

The mPower DC power supplies are especially suited to test and industrial applications due to their accuracy, programmability, wide selection of power ranges, and each unit's autoranging power delivery.

Apart from basic functions of power supplies, set point curves for voltage and/or current can be generated by the function generator (sine, rectangular, triangular and other curve types). Arbitrary generator curves can be saved to and loaded from a USB drive.

Configuration and control is possible using the built-in control panel and through various remote control methods. For remote control using a computer or PLC, the system includes both a USB port and an Ethernet port, as well as an analog interface. All interfaces are galvanically isolated. Additionally, the integrated Anybus® port allows user changeable plug-in modules for RS232, Profibus, ProfiNet, Modbus TCP, CAN, CANopen or EtherCAT.

For increased capacity, these systems can be combined in parallel to acheive greater power and current capacity. Up to 64 identical, or even some mixing of, models can be controlled from the configuration of a single unit. A built-in Share Bus manages the current load sharing between units.

The block diagram illustrates the main functions inside the power supply, and their relationships.
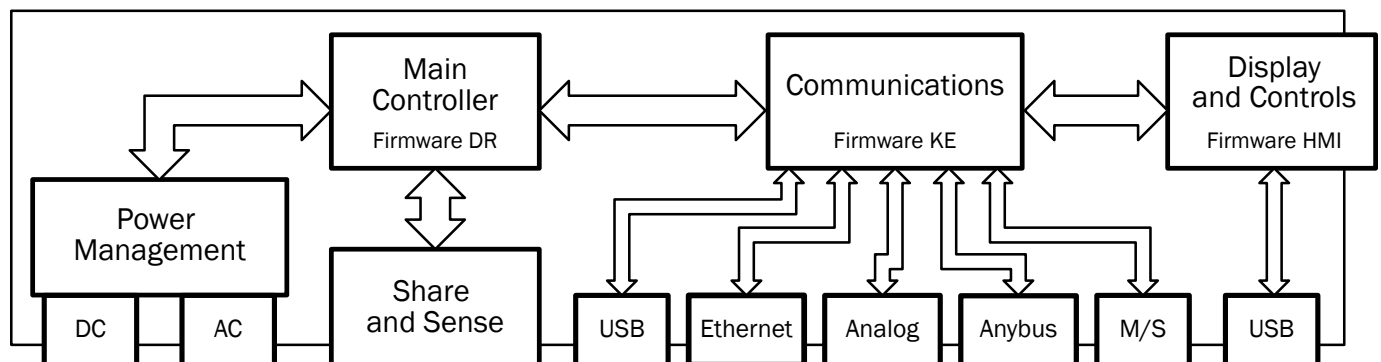
3.2 Operation Features

The mPower 311 is an advanced and versatile programmable DC power supply.

- Operates in constant voltage, constant current, or constant power mode.
- Function generator with multiple common waveforms, arbitrary wave forms, and built-in simulations.
- Autoranging power output enables the system to deliver 100% power over a wide range of voltage and current.
- Parallel output connectivity of up to 64 units to create a total power output of up to 1,920 kW.
- Output Share Bus which automates the regulation of current loading among parallel-connected units.
- Output Voltage Sense Bus which monitors voltage at the load, instead of the output terminals, to compensate for minor losses in output cables.
- USB, Ethernet, and Anybus digital interfaces for remote control using your own custom scripting. Anybus accepts modules enabling RS232, CAN, CANopen, Profibus, Profinet, ModbusTCP, and EtherCAT.
- Programmable control over mode, set values, alarms, and function generator using Modbus and SCPI protocols.

- Programmable control through Windows®, LabView®, and your own custom scripts.
- Analog Interface for remote control and monitoring of key operational parameters of the system using a PLC or your own custom control circuitry.
- Touchscreen graphical display user interface with two rotary controls (which speed up data entry) allows for complete local configuration, control, and monitoring without a PC.
- Safety features including user interface lockout and discharge circuitry. Built-in alerts for over voltage, current, power, and temperature.

3.3 Control Elements

3.3.1 The Control Panel

The control panel consists of a touch display, two rotary knobs with a push function, and DC on/off button. All of the unit's configuration and control capabilities can be managed from this control panel.
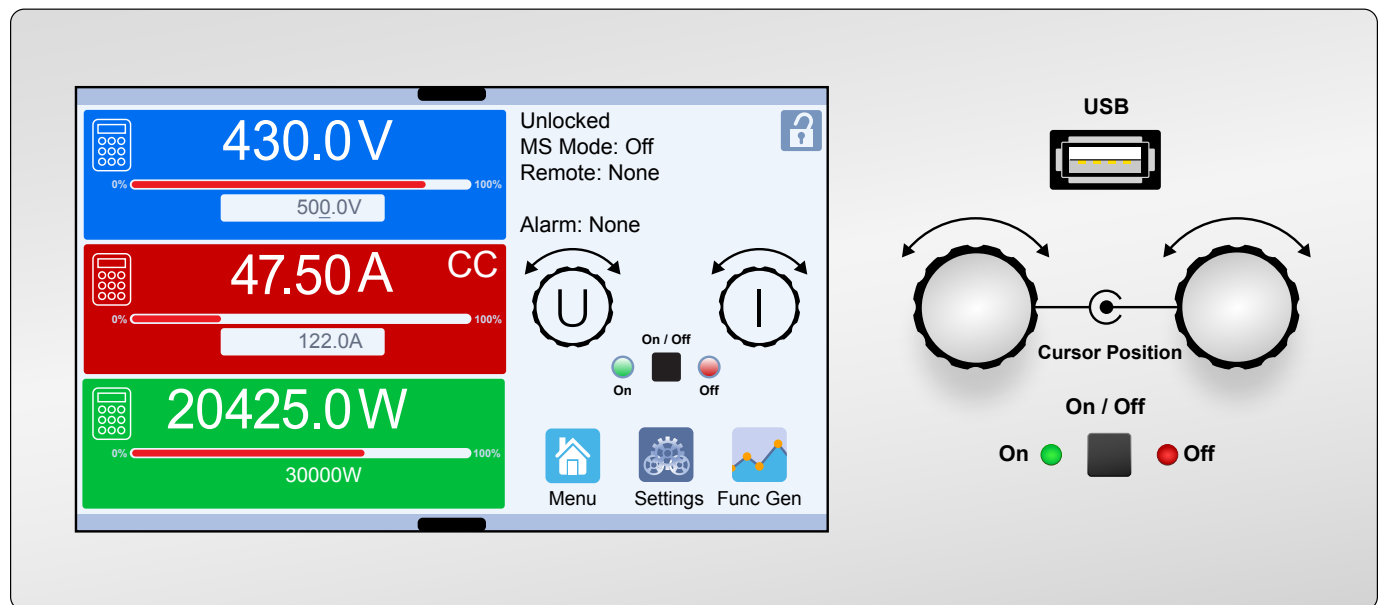
3.3.2 Sense Connectors

Use the Sense connection when it is important that adjusted output voltage is held constant at the load terminals rather than at the power supply's DC output terminals. These are effective during constant voltage operation only. Refer to the *Installation Guide* for cabling and other details.

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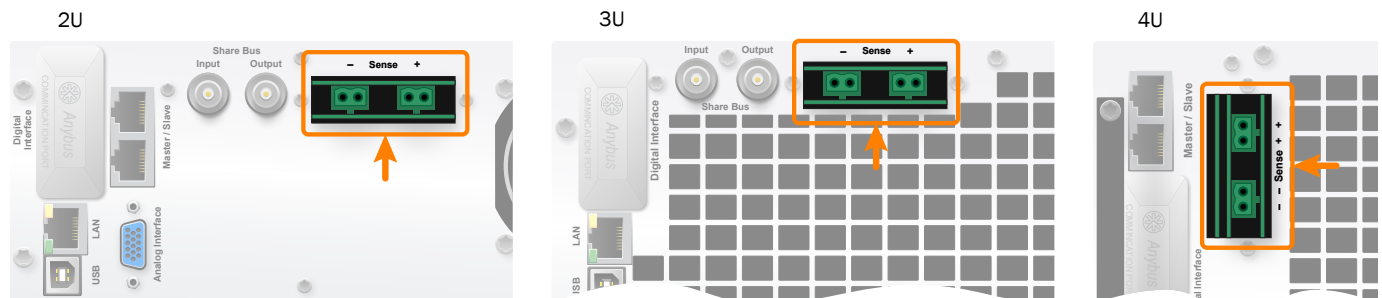
3.3.3 Share Connectors

The two BNC sockets labeled Share Bus are part of the communications system used in multi-unit, parallel operation. Refer to the *Installation Guide* for cabling and other details.
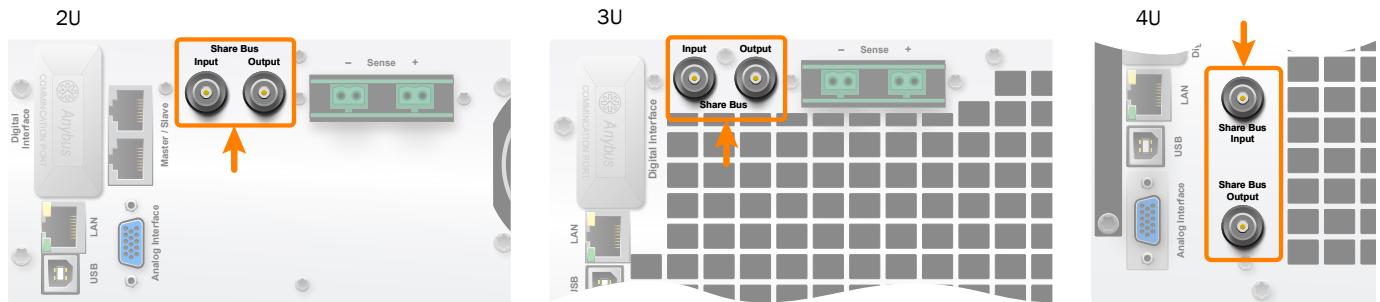
3.3.4 Master/Slave Connectors

The RJ45 Master/Slave connectors work with the Share Bus in multi-unit, parallel operation. Do not connect these to Ethernet. Refer to the *Installation Guide* for cabling and other details.
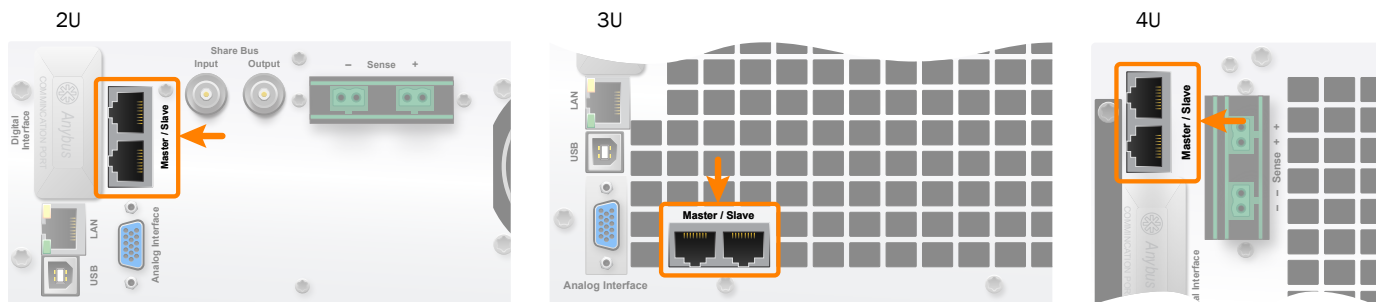
3.3.5 USB Connector, Rear

The USB port on the back of the power supply is provided for connection to a PC for remote control and for firmware updates. A USB driver, available for Windows®, should be installed. Refer to the *Installation Guide* for driver installation details, and information about USB drivers for other operating systems. Information about using remote commands can be found in 10 Programming Introduction (p 94).
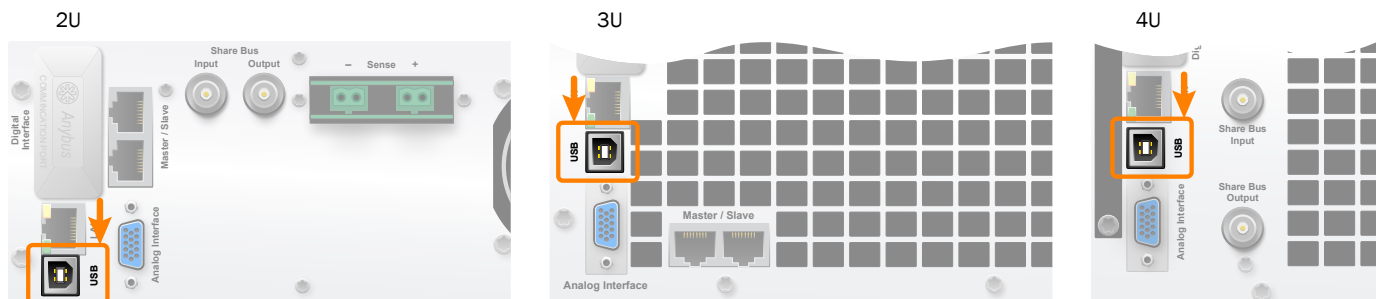
3.3.6 USB Connector, Front

The front USB connector is intended for data transfer to and from a USB thumb drive. It is not intended for remote control connectivity. Refer to 5.4 Front USB File System (p 41) for data and file formats, and other usage details.

3.3.7 LAN Ethernet Connector

The LAN port on the back of the power supply is provided for connection to a PC for remote control. A simple website is accessible in a standard browser which provides a configuration page for network parameters, as well as an input field for SCPI commands. Additionally, TCP/IP access on a configurable port (typically 5025) provides communication with the system for control using Modbus and SCPI based protocols through most of the common programming languages. For commands wrapped in protocols such as CANopen, Profinet, ModbusTCP and others, use an Anybus module. Information about using remote commands starts in 10 Programming Introduction (p 94).
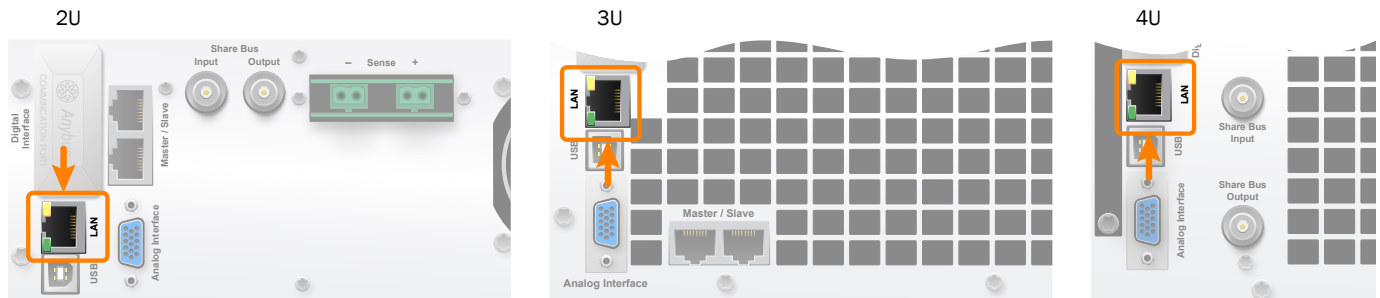
3.3.8 Anybus Modules

A number of optional interface modules can be installed by the end user. Refer to the Installation Guide for installation details. Information about using the port modules can be found in 10 Programming Introduction (p 94).
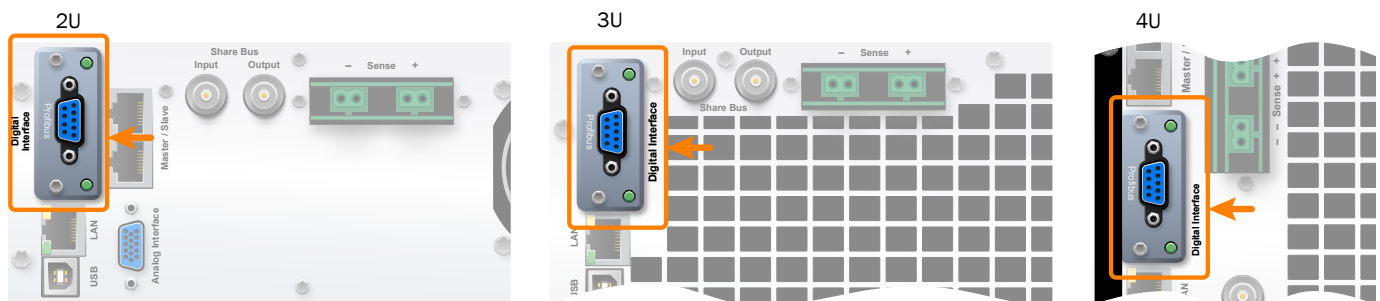
3.3.9 Analog Interface Connector

The 15-pin, Sub-D socket on the back of the unit is provided for remote control via analog and discrete signals. To connect this to an external controller (PC, PLC, or other), a standard mating plug is necessary (not included in shipment). Refer to the *Installation Guide* for pinout and wiring options. Operation details are covered in 9.4 Remote Control with the Analog Interface (p 89).
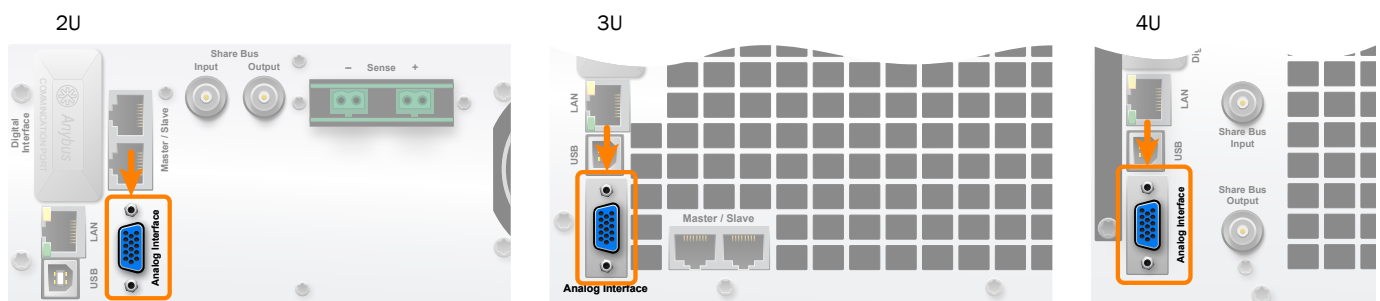
4 Operation

⚠️
- To help ensure safety when operating the unit, it is essential that persons who operate the unit are fully trained and acquainted in the required safety measures to be taken when working with dangerous electrical voltages.
- For models which can generate a voltage which is dangerous by contact, or is connected to such models, the included DC terminal cover, or an equivalent, must always be used.
- Whenever the load and DC output are being re-configured, the unit should be disconnected from the AC mains. Do not rely only on the DC output being switched off.

⚠️
- Operation of a power supply without any load or a very small load (<0.5% of INom) is not considered as a normal operation mode.
- It is recommended to run a power supply always with at least 10% voltage and current load.

4.1 Operating Modes

A power supply uses internal electronic controls to regulate voltage, current, and power to user-adjusted values, and hold them constant within certain range limits. Given well established engineering relationships between voltage, current, and power, each operating mode has its own characteristics. Each is explained in short form below.

🛈
- Unloaded operation isn't considered as a normal operation mode and can lead to false measurements, for example when calibrating the unit.
- The optimal working point of the unit is between 50% and 100% voltage and current. Autoranging extends the generally usable range to approximately 35% of current and voltage. Outside of that range, accuracy and repeatability may not be sufficient for precision work.
- It's recommended to not run the unit below 10% voltage and current, in order to meet technical values like ripple or transient times.

4.1.1 Voltage Regulation / Constant Voltage

Voltage regulation is also called constant voltage operation (CV).

During constant voltage operation, the DC output voltage of a power supply is held constant at the user-adjusted value — unless the output current or output power reaches an equipment or user-adjusted limit. If a limit is reached, the system will automatically change modes to operate as constant current (CC) or constant power (CP) where the limit becomes the new automatically sustained value. At such a point, the output voltage can't be held constant any more, and will drop to a value resulting from Ohm's law.

The set value should be viewed as a maximum limit. Depending on the configuration of the current and power set values (and seperate limit value settings) conditions may result in the voltage being automatically adjusted lower than the set value.

While the DC output is enabled, and constant voltage mode is active, the condition "CV mode active" will be indicated on the graphic display using the abbreviation CV next to the voltage values. This state will also be indicated as a signal on the analog interface, and stored as a status message readable through one of the digital interfaces.

4.1.1.1 Transient time after load step

When working in constant voltage regulation (CV), the device's internal voltage regulator requires a small transient time to settle the voltage after a change in load (a.k.a. load step). Load steps, when positive (increasing) or negative (decreasing), will incur a short collapse or overshoot respecively until compensated by the voltage regulator.

The amplitude of the collapse and overshoot depends on the unit model's nominal ratings, the currently adjusted output voltage, and the capacity on the DC output. Therefore, the amplitude cannot be stated as a specific value. The transient time is approximately ≤ 1.5 µs, and can be influenced by a user adjustable setting **Voltage control speed** with a selection of Slow, Normal, or Fast. Normal is the default. The Slow setting results in a longer transient time and a greater collapse profile, but less overshoot. The Fast setting results in a shorter transient time and smaller voltage collapse, but greater overshoot amplitude. The exact metrics for a given setup can be characterized on an oscilloscope if necessary.
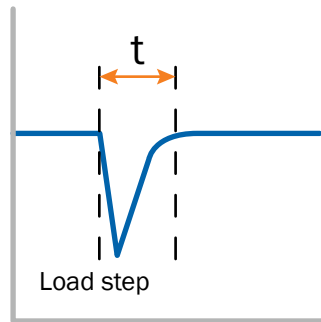
For a positive load step: the DC output will collapse below the adjusted value for a short time (t). (The depiction is conceptual, not relative to the full scale of the nominal ratings.)
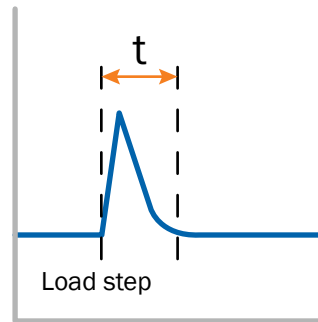
For a negative load step: the DC output will rise above the adjusted value for a short time (t). (The depiction is conceptual, not relative to the full scale of the nominal ratings.)

4.1.2 Current Regulation / Constant Current

Current regulation is also known as current limiting or constant current mode (CC).

With a device connected to the DC output, the device will be exposed to the DC voltage set value. Depending on the resistance of the device, a certain current will be drawn through the DC output. For discussion, let's say that current draw is 40 amps. If the set value for current is adjusted to 50 amps, the power supply would be in constant voltage mode (let's ignore constant power for now) as the current limit has not been reached.

If, however, the set value for current is adjusted to 30 amps, the power supply would automatically switch to constant current mode, and limit the current flow to 30 amps. This would result in the voltage being automatically reduced below its set value. The value of the current is prioritized over the value of the voltage.

The set value should be viewed as a maximum limit. Depending on the configuration of the voltage and power set values (and seperate limit value settings) conditions may result in the current set value not being reached.

It is possible that during CC operation, a significant change in either the current limit setting, or a sudden drop in load current will result in a brief voltage surge of 1–2% of the rated voltage while the power supply attempts to regulate the voltage in reaction to the current change. Duration depends on the capacitance of the device connected to the power supply.

While the DC output is enabled, and constant current mode is active, the condition "CC mode active" will be indicated on the graphic display using the abbreviation CC next to the current values. This state will also be indicated as a signal on the analog interface, and stored as a status message readable through one of the digital interfaces.

4.1.3 Power Regulation / Constant Power

Power regulation, also known as power limiting or constant power (CP), works to keep the DC output power of a power supply constant. This is done in reaction to the combination of voltage, current, and the load's resistance.

Power limiting operates according to the autorange principle such that at lower output voltages higher current flows are allowed, and vice versa. Compared to a traditional power supply, the mPower is designed to operate with higher voltages and currents in combinations which result in the same peak power consumption.

While the DC output is enabled, and constant power mode is active, the condition "CP mode active" will be indicated on the display using the abbreviation CP next to the power values. This state will also be indicated as a signal on the analog interface, and stored as a status message readable through one of the digital interfaces.

Range Envelopes for the
Same Maximum Power

Output Voltage

Auto-ranging max. power envelope

Traditional max. power envelope

Output Current
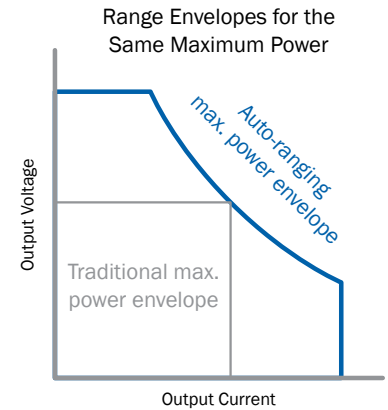
> **!** When using remote sensing, the power supply may deliver a higher voltage on the DC output than the adjusted setting, which results in additional power and may also cause the system to enter power limitation without explicitly indicating "CP" in the display.

4.1.4 Internal Resistance Regulation / Constant Resistance

Internal resistance control, or constant resistance (CR) of power supplies is the simulation of a virtual internal resistor which is in series to the load. According to Ohm's law, this resistance causes a voltage drop, which will result in a difference between the output voltage setting and the actual output voltage.

CR mode is actually running a modified CV mode, but the display will indicate "CR" once the adjusted resistance value is reached. (The significance of this indication is explained in the sections covering the operation of the display.)

The adjustable resistance range of a particular model is listed in the technical specifications.

Note that the function generator is not available when CR mode is unavailable, and the power indicated on the display does not include the simulated power dissipation.

4.1.5 Determining the Operating Mode

The operating mode of CV, CC, CP, or CR is determined automatically by the power supply control system depending on target values (called "set values") entered by the operator, and the behavior of the connected device.

For example, if we assume a given setup with a device that has variable resistance, and set values of 80 volts, 16 amps, and 1200 watts, the system could end up in CV, CC, or CP mode depending on the resistance of the load device.

When the DC output is on, the power supply will try to apply 80 V. As long as the power consumed is less than 1200 watts, and the current is less than 16 amps, the power supply will operate at 80 V in CV mode. If the device resistance is adjusted to draw 1200 watts through the power supply, the power supply will enter CP mode to regulate the power at the 1200 watt set value. To achieve this, voltage will automatically be lowered.

In this manner, the operating mode will change automatically to conform to the limits of the set values, based on the conditions of the connected load device.

In order to "manually run" in a specific mode, the operator will need to know what to expect from the connected device, and enter set values which are unlikely to invoke the unwanted operating modes. In our example above, to ensure running at 80 V in CV mode, the current and power set values will have to be large enough to not be reached. However, it may be prudent to set values just above the expected tolerances of the device to possibly help prevent damage from an accidently incorrect setting. For example, if the device is rated for 20 A, it may be better to have a current set value of 22 A instead of just arbitrarily entering something like 100 just to avoid CC mode.

4.2 Main Power On/Off

The main power switch (left front of the unit) enables and disables AC power to the system.

After switching on, the display will first show device model, firmware version, and other information. Then a language selection prompt shows for 3 seconds. After that, the main operation controls are shown.

In the menu **Settings** > **DC Output** is a option **State after power ON** in which the user can determine the condition of the DC power stages after power-up. The factory default is **Off**, meaning that the DC power stage on power-up isalways switched off. **Restore** means that the last condition will be restored, either on or off.

Upon AC switch-off, the last DC output state, and the most recent set values are saved. The DC output is immediately switched off, the internal fans will continue to run for a while, and a few seconds after they have shut down the unit will be completely powered off.

When powering the unit down, a PF alarm (power failure) will be reported. It is not possible to distinguish a shutoff from an unexpected loss of AC power, so the alarm is generated, but it can be ignored when the power shutoff is intentional.

> ❗ For the duration of the startup, the analog interface can signal undefined statuses on its discrete outputs. These must be ignored until the system has finished booting, and is ready to work.

4.3 Control Panel Overview
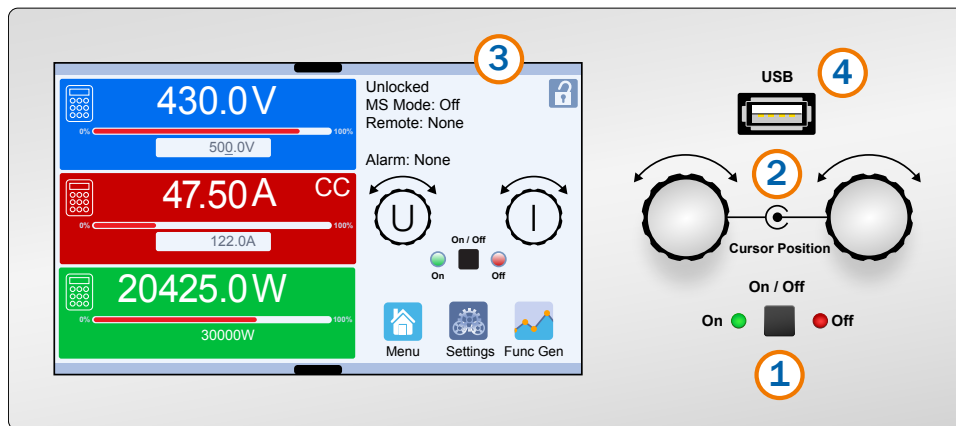
Overview of the elements on the control panel

(1) On/Off Button for DC output
Used to toggle the DC output between on and off, also used to start a function run. The LEDs "On" and "Off" indicate the state of the DC output, whether the unit is manually controlled or remotely controlled.

(2) Rotary knobs with push button function
Left knob (turn): voltage set value adjustment
Left knob (push): shift the decimal position (cursor) of the voltage value for adjustment
Right knob (turn): current, power or resistance set value adjustment (tap to select which one)
Right knob (push): shift the decimal position (cursor) of the currently selected value for adjustment

(3) Touchscreen display
Used for changing operating modes, entering set values, and changing settings, as well as display of actual values and status. The touchscreen can be operated with the fingers or with a stylus.

(4) Port for USB drive
For the connection of a standard USB thumb drive. See 5.4 Front USB File System (p 41) for more details.

4.4 DC Power On/Off Button

Generally, this button just enables or disables power at the DC output. However, if the function generator has been configured to run a specific function, this button also starts and stops that function (with the DC power being enabled/disabled correspondingly).

To manually switch the DC output on or off

- As long as the touchscreen is not locked, press the button On/Off. Otherwise you'll be prompted to disable the HMI lock. If the HMI lock is configured with a PIN, you'll be prompted to enter the PIN first.
- With the display unlocked, the On/Off button toggles the DC output state, as long as this is not restricted by an alarm, or the system being in remote control.

To remotely switch the DC output on or off using the analog interface

- The analog interface can be used to switch the DC output off, and it can be used to switch it back on again after it was already enabled with the DC On/Off button. The analog device cannot be used turn the DC output on initially. See also **REM-SB Action** in 5.5.1.6 Settings > Analog Interface (p 44).
- For wiring details, see 9.4.6 DC Output On/Off using REM-SB (p 92).

To remotely switch the DC output on or off using a digital interface

- See the programming documentation starting in 10 Programming Introduction (p 94) if you are using custom software, or refer to the separate documentation for EA Power Control or LabView VIs.

4.5 Rotary Knobs

The two rotary knobs are used during set value entry, and during some menu operations.

As described in 4.7 Adjusting Set Values (p 27), the left knob is always used for setting the voltage. The right knob can be configured to adjust current, power, or resistance. Turning the knob increases or decreases the value, and pressing the knob moves a cursor to change which digit is being changed.

For some menu operations, the knobs can be used to select from a list of options, and pressing the knob checks or unchecks options.

Each of these main uses of the knobs is covered in detail in other relevant sections.

4.6 Touchscreen Display

During normal operation, the left side of the display is used to show actual values and set values. The upper right side is used to display status information. The lower right includes icons to access to commonly used features.

This illustration shows some elements which would not be displayed at the same time. For example, only one of the CV, CC, CP indicators would be visible at one time. Likewise, only two set-value fields would be editable at one time.

Actual voltage display	Tap/pull for more status
Voltage set-value field	Status area
Actual current display	Active mode indicator
Current set-value field	Touch area for rotary knob assigment
Actual power display	DC output status
Power set-value field	Touch menus
	Tap/pull for quick menu
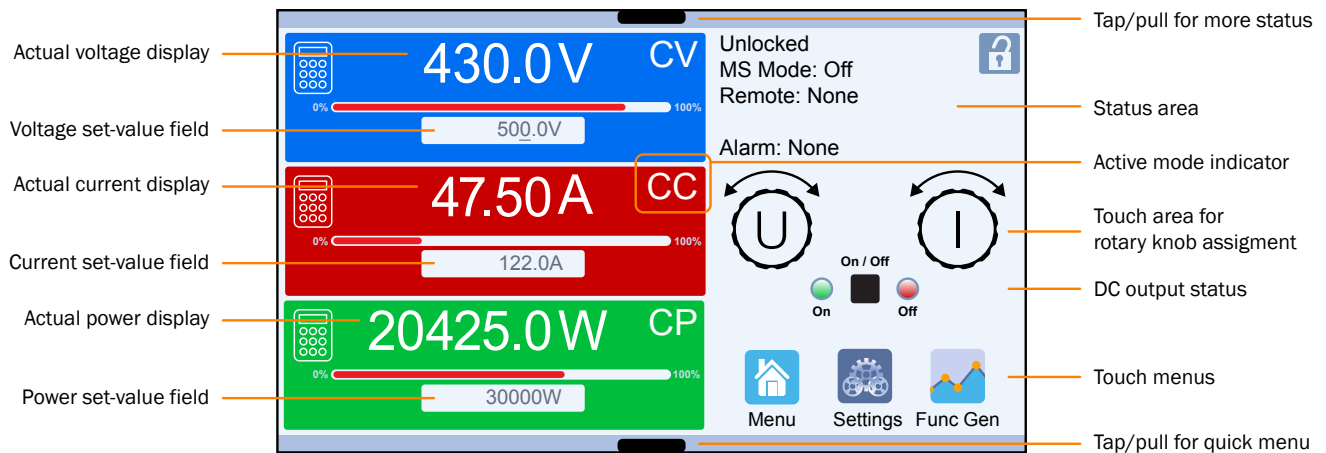
Depending on the control context, touch widgets may be in an enabled or disabled state. When disabled, a widget icon will be the same, but will have a grayed label, or may have a padlock icon.

Black text = enabled   Gray text = temporarily disabled
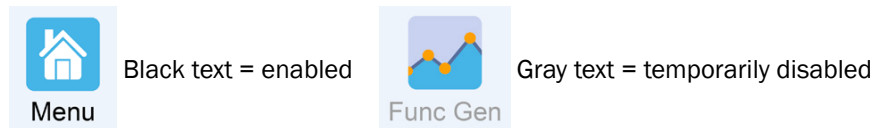
4.6.1 Value Display Area

> Two terms to understand are **actual values** and **set values**. Actual values are the values measured as outputs of the power supply. Set values are setpoints or targets which the control system is configured (set) to acheive.

During normal operation, the DC output values (large numbers) and set values (small numbers) for voltage, current, and power are displayed. Resistance set value (a simulated, variable internal resistance) is displayed in a fourth row only during active resistance mode.

When the DC output is switched on, the active regulation mode is displayed as CV, CC, CP or CR, next to the corresponding actual value (only one mode is active/shown at a time).

The voltage set value is always adjustable with the left rotary knob. Only one of the other three values is adjustable at any one time using the right rotary knob — this can be changed by tapping on the right rotary icon to change which value is editable. See 4.7.1 Adjusting Set Values by Knobs (p 27) for more details.

All set values can be edited at any time using the keypad to key in a value. See 4.7.2 Adjusting Set Values by Keypad (p 28) for more details.

4.6.2 Value Range and Resolution

In the display, the actual and set values are governed by some general limits regarding range and resolution. (Accuracy is a separate discussion.) Many of these will be related to the nominal rating of the voltage, current, and power of the model.

This table explains the ranges of values which are both displayed ("actual") and entered ("set").

Display	Unit	Range	Description
Actual voltage	V	0.2–125% U_{Nom}	Actual values of DC output voltage
Set value of voltage [1]	V	0–102% U_{Nom}	Set value for limiting the DC output voltage
Actual current	A	0.2–125% I_{Nom}	Actual value of DC output current
Set value of current [1]	A	0–102% I_{Nom}	Set value for limiting the DC output current
Actual power	W, kW	0.2–125% P_{Nom}	Actual value of output power, P = U * I
Set value of power [1]	W, kW	0–102% P_{Nom}	Set value for limiting DC output power
Actual value of resistence	Ω	0–99999	
Set value of internal resistance [1]	Ω	$x^{[2]}$–102% R_{Nom}	Set value for the simulated internal resistance
Adjustment limits		0–102% nom	U-max, I-min etc., related to the measured values
Protection settings		0–110% nom	OVP, OCP etc., related to the measured values

[1] Valid also for values related to these physical quantities, such as OVD for voltage and UCD for current
[2] X = the low limit listed in the Model Specifications tables (which varies by model).

The number of decimal places used for display and data entry depends on the nominal power related values of any given model. The values will have 3 to 5 digits. Actual and set values for a given measurement always have the same number of digits on any one given model.

This table shows the adjustment resolution and number of digits of set values in the display.

Voltage OVP, UVD, OVD, U-min, U-max			Current OCP, UCD, OCD, I-min, I-max			Power OPP, OPD, P-max			Resistance R-max		
Nominal	Digits	Min. increment	Nominal	Digits	Min. increment	Nominal	Digits	Min. increment	Nominal	Digits	Min. increment
≤ 80 V	4	0.01 V	<100 A	4	0.01 A	30000 W	5	1 W	<10 Ω	5	0.0001 Ω
200 V	5	0.01 V	>100 A	4	0.1 A	MS <100 kW	4	0.01 kW	25 Ω / 90 Ω	5	0.001 Ω
360 V	4	0.1 V	≥1000 A	5	0.1 A	MS >100 kW	4	0.1 kW	170 Ω - 650 Ω	5	0.01 Ω
500 V	4	0.1 V	MS ≥3000 A	4	1 A	MS >1000 kW	5	0.1 kW	>1000 Ω	5	0.1 Ω
750 V	4	0.1 V	MS >10000 A	5	1 A						
≥1000 V	5	0.1 V									

4.6.3 Status Display Area

The upper right area displays various status indicators and messages. This table lists the icons and messages, and what they mean.

Display	Description
🔒 🔓	The touchscreen is locked or unlocked
Remote:	The unit is under remote control from:
Analog	— the built-in analog interface
Ethernet	— the built-in Ethernet interface
USB & others	— the built-in USB port or a plug in interface module
Local	The unit has been locked by the user explicitly against remote control
Alarm:	The listed alarm condition has not been acknowledged or still exists.
Event:	The listed user-defined event has occurred which isn't yet acknowledged.
MS mode: Master	Master-slave mode activated, unit is master
MS mode: Slave	Master-slave mode activated, unit is slave
FG:	The listed function is loaded and activated
💾 💾	Data logging to USB thumb drive active or failed

4.7 Adjusting Set Values

Set values can be entered manually in two ways: via rotary knob or keypad input. The rotary knobs adjust values continuously, and can be a more convenient way to make small adjustments. Using the on-screen numeric pad can be faster for making larger changes to values, and can be used without having to change the mode of the right knob — just tap the keypad corresponding to the value to be changed.

Voltage, current, and power are the primary variables in the operation of the power supply for most applications. The actual values and set-value fields for these parameters are visible during operation. A fourth value for internal resistance (R), must be activated before it is visible. See 4.9 The Quick Menu (p 30) for one way to do this.

> A changed value is immediately applied when submitted — whether the DC output is on or off.

> When adjusting set values, upper and/or lower limits may come into effect. See section 4.8 Set Value Limits (p 29). Once a limit is reached, the display will show a message like "Limit: U-max" etc. for about 1-1/2 seconds next to the set value field.

4.7.1 Adjusting Set Values by Knobs

To change the voltage set value, rotate the left physical knob. To change current, power, or resistence, first check if the value you want to change is already assigned to the right knob (indicated with I, P, or R). If the knob assignment is already what you want, just rotate the physical knob. Otherwise, tap the right rotary icon, and the display (and assignment) iterates through the three operation mode options.

Left knob: voltage
Right knob: current

Left knob: voltage
Right knob: power

Left knob: voltage
Right knob: resistance
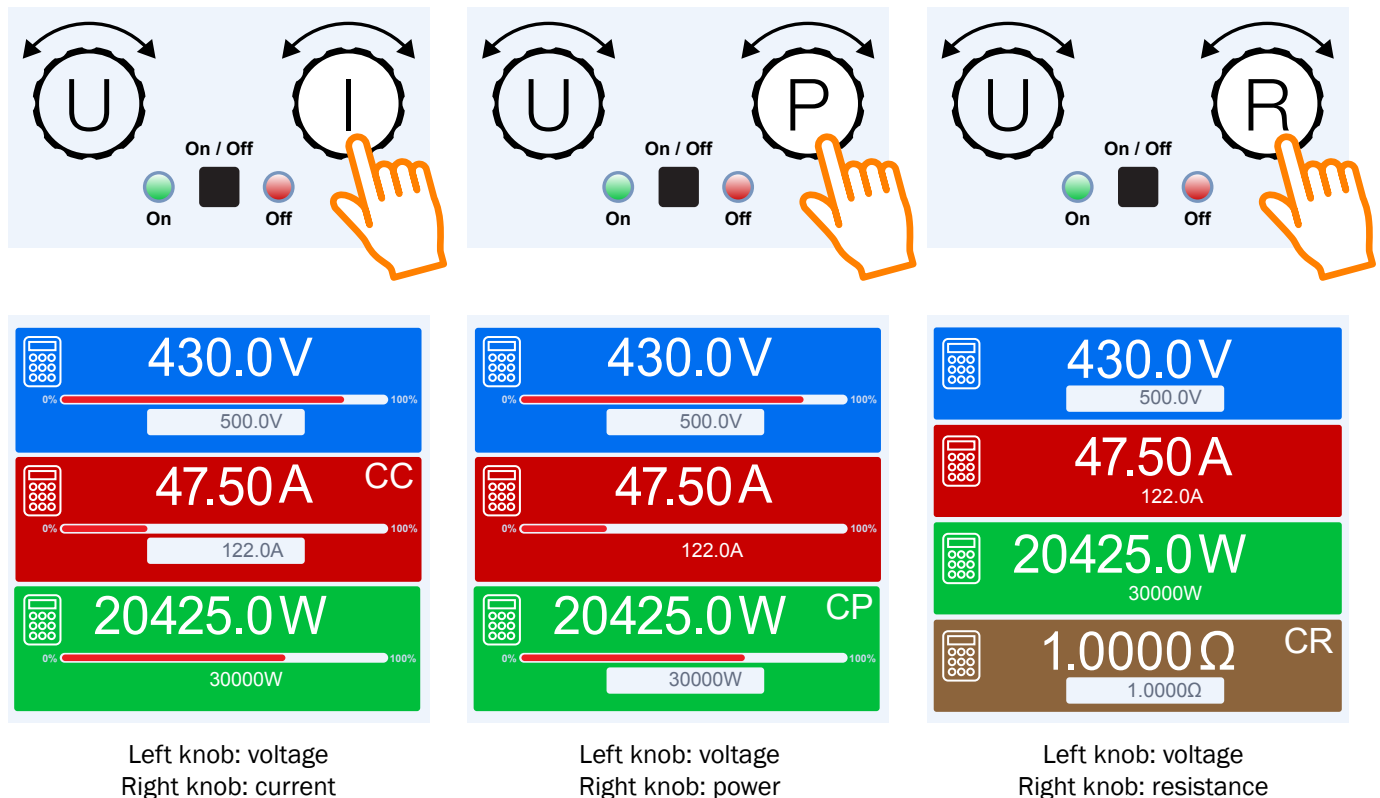
Physical knob rotation

As long as the unit is in manual operation, the two rotary knobs are used to adjust set values — turning right to increase the value, and turning left to decrease the value.

Physical knob push

The rotary knobs also have a pushbutton function. Push the knob to advance the cursor to the next digit in the value. Then rotate the knob to change the number in that position. The cursor in data entry fields is shown as an underline of the target character position.

47.50A → 47.50A → 47.50A

4.7.2 Adjusting Set Values by Keypad

Set values can always be adjusted directly using keypad data entry. This can be useful when the right knob is not assigned to the value you want to adjust. For example, when the right knob is assigned to current, and you want to adjust the power set value, tap the keypad icon in the power section. The keypad can also be useful for making large changes to a value that would otherwise require numerous revolutions of the rotary knob.

After tapping the keypad icon, a numerical keypad is displayed. Enter the value as desired. The units are displayed as a reminder.

The **[C]** key clears the value (like a calculator).

Upon pressing **Enter**, the keypad is closed, and the new set value takes affect immediately (even if the DC is switched on).

			54.3V
7	8	9	C
4	5	6	⌫
1	2	3	
	0	.	Enter
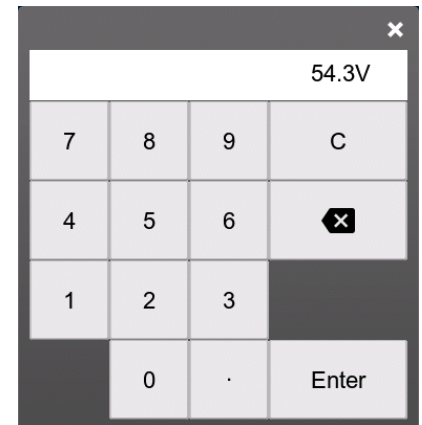
> **!** When entering a value which would exceed the upper/lower adjustment limit, it will be rejected and a short message will display.

4.8 Set Value Limits

In the previous section, set values were discussed. Vy default, the range of set values (U, I, P, R) are adjustable from 0 to 102% of the nominal ratings for the unit.

There may be times the power supply is connected to a device which cannot sustain the full capability of the power supply. It may be desired to ensure that a 600 V rated device does not get exposed the the full 750 V capability of the power supply by accident.

For purposes like this, it is possible to restrict the range of accepted set values using adjustment **Limits**.

Both voltage and current can be configured with minumum and maximum limits. Power and resistance have only maximum limits.

‹ Status	Settings	☰
Presets	U-min:	00.00V
Protection	U-max:	81.60V
Limits	I-min:	(PS) 0000.0A
	I-max:	(PS) 1020.0A
User events	P-max:	(PS) 30600W
General	R-max:	(PS) 754.81Ω
Analog interface		
DC terminal		
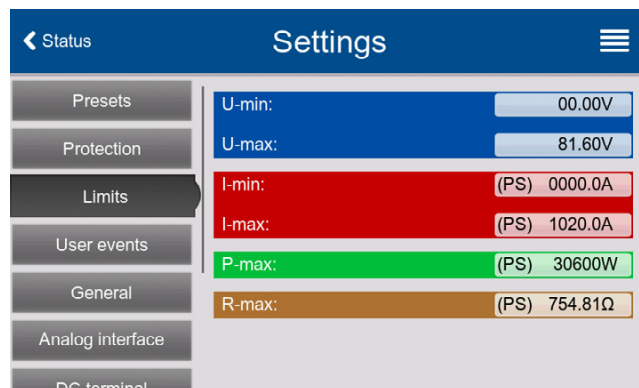
How to configure the adjustment limits

1. While the DC output is switched off, tap **Settings** on the main view.
2. Tap on menu item **Limits** on the left side to open the list of limits. They are grouped and colored as they are on the main display. Values are adjusted by first tapping on them, in a window popping up with a numeric pad. Values further down in the list are accessed by swiping the list up.
3. Adjust the desired value and submit with **Enter**.

> ❗ The adjustment limits are coupled to the set values in a way that an upper limit may not be set lower than the set value. Before setting the limits, the set values should be within the range of what the new limits will be. For example, if the set value for volts is currently 300 V, and it is desired to condigure a U-max limit of 200 V, the set value must first be adjusted to 200 V or less.

4.9 The Quick Menu

The system includes a quick menu which allows for quick access to commonly used features which otherwise require access into the Settings menu. It can be opened by swiping up from the bottom edge of the display or tapping the bar.

Tapping a button activates and then deactivates the function again. Buttons with black on white indicate an activated feature:

Symbol	Belongs to	Meaning
(USB logging icon)	USB logging	USB logging is running (the button is only available when USB logging has been activated in menu "Settings")
(M)	Master-slave	Master-slave activated, system is master
(S)	Master-slave	Master-slave activated, system is slave
(Off)	Master-slave	Master-slave deactivated
(Ω)	Resistance mode	R mode = on
(alarm icon)	Display	Alarm sound = on
(speaker icon)	Display	Key sound = on
(graph icon)	Display	Opens the graph view
(backlight slider)	Display	Adjust backlight intensity
(Menu)	Display	Opens the main menu

4.10 The Graph

The display can be used to show a graph of voltage, current, and power actual values plotted over time. This isn't an automatic data recording feature. For data recording in the background use the USB logging feature discussed in 5.4.1 Logging to USB Thumb Drive (p 42).

During normal operation, the graph can be viewed any time using the quick menu. An extra menu step is required when the function generator is running, but it is still available. Once opened, it fills the entire display.
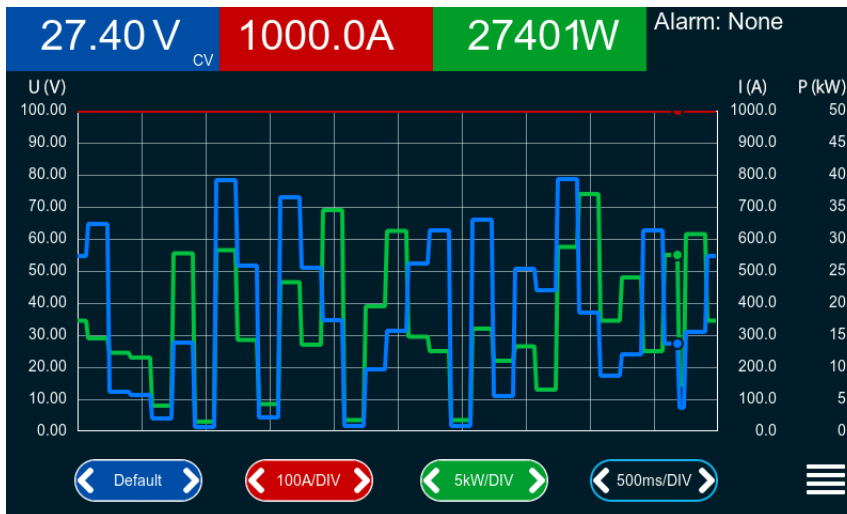
Controls:

- Tapping the **middle** of the three colored touch area deactivates/activate the corresponding plot.
- Tapping the **sides** (arrows left/right) of the three colored touch areas increases/decreases the vertical scaling.
- Tapping the **sides** (arrows left/right) of the black touch area increases/decreases the horizontal scaling.
- Swiping on the three scales moves them up or down.
- Tapping the menu icon (≣) exits the graph.

4.11 Alarm Conditions

> ❗ This section only gives an overview about system alarms. What to do in case your system indicates an alarm condition is described in 5.1 Alarms and Monitoring (p 35).

4.11.1 Alarm Signals

The power supply controls offer several options for signaling alarm conditions. They will be signaled on the display, can trigger an alarm tone (if the feature is configured as active), and will be a readable status on any digital interface. The digital interfaces also keep track of an alarm count. In addition, the alarms OT and OVP are reported as signals on the analog interface.

All alarms will cause the system to switch off the DC output.

Alarms signal labels and their meaning are shown in the table below.

Signal **OT** OverTemperature	• Non-critical • Overheating of the unit • DC output will be switched off
Signal **OVP / SOVP** OverVoltage	• Critical • Overvoltage shutdown of the DC output due to excess of the preset limit • The unit and/or the load could be damaged
Signal **OCP** OverCurrent	• Non-critical • Shutdown of the DC output due to excess of the preset limit • Protects the load from excessive current consumption
Signal **OPP** OverPower	• Non-critical • Shutdown of the DC output due to excess of the preset limit • Protects the load from excessive power consumption
Signal **PF** Power Fail	• Critical on overvoltage! • DC output shutdown due to AC undervoltage or defect in the AC input • AC input circuit could be damaged
Signal **MSP** Master-Slave Protection	• Non-critical • DC output shutdown due to communication problems on the master-slave bus
Signal **SF** Share Bus Fail	• Non-critical • DC output shutdown due to signal distortion on the Share bus
Signal **FOVP** Float OVP	• Critical when coming from an external source • Shutdown of the DC output due to an overvoltage between DC and GND

4.11.2 Power Fail

Power Fail (PF) indicates an alarm condition which may be caused by:

- AC input voltage too low (mains undervoltage, mains failure).
- Defect in the input circuit.

> ⓘ When powering the unit down, a PF alarm (power failure) will be reported. It is not possible to distinguish a shutoff from an unexpected loss of AC power, so the alarm is generated, but it can be ignored when the power shutoff is intentional.

4.11.3 Overtemperature

An overtemperature alarm (OT) occurs when there's excess temperature inside the unit. This is usually due to the ambient temperature exceeding the specified operating temperature range of the unit. After cooling down, the system can automatically switch the DC terminal back on, depending on the setting of **DC Terminal** > **State after OT alarm**. The alarm will remain in the display as a notification which can be cleared any time.

4.11.4 Overvoltage Protection

Causes for an overvoltage alarm (OVP) include:

- The power supply itself, as a voltage source, generates an output voltage higher than set for the user-adjustable overvoltage OVP threshold, or the connected load somehow returns voltage higher than this threshold.
- The OVP threshold has been adjusted too close above the output voltage. If the system is in CC mode, and if it then experiences a negative load step, the voltage may rise quickly, resulting in an voltage overshoot for a short moment which can already trigger the OVP.

This alarm (along with its threshold setting) can be used to warn the operator of an excessive voltage which could damage the connected load device.

> ⚠ • The unit does not have internal protection from external overvoltage sources.
> • The changeover from operation modes CC > CV can generate voltage overshoots.

4.11.5 Overcurrent Protection

An overcurrent alarm (OCP) will occur when the output current at the DC output reaches the user-adjustable OCP threshold.

This alarm (along with its threshold setting) can be used to warn the operator of an excessive current which could damage the connected load device.

4.11.6 Overpower Protection

An overpower alarm (OPP) will occur when the product of the output voltage and output current at the DC output reaches the user-adjustable OPP threshold.

This function serves to protect the connected load application so that this isn't overloaded and possibly damaged due to an excessive power consumption.

4.11.7 Share Bus Fail

A Share bus fail alarm (SF) will occur if:

- Too many units have been connected, which decreases the bus impedance and distorts the signal.
- A short-circuit on the Share bus has occurred, for example due to a damaged BNC cable.

This function serves to prevent sending irregular control signals to the expansion units via the Share bus or to cause them to react differently. This alarm has to be acknowledged after the cause has been removed.

4.12 SEMI F47

SEMI F47 is a semiconductor industry specification that demands a device to continue working without interruption in the event of a utility power failure in form of an AC undervoltage of up to 50% of the rated line voltage with a duration up to 1.7 seconds. From firmware KE 3.02 and HMI 3.02 this has been implemented for all 311 series devices, but cannot be obtained by installing an update.

As a byproduct of meeting these requirements, when F47 mode is enabled, the power supply will have a power derating which is detailed in the technical specifications for the model.

5 Manual operation

5.1 Alarms and Monitoring

5.1.1 System Alarms vs. User Events

There are two event types which can trigger automatic responses — system alarms and user events.

System alarms are generally fixed triggers designed to protect the power supply itself (such as overheating). Some have user-adjustable settings to reflect the unique needs of the load connected to the DC output. However, all are designed to inherently switch off the DC output when triggered.

User events (which are not required to be configured) are intended to raise awareness of specific power conditions (such as under voltage), but are not necessarily a critical product protection issue. These events have a little more configurability in what they trigger as a response.

5.1.2 System Alarms

A system alarm incident will lead to the DC output being switched off, the appearance of a pop-up window in the middle of the display and, if activated, an audible alarm to get operator attention. An alarm must always be acknowledged before additiopnal operation can be performed on the display.

How to acknowledge an alarm in the display

- If the alarm is indicated as a pop-up, tap **Acknowledge**.
- If the alarm has already been acknowledged, but is still displayed in the status area, then first tap the display Status Area to re-display the pop-up, and then **Acknowledge**.
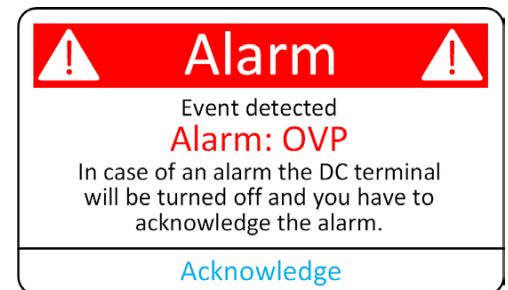
How to acknowledge an alarm remotely

- To acknowledge an alarm during analog remote control, see 9.4.3 Acknowledging alarms (p 90).
- To acknowledge an alarm with one of the digital interfaces, refer to 11.9.2 Register 411 (p 119) for Modbus, and 12.16 Alarm Management Commands (p 168) for SCPI.

There are three system alarms where the trigger point can be configured. As with all system alarms, the DC output is automatically switched off, and the display and remote interfaces respond the same as with all other system alarms. The difference is that the trigger point is adjustable by the operator to suit the device which is connected to the DC output.

Label	Name	Description	Range	Indication
OVP	OverVoltage Protection	Triggered when the DC output reaches the defined threshold for the measured value. The DC output will be switched off.	$0\ V – 1.1 * U_{Nom}$	Display Analog interface Digital Interfaces
OCP	OverCurrent Protection		$0\ A – 1.1 * I_{Nom}$	
OPP	OverPower Protection		$0\ W – 1.1 * P_{Nom}$	

These system alarms do not have adjustable trigger points. All are based on internally determined triggers. However, note that some do have some user adjustable behaviors.

Label	Name	Description	Indication
PF	Power Fail	AC supply over/undervoltage. Triggered if the AC supply is out of specification, or when the system is cut from supply. The DC output will be switched off — which may be only temporarily, depending on the AC behavior. and the setting **DC output after PF alarm**.	Display Analog interface Digital Interfaces
OT	OverTemperature	Triggered if the internal temperature reaches a certain limit. The DC output will be switched off — which may be only temporarily, depending on the temperature behavior, and the setting **DC output after OT alarm**.	
MSP	Master-Slave Protection	Triggered if the master unit loses contact to any slave unit. The DC output will be switched off. The alarm can be cleared by reinitializing the MS system.	
SF	Share Bus Fail	Triggered when too many units are connected on their Share bus connectors or, more likely, the cabling is dampening too much due to wrong or damaged (shorted) BNC cables.	

How to configure the thresholds of the adjustable system alarms

1. While the DC output is switched off, tap **Settings** on the main view.
2. In the menu, tap the menu item **Protection**. On the right side of the display is a list of all system alarms with their adjustable thresholds. These are continuously compared to the actual values of voltage, current, and power on the DC output.
3. Set the threshold for the protections relevant to your application if the default value of 110% is unsuitable.

The user also has the possibility of selecting whether an additional acoustic signal will be sounded if an alarm or user defined event occurs.

How to configure the alarm sound

1. Swipe with your finger up from the bottom edge of the display, or directly tap on the bottom bar:

2. The quick menu will open. Tap on ⊘ to activate the audio alarm, or on 📢 to deactivate it.

3. Close the quick menu by tapping ≡.

5.1.3 User Defined Events

A user defined event is threshold setpoint determined by the user to trigger an alert. These are separate from the system alarms (5.1.1 System Alarms vs. User Events (p 35)).

By default, events are not activated, and contrary to system alarms, when activated the events only work while the DC output is switched on.

The following table lists user events, all of which can be configured independently.

Event	Meaning	Description	Range
UVD	UnderVoltage Detection		$0–U_{Nom}$ Volts
OVD	OverVoltage Detection		$0–U_{Nom}$ Volts
UCD	UnderCurrent Detection	Triggers an event when the measured value falls below or exceeds (as appropriate) the defined threshold.	$0–I_{Nom}$ Amps
OCD	OverCurrent Detection		$0–I_{Nom}$ Amps
OPD	OverPower Detection		$0–P_{Nom}$ Watts

How to configure user defined events

1. While the DC output is switched off, tap **Settings** on the main view.
2. On the left side tap menu item **User events**.
3. Tap on the values to adjust them with the numeric keypad. Note that the adjustable range here is not restricted by the Limits settings.
4. Set the **Action** for the event with the drop-down selector. See the table below for what these Actions mean.

> 🛈 User events are a part of the user profile. Thus, if another user profile or the default profile is loaded, the user events configuration could be different.

Action Name	Action Response	Example
None	User defined event is disabled. There is no response.	
Signal	Adds a text message in the status area of the display.	Event: UVD
Warning	Adds a text message in the status area of the display, and a popup window for a more noticeable warning message.	⚠ **Warning** ⚠ Event detected Event: OCD In case of a warning the DC terminal will not change, but the warning has to be acknowledged. Acknowledge
Alarm	Adds a text message in the status area of the display, a popup window for a more noticeable warning message, and triggers the auible alarm if it is activated. The DC output is switched off.	⚠ **Alarm** ⚠ Event detected Event: OCD In case of an alarm the DC terminal will be turned off and you have to acknowledge the alarm. Acknowledge

5.2 User Profiles

Despite its name, a user profile is not about users, but rather about a collection of settings which are configurable by a user (operator), and can be loaded at any time as a convenient alternative to re-entering the settings. A profile includes set values, limits, monitoring thresholds, and various settings.

In **Menu** > **Profiles**, there are six selections labeled Default, then numerically 1–5. The default profile is not editable, and contains standard factory defaults. This profile can be loaded whenever an operator wants to start with a clean factory set of settings.

Whenever set values, settings, etc. are edited, they belong to a working profile. At any time, the operator can pull up the Profiles menu page, and save the current state of settings to a specific user profile (and then later load it).

The **Menu** > **Profiles** page will display the set values for the user profile, but they're not editable here.

How to save a user profile

1. While the DC output is switched off, tap the **Menu** icon on the main view.
2. In the main menu, tap the **Profiles** menu item.
3. In the next view (example to the right) tap one of the five profiles. (The set values are shown to help distinguish the profile's purpose.)
4. Tap on **Save/Load**, and at the prompt, **Save** the settings into the user profile.
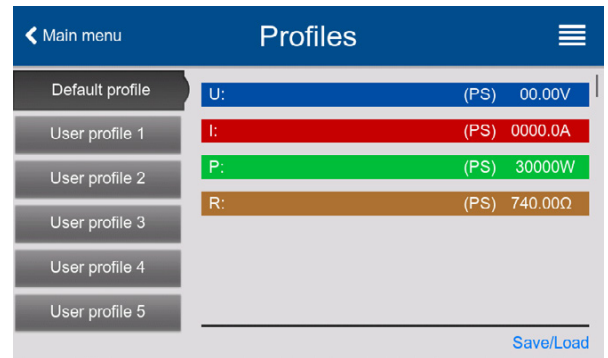
How to load a user profile

1. While the DC output is switched off, tap the **Menu** icon on the main view.
2. In the main menu, tap the **Profiles** menu item.
3. In the next view (example to the right) tap one of the five profiles. (The set values are shown to help distinguish the profile's purpose.)
4. Tap on **Save/Load**, and at the prompt, tap **Load**.

User Profile Import/Export

An individual profile can be imported or exported to a USB thumb drive using the **USB Import/Export** option.

5.3 Locking User Access

> ⚠️ Be careful using the PIN requirement for the lock feature. A forgotten PIN cannot be recovered or overidden. Changing a PIN requires knowing what the existing one is. Forgotten PINs can only be overridden by resetting the system to factory default.

5.3.1 Locking the Control Panel

To avoid accidental alteration of a value during manual operation, the rotary knobs and touchscreen can be locked so that no alteration of values will be accepted without prior unlocking.

How to lock the HMI

1. In the main page, tap the lock symbol 🔒 🔓 (upper right corner).
2. The Lock menu view will appear where you can select to lock the "HMI" (the touchscreen and knobs) with some options. First, you can choose to enable **On/Off possible during HMI lock** which allows the DC output switch to work while the other controls are locked. Secondly, you can choose to enable **PIN for user interface lock**. This forces the control system to request a PIN (short sequence of numbers) to unlock the HMI.
3. Once the settings are configured, activate the lock with **Start**. The display will show the main view as dimmed.

If an attempt is made to tap the display or rotate a knob while the HMI is locked, the operator is prompted to first confirm an unlock.

How to unlock the HMI

1. Tap the touchscreen, or rotate either knob. The DC On/Off button can be pressed also if it is included in the lock.
2. The operator will be prompted to confirm an unlock.
3. Tap **Unlock** within 5 seconds. If the lock is configured with a PIN code, another prompt will appear asking for the PIN before the unlock is allowed. The initial unlock prompt can be ignored. After 5 seconds it will close leaving the lock enabled.
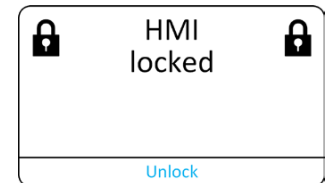
5.3.2 Locking Limits and Profiles

To avoid changes to the set value limits (4.8 Set Value Limits (p 29)) and to user profiles (5.2 User Profiles (p 38))
by an unprivileged user, the settings can be locked by a PIN code. This will lock the menu view Limits, and to protect the
limits settings from being overriden through User Profile data, thet Profiles menu views are locked as well.

How to lock the Limits and Profiles

1. In the main page, tap the lock symbol 🔒 🔓 (upper right corner).
2. Enable the setting **Lock limits and profiles with user PIN**.
3. Close the Settings menu.

How to unlock the Limits and Profiles

1. While the DC output is switched off, in the main view, tap the **Menu** icon.
2. Tap **HMI setup**, then tap **Lock**.
3. Tap **Unlock limits and profiles**. You will be prompted to enter the PIN.
4. Upon entering the correct PIN, the lock will be deactivated.

5.4 Front USB File System

The front USB port is intended for the connection of standard USB thumb drives (not a remote programming connection). A thumb drive can be used for loading or saving sequences for the arbitrary and the XY generator, as well as for recording measured data during a running operation.

USB 2.0 thumb drive are widely accepted. USB 3.0 thumb drives work, but not from all manufacturers. The thumb drive must be FAT32 formatted, and should have a maximum capacity of 32 GB. All supported files must be held in a designated folder in the root path of the USB drive in order to be found. This folder must be named **HMI_FILES**, such that a PC would recognize the path G:\HMI_FILES if the drive were to be assigned the letter G.

The control panel of the unit can read the following file types and names from a thumb drive:

File Name Format	File Purpose
wave_u*USERTXT*.csv wave_i*USERTXT*.csv	Function generator for an arbitrary function on voltage (U) or current (I) The name must begin with *wave_u / wave_i*, the rest is user defined.
profile_*USERTXT*.csv	Previously saved user profile. A max. of 10 files to select from is shown when loading a user profile.
iu*USERTXT*.csv ui*USERTXT*.csv	IU or UI table for the XY function generator. The name must begin with *iu* or *ui*, the rest can be user defined.
pv*USERTXT*.csv fc*USERTXT*.csv	PV or FC table for the XY function generator. The name must begin *with pv* or *fc*, the rest can be user defined.
pv_day_et_*USERTXT*.csv pv_day_ui_*USERTXT*.csv	Day trend data file to load for the simulation modes DAY I/T and DAY U/I of the extended PV function.

The control panel of the unit can save the following file types and names to a USB thumb drive:

File Name Format	File Purpose
usb_log_*NMBR*.csv	File with log data recorded during normal operation in all modes. The file layout is identical to the those generated from the Logging feature in the Power Control software. The *NMBR* field in the file name is automatically counted up if equally named files already exist in the folder.
profile_*NMBR*.csv	Saved user profile. The number in the file name is a counter and not related to the actual user profile number in the HMI. A max. of 10 files to select from is shown when loading a user profile.
pv*NMBR*.csv	PF function table data, as calculated by the unit. Can be loaded again.
fc*NMBR*.csv	FC function table data, as calculated by the unit. Can be loaded again.
wave_u*NMBR*.csv wave_i*NMBR*.csv	Set point data (here: sequences) from arbitrary function generator of either voltage U or current I
pv_record_*NMBR*.csv	Data from the data recording option in the extended PV function according to EN 50530.

5.4.1 Logging to USB Thumb Drive

5.4.1.1 Configuration

The system can log a series of time-stamped data records directly to a USB thumb drive, but must first be enabled in Settings. There are several adjustable parameters regarding the logging control, and the CSV file format, to consider which can all be found in the menu **Settings** > **USB Logging**.

5.4.1.2 Recording Start/Stop

With setting **Start/stop** set to **At DC on/off** logging will start each time the DC output of the system is switched on, whether it was switched on manually with the front button or remotely via analog or digital interfaces.

With the setting set to **Manual**, logging is started and stopped only when the user presses the record button in the quick menu.

Soon after logging starts, the symbol [icon] indicates active logging. If there is an error while logging, such as the USB thumb drive is full or removed, the symbol changes to [icon].

After every manual stop or switching the DC output off, the logging is stopped and the log file closed. Therefore, with every start, a new file is created — each is sequentially numbered as shown in the file name table in the section above.

5.4.1.3 Log file format

The log is a CSV text file. Formatting uses European or American details governed by the settings **USB logging with units (V,A,W)** and **USB decimal point format** in **MENU** > **Settings > USB Logging**.

- Column 1: **U set**, voltage decimal with optional trailing "V"
- Column 2: **U actual**, voltage decimal with optional trailing "V"
- Column 3: **I set**, current decimal with optional trailing "A"
- Column 4: **I actual**, current decimal with optional trailing "A"
- Column 5: **P set**, power integer with optional trailing "W"
- Column 6: **P actual**, power integer with optional trailing "W"
- Column 7: **R set**, resistance decimal (only if R is enabled)
- Column 8: **R actual**, resistance decimal (only if R is enabled)
- Column 9: **R mode**, ON or OFF
- Column 10: **Output**, ON or OFF
- Column 11: **Device mode**, CV, CC, CP, CR
- Column 12: **Error**, hardware error codes
- Column 13: **Time**, elapsed time since logging start

5.4.1.4 Special notes and limitations

- Max. log file size (due to FAT32 formatting): 4 GB.
- Max. number of log files in folder HMI_FILES: 1024.
- With setting **Start/stop with DC output ON/OFF**, the logging will also stop on alarms or events with action Alarm since they switch off the DC output.
- With setting **Manual start/stop** the system will continue to log even on occurring alarms, so this mode can be used to determine the period of temporary alarms like OT or PF.

5.5 Settings Menu Reference

The Settings menu is the entry point for the configuration of all operating options other than the set values. The menu is accessed directly with the **Settings** icon on the main view, or from inside the **Main Menu** — however only while the DC output is switched off. Access to Settings are disabled while the DC output is on.

On all settings views, direct entry values are edited with an on-screen keypad.
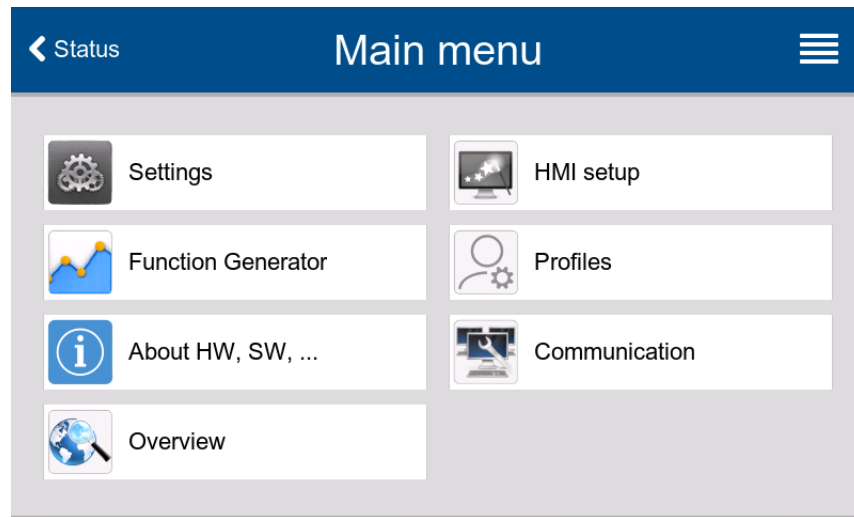
5.5.1 Menu "Settings"

5.5.1.1 Settings > Presets

Allows for the pre-setting of set values (U, I, P, R).

5.5.1.2 Settings > Protection

Adjust the setpoints for the OVP, OCP, OPP alarms. See 4.11 Alarm Conditions (p 32) and 5.1 Alarms and Monitoring (p 35).

5.5.1.3 Settings > Limits

Defines the set value adjustment limits. See 4.8 Set Value Limits (p 29).

5.5.1.4 Settings > User events

Adjust the setpoints and responses for the user events. See 5.1.3 User Defined Events (p 37).

5.5.1.5 Settings > General

Allow remote control — If remote control is allowed, the system can be controlled remotely over either the digital or analog interfaces. The Local or Remote state will be shown in the status area on the main view.

R mode — Activates or deactivates the internal resistance control. If activated, the resistance set value, and actual value will be shown the main view. For details refer to 4.1.4 Internal Resistance Regulation / Constant Resistance (p 21) and 4.7 Adjusting Set Values (p 27).

Voltage control speed — Selects the internal voltage controller speed which, as a result, impacts the voltage settling time. This is available only on system which sjipped from the factory with KE 3.02 (it is not available if upgraded in the field). See the discussion in 4.1.1.1 Transient time after load step (p 20).

- Slow = the voltage controller will be a little slower, the peaks will be lower, but wider.
- Normal = the voltage controller is on standard speed (Default).
- Fast = the voltage controller will be a little faster, the peaks will be higher but narrower.

SEMI F47 — Activates or deactivates a feature called SEMI F47 which is related to the standard. This is available only on system which sjipped from the factory with KE 3.02 (it is not available if upgraded in the field). See the discussion in 4.12 SEMI F47 (p 34).

5.5.1.6 Settings > Analog Interface

Range — Selects the voltage range for the analog set values, actual values, and reference voltage output. See 9.4 Remote Control with the Analog Interface (p 89).

- 0–5 V = Range is 0–100% for set /actual values, reference voltage will be 5 V.
- 0–10 V = Range is 0–100% for set /actual values, reference voltage will be 10 V.

REM-SB Level — Selects how the input REM-SB (pin 13) of the analog interface will operate regarding levels and logic. See 9.4.5 Analog Interface Specification (p 91).

- Normal = Levels and function as described in 9.4.5 Analog Interface Specification (p 91).
- Inverted = Levels and function will be inverted.

REM-SB Action — Selects how the input REM-SB (pin 13) of the analog interface will operate regarding the DC output state outside of analog remote control.

- DC Off = The pin can only switch the DC power stage off.
- DC On/Off = The pin can switch the DC power stage off and on again, if it has been switched on before from a different control location.

Pin 6 — Pin 6 (ALARMS1) of the analog interface is by default assigned to signal both system alarms OT and PF. This parameter alters pin 6 to enable signaling only one or both alarms.

- Alarm OT = Signals only when OT is triggered
- Alarm PF = Signals only when PF is triggered
- Alarm PF + OT = Default, signals when either PF or OT is triggered

Pin 14 — Pin 14 (ALARMS 2) of the analog interface is by default assigned to only signal the system alarm OVP. This parameter alters pin 14 to signal the system alarms OCP and OPP in 7 possible combinations.

- Alarm OVP = Signals only when OVP is triggered
- Alarm OCP = Signals only when OCP is triggered
- Alarm OPP = Signals only when OPP is triggered
- Alarm OVP + OCP = Signals when either OVP or OCP is triggered
- Alarm OVP + OPP = Signals when either OVP or OPP is triggered
- Alarm OCP + OPP = Signals when either OCP or OPP is triggered
- Alarm OVP + OCP + OPP = Signals when any of these are triggered

Pin 15 — Pin 15 (STATUS) of the analog interface is by default assigned to signal only the regulation mode CV. This parameter alters pin 15 to signal the DC output status instead.

- Regulation mode = Signals only CV mode.
- DC status = Signals only the DC output status.

5.5.1.7 Settings > DC terminal

State after power ON — Determines the state of the DC output after power-up.

- Off = Default, DC output is always off after switching the unit AC power on.
- Restore = DC output state will be restored to the last known state at the time that AC power was switched off.

> ⚠️ Using Restore must be done with great caution. This allows the DC output to be on after boot up which may not be expected, and which could result in dangerous situations to personnel.

State after PF alarm — Determines the state of the DC output after a power fail (PF) alarm.

- Off = Default, DC output remains off.
- Auto = DC output will switch on again after the PF alarm cause is gone, if it was switched on before the alarm occurred.

State after remote — Determines the state of the DC output after exiting remote control either manually or by command.

- Off = Default, DC output will always switch off after exiting remote control.
- Auto = DC output will stay in its existing state during a transition from remote to local control.

State after OT alarm — Determines the state of the DC output after an overtemperature (OT) alarm subsides when the system has cooled down.

- Off = DC output will remain off.
- Auto = Default, DC output state will be restored to the pre-existing state before the OT alarm.

5.5.1.8 Settings > Master/Slave

Mode — Selecting Master or Slave enables the master-slave mode, and defines the role of the unit in the M/S system.

Termination resistor — Activates or deactivates termination of the digital M/S bus via a switchable resistor.

Bias resistors — In addition to the termination resistor there are two bias resistors which can be activated to help stabilize the MS bus further. Tap on the information icon for a graphical depiction.

Backlight off after 60s — When activated, the display's backlight will switch off after 60 seconds of inactivity. This setting is primarily intended for slave units where the display isn't needed to be permanently on. This setting is identical to the setting in the "HMI setup" menu.

Initialize system — Tapping this menu item will repeat the initialization of the master-slave system. Use this when the detection of all slave units by the master is unsuccessful, or when a slave connection has failed.

5.5.1.9 Settings > USB Logging

Log file separator format — Defines the format of CSV files generated from logging files. This setting also affects all other file system features where a CSV file can be loaded or saved.

- US = Comma as column separator (US standard for CSV files)
- Default = Semicolon as column separator (German/European standard for CSV files)

Logging with units (V,A,W) — By default, CSV files generated by USB logging add units label to values (e.g. 80.2V, 30.5A). This can be deactivated to make it easier to use the data for graphing or other mathematical processing.

USB logging — Activates/deactivates logging to USB thumb drive. See 5.4 Front USB File System (p 41).

Logging interval — Defines the time between each record in the log file. Options iclude 500 ms, 1 s, 2 s, 5 s.

Start/stop — Defines how USB logging is started and stopped. Note that every start event will create a new log file regardless of whether the start is triggered manually or automatically upon the DC on state.

- Manual = Logging starts and stops only upon manual tapping of the recording icon in the quick menu.
- At DC on/off = Logging starts and stops with every change of state on the DC output, no matter if caused by the user, software, or a system alarm.

5.5.1.10 Settings > Reset/Restart

Reset system to defaults — This touch area will initiate a reset of all settings and user profiles to factory default.

Restart — Triggers a reboot of the software.

5.5.2 Menu "Profiles"

Load and Save user profiles of settings and adjustments. See 5.2 User Profiles (p 38).

5.5.3 Menu "Overview"

This menu page displays an overview of the set values (U, I, P or U, I, P, R), system alarm thresholds, event settings, adjustment limits, as well as an alarm history which lists the number of system alarms that occurred since the system has been powered.

5.5.4 Menu "About HW, SW, ..."

This menu page displays an overview of system relevant data such as serial number, model number etc.

5.5.5 Menu "Function Generator"

You may import a function table or export it to a USB thumb drive with USB Import/Export. See 5.4 Front USB File System (p 41).

5.5.6 Menu "Communication"

This sub menu includes settings for all digital communication interfaces including the built-in Ethernet port and the optional Anybus modules. The USB port doesn't require any settings.

5.5.6.1 Communication > Ethernet (internal)

DHCP — Allows a DHCP server to allocate an IP address, a subnet mask and a gateway. If no DHCP server is in the network then network parameters will be set as defined by the manual entries below.

IP address — Manually define the unit's IP address for when DHCP is not active.

Subnet mask — Manually define the unit's mask for when DHCP is not active.

Gateway — Manually define the unit's gateway address for when DHCP is not active (if required).

DNS address — Define the unit's DNS server address (if required).

Port — Define the unit's Modbus and SCPI port. Default is 5025.

Host name — Enter a user meaningful name for the unit.

Domain — Enter a domain name for the unit.

5.5.6.2 Communication > CANOpen

Baud Rate — Selecting

Mode — CAN bus baud rate selection that is used by the CANopen interface.
- Auto = Automatic detection.
- LSS = Baud rate and node address are assigned by the bus master.
- Fixed baud rates: 10 kbps, 20 kbps, 50 kbps, 100 kbps, 125 kbps, 250 kbps, 500 kbps, 800 kbps, 1Mbps.

Node Address — Selection of the CANopen node address in the range 1–127.

5.5.6.3 Communication > Profibus

Node Address — Selection of the Profibus node address in the range 1–125.

Function Tag — User-definable text which describes the Profibus slave function tag. 32 characters maximum.

Location Tag — User-definable text which describes the Profibus slave location tag. 22 characters maximum.

Installation Date — User-definable text which describes the Profibus slave installation date tag. 40 characters maximum.

Description — User-definable text which describes the Profibus slave. 54 characters maximum.

Manufacturer ID — Registered manufacturer ID with the Profibus organization.

Ident number — Product identification number, same as in the GSD file.

5.5.6.4 Communication > Slot Ethernet, Modbus-TCP (1 & 2 Port)

DHCP — Allows a DHCP server to allocate an IP address, a subnet mask and a gateway. If no DHCP server is in the network then network parameters will be set as defined by the manual entries below.

IP address — Manually define the unit's IP address for when DHCP is not active.

Subnet mask — Manually define the unit's mask for when DHCP is not active.

Gateway — Manually define the unit's gateway address for when DHCP is not active (if required).

DNS address — Define the unit's DNS server addresses (if required).

Port — Define the IP port. Default is 5025 for Modbus RTU. Port 502 is rserved for Modbus TCP.

Host name — Enter a user meaningful name for the unit.

Domain — Enter a domain name for the unit.

Speed / Duplex Port 1 — Selection of transmission speed (10MBit/100MBit) and duplex mode (full/half). It's recommended to use the "Auto" option and only revert to another option if Auto fails.

Speed / Duplex Port 2 — Selection of transmission speed (10MBit/100MBit) and duplex mode (full/half). It's recommended to use the "Auto" option and only revert to another option if Auto fails.

5.5.6.5 Communication > Profinet/IO (1 & 2 Port)

Host name — Choice of host name.

Domain name — Choice of domain.

Function Tag — User-definable text which describes the Profibus slave function tag. 32 characters maximum.

Location Tag — User-definable text which describes the Profibus slave location tag. 22 characters maximum.

Installation Date — User-definable text which describes the Profibus slave installation date tag. 40 characters maximum.

Description — User-definable text which describes the Profibus slave. 54 characters maximum.

Station Name — User-definable text which describes the Profinet station name. 200 characters maximum.

5.5.6.6 Communication > CAN

Baud rate — Select the CAN bus speed. Default: 500 kbps.

ID Format — Selection of the CAN ID format and range between Standard (11 Bit) and Extended (29 Bit).

Termination — Activates or deactivates CAN bus termination with a built-in resistor. Default is off.

Data length — Determines the DLC (data length) of all messages sent from the system.

- Auto = length can vary between 3 and 8 bytes.
- Always 8 Bytes = length is always 8, filled up with zeros.

Base ID — Setup of the CAN base ID (11 Bit or 29 Bit, hex format). Default is 0h.

Broadcast ID — Setup of the CAN broadcast ID (11 Bit or 29 Bit, hex format). Default is 7ffh.

Base ID Cyclic Read — Setup of the CAN base ID (11 Bit or 29 Bit, hex format) for cyclic read of several object groups. The system will automatically send object data to the IDs defined with this setting. See the programming section for more details. Default is 100h.

Base ID Cyclic Send — Setup of the CAN base ID (11 Bit or 29 Bit, hex format) for cyclic send of set values along with status. See the programming section for more details. Default is 200h.

Cyclic Read Time Status — Activation/deactivation and time setting for the cyclic read of status from the "Base ID Cyclic Read" setting. Range is 20–5000 ms. Default is 0 ms (deactivated).

Cyclic Read Time Set — Activation/deactivation and time setting for the cyclic read of set values of U & I from the "Base ID Cyclic Read + 2" setting. Range is 20–5000 ms. Default is 0 ms (deactivated).

Cyclic Read Time Limits 1 — Activation/deactivation and time setting for the cyclic read of adjustment limits of U & I from the "Base ID Cyclic Read + 3" setting. Range is 20–5000 ms. Default is 0 ms (deactivated).

Cyclic Read Time Limits 2 — Activation/deactivation and time setting for the cyclic read of adjustment limits of P & R to the "Base ID Cyclic Read + 4" setting. Range is 20–5000 ms. Default is 0 ms (deactivated).

Cyclic Read Time Actual — Activation/deactivation and time setting for the cyclic read of actual values from the "Base ID Cyclic Read + 1" setting. Range is 20–5000 ms. Default is 0 ms (deactivated).

Module firmware — CAN module firmware version.

5.5.6.7 Communication > RS232

Baud rate — The baud rate is selectable from the options 2400, 4800, 9600, 19200, 38400, 57600, 115200. Other serial settings are fixed as data bits = 8, stop bit = 1, parity = none.

5.5.6.8 Communication > Timeouts

TCP keep-alive — Activates keep-alive network functionality for the Ethernet port, which is used to keep the socket connection open. As long as keep-alive is valid in the network, the system will disable the Ethernet timeout. See "Timeout ETH" below as well.

Timeout USB/RS232 — Defines the maximum time between two subsequent bytes or blocks of a transferred message. For more information about the timeout refer to the programming section. Range: 5–65535 ms. Default is 5 ms.

Timeout ETH — Defines a timeout after which the system will close the socket connection if there was no command communication between the system and controlling unit (PC, PLC etc.). The timeout is ineffective as long as option "TCP keep-alive" is enabled and the keep-alive network service is running. Range is 5–65535 s. Default value is 5 s.

5.5.6.9 Communication > Protocols

Communication protocols — Enable or disable SCPI or Modbus communication protocols for the system. The change is immediately effective. Only one or the other can be disabled, not both.

Modbus specification compliance — Toggles the control system's compliance mode for Modbus message formats. See the discussion in 11.1 Firmware Changes (p 104).

- Limited — The default mode which keeps legacy behavior and compatibility.
- Full — Changes Modbus addressing and read coils behavior for better standards compliance.

5.5.7 Menu "HMI setup"

Language — Selection of the display language between German, English (default), Russian or Chinese.

Sound — Activate or deactivate sounds.

- Key sound — Activates or deactivates sounds when touching controls in the display.
- Alarm sound — Activates or deactivates the audio alert sound of an alarm, or user defined event which has been configured as an Alarm.

Clock — Internal clock and date setup.

Backlight — Configure the backight options.

- Backlight off after 60s — Set whether the backlight remains permanently on (default), or whether it will after there is no controls activity for 60 seconds. As soon as there is input, the backlight lights automatically.
- Intensity — Adjust the backlight brightness.

Lock — Sets whether the controls are locked, and whether a PIN is required to unlock. See 5.3 Locking User Access (p 39).

6 The Function Generator

6.1 Introduction

The built-in function generator is able to create various signal forms and apply these to the set value of voltage or current.

The standard functions are based on an arbitrary generator, and are directly accessible and configurable using the touchscreen during manual operator control. During remote control, a single, customizable arbitrary generator is used to replicate the standard functions with sequences containing 8 parameters each.

Other functions, such as IU, PV, or FC are based on an XY generator that works with a table of 4096 values which are either loaded from a USB thumb drive, or calculated based upon adjustable parameters.

The following functions are retrievable, configurable, and controllable:

Function	Description
Sine	Sine wave generation with adjustable amplitude, offset, and frequency.
Triangle	Triangular wave signal generation with adjustable amplitude, offset, rise, and fall times.
Rectangular	Rectangular wave signal generation with adjustable amplitude, offset, and duty cycle.
Trapezoid	Trapezoidal wave signal generation with adjustable amplitude, offset, rise time, pulse time, fall time, idle time
DIN 40839	Simulated automobile engine start curve according to DIN 40839 / EN ISO 7637, split into 5 curve sequences, each with a start voltage, final voltage, and time.
Arbitrary	Generation of a process with up to 100 freely configurable curve points, each with a start and end value (AC/DC), start and end frequency, phase angle, and total duration.
Ramp	Generation of a linear rise or fall ramp with start and end values, and time before and after the ramp.
IU	XY generator, USB thumb drive loadable current curve (value table, CSV).
PV, FC	Functions to simulate a solar panel (PV function) or fuel cells (FC function), both with table calculation based upon adjustable parameters, also for EN 50530.

6.1.1 Modes and Limits

In manual mode, the power supply is always working with the three set values U, I and P. This is true for the function generator mode as well.

A function can be applied to voltage or current. The two remaining values (U/P or I/P) are then treated as constants, and have a limiting effect just as with CV, CC, CP modes. That means if, for example, if a voltage of 30 V is set for the DC output, and a sine wave function operating on the current with an amplitude of 300 A and offset 400 A, then the function generator is expected to create a sine wave of current between 100 A and 700 A. This will result in an output power between 3,000 W and 21,000 W. The output power, however, is limited to its set value just as with manual operation. If the set value were 18,000 W then, the current would be limited to 600 A. An oscilloscope would show the sine wave to be truncated at the positive peak to 600 A, and never reach the peak of 700 A.

Parallel setups have further characteristics which have to be considered. For example, at the end of the configuration of every standard function you are requested to set up global set values labeled as the U/I/P Limits. These limits are transferred to all units of the parallel setup. Carefully configure these so the setup can work as expected, and one of the parallel units won't impact the function run in a negative way (particularly if units are not identical).

6.1.2 Limitations

The function generator is not accessible, neither for manual access nor for remote control, if resistance mode (R mode, also called UIR) is active.

The power supply unit can't be considered a high power function generator, because its power stages are post-connected to the function generator. Thus the typical characteristics of a voltage and current source remain. Rise and fall times, caused by capacitor charge/discharge, affect the resulting signal on the DC output. While the function generator is able to generate a sine wave with 1000 Hz or more, the power stages will never be able to follow the generated signal perfectly.

The wave on the DC output depends significantly on the frequency/period of the selected wave, its amplitude and also the output capacitance. The effects of the power stages on the wave can only be partially compensated. For example, the resulting wave form on the DC output could be improved by attaching and additional load (fixed and ohmic, or variable and electronic) to the application load. This can significantly improve down-ramping.

6.1.3 Resolution

Amplitudes generated by the arbitrary generator have an effective resolution of approx. 52,428 steps. If a programmed sequence amplitude is very low, and the time long, the system will generate fewer steps and set multiple identical values in a row, generating a more pronounced staircase effect. Additionally, keep in mind that it's not possible to generate every possible combination of time and amplitude ramping (slope).

6.1.4 Minimum Slope / Maximum Ramp Time

For systems shipped starting early 2022

As of early 2022, units shipped with firmware versions KE 3.02 and DR 1.0.2.20 have a change regarding the legacy slope and ramp time limits. The section below discusses those limits for older firmware, which no longer apply to the newer units. Newer systems can have the time of a sequence point as long as 36,000 seconds.

For systems prior to KE 3.02 / DR 1.0.2.20

When using a rising or falling offset (i.e. DC part) in functions like ramp, trapezoid, triangle, and even sine wave, a minimum slope, calculated from the rated values of voltage or current, is required or else the adjusted settings would be neglected by the system. Calculating the minimum slope can help to determine if a certain ramp over time can be achieved by the system or not.

For example, assume an 80 V / 1000 A rated model is going to be used.

> Using the formula: minimum slope = 0.000725 * rated value / s.

For our example model, this results in $\Delta U/\Delta t$ of 58 mV/s and $\Delta I/\Delta t$ of 725 mA/s.

The maximum time which can be achieved with the minimum slope always calculates as approximately 1,379 seconds according to formula t_{Max} = rated value / minimum slope.

6.2 Manual Operation

6.2.1 Function Selection

The function generator can be fully configured and controlled from the touchscreen. Keep in mind, the function generator menu system is available only when the DC output is switched off, and resistence mode is disabled.

How to select a function and adjust parameters

1. While the DC output is switched off, tap **Func Gen** on the main view.

2. In the menu, select the desired function by tapping the menu item on the left.

3. Depending on the function, the first configuration is to set whether the function will apply to Voltage or Current.

4. Each function has a diagram to illustrate the parameter variables. Tap on the variable fields to adjust the parameters using the on-screen keypad or selection lists. Press **Next** to continue.

5. Adjust the limits of voltage, current, and power, generally for overall load-protection. Press **Next** to continue.

6. Configure default set values. These values will be the default set values while the function is not running, but the DC output is still active. Some fundtion start immediately, and some do not. So, for some functions, this means that these set values will be applied to the DC output before the function starts running as well as after it stops running.
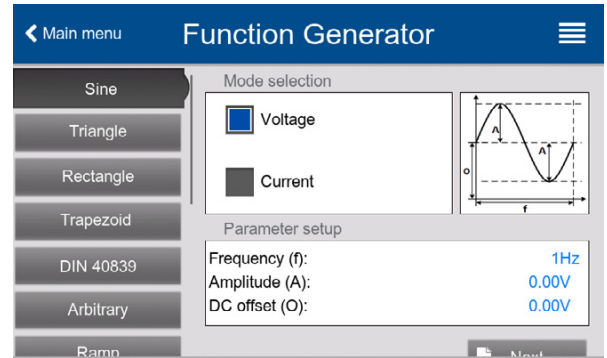
> ⚠ The global set values of U, I and P become instantly active when returning to the control view of the function generator, because the DC output is switched on automatically to settle the start state. Therefore, correct setup (according to the run needs) here is important, especially when running the function on a parallel setup.

7. Pressing **Next** exits the configuration, and enters the function generator control view.

6.2.2 Function Start/Stop

After the function generator view has been reached, the function is ready to run. Before and while the function is running, some global and also some function related values can be adjusted anytime.

How to start and stop a function

1. The function can be started either by tapping **Start** or if the DC output is currently switched off, by pushing the DC **On/Off** controls button.

2. The function can be stopped by tapping **Stop** or pushing the **On/Off** button. However, there is a difference:

    a) The on-screen **Stop** button only stops the function — that is, the wave form manipulation — *but the DC output remains ON* with the global set values in effect.

    b) The **On/Off** button stops the function, and switches the DC output off.
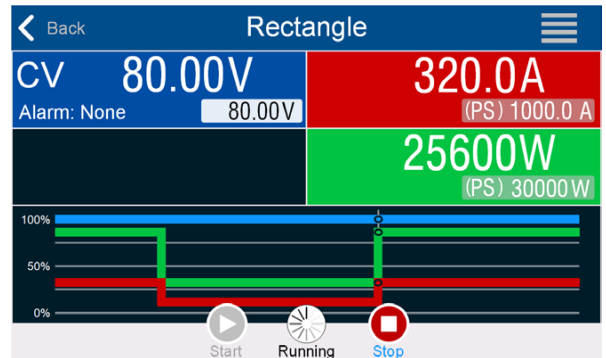
> **!** Any system alarm (power fail, overtemperature etc.), protection (OPP, OCP) or event with Action = Alarm stops the function progress automatically, switches off the DC output, and reports the alarm.

6.3 Sine Wave Function

The following parameters can be configured for a sine wave function:

Parameter	Range	Description
Frequency (f)	1–10,000 Hz	Static frequency of the signal to be generated
Amplitude (A)	0–(Nominal value - O) of U, I	Amplitude of the signal to be generated
Offset (O)	A–(Nominal value - A) of U, I	Offset, based on the zero point of the mathematical sine curve, may not be smaller than the amplitude.

Schematic diagram:
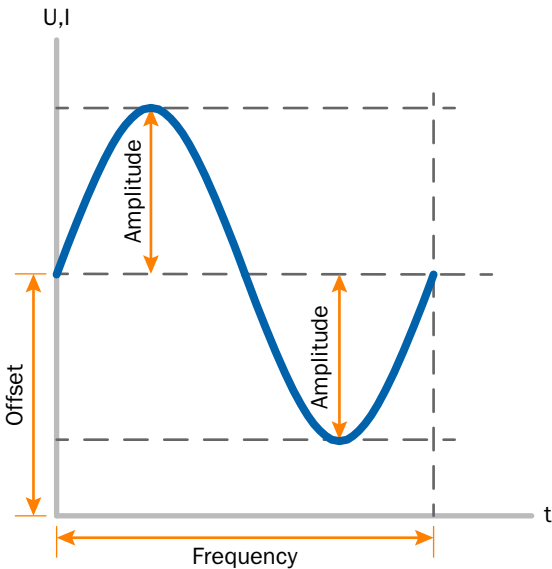
Application and result:

A normal sine wave signal is generated, and applied to the selected set value (volts or amps). At a constant load resistance, the output voltage, and thus also the output current will follow a sine wave.

For calculating the maximum power output, the amplitude and offset values for the current have to be added.

Example: An output voltage of 100 V is set together with sine current with an amplitude of 30 A, and an offset of 50 A. The resulting maximum power output is then achieved at the highest point of the sine wave which is (30 A + 50 A) * 100 V = 8,000 W.

This means, the global power limit would have to be set to at least 8,000 W in order to achieve a function run as expected.

6.4 Triangular Function

The following parameters can be configured for a triangular wave function:

Parameter	Range	Description
Amplitude (A)	0–(Nominal value - O) of U, I	Amplitude of the signal to be generated
Offset (O)	0–(Nominal value - A) of U, I	Offset, based on the foot of the triangular wave
Time t1	0.1 ms–36,000,000 ms	Rising edge time Δt of the triangular wave signal
Time t2	0.1 ms–36,000,000 ms	Falling edge time Δt of the triangular wave signal

Schematic diagram:
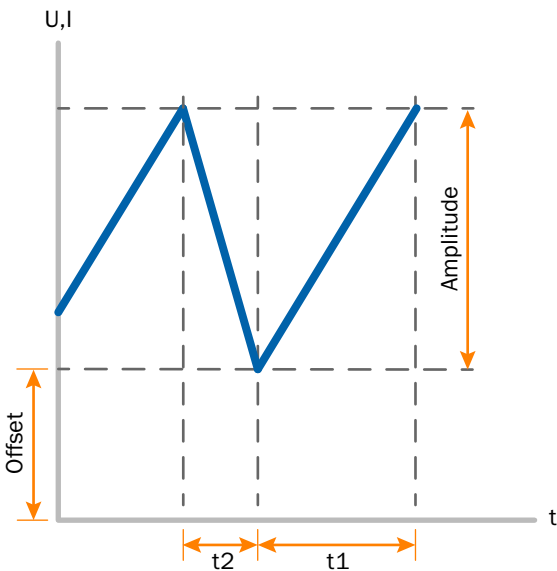
Application and result:

A triangular wave signal for output current (only effective in current limiting) or output voltage is generated. The positive and negative slope times can be set independently.

The offset shifts the signal on the Y-axis.

The sum of the intervals t1 and t2 gives the cycle time, and its reciprocal—frequency.

Example: A frequency of 10 Hz is required which would lead to periodic duration of 100 ms. This 100 ms can be freely allocated to t1 and t2, e.g. 50 ms:50 ms (isosceles triangle) or 99.9 ms:0.1 ms (right-angled triangle or sawtooth).

6.5 Rectangular Function

The following parameters can be configured for a rectangular wave function:

Parameter	Range	Description
Amplitude (A)	0–(Nominal value - O) of U, I	A = Amplitude of the signal to be generated
Offset (O)	0–(Nominal value - A) of U, I	Offs = Offset, based on the foot of the rectangular wave
Time t1	0.1 ms–36,000,000 ms	Time (pulse width) of the upper level (amplitude)
Time t2	0.1 ms–36,000,000 ms	Time (pause width) of the lower level (offset)

Schematic diagram:
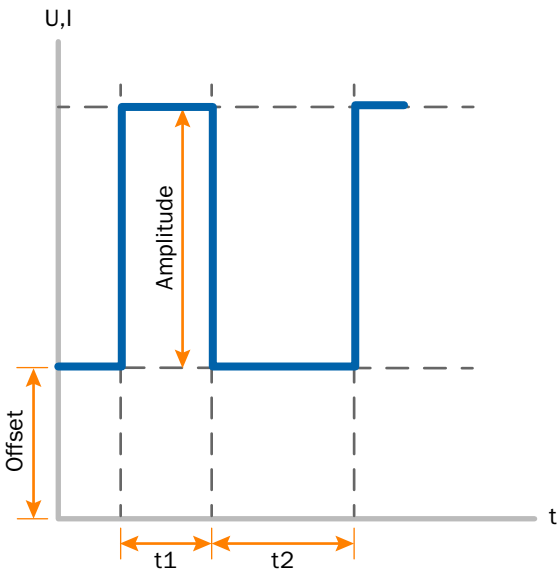
Application and result:

A rectangular or square wave signal for input current (direct) or input voltage (indirect) is generated. The intervals t1 and t2 define how long the value of the amplitude (pulse) and how long the value of the offset (pause) are effective.

The offset shifts the signal on the Y axis.

Intervals t1 and t2 can be used to define a duty cycle. The sum of t1 and t2 gives the period, and its reciprocal—frequency.

Example: A rectangular wave signal of 25 Hz and a duty cycle of 80% are required. The sum of t1 and t2, the period, is 1/25 Hz = 40 ms. For a duty cycle of 80% the pulse time (t1) is 40 ms*0.8 = 32 ms and the pause time (t2) is 8 ms.

6.6 Trapezoidal Function

The following parameters can be configured for a trapezoidal curve function:

Parameter	Range	Description
Amplitude (A)	0–(Nominal value - O) of U, I	Amplitude of the signal to be generated
Offset (O)	0–(Nominal value - A) of U, I	Offset, based on the foot of the trapezium
Time t1	0.1 ms–36,000,000 ms	Time for the positive slope of the trapezoidal wave signal.
Time t2	0.1 ms–36,000,000 ms	Time for the top value of the trapezoidal wave signal.
Time t3	0.1 ms–36,000,000 ms	Time for the negative slope of the trapezoidal wave signal.
Time t4	0.1 ms–36,000,000 ms	Time for the base value (offset) of the trapezoidal wave signal

Schematic diagram:
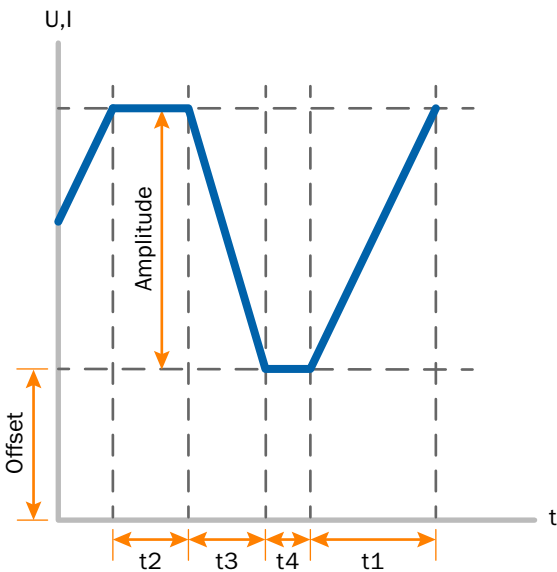
Application and result:

Here a trapezoidal signal can be applied to a set value of U or I. The slopes of the trapezium can be varied by setting different times for rise and fall.

The periodic duration and repetition frequency are the result of four time elements. With suitable settings, the trapezium can be deformed to two triangular or two rectangular pulses. Therefore, it has uses other than trapezoidal shapes.

6.7 DIN 40839 Function

This function is based on the curve defined in DIN 40839 / EN ISO 7637 (test impulse 4), and is only applicable to voltage. It replicates the progress of automobile battery voltage during engine starting. The curve is divided into 5 sequence points (see diagram below) which each have the same parameters. The standard values from the DIN are set already as default values for the five points.

The following parameters can be configured for the DIN40839 function:

Parameter	Range	Seq	Description
Start	0–Nominal value of U	1-5	Start voltage of the ramp in part 1-5 (sequence point)
Uend	0–Nominal value of U	1-5	End voltage of the ramp in part 1-5 (sequence point)
Time	0.1 ms–36,000,000 ms	1-5	Time of the ramp
Cycles	0–999	-	Number of repetitions of the entire curve (0 = ∞)
Time t1	0.1 ms–36,000,000 ms	-	Time after cycle before repetition (cycle <> 1)
U(Start/End)	0–U_{Nom}	-	Voltage setting before and after the function run
I/P	0–I_{Nom}/P_{Nom}	-	Global set values of current and power

Schematic diagram:
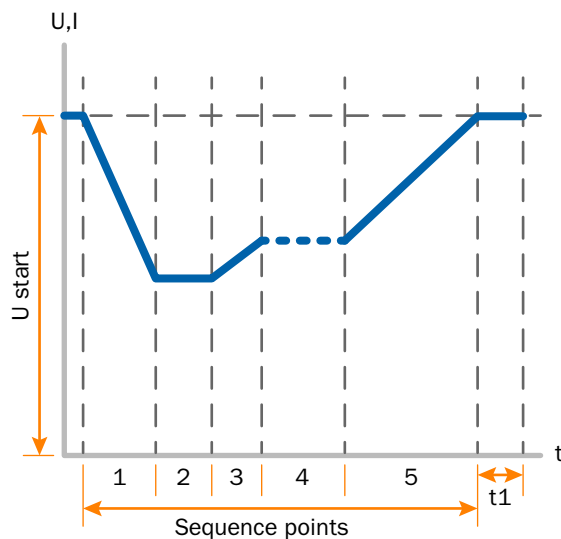
Application and result:

The function isn't suitable for standalone operation of a power supply, but optimal for a power supply operation in conjunction with an electronic load. The load acts as a sink for the rapid fall of the output voltage of the power supply enabling the output voltage progress to follow the DIN curve.

The curve conforms to test impulse 4 of the DIN. With suitable settings, other test impulses can be simulated. If the curve in sequence point 4 should be a sine wave, then these 5 points would have to be transfered to the arbitrary generator.

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6.8 Arbitrary Function

The arbitrary (freely definable) function offers the user a wider scope of options. There are 99 segments (or sequence points) available for use on either voltage or current, all of which have the same set of parameters, but can be uniquely configured, so that a complex function curve can be constructed. An arbitrary number out of the 99 sequence points can run in a sequence block, and this block can then be repeated up to 999 times, or set to run infinitely. Since the function must be assigned to either current or voltage, mix assignments of sequence point to both is not possible.

The arbitrary curve can overlay a linear progression (DC) with a sine curve (AC) whose amplitude and frequency is shaped between start and end. When both start frequency and end frequency are 0 Hz, the AC overlay has no impact, and only the DC part is effective. Each sequence point is allocated a sequence point time in which the AC/DC curve from start to end will be generated.

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

Parameter	Range	Description
AC start AC end	0–50% Nominal value of U or I	Start/end amplitude of the sinusoidal AC part
DC start	AC start–((Nominal of U or I) - (AC start))	Start amplitude of the DC part
DC end	AC end–((Nominal of U or I) - (AC end))	End amplitude of the DC part
Frequency (f) start Frequency end	0 Hz–10000 Hz	Start/end frequency of the sinusoidal AC part
Angle	0°–359°	Start angle of the sinusoidal AC part
Time	0.1 ms–36,000,000 ms	Time for the selected sequence

> The sequence point time and the start and end frequency are related. The minimum value for Δf/s is 9.3. Thus, for example, a setting of start frequency = 1 Hz, end frequency = 11 Hz and time = 5 s would not be accepted as Δf/s is only 2. A time of 1 s would be accepted or, if the time remains at 5 s, then an end frequency = 51 Hz must be set.

> The amplitude change between start and end is related to the sequence time. A minimal change over an extended time isn't possible and in such a case the system will report an inapplicable setting.

After the settings for the selected sequence point are accepted with **SAVE**, further points can be configured. If the button **NEXT** is touched a second settings view appears in which global settings for all 99 sequence points are displayed.

The following parameters can be set for the total run of an arbitrary function:

Parameter	Range	Description
Cycles	0 / 1–999	Number of cycles to run the sequence point block
Start sequence	1–End sequence	First sequence point in the block
End sequence	Start sequence–99	Last sequence point in the block

Schematic diagram:
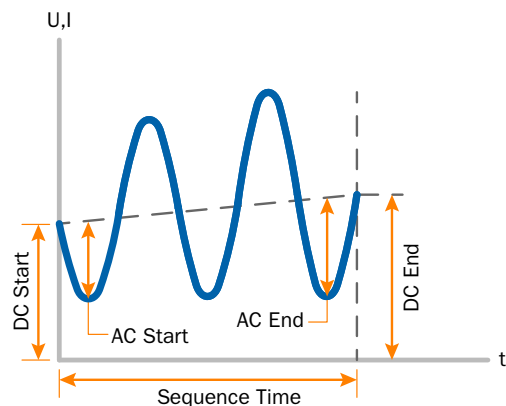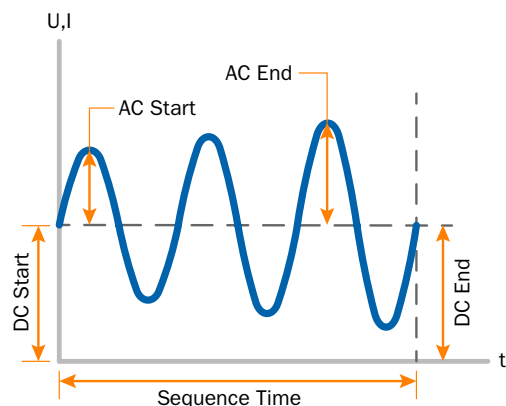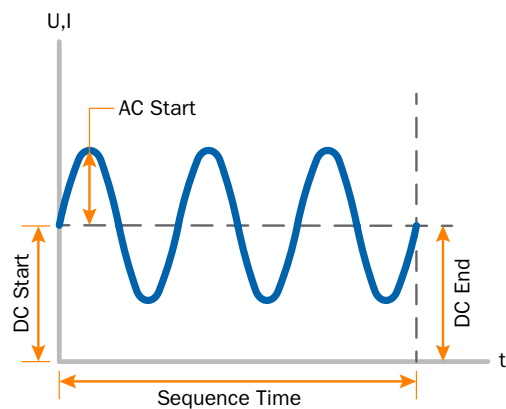
Applications and results:

Example 1

Focusing on 1 cycle of 1 sequence point:

DC values for start and end are the same, also the AC amplitude. With a frequency >0 a sine wave progression of the set value is generated with a defined amplitude, frequency and offset (DC value at start and end).

The number of sine waves per cycle depend on the sequence point time and the frequency. If the time were 1 s and the frequency 1 Hz, there would be exactly 1 sine wave. If the time were 0.5 s at the same frequency, there would only be a half sine wave.

Example 2

Focusing on 1 cycle of 1 sequence point:

The DC values at start and end are the same but the AC (amplitude) not. The end value is higher than the start so that the amplitude increases with each new half sine wave continuously through the sequence. This, of course, only if the sequence time and frequency allow for multiple waves to be created. e.g. for f=1 Hz and Seq. time = 3 s, three complete waves would be generated (for angle = 0°) and reciprocally the same for f=3 s and Seq. time=1 s.

Example 3

Focusing on 1 cycle of 1 sequence point:

The DC values at start and end are unequal, as are also the AC values. In both cases the end value is higher than the start so that the offset increases from start to end (DC) and the amplitude also with each new half sine wave.

Additionally the first sine wave starts with a negative half wave because the angle is set at 180°. The start angle can be shifted at will in 1° steps between 0° and 359°.

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Schematic diagram:
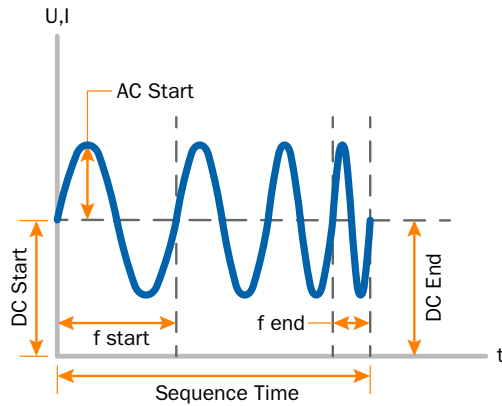
Applications and results:

Example 4

Focusing on 1 cycle of 1 sequence point:

Similar to example 1 but with another end frequency. Here this is shown as higher than the start frequency. This impacts the period of the sine waves such that each new wave will be shorter over the total span of the sequence time.

Example 5

Focusing on 1 cycle of 1 sequence point:

Similar to example 1 but with a start and end frequency of 0 Hz. Without a frequency no sine wave part (AC) will be created and only the DC settings will be effective. A ramp with a horizontal progression is generated.
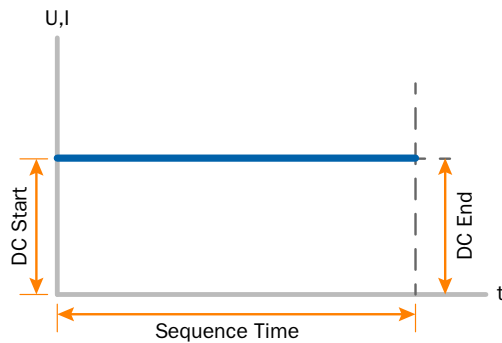
Example 6

Focusing on 1 cycle of 1 sequence point:

Similar to example 1 but with a start and end frequency of 0 Hz. Without a frequency no sine wave part (AC) will be created and only the DC settings will be effective. Here start and end values are unequal and a steadily increasing ramp is generated.
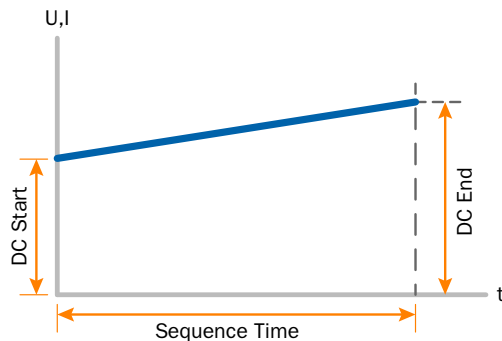
By linking together a number of differently configured sequence points, complex progressions can be created. Smart configuration of the arbitrary generator can be used to match triangular, sine, rectangular or trapezoidal wave functions and thus, e.g. a sequence of rectangular waves with differing amplitudes or duty cycles could be produced.

> Assignment to either U or I makes up to 99 sequence points available for either current or voltage but not a mix.

Schematic diagram:
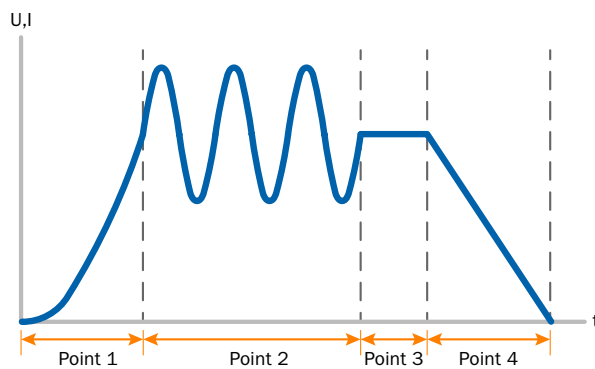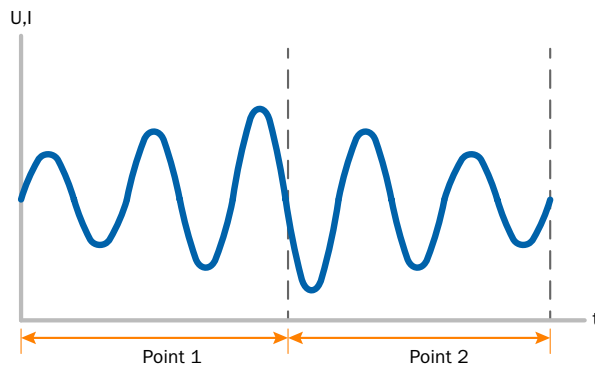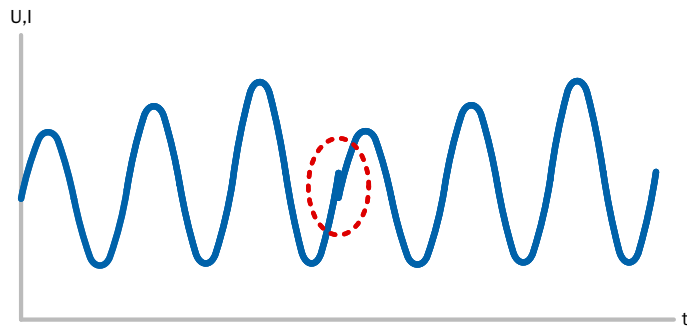
Applications and results:

Example 7

Focusing on 2 cycles of 1 sequence point:

A sequence point, configured as in example 3, is run. Because the settings demand that the end offset (DC) is higher than the start, the second cycle will revert to the same start level as the first, regardless of the values achieved at the end of the first run. This can produce a discontinuity in the total progression (marked in red) which may only be compensated with careful choice of settings.

Example 8

Focusing on 1 cycle of 2 sequence points:

Two sequences run consecutively. The first generates a sine wave with increasing amplitude, the second with a decreasing amplitude. Together they produce a progression as shown left. In order to ensure that the maximum wave in the middle occurs only once, the first sequence must end with a positive half wave and the second start with a negative half wave as shown in the diagram..

Example 9

Focusing on 1 cycle of 4 sequence points:

Point 1: 1/4th sine wave (angle = 270°)

Point 2: Three sine waves (ratio of frequency to sequence point time: 1:3)

Point 3: Horizontal ramp (f = 0)

Point 4: Falling ramp (f = 0)

6.8.1 Loading and Saving the Arbitrary Function

The 99 sequence points of the arbitrary function, which can be manually configured with the control panel of the system and which are applicable either to voltage (U) or current (I), can be saved to or loaded from a common USB thumb drive via the front side USB port. Generally, all 99 sequence points are saved or loaded using a text file of type CSV (semicolon separator), which represents a table of values.

In order to load a sequence table for the arbitrary generator, following requirements have to be met:

- The table must contain 99 row (100 are also accepted for compatibility to previous firmwares), with 8 subsequent values in 8 columns and must not have gaps
- The column separator (semicolon, comma) must be as selected by MENU parameter "USB file separator format"; it also defines the decimal separator (dot, comma)
- The files must be stored inside a folder called HMI_FILES which has to be in the root of the USB thumb drive
- The file name must always start with WAVE_U or WAVE_I (not case-sensitive)
- All values in every row and column have to be within the specified range (see below)
- The columns in the table have to be in a defined order which must not be changed

Following value ranges are given for use in the table, related to the manual configuration of the arbitrary generator (column headers like in Excel):

Column	Connected to HMI parameter	Range
A	AC start	See table in 6.8 Arbitrary Function (p 60)
B	AC end	See table in 6.8 Arbitrary Function (p 60)
C	Start frequency	0–10000 Hz
D	End frequency	0–10000 Hz
E	Angle	0–359°
F	DC start	See table in 6.8 Arbitrary Function (p 60)
G	DC end	See table in 6.8 Arbitrary Function (p 60)
H	Time	100–36.000.000.000 (36 billion µs)

Example CSV:

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

The example shows that only the first two sequences are configured, while all others are set to default values. The table could be loaded as WAVE_U or WAVE_I when using, for example, a model with 500 V / 180 A, because the values would fit both, voltage and current. The file naming, however, is unique. A filter prevents you from loading a WAVE_I file after you have selected "Arbitrary --> U" in the function generator menu. The file would not be listed all.

How to load a sequence point table from a USB thumb drive:

1. Do not plug the USB thumb drive yet or remove it.
2. With the DC output switched off, tap **Func Gen** to access the function selection menu. Tap menu item **Arbitrary** which will then show the settings.
3. Swipe up to go down to the **Sequence setup** part and tap on **Import/Export**, then on **Load** and follow the instructions.

   Select from the available files.
4. To finally load the file, tap on the check mark. The selected file is then checked for validity and loaded. In case of format errors, a message will be displayed. The file would have to be checked and tried again.

< Main menu	Function Generator	≡

Arbitrary	Sequence setup	
Sine	Sequence point	1
	AC start:	0.00V
Triangle	AC end:	0.00V
	DC start:	0.00V
Rectangle	DC end:	0.00V
	Start frequency:	0Hz
Trapezoid	End frequency:	0Hz
	Angle:	0°
DIN 40839	Time:	0.00ms
Ramp		Import/Export
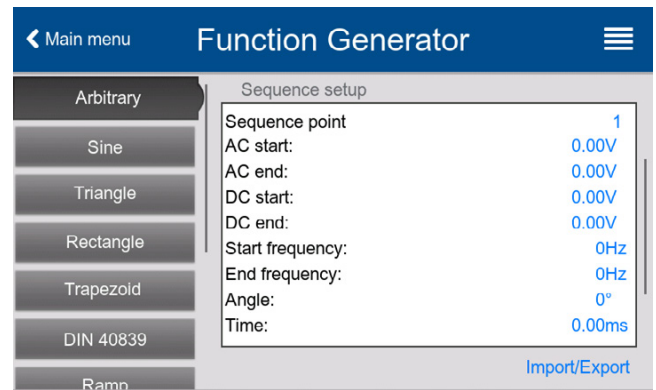
How to save a sequence point table to a USB thumb drive:

1. Do not plug the USB thumb drive yet or remove it.
2. With the DC output switched off, tap **Func Gen** to access the function selection menu. Tap menu item **Arbitrary**.
3. Swipe up to go down to the **Sequence setup** part and tap on **Import/Export**, then on **Save** and follow the instructions. In the file open dialog you can either select an existing file, if at least one compatible file is listed, or you can create a new one by not selecting any file.
4. Save the file, new or overwriting, by tapping on the check mark.

6.9 Ramp Function

The following parameters can be configured for a ramp function.

Parameter	Range	Description
Start / End	0–Nominal value of U, I	Start and end value of the ramp
Time t1	0,1 ms–36,000,000 ms	Time before ramp-up or ramp-down
Time t2	0,1 ms–36,000,000 ms	Ramp-up or ramp-down time

Schematic diagram:
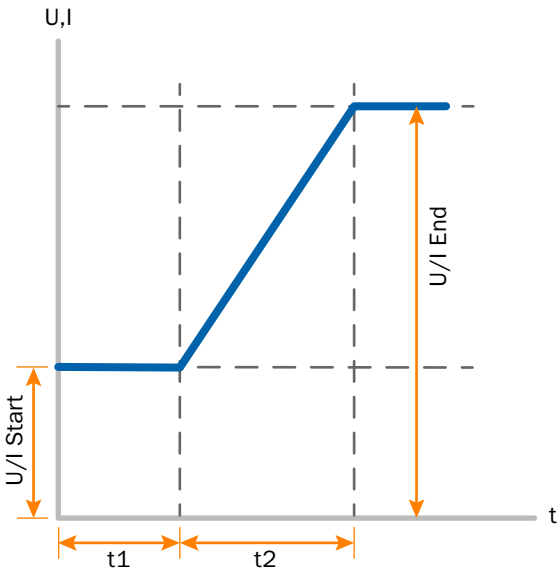
Application and result:

This function generates a rising or falling ramp between start and end values over the time t2. Time t1 creates a delay before the ramp starts.

The function runs once and stops at the end value. To have a repeating ramp, function Trapezoid would have to be used instead.

Important to consider are the static values of U or I which define the start level before the ramp generation. It's recommended that the corresponding static value is set equal to value **Start**, unless the load at the DC output shall not be provided with a voltage before the actual start of the ramp (time t1) . In that case the static value should be set to zero.

6.10 IU Table Function (XY Table)

The IU function offers the ability to set a DC output current dependent on the DC output voltage. (Note that unlike the previous 310 Series, there is no UI table.)

The function is table driven with exactly 4,096 values. The 4,096 values are allocated in equal steps to 0–125% of nominal voltage (to match internal value management), though only 0–100% is effective on the DC output. The table can either be uploaded from a USB thumb drive through the front USB port, or via remote control (Modbus RTU protocol or SCPI).

The function's definition is I = f(U).

In the IU function, an internal circuit measures the voltage on the DC output. That value is correlated to one of the 4,096 steps. For every possible actual voltage on the scale of 0–125%, the loaded IU table holds a current value, which can be any value between 0 and rated current.

> The values uploaded from a USB thumb drive will always be interpreted as current values even if the user calculated them as voltage values and loaded them as an IU table due to wrong file naming. File validation is checked during loading to ensure values are not too high and the number of values is correct. If errors are reported, the table will not have been loaded.

> The 4,096 values in the table are only checked for scale and count. If all values were to be graphically plotted, a curve would be created which could include significant step changes in current or voltage. Such steps could lead to complications for connected loads if, for example, the internal current measurement in the power supply swings slightly so that the voltage jumps backwards and forwards between two values in the table, which, in the worst case, could be 0 and max voltage.

6.10.1 Loading IU Tables from USB Thumb Drive

The IU value tables can be loaded from a file on a standard USB thumb drive formatted as FAT32. In order to load the file, it has to meet following specifications:

- The file(s) have to be inside a folder named **HMI_FILES** in the root of the thumb drive.
- The file name always begins with IU (not case-sensitive), and ends with .csv. The rest of the name is user defined.
- The file must be a CSV text file with only one column having exactly 4,096 values without gaps. If your function doesn't need current data for steps 0–10, the file must still have values (even if they're 0) in those positions.
- Values with decimal places must use the decimal separator that matches the setting in **USB file separator format**, which also defines the decimal separator between dot and comma (US default should be dot).
- No value may exceed the nominal current value of the system. For example, if you have a 420 A model, none of the values in the table may be higher than 420.0. The adjustment limits from the system's front panel do not apply here.

If these specifications are not met, the system won't accept the file, and displays an error message. Files with names not beginning with IU are not recognized. The USB thumb drive may contain multiple IU files with different names.
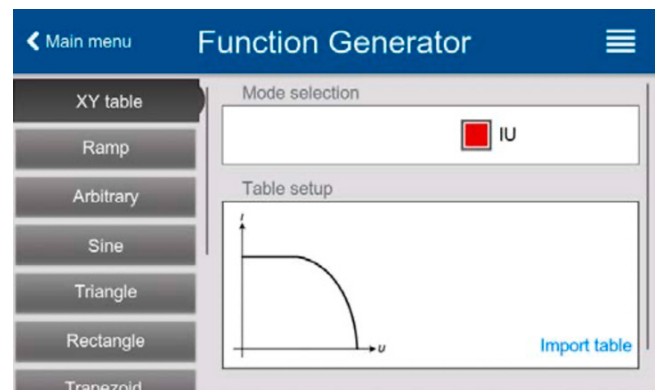
How to load an IU table from a USB thumb drive:

1. With the DC output switched off, tap **Func Gen**, then select menu item **XY table**.
2. On the right side, select the function **IU table**.
3. Insert the USB thumb drive, if not already done, then tap on **Import table**, and in the file selector choose the file to be loaded, and confirm with a tap on the check mark. (If an error is shown, and the file is not accepted, correct the file format and content, and try again.)
4. Tap **Next** to proceed to adjusting the global set values.
5. Tap **Next** to proceed to the function control view.

6.11 Photovoltaic (PV) Table Function

6.11.1 Preface

This function uses the standard XY generator to let the power supply simulate photovoltaic solar panels or solar cells with certain characteristics. The system calculates an IU table from four typical values.

While the function is running, the user can adjust a 5th parameter named **Irradiance** to simulate different light conditions.

The most important characteristics of a solar cell are:

- The short-circuit current (I_{SC}), the maximum current at almost 0 V.
- The open circuit voltage (U_{OC}), which almost reaches its maximum value even in low light situations.
- The maximum power point (MPP), at which the solar panel can provide the maximum output power.

The voltage of the MPP (U_{MPP}) lies typically 20% below U_{OC}, the current of the MPP (I_{MPP}) lies typically 5% below I_{SC}. In case there are no definite values for the simulated solar cell available, I_{MPP} and U_{MPP} can be set to this rule of thumb. The system limits the I_{MPP} value to I_{SC} as an upper limit, the same applies to U_{MPP} and U_{OC}.
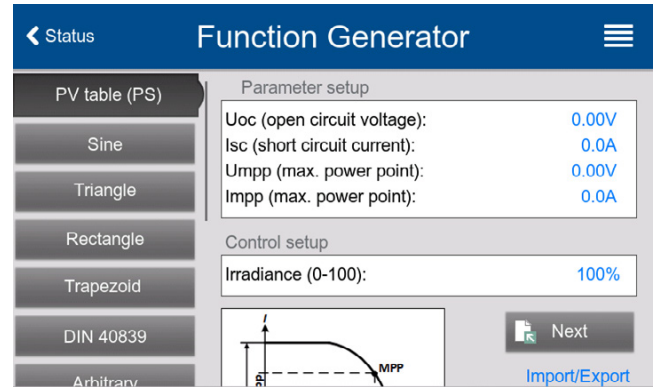
6.11.2 Safety Notices

⚠️ Due to high capacities on the DC outputs of the power supplies of this series, not every available solar inverter can be operated without problems. Check the technical specifications of the solar inverter and probably contact the inverter's manufacturer for an evaluation.

6.11.3 Usage

In the PV table function, which is based upon the XY generator with IU characteristics, the MPP is defined by the two adjustable parameters **Umpp** and **Impp** (also see diagram below). These parameters are usually stated in data sheets of solar panels and have to be entered here.

The following parameters can be set for the PV table function:

Parameter	Range	Description
Uoc	Umpp–Nominal system voltage	Open circuit voltage at no load
Isc	Impp–Nominal system current	Short-circuit current at max. load and low voltage
Umpp	0 V–Uoc	DC output voltage at the MPP
Impp	0 A–Isc	DC output current at the MPP

Schematic diagram:
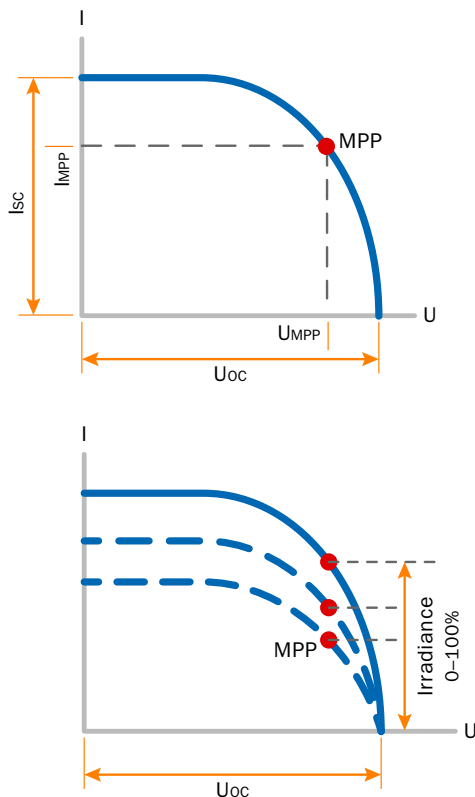
Application and result:

Adjust all four parameters to the desired values. Whether the calculated IU and P curves, which result from those values, make sense or not can be verified with a tool which can be obtained upon request. The tool visualizes the curves as calculated from the adjusted values.

While the simulation is running, the user can see from the actual values (voltage, current, power) of the DC output, where the operating point of the power supply reletaive to the simulated solar panel is.

The adjustable value **Irradiance**, available in the function control view, adjusts from 0%–100% in 1% steps to help simulate different light situations from darkness (no power output) to the minimal amount of light that is required to make the panel provide full power. Varying this parameter shifts the MPP and the PV curve along the Y axis. The value **Irradiance** is here used as a factor for the current I_{MPP}. The curve itself isn't permanently re-calculated.

How to configure the PV table

1. In the function generator menu swipe up to find the menu item **PV table** and tap it.
2. Adjust the four parameters as required for the simulation. Tap **Next**.
3. Adjust the global limits for voltage and power. The voltage (U) setting is automatically set as high as U_{oc} and should not be lower, but can be higher. Tap **Next**.
4. In the function control view, contrary to other functions, the DC output is not automatically switched on. The function is started only when the operator switches the DC **On/Off** on.

From the function control view, you can go back to the first view of PV table function and use a formerly locked **Import/ Export** action and select **Save** to write the calculated table to a USB thumb drive. In order to do so, follow the on-screen instructions. The exported table can be used to analyze/visualize the values in Excel or similar tools.

How to work with the PV table function

1. With a load connected, such as solar inverter, start the function.
2. Adjust **Irradiance** with any rotary knob or using touch input between 100% (default) and 0%l. The actual values on the display indicate the working point, and can show whether the simulation has arrived at the MPP or not.
3. Stop the function run any time by the **Stop** button or by switching off the DC output.
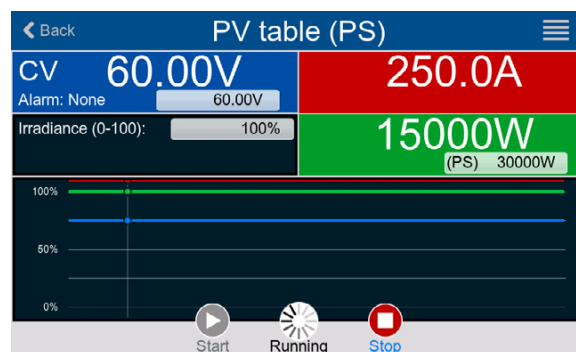
6.12 Fuel Cell (FC) Table Function

6.12.1 Preface

The FC table function is used to simulate the characteristics of voltage and current of a fuel cell. This is achieved by setting up some parameters which define points on a typical fuel cell curve, which is then calculated as a UI table and passed to the internal function generator.

The user has to adjust four support points. The system will request to enter them step by step, indicating the actual point with small graphics. When finished, these points will be used to calculate the curve.

Generally, the following rules apply when setting these values:

- $U_{OC} > U_{Point2} > U_{Point3} > U_{Point4}$
- $I_{SC} > I_{Point3} > I_{Point2} > I_{Point1}$
- Values of zero are not accepted

To express the rules in a simplified way, the voltage has to decrease from point 1 to point 4, while the current has to increase. If the rules are not followed, the system will reject the settings, and reset them to 0.

6.12.2 Usage

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

Value	Range	Description
Point 1: Uoc	0 V–U_{Nom}	Open circuit voltage at no load
Point 2+3: U	0 V–U_{Nom}	Voltage and current define the position of these two points in the U-I coordinate system, which represent two supporting points on the curve to be calculated
Point 2+3: I	0 A–I_{Nom}	
Point 4: Isc	0 A–I_{Nom}	DC output current during short-circuit
U	0 V–U_{Nom}	Global voltage limit, should be ≥Uoc
P	0 W–P_{Nom}	Global power limit, mustn't be 0 to have the function run as expected

> All these parameters all freely adjustable, and the curve calculation may fail. If there is a failuer, the system displays an error message. Check the settings, adjust, and try again.
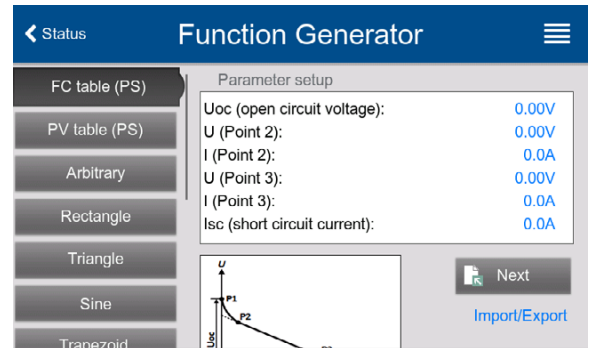
Schematic diagram:
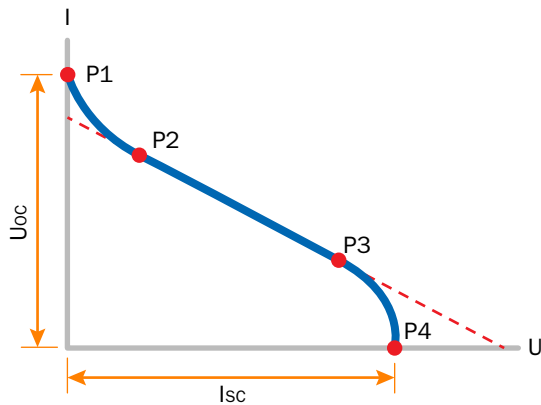
Application and result:

After setting up the four supporting points P1 thru P4, where P1 is at position Uoc and 0 A, and P4 is at position Isc and 0 V, the system will calculate the function as a UI table, and load it to the XY generator.

Depending on the load current, which can be between 0 A and Isc, the system will set a variable output voltage, whose progress between 0 V and Uoc should result in a curve similar to the one depicted to the left.

The slope between P2 and P3 is depending on the values adjusted for P2 and P3, and can be freely modified as long as P3's voltage is lower than the one of P2 and P3's current is higher than the one of P2.

How to configure the FC table

1. In the function menu's list of functions, tap on menu item **FC table (PS)**.
2. Adjust the parameters of the four supporting points, as required for the simulation. Tap **Next**.
3. Adjust the global limits for voltage and power. The voltage (U) setting is automatically set as high as U_{oc} and should not be lower, but can be higher. Tap **Next**.
4. After the function has been loaded to the internal XY generator, the simulation is ready to start.
5. In the function control view, contrary to other functions, the DC output is not automatically switched on. The function is started only when the operator switches the DC **On/Off** on.

From the function control view, you can go back to the first view of FC table function and use a formerly locked **Import/ Export** action and select **Save** to write the calculated table to a USB thumb drive. In order to do so, follow the on-screen instructions. The exported table can be used to analyze/visualize the values in Excel or similar tools.

How to work with the FC table function

1. With an appropriate load connected, for example a DC-DC converter, start the function by switching the DC output on.
2. The output voltage will be set depending on the load current, which is defined by the connected load, and will decrease with increasing current. Without any load, the voltage will rise to the adjusted Uoc value.
3. Stop the function run any time with the **Stop** button or by switching off the DC output.
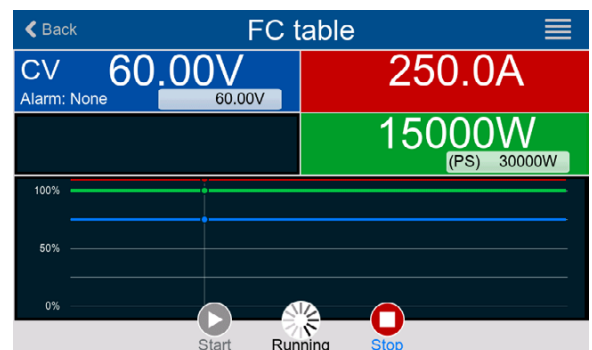
6.13 Extended PV Function (EN 50530)

6.13.1 Introduction

The extended PV table function, as defined by standard EN 50530, is used to simulate solar panels in order to test and rate solar inverters. It offers manual configuration and control, as well as remote control. It's also based on the XY generator, same as the simple PV table function, but allows for more specific tests and evaluations due to added adjustable parameters. The impact of the parameters on the PV curve and the simulation is described in the standard paper of EN 50530, which an operator can refer to in case more detailed description is required. This section describes only the configuration and control of the PV simulation.

6.13.2 Differences From the Basic PV Function

The extended PV function has five additional characteristics compared to the simple PV function.

- The simulation distinguishes between a single test run and an automatic test run, called day trend, which is based upon a user-defined curve built from up to 100,000 points.
- There are two invariable and one variable panel technologies to choose from.
- There are more parameters available to adjust during runtime.
- It allows for data recording during runtime, and to save the data to USB thumb drive, or read from a digital interface.
- It allows selection between two different parameter sets to adjust during runtime.

6.13.3 Technologies and Their Parameters

When configuring the PV simulation it's required to select the solar panel technology to simulate. The technologies cSI and Thin film are invariable in their parameters, while technology Manual is variable in all parameters within specific limits. This allows for variation of the simulation, and when copying the fixed parameter values from cSi or Thin film to Manual, it even enables customization of those models as well.

One advantage of the invariable technologies is that their technology parameters are automatically set to their defined defaults in the configuration procedure.

Overview of the technology parameters used in the PV curve calculation and their defaults:

Abbr.	Name	Manual	cSI	Thin film	Unit
FFu	Fill factor for voltage	>0–1 (0.8)	0.8	0.72	-
FFi	Fill factor for current	>0–1 (0.9)	0.9	0.8	-
Cu	Scaling factor for U_{OC} [1]	>0–1 (0.08593)	0.08593	0.08419	-
Cr	Scaling factor for U_{OC} [1]	>0–1 (0.000109)	0.000109	0.0001476	m²/W
Cg	Scaling factor for U_{OC} [1]	>0–1 (0.002514)	0.002514	0.001252	W/m²
alpha	Temperature coefficient for I_{SC} [2]	>0–1 (0.0004)	0.0004	0.0002	1/°C
beta	Temperature coefficient for U_{OC} [1]	-1–<0 (-0.004)	-0.004	-0.002	1/°C

(1 Uoc = Open circuit voltage of a solar panel
(2 Isc = Short-circuit current (=max. current) of a solar panel

6.13.4 Simulation Mode

Apart from the panel technology, there is also a simulation mode to select. There are four options:

Mode	Description
U/I	Controllable simulation. Voltage (U_{MPP}, in V) and current (I_{MPP}, in A) in the maximum power point (MPP) are variable during runtime. The purpose of this mode is to directly shift the MPP into various directions.
E/T	Controllable simulation. During runtime, the irradiation (E from the German term Einstrahlung, in W/m²) and surface temperature (T, in °C) of the simulated solar panel are adjustable. This also impacts the curve and the resulting MPP. The purpose of this mode is to analyze the impact of temperature and/or irradiation on the performance of a solar panel.
DAY U/I	Automatic simulation run, processing a day trend curve consisting of up to 100,000 points defined by values for U_{MPP}, I_{MPP} and time.
DAY E/T	Automatic simulation run, processing a day trend curve consisting of up to 100,000 points defined by values for irradiation, temperature and time.

6.13.5 Day Trend

The day trend is a special simulation mode for long-term tests. It processes a curve consisting of up to 100,000 user-definable points. For every processed point on that curve, the PV curve is calculated anew.

Every point is defined by three values of which one is the dwell time. When defining long dwell times, the day trend curve can be supported by an optionally activated interpolation feature. This will calculate and set intermediate points between two succeeding curve points.

The day curve points have to be loaded into the system, either from a CSV file on USB thumb drive, or programmatically through a digital interface. The user selects the number of points according to the requirements of the simulation.

Mode "DAY E/T CSV" file format

The required file name format is PV_DAY_ET_*USERTEXT*.csv.

	A	B	C	D
1	1	100	25	300000
2	2	101	25	2000
3	3	102	25	2000
4	4	103	25	2000
5	5	104	25	2000
6	6	105	25	2000
7	7	106	25	2000
8	8	107	25	2000
9	9	108	25	2000

Column A = Index — An ascending number between 1 and 100,000 (the first empty index will cause the simulation to stop).

Column B = Irradiance (E) in W/m² — Allowed range: 0–1500.

Column C = Temperature (T) in °C — Allowed range: -40–80.

Column D = Dwell time in milliseconds (ms) — Allowed range: 500–1,800,000.

Mode "DAY U/I" CSV File Format

The required file name format: PV_DAY_UI_*USERTEXT*.csv.

> ⚠️ Attention! The values in columns B and C are real values which must not exceed the ratings of the system or the system will neglect to load the file.

	A	B	C	D
1	1	63.5	120.3	500
2	2	63.6	121.1	500
3	3	63.7	121.9	500
4	4	63.8	122.7	500
5	5	63.9	123.5	500
6	6	64	124.3	500
7	7	64.1	125.1	500
8	8	64.2	125.9	500
9	9	64.3	126.7	500

Column A = Index — An ascending number between 1 and 100,000 (the first empty index will cause the simulation to stop).

Column B = Voltage U_{MPP} in V — Allowed range: 0–rated output voltage of the system.

Column C = Current I_{MPP} in A — Allowed range: 0–rated output current of the system.

Column D = Dwell time in milliseconds (ms) — Allowed range: 500–1,800,000

> ⓘ The number format and the column separator in the CSV files is determined by the regional settings of the PC or the software used to create the files. The format must match the selection for the system setting **USB file separator format** in General Settings, or the system will not load the file.

6.13.6 Interpolation

The interpolation feature can calculate and set intermediate steps when running the PV function in one of the day trend modes. The calculation is always done between two succeeding points on the day trend curve. The dwell time of every curve point is adjustable between 500 and 1,800,000 milliseconds. While there are no extra points calculated when using the minimum time of 500 ms, interpolation can apply to higher dwell time definitions:

- The number of intermediate steps is determined from the dwell time, and are spread as equally as possible, where any of the steps can have its own dwell time between 500 and 999 ms
- The intermediate steps also respect the slope between the current and the next day trend curve point and thus every step also includes a corresponding value alteration
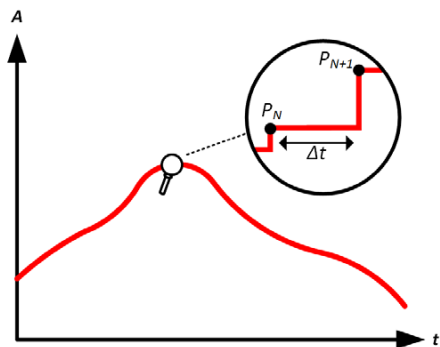
Without interpolation - the curve results in steps
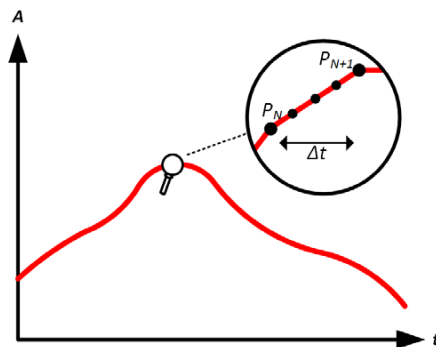
With interpolation - the curve remains linear

An example — The dwell time of the 3450th curve point is defined as 180 seconds. There will be (180/0.5)−1 = 359 intermediate steps calculated and set until reaching the 3451st point. In mode DAY U/I, the MPP voltage changes from 75 V to 80 V, and the MPP current changes from 18 A to 19 A. When calculated, this would mean a ΔU/Δt of 27.7 mV/s, and a ΔI/Δt of 5.5 mA/s. Depending on the unit in use, such small steps in voltage or current may not be possible. However, the system would try to set the first intermediate step with 75.0138 V and 18.0027 A.

6.13.7 Data Recording

There is the option to record data during the simulation run, in any mode. The data can be stored to USB thumb drive once the simulation is finished, or read via digital interface which allows for reading the data while the simulation is still running.

As long as the simulation is running, the system will record one data set every 100 ms into an internal buffer. This interval isn't adjustable. The maximum number of data sets, also called indexes, is 576,000. This results in a maximum recording time of 16 hours. The indexes are internally counted with every new record. When reaching the maximum number, the index will restart from 1, overwriting former data. Every index will contain 6 values.

When configuring the PV simulation, the recording feature is locked at first (button greyed out). Only when stopping the simulation and leaving the control view back to the configuration, the button becomes accessible. It then allows storing a CSV with a specific number of rows. This number depends on the current index counter. Contrary to remote control where it's possible to address every index of the max. 576,000, the save to USB feature will always store all indexes between 1 and the counter. Every simulation run resets the counter. All this means is that if a run only generates 180,000 rows, then only 180,000 rows are saved to the USB file.

CSV file format when saving the recorded data to USB thumb drive (in the example all values are with unit):

	A	B	C	D	E	F	G
1	Index	U actual	I actual	P actual	Umpp	Impp	Pmpp
2	1	0,29V	0,000A	0,0W	0,00V	0,000A	0,0W
3	2	0,29V	0,000A	0,0W	0,00V	0,000A	0,0W
4	3	0,29V	0,000A	0,0W	0,00V	0,000A	0,0W
5	4	0,29V	0,000A	0,0W	0,00V	0,000A	0,0W
6	5	0,30V	0,000A	0,0W	0,00V	0,000A	0,0W
7	6	0,28V	0,000A	0,0W	0,00V	0,000A	0,0W
8	7	0,28V	0,000A	0,0W	0,00V	0,000A	0,0W
9	8	0,28V	0,000A	0,0W	0,00V	0,000A	0,0W

Index = Ascending number

Uactual = Actual voltage on the DC output

Iactual = Actual current on the DC output

Pactual = Actual power on the DC output

Umpp / Impp / Pmpp = Voltage, current and power in the MPP of the currently calculated PV curve

The global parameter **USB logging with units (V,A,W)** in the General Settings selects whether the values in the CSV file are with or without a unit label. The default setting includes the unit. Another parameter, **USB decimal point format** selects whether the system saves the CSV with comma (US) or semicolon (Default), and defines the decimal point beteen a dot or comma. The example CSV above shows the default european format — which likely needs changed for US users.

6.13.8 Configuration Step by Step
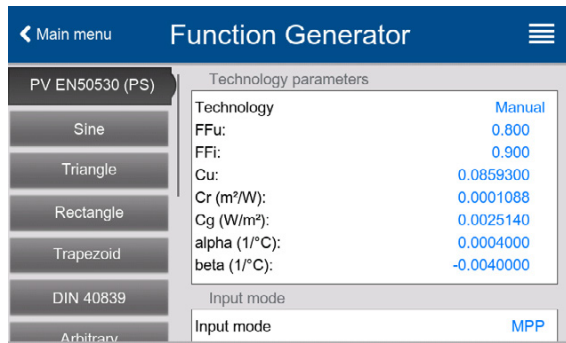
From the main display view, tap the sequence **Func Gen** > **PV EN50530 (PS)**
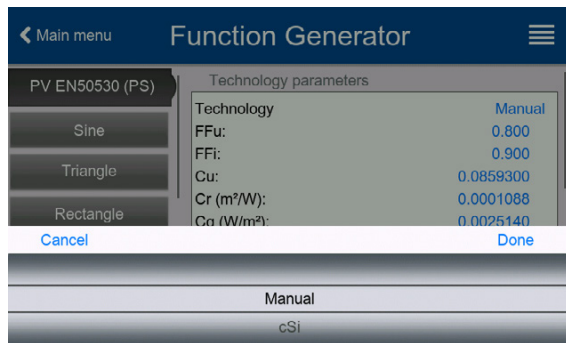
Step 1A: Technology selection

The extended PV function requires selecting the panel technology which is going to be simulated. If **cSI** or **Thin Film** don't match your requirements or you are not sure about their technology parameters, select **Manual**.

When selecting Thin film or cSI, the configuration continues with Step 2.

Step 1B: Adjust technology parameters

If technology Manual was selected in the previous view, all displayed technology parameters can be adjusted by tapping on them, and entering the desired value. It's recommended to adjust these values very carefully, because wrong settings can result in a PV curve which doesn't work as expected.

When resetting the system, these values are reset to defaults which are the same as with technology cSI —and they don't necessarily have to be adjusted. If any of the other technologies was selected, this view would be skipped and these parameters set to the defined values.
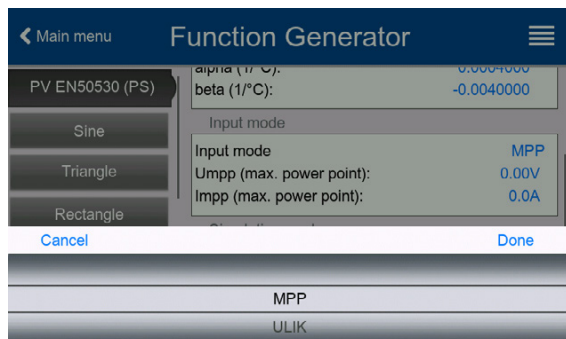
Step 2: Input mode and solar panel base parameters

Selecting the input mode between MPP and ULIK determines what pair of parameters have to be configured. When setting pair **Uoc/Isc**, the other pair is calculated and automatically set.

The open circuit voltage (Uoc) and the short-circuit current (Isc) are upper limits which are usually read from the data sheet of a solar panel and entered here for the simulation. Two parameters each are connected via the fill factors:

$U_{MPP} = U_{OC} \times FF_u$ / $I_{MPP} = I_{SC} \times FF_i$
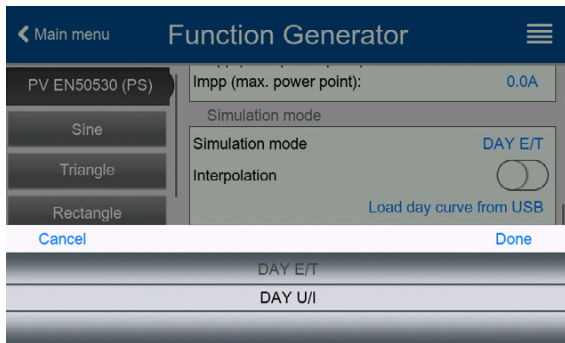
Step 3A: Select simulation mode

When selecting **E/T** or **U/I** the configuration continues with Step 4, otherwise an additional step is required
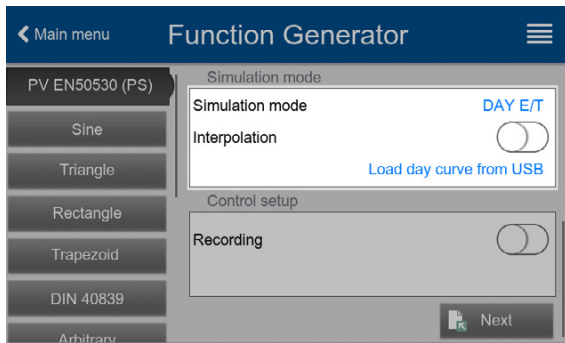
Step 3B: Load day trend data

If mode **DAY E/T** or **DAY U/I** was selected this additional view will appear where you can load the required day trend data (1-100,000 points) with button **Load day curve from USB**, in form of a CSV file with a specific format and name.

Additionally, set whether interpolation is to be used.
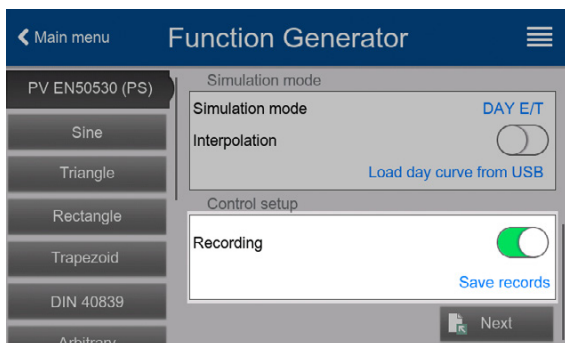
Step 4: Wrapup

One of the last two steps is the option to enable the recording feature. The data is not stored on-the-fly to USB thumb drive, but after stopping the simulation and coming back to this view, the button **Save records** is enabled.

Press **Next**, to proceed to the next view. Here you adjust global set values for voltage and current. These will be already set to levels suitable for the simulation.

The configuration is finished. Settings are stored when **Next** is pressed. The function control view is shown.

6.13.9 Controlling the Simulation

After loading the configured parameters, the funtion generator will switch to control mode. The simulation can be started with either the **On/Off** button or on-screen **Start** button.

The adjustable simulation parameters (depending on the configured simulation mode), can be modified with keypad input, not by the rotary knobs (which would leadto every step of the knob the curve would be re-calculated).

The display example on the right shows simulation mode **E/T**.
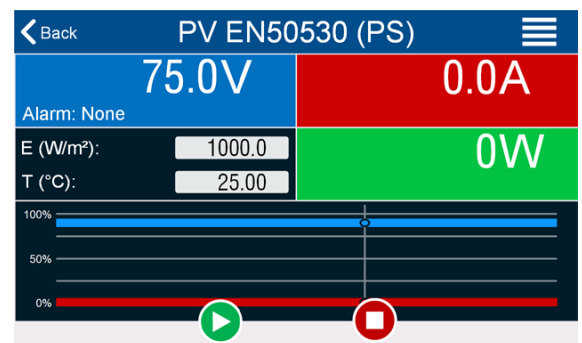
6.13.10 Unexpected Stops

An active simulation run could unexpectedly stop due to several reasons.

1.   A system alarm occurred, which would switch off the DC output (PF, OVP, OCP, OPP).

2.   A user event occurred whose action has been defined to cause an alarm, which means to switch off DC.

Situation 2 can be avoided by carefully setting up user event parameters When the simulation stop, the data recording also stops.

6.13.11 Test Analysis

After a simulation stops by whatever reason, recorded data can be saved to a USB thumb drive, or read via digital interface—of course, only if data recording was activated in the configuration. Activating the data recording feature during the simulation run isn't possible when manually operating the function generator, but it is with remote control. When saving to USB thumb drive, only the number of records generated by the latest run are saved. Via digital interface there is the ability to read any portion of the data, which will also have an impact on the time required to read the data.

The data can later be used to visualise, analyze, and determine characteristics of the simulated solar panel, and also of the solar inverter which is usually used as a load when running such tests.

6.13.12 Reading the PV Curve

The last PV curve (or table) which has been calculated during the simulation run can later be read from the system via digital interface (partly or completely), or stored to USB thumb drive. This can serve to verify the adjusted parameters. When running mode DAY E/T or DAY U/I this makes less sense, because with these, the curve would be re-calculated with every processed index, and the curve being read would always be the one belonging to the last day trend curve point.

When reading the PV table, there will be up to 4096 current values. The table data could be visualised in an XY diagram in tools like Excel.

6.14 Remote Control of the Function Generator

The function generator can be remotely controlled, but configuration and control of the functions with individual commands is different from manual operation. The programming section explains what is required. In general the following items apply:

• The analog interface can't be used to control the function generator, but the REM-SB pin can be used to stop and restart an active function.
• The function generator is not available if R mode (resistance) is activated. If R mode is active, sending remote commands for the function generator are ignored.

7 Parallel Setups

7.1 Overview

A Note About Terminology — The terms master-slave are still built into the software, but as we move to change that, this documentation will use the terms parallel operation (master-slave mode), control unit (master), and expansion unit (slave) in places which are not referring to literal terms used in software labels and menus, and for the back panel connectors.

Up to 64 units of 311 Series models, one control unit, and up to 63 expansion units, can be connected in parallel in order to create a system with greater total current and power. The default assumption is that all units arer identical. However, if each unit in the setup has version KE 3.02 firmware or later, the models do not have to be identical. Even with KE 3.02, it is recommended that all units have the same voltage rating to avoid accidental damage to units with lower voltages. Also, when mixing units of different power capacity, always choose a unit with the highest power capacity at the control unit. For example, if combining a 30 kW and a 3 kW system, the 30 kW unit should be the master.

For parallel operation mode, the units are connected with their DC outputs, their Share bus, and their Master/Slave bus each daisy-chained. The first and last units are *not* connected to complete a loop.

The combination of these connections makes the system work as one big unit when it comes to adjusted values, actual values, and status. These connections balance the units dynamically. In order for this to work correctly, the DC minus poles of all units must be connected, because DC minus is the reference the Share bus uses when making automated adjustments.

7.1.1 Limitations

Compared to normal operation of a single unit, parallel operation has some differences.

- The combined system reacts a little differently in alarm situations (descibed in 7.4.1).
- Using the Share bus helps the system react as responsively as possible, but it's still not as responsive as a single unit operating by itself.
- Connection to units from other series (300, 310, 320) is not supported. All models must be 311 Series.
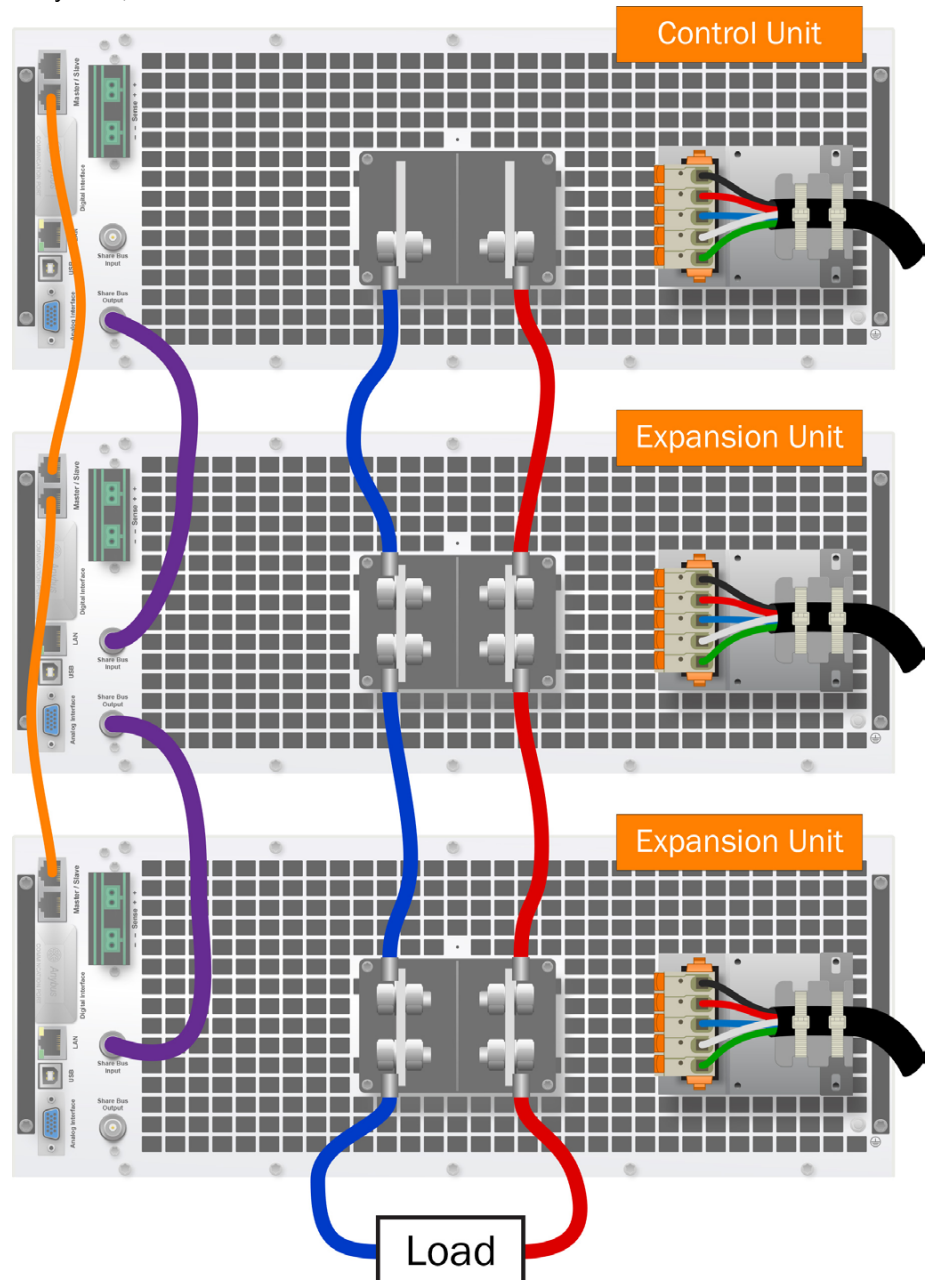
7.2 Parallel Connections

7.2.1 DC Connections

With the AC power of each unit switched off, the DC output of every unit in the parallel setup is connected with correct polarity to the next unit, using cables or copper bars with a cross section suitable for the total system current. Use as short a length as possible, so the inductance is as low as possible.

7.2.2 Share Bus Connection

With the AC power of each unit switched off, the Share bus is wired from unit to unit with standard BNC cables (coaxial, 50 Ω type) with a length of 18" or similar. Both sockets are internally connected, and are not specifically input or output. The labeling is only for convenience.

The Share connectors are the legacy component of parallel operation. The main purpose of the Share bus is to balance the voltage of multiple units in parallel operation, which is particularly advantageous when using the function generator of the master unit to drive the voltage profile of all units.

7.2.3 Master/Slave Bus Connection

The Master/Slave bus expands on the legacy share bus to automate the sharing of set values, staus, and many settings across all units in the setup. This bus is what drives the convenience of managing almost everything in a parallel setup from the single control unit without having to manually adjust all expansion units to match the run requirements.

The Master/Slave connectors are connected using RJ45 network patch cables ≥ CAT3. With the AC power of each unit switched off, daisy chain the RJ45 connections. There is not a designated input and output, though it may be less confusing to adopt a standard pattern.

Once all units are connected, M/S configuration can be done manually or by remote control.

> ⚠ The Master/Slave bus ports must *not* be wired using crossover cables or to an Ethernet network.

7.2.3.1 Master/Slave Bus Termination

The first and last units at the ends of the M/S bus must be terminated. The control unit, regardless of where it is on the chain, is always terminated as well. Termination is done from within the **Settings** > **Master-slave** menu, and needs to be set before the system is initialized.

Two settings control internal electronic switches to enable optional resistors. The internal configuration allows to separately enable a termination resistor (TERM), and additional BIAS resistors.

Suggested starting points for terminating units:

- Control unit at an end — BIAS + TERM
- Control unit in the middle — BIAS
- Expansion unit at an end — TERM
- Expansion unit in the middle — (none)
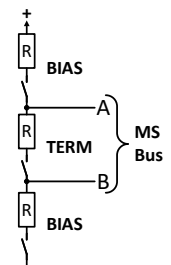
7.3 Parallel Mode Configuration

With all wiring in place, the setup can be configured. It's recommended to configure all the expansions units first, and then the control unit. Note that the control unit does not have to an end unit. It can be any unit in the daisy chain.

The details below are specific to setting the Master-slave mode settings. Be sure to also set the termination settings (see the previous section above) during the setup process before the control unit is triggered to be Master and starts the initialization process.

Step 1: Configuring all expansion units

1. While the DC output is switched off, tap on **Settings** in the main view to access the Settings menu. Swipe up to find the menu item **Master–slave**, and tap it.

2. Tapping on the blue button text next to **Mode** will open a selector. By selecting **Slave**, if not already set, the master-slave mode is activated, and the system is defined as an expansion unit.

3. Close the Settings menu.

After this, the unit is fully configured for parallel operation. Repeat the procedure for all other expansion units.

> ⓘ When the function generator is used with parallel systems, the last step of the function configuration requires entering global set values. It is important to set these to proper levels, because they are transferred to all units which would otherwise remain at 0 V, 0 A, and 0 W.

Step 2: Configuring the control unit

1. While the DC output is switched off, tap on **Settings** in the main view to access the Settings menu. Swipe up to find menu item **Master–slave**, and tap it.

2. Tapping on the blue button text next to **Mode** will open a selector. By selecting **Master**, if not already set, the master-slave mode is activated, and the system is defined as the control unit.

Step 3: Initializing the control unit

When setting a control unit to Master mode, the control system will immediately try to initialize the setup, and the result is displayed in the same window. If the initialization is not successful at all, or the number of units, or the total power sum is wrong, initialization can be repeated.

Initialization state	Initialized
Number of slaves	1
System voltage	80.00V
System current	2000.0A
System power	60.00kW
System resistance	5.0000Ω
	Initialize system

Tapping **Initialize system** repeats the search for expansion units. This can be done when the detected number of units is less than expected, not all expansion units were set in Slave mode, the setup has been reconfigured, or the cabling/termination is still not OK. The result window shows the number of units plus the total current and power, and resistance of the parallel setup.

If there are no expansion units found at all, the control unit will still initialize a Master-slave mode system with only itself.

> ⓘ The M/S mode settings are retained across AC power cycles. As long as M/S mode is activate, the initialization process of the whole setup will be repeated each time the control unit is powered.

7.4 Parallel Mode Operational Behaviors

After successful configuration and initialization of the control and expansion units, each will show their status on their own displays. The control unit will show **MS mode: Master** while the expansion unit(s) will show **MS mode: Slave** plus an additional line of **Remote: Master-slave**, as long they are in remote control by the control unit.

From now on, the expansion units can no longer be controlled manually or remotely, neither via the analog nor via digital interfaces. They can, if needed, be monitored through these interfaces by reading actual values and status data.

The display on the control unit will reconfigure after initialization, and all set values are reset. The control unit will now display the set values and actual values of the total combined system. For example, if 5 units each with a power of 30 kW are connected together into a 150 kW system, then the control unit can have a set value in the range 0–150 kW. This applies to Limit values as well.

Depending on the number of units, the adjustable current and power range will multiply, but the resistance range will decrease. Then following notes apply:

- The system, represented by the controll unit, can be treated like a standalone unit.
- The control unit shares the set values etc. across the expansion units, and controls them.
- The control unit is remotely controllable via the analog or digital interfaces much like a single unit would be.
- All settings for the set values U, I, P, and R on the control unit, plus also all related values from supervision, limits etc. will be updated to the new total values.
- All initialized expansion units will reset any limits (U_{Min}, I_{Max} etc.), supervision thresholds (OVP, OPP etc.), and event settings (UCD, OVD etc.) to default values, so these don't interfere with the control unit settings. As soon as these values are modified on the control unit, they are transferred to the expansion units.
- Note that during operation, it might occur that an expansion unit experiences an alarm or an event slightly sooner than the control unit due to imbalanced current, or slightly faster reaction.
- If one or more expansion units report a system alarm, it will be signaled on the control unit, and must be acknowledged at the control unit so that the expansion units can continue their operation. Remember that an alarm causes all DC outputs to be switched off, (except where PF and OT can be configured for auto-restoration of DC), so intervention from an operator or remote control software may be necessary.
- Loss of connection to any expansion unit will result in shutdown of all DC outputs as a safety measure. The control unit will report this situation in the display with a popup window with a "Master-slave security mode" message. The parallel mode initialization will have to be repeated to restore operation.
- All units in the setup can have their DC outputs externally shut down using the pin REM-SB of the analog interface. This should not be used as a true emergency power off button (a proper EPO should disconnect AC power to all units), it can be used as a convenient DC override for non-emergency applications. See 9.4.6 DC Output On/Off using REM-SB (p 92) for wiring information.

7.4.1 Alarms and Other Problem Situations

Parallel mode operation, due to the connection of multiple units and their interaction, can cause problem situations which do not occur when operating individual units. For such occurrences the following operational behaviors are defined.

- Generally, if the control unit loses connection to any expansion unit, it will generate an MSP (master-slave protection) alarm, generate a display popup message, and switch off its DC output. All expansion units will revert to stand-alone mode, and also switch off their DC output. The MSP alarm can be deleted by either initializing the parallel mode again. This can be triggered in the MSP alarm popup, or in the MENU of the control unit (as explained in 7.3 Parallel Mode Configuration (p 82)), or via remote control. The alarm is cleared by deactivating master-slave mode on the master unit (with the quick menu for example).
- If one or more expansion units lose AC supply (power switch, blackout, undervoltage), then are powered again, they're not automatically initialized and re-included in the parallel operation. Parallel mode initialization has to be repeated.
- If the control unit loses AC supply (power switch, blackout, undervoltage), then is powered again, the unit will automatically power up as the control unit, and the setup as a whole will automatically initialize for parallel mode, searching for expansion units as with normal initialization. In this manner, parallel mode is restored automatically.

- If multiple units are defined as a control unit, the parallel mode initialization will not complete.

In situations where one or multiple units generate a system alarm like OVP etc. the following behaviors apply.

- Any alarm of an expansion unit is indicated on that unit's own display and on the control unit's display.
- If multiple alarms happen simultaneously, the control unit indicates only the most recent alarm event. Whenever there is any alarm, reviewing the display, or remote signals/data, of every expansion unit should be done to verify whether there is additional alarms not apparent from the control unit status display.
- All units in the parallel setup supervise their own values regarding overvoltage, overcurrent, and overpower, and upon an alarm they report the alarm to the control unit. In situations where the current is out of balance between the units, it is possible that one unit generates an OCP alarm relative to its own limits, even though the global OCP limit of the parallel setup was not reached. The same can occur with the OPP (over power) alarm.

8 Series Setups

8.1 Overview

Series connection of two or multiple systems is possible. But for reasons of safety and isolation, the following restrictions apply.

> ⚠️
> - Both output poles, negative (DC–) and positive (DC+), are connected to GND via type X capacitors.
> - No DC minus pole of any unit in the series connection must have a potential against ground (GND) higher than what is specified in the technical data. The maximum allowed potential shift varies from model to model, and is different for DC plus and DC minus. Verify the details.
> - Series connection is only allowed with units of the same series (311 series) and model number (i.e. the same nominal voltage and current ratings).
> - Remote sensing must <u>not</u> be used.

Series connection in Master-Slave mode is <u>not</u> supported. This means each units in the setup have to be configured and will be controlled individually regarding set values and DC output status, whether it's manual control or remote control (digital or analog).

Due to the maximum allowed potential shift on the DC output, certain models are not eligible for series connection at all. For example, the 1000 V models cannot be used for serial connection, because the DC plus is isolated up to only 1000 V maximum to start with. However, two 500 V models are eligible for series connection.

Analog interfaces on the units in serial connection can be connected in parallel, because they are galvanically isolated. It's also allowed to ground the GND pins of the analog interfaces connected in parallel, which may happen automatically when connecting them to a controlling device such as a PC, where grounds are directly tied to GND.

9 Remote Control

9.1 One Remote Interface in Control

Remote control is possible through any of the built-in interface ports: USB, LAN, Analog, or Anybus module.

It is important to note that only one interface can be in control at any one time. This means that if, for example, an attempt were to be made to switch to remote control using the USB interface while analog remote control is active, the system would report an error at the USB interface. In the opposite direction a switch-over via pin Remote would be ignored.

However, regardless of which interface is being used for control, all interfaces can be used to monitor status and actual data values at any time.

9.2 Control Locations

Since the power supply can be controlled from the onboard controls, and from a variety of remote control interfaces, we have the concept of control location—that is, the location, or source, of where control is being managed. The power supply software concerns itself with this concept by managing whether control is allowed from the local controls only, from remote controls only, or from either location.

The control location is shown in the display status area with a message.

Status message	Description
Remote: None	If neither of the other locations is displayed then manual control is active, and access from the analog and digital interfaces is allowed.
Remote: [*interface_name*]	Remote control is active, and the specific active interface is identified.
Local	Remote control is locked, only manual operation is allowed.

A configuration setting **Settings** > **Allow remote control** is used to enable or disable remote control of the system.

Changing this setting to indicate **Local** results in remote control being blocked. Activating this block would be useful for safety purposes — a user can temporarily disable remote control in order to safely access the system to change some wiring, or just change a setting, without unexpected interference from a remote command.

Activating condition **Local** causes the following:

- If remote control was active through a digital interface, then remote control is immediately terminated, and would have to be reactivated at the PC once **Local** is no longer active.
- If remote control is active through the analog interface, then remote operation is interrupted temporarily until remote control is allowed again. This is because pin **Remote** would continue to signal "remote control = on" unless it was otherwsie disabled. If the level of pin **Remote** is changed during the **Local** phase, then remote operation would not be reinstated.

9.3 Remote Control with a Digital Interface

9.3.1 General

The system supports built-in digital interfaces of USB, Ethernet, and a variety of others through user-installed Anybus modules. The USB interface requires no setup on the power supply itself. The Ethernet interface typically requires network setup, but can also be used with its default parameters right from the start if the computer is able to connect to the preset LAN settings described in 5.5.6.1 Communication > Ethernet (internal) (p 47).

Using a digital interface, the set values (voltage, current, power) and system conditions can be set and monitored. The function generator can also be configured and controlled through remote programming. Lastly, various other functions are supported as described in the programming documentation.

When changing to remote control, the existing set values (whether configured in remote or local modes) will be used. therefore switching in and out of remote and local contol modes will not inherently change the set values.

9.3.2 Remote control with USB

The USB-B port on the back of the power supply is provided for connection to a PC for control communication. A Windows device driver installs as a virtual COM port. The driver is available from our web site. Refer to the *Installation Guide* for acquiring and installing the driver.

Using the USB port, the system can be controlled using commands with Modbus RTU or SCPI protocols. The system will automatically detect the type of message, so there's no need to pre-configure which protocol will be used.
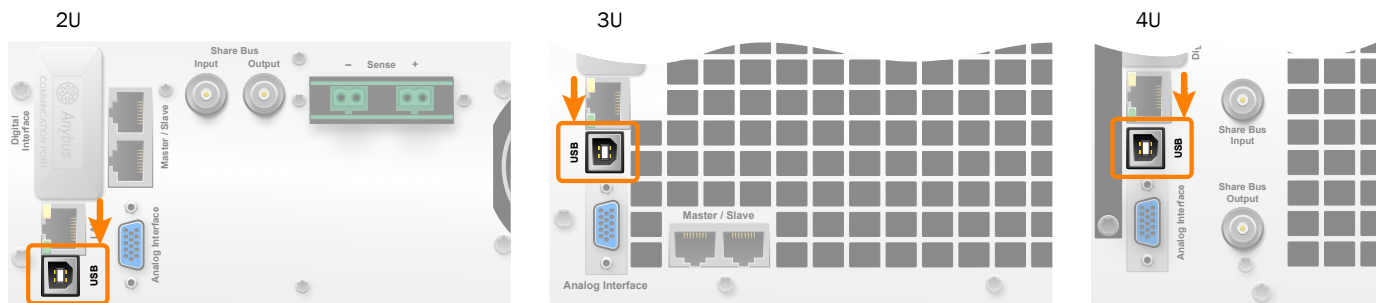
9.3.3 Remote control with Ethernet

The Ethernet port provides two interfaces for remote control and monitoring.

First, a simple website is accessible from a standard browser which provides a configuration page for network parameters, as well as an input field for SCPI commands.

Second, TCP/IP access on a configurable port (typically 5025) provides communication with the system for control using Modbus and SCPI based protocols through most of the common programming languages.
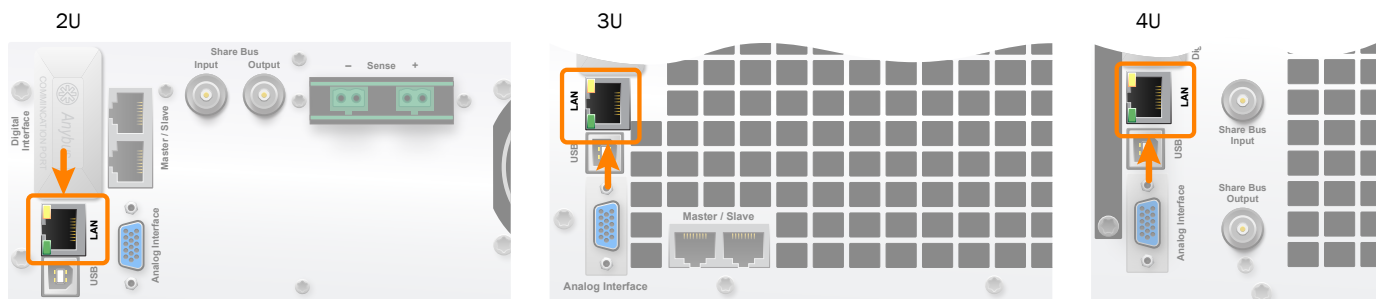
Using the Ethernet port, the system can be controlled using commands with Modbus RTU or SCPI protocols. The system will automatically detect the type of message, so there's no need to pre-configure which protocol will be used.

The network setup can be done manually using the on-board control panel or by DHCP. The transmission speed is set to **Auto negotiation** (using 10MBit/s or 100MBit/s). Duplex mode is always full duplex. For the network port setup refer to 5.5.6 Menu "Communication" (p 47).

9.3.4 Anybus Interfaces

All models of the 311 Series include built-in USB, Ethernet, and Anybus ports. The Anybus port supports optionally available interface modules as listed in the table below.

For technical details of the various modules see the 10 Programming Introduction (p 94) documentation.

Configuration settings for various modules are listed in 5.5.6 Menu "Communication" (p 47).

The diagrams here show one of the interfaces. The hardware connection will be different for different modules.
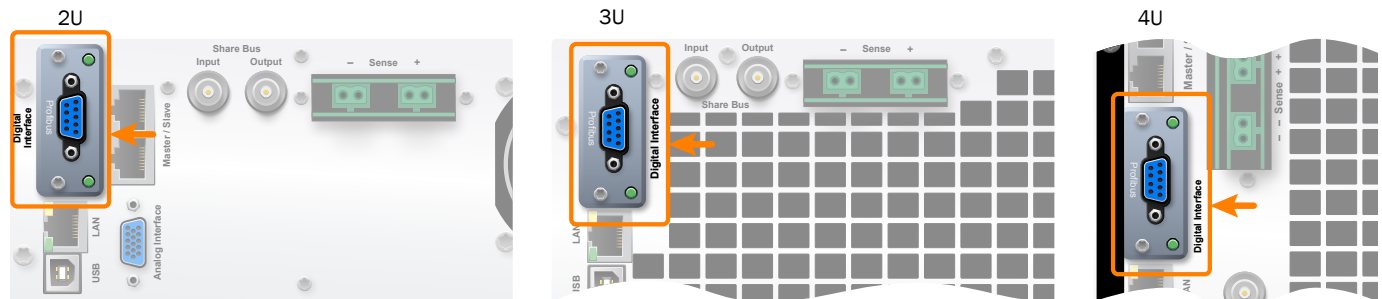
Part Number	Name	Description
MPW OPT3-001	IF-AB-RS232	RS 232, 1x Sub-D 9pole male (null modem)
MPW OPT3-002	IF-AB-PBUS	Profibus DP-V1 Slave, 1x Sub-D 9pole female
MPW OPT3-003	IF-AB-CANO	CANopen, 1x Sub-D 9pole male
MPW OPT3-004	IF-AB-MBUS1P	Modbus TCP, 1x RJ45
MPW OPT3-005	IF-AB-MBUS2P	Modbus TCP, 2x RJ45
MPW OPT3-006	IF-AB-ETH1P	Ethernet, 1x RJ45
MPW OPT3-007	IF-AB-ETH2P	Ethernet, 2x RJ45
MPW OPT3-008	IF-AB-PNET1P	ProfiNET IO, 1x RJ45
MPW OPT3-009	IF-AB-PNET2P	ProfiNET IO, 2x RJ45
MPW OPT3-010	IF-AB-CAN	CAN, 1x Sub-D 9pole male
MPW OPT3-011	IF-AB-ECT	EtherCAT, 2x RJ45

9.3.5 Programming

Programming concepts and protocol details for all built-in and Anybus interfaces are discussed in 10 Programming Introduction (p 94), 11 Modbus Protocol (p 104), and 12 SCPI protocol (p 129).

9.4 Remote Control with the Analog Interface

9.4.1 General

The built-in, galvanically isolated (up to 1500 V DC), 15-pole analog interface is located on the rear side of the unit and offers the following functions:

- Remote control of current, voltage and power
- Remote status monitoring (CC/CP, CV)
- Remote alarm monitoring (OT, OVP, PF)
- Remote monitoring of actual values
- Remote on/off switching of the DC output

Setting the three set values via the analog interface always takes place concurrently. This means that for example the voltage can not be set through the analog interface, and current and power set by the rotary knobs, or vice versa. The R-mode resistence can also be configured with the analog interface.

The OVP set value and other supervision (events) and alarm thresholds cannot be set via the analog interface, and therefore must be adjusted on the control panel before the analog interface is put in operation. Analog set values can be fed in by an external voltage or generated by the reference voltage on pin 3. As soon as remote control via the analog interface is activated, the values shown as set values on the display will be those provided by the interface.

The analog interface can be operated in the common voltage ranges 0–5 V and 0–10 V. In each case, they represent 0–100% of the nominal value (the nominal rating of the power supply). The selection of the voltage range can be done in the system setup. See 5.5.1.6 Settings > Analog Interface (p 44). The reference voltage sent out from pin 3 (VREF) will be adapted accordingly and is then:

- **0-5 V**: Reference voltage = 5 V, 0–5 V set values (VSEL, CSEL, PSEL, RSEL) correspond to 0–100% nominal values, 0–100% actual values correspond to 0–5 V at the actual value outputs (CMON, VMON).
- **0-10 V**: .Reference voltage = 10 V, 0–10 V set values (VSEL, CSEL, PSEL, RSEL) correspond to 0–100% nominal values, 0–100% actual values correspond to 0–10 V at the actual value outputs (CMON, VMON).

Input of excess set values (e.g. >5 V in selected 5 V range, or >10 V in the 10 V range) are clipped by setting the set value at 100%.

Before you begin, please read these important notes for use of the interface:

- Analog remote control of the system must be activated by switching pin "REMOTE" (5) first. The only exception is pin REM-SB, which can be used independently.
- Make sure that the hardware that will control the analog interface cannot supply voltage to the pins higher than specified (i.e. the 5 or 10 V limit).
- Set value inputs, such as VSEL, CSEL, PSEL, and RSEL must not be left unconnected (i.e. floating).
- It is always required to provide all set values at once. In case any of the set values is not used for adjustment, it can be tied to a known level you prefer, or routed to pin VREF, so it gives 100%.

> After powering the system and during the start phase, the analog interface signals have undefined states on the output pins. Those must be ignored until the system is ready to work.

> The analog interface is galvanically isolated from the DC output. Therefore do not connect any ground of the analog interface to the DC– or DC+ output, if not absolutely necessary.

9.4.2 Resolution

The analog interface is internally sampled and processed by a digital microcontroller. This causes a limited resolution of analog steps. The resolution is the same for set values (VSEL etc.) and actual values (VMON/CMON) and is 26,214 steps when working with the 10V range. Using the 5V range cuts the resolution by half. Due to tolerances, the truly achievable resolution may be slightly less.

9.4.3 Acknowledging alarms

System alarms are always indicated on the display, and some are also reported on the analog interface. There are fewer pins available than the number of alarms, so some pins can be configured to indicate specific alarms. See 5.5.1.6 Settings > Analog Interface (p 44).

The alarms MSP, OVP, OCP, and OPP have to be acknowledged after any of them occur. Acknowldgement is done with pin REM-SB switching the DC output off and on again with the pattern HIGH-LOW-HIGH edge with a minimum of 50ms for LOW (when using the default level setting for this pin). The same acknowldgement is required for PF and OT alarms when the related **Settings** > **DC output** > **State after PF alarm** or **State after OT alarm** are set to Off.

There is one exception — the SOVP (Safety OVP) alarm, which is only featured with the 60 V model of this series. This alarm can't be acknowledged, and requires to AC power-cycle the unit to reset it. The alarm can be monitored via the analog interface, however. It manifests by the alarms PF and OVP being signaled at the same time. To monitor for it, select the alarm indication on pin 6 to to detect signal PF, and select pin 14 to detect signal OVP.

9.4.4 Analog Interface Wiring

	Digital Input (DI)
	The internal circuit requires that a switch with low resistance should be used (relay, switch, circuit breaker etc.) in order to send a clean signal to the DGND. A digital output from a circuit or PLC may not be sufficient if not an "open collector".
	Digital Output (DO)
	A quasi open collector, realised as high resistance pull-up against the internal supply. In condition LOW it can carry no load, merely switch, as shown in the diagram with a relay as example.
	Analog Input (AI)
	High resistance input (impedance >40 k–.100 kΩ) for an OA circuit.
	Analog Output (AO)
	Output from an OA circuit, only minimally impedant. See specifications table below.

9.4.5 Analog Interface Specification

Pin	Name	Type[1]	Description	Default levels	Electrical specifications
1	VSEL	A-IN	Set voltage value	0–10 V or. 0–5 V correspond to 0..100% of U_{Nom}	Accuracy 0-5 V range: < 0.4% [5] Accuracy 0-10 V range: < 0.2% [5] Input impedance R_i >40 k–100 k
2	CSEL	A-IN	Set current value	0–10 V or. 0–5 V correspond to 0..100% of I_{Nom}	
3	VREF	A-OUT	Reference voltage	10 V or 5 V	Tolerance < 0.2% at I_{max} = +5 mA Short-circuit-proof against AGND
4	DGND	POT	Digital ground		For control and status signals
5	REMOTE	DI	Switching internal / remote control	Remote = LOW, U_{Low} <1 V Internal = HIGH, U_{High} >4 V Internal = Open	Voltage range = 0–30 V I_{Max} = -1 mA at 5 V $U_{LOW\ to\ HIGH\ typ.}$ = 3 V Rec'd sender: Open collector against DGND
6	ALARMS 1	DO	Overheating or power fail alarm	Alarm = HIGH, U_{High} > 4 V No alarm = LOW, U_{Low} <1 V	Quasi open collector with pull-up against Vcc [2] With 5 V on the pin max. flow +1 mA I_{Max} = -10 mA at U_{CE} = 0,3 V U_{Max} = 30 V Short-circuit-proof against DGND
7	RSEL	A-IN	Set internal resistance value	0–10 V or. 0–5 V correspond to 0..100% of R_{Max}	Accuracy 0-5 V range: < 0.4% [5] Accuracy 0-10 V range: < 0.2% [5] Input impedance R_i >40 k–100 k
8	PSEL	A-IN	Set power value	0–10 V or. 0–5 V correspond to 0..100% of P_{Nom}	
9	VMON	A-OUT	Actual voltage	0–10 V or. 0–5 V correspond to 0..100% of U_{Nom}	Accuracy 0-5 V range: < 0.4% [5] Accuracy 0-10 V range: < 0.2% [5] at I_{Max} = +2 mA Short-circuit-proof against AGND
10	CMON	A-OUT	Actual current	0–10 V or. 0–5 V correspond to 0..100% of I_{Nom}	
11	AGND	POT	Analog ground		For xSEL, xMON and VREF
12	R-ACTIVE	DI	R mode on / off	Off = LOW, U_{Low} <1 V On = HIGH, U_{High} >4 V On = Open	Voltage range = 0–30 V I_{Max} = -1 mA bei 5 V $U_{LOW\ to\ HIGH\ typ.}$ = 3 V Rec'd sender: Open collector against DGND
13	REM-SB	DI	DC output OFF (DC output ON) (ACK alarms [4])	Off = LOW, U_{Low} <1 V On= HIGH, U_{High} >4 V On = Open	Voltage range = 0–30 V I_{Max} = +1 mA at 5 V Rec'd sender: Open collector against DGND
14	ALARMS 2	DO	Overvoltage alarm Overcurrent alarm Overpower alarm	Alarm = HIGH, U_{High} > 4 V No alarm = LOW, U_{Low} <1 V	Quasi open collector with pull-up against Vcc [2] With 5 V on the pin max. flow +1 mA I_{Max} = -10 mA at U_{CE} = 0,3 V, U_{Max} = 30 V Short-circuit-proof against DGND
15	STATUS[3]	DO	Constant voltage regulation active	CV = LOW, U_{Low} <1 V CC/CP/CR = HIGH, U_{High} >4 V	
			DC output	Off = LOW, U_{Low} <1 V On = HIGH, U_{High} >4 V	

[1] A-IN, A-OUT = Analog Output, DI = Digital Input, DO = Digital Output, POT = Potential
[2] Internal Vcc approx. 10 V
[3] Only one of both signals possible
[4] Only during remote control
[5] The error of an analog input/output adds to the general error of the related value on the DC output of the unit

9.4.6 DC Output On/Off using REM-SB

Analog connector pin REM-SB can be used to switch the DC output of the unit off and on. However, the DC output must be switched on the first time using either the control panel switch, or a digital interface remote command. After that, depending on the settings, the REM-SB pin can be used to switch the DC only off, or switch the DC off and on again.

Enabling DC output when the switch is connected requires the unit be in remote control mode. However, even without remote control being active, in both manual control and remote control modes, this switch circuit can be used to block the DC terminal from being switched on.

It is recommended that a low resistance contact such as a switch, relay, or transistor is used to switch the pin to ground (DGND).
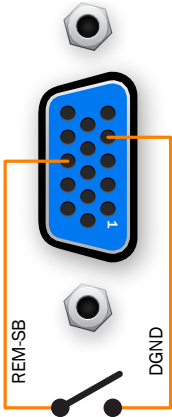
> ⓘ A digital output, e.g. from a PLC, may be unable to cleanly pull down the pin as it may not be of low enough resistance. Check the specification of the controller. Also see the pin diagrams above.

When remote control is activate

During remote control via analog interface, only pin REM-SB determines the state of the DC output, according to the levels definitions in 9.4.5 Analog Interface Specification (p 91). The function logic and the default levels can be inverted by a parameter in the setup menu of the unit. See 5.5.1.6 Settings > Analog Interface (p 44).

> ⓘ BE AWARE — If REM-SB is not connected, or the connected contact is open, the pin will be HIGH. With parameter **Analog interface REM-SB** being set to **Normal**, this results in the DC output being on. So, when activating remote control, the DC output will instantly switch on.

When remote control is not active

When the system is in a manual mode, pin REM-SB can serve as a DC lock, preventing the DC output from being switched on by any means. This results in the following possible situations:

DC output	+	Level on pin REM-SB	+	Parameter "Analog interface Rem-SB"	➜	Behavior
is off	+	HIGH	+	Normal	➜	The DC output isn't locked. It can be switched on by pushbutton "On/Off" (front panel), or via digital interface command.
		LOW	+	Inverted		
	+	HIGH	+	Inverted	➜	The DC output is locked. It cannot be switched on by pushbutton "On/Off" (front panel), or via digital interface command. When trying to switch DC ouput on, an an error message will be generated.
		LOW	+	Normal		

When the DC output is already switched on, toggling the pin will switch the DC output off, similar to what it does in analog remote control:

DC output	→	Level on pin REM-SB	+	Parameter "Analog interface Rem-SB"	→	Behavior
is on	→	HIGH	+	Normal	→	The DC output remains on, nothing is locked. It can be switched on or off by pushbutton or digital command.
		LOW	+	Inverted		
	→	HIGH	+	Inverted	→	The DC output will be switched off and locked. Later it can be switched on again by toggling the pin. During lock, pushbutton or digital command can delete the request to switch on by pin.
		LOW	+	Normal		

9.4.7 Remote Control of Current and Power

The set values VSEL and CSEL are generated from the reference voltage VREF, using potentiometers for each. Hence the power supply can selectively work in current limiting or power limiting mode. According to the specification of maximum 5 mA for the VREF output, potentiometers of at least 10 kΩ must be used.

The power set value PSEL is always tied to VREF and will thus be permanently 100%.

If the control voltage is fed from an external source, it is necessary to consider the input voltage ranges for set values (0–5 V or 0–10 V). Keep in mind that using the 0–5 V range for 0–100% cuts the effective resolution in half.

9.4.8 Reading Values

The DC output values of current and voltage can be monitored through the analog interface using a standard multimeter or anything else that records analog signals.

Control with potentiometers
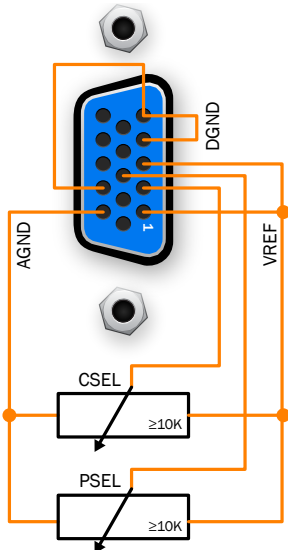
Control with external voltage sources
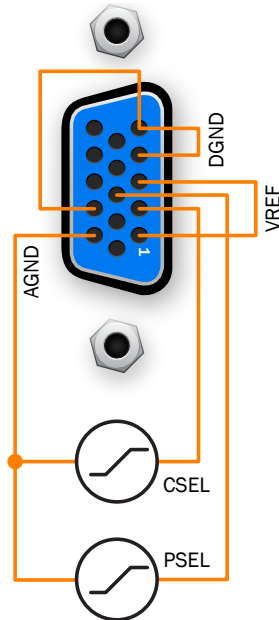
Reading actual values
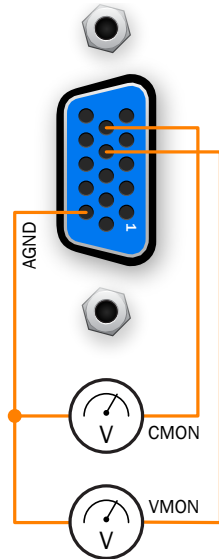
10 Programming Introduction

This section include general concepts and details to be aware of when programming and running remote control.

10.1 Remote Communication Interfaces

The mPower 311 Series supports built-in digital interfaces of USB, Ethernet, and a variety of others through user-installed Anybus modules. See 9.3 Remote Control with a Digital Interface (p 87).

On these interfaces, essentially two protocols are supported: Modbus and SCPI. The command messges of these protocols may be wrapped within other protocols to create compatibility with other field buses.

The table below identifies which interfaces support which protocols.

Interface	Modbus RTU	Modbus TCP	SCPI	Notes
USB (Type B)	Yes	x	Yes	
Built-in Ethernet	Yes	Yes	Yes	
Built-in GPIB	x	x	Yes	
IF-AB-CAN : CAN	PDU[1]	x	x	§15 CAN (p 185)
IF-AB-CANO : CANopen	PDU[1]	x	x	§14 CANopen (p 182)
IF-AB-RS232 : RS232	Yes	x	Yes	
IF-AB-PBUS : Profibus	PDU[1]	x	x	§13 Profibus & Profinet (p 176)
IF-AB-PNET1P : ProfiNet	PDU[1]	x	x	§13 Profibus & Profinet (p 176)
IF-AB-PNET2P : ProfiNet	PDU[1]	x	x	§13 Profibus & Profinet (p 176)
IF-AB-ETH1P : Ethernet	Yes	Yes	Yes	
IF-AB-ETH2P : Ethernet	Yes	Yes	Yes	
IF-AB-MBUS1P : Modbus TCP	x	Yes	x	
IF-AB-MBUS2P : Modbus TCP	x	Yes	x	
IF-AB-ECT : EtherCAT	PDU[1]	x	x	§16 EtherCAT (p 193)

1 — Modbus PDUs/registers are used as the core command payload, but the communication wrappers are different.

> When using Modbus on a standard Ethernet interface, use the Modbus RTU format on any available TCP port other than 502. To use Modbus TCP, port 502 must be used.

10.2 USB Ports

All mPower 311 systems include a USB Type B port on the rear panel, and a USB Type A port on the front panel.

The rear USB Type B port is intended for full programmatic control of the system. Either of the Modbus RTU or SCPI protocols can be used. If you plan to use this port for remote control of the power supply, you can skip the discussions below for Anybus.

Type B   Type A

The front USB Type A port is not used for remote control purposes. Rather, it is for file access to a USB thumb drive.
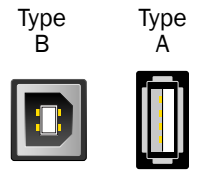
10.3 Ethernet

Ethernet can be utilized in one of two access modes: HTTP to access a basic web browser interface, or plain TCP for Modbus and SCPI commands.

10.3.1 Access via HTTP

The built-in Ethernet port, and Ethernet-based Anybus modules offer a web user interface. The web UI is accessible through common web browsers by simply entering the IP address of the power supply (or the DNS address if your IT infrastructure has assigned it one).

In addition to presenting some configuration tools, the website gives the user full control over the system through a field to manually enter and execute SCPI commands. This interface primarily serves to help with command testing purposes. It's not intended to be a general purpose dashboard or control panel.

The default IP is 198.168.0.2. All network parameters for the system/network interface can be changed, or reset to defaults, in the Settings menu of the system (locally or by remote software). As is standard for HTTP, the web interface uses port 80.

The currently active IP address, along with other network related parameters such as gateway, subnet mask, DNS address, and MAC address can also be adjusted from the Settings menu. See 5.5.6 Menu "Communication" (p 47).

The CONFIGURATION page of the web interface allows for setting up network-specific parameters. This requires prior activation of remote control by command SYST:LOCK ON.

10.3.2 Access via TCP

All Anybus Ethernet modules, as well as the integrated port of 311 Series offer TCP access via the default port 5025 (which is user adjustable). TCP data transfer can be used for communication using SCPI or Modbus RTU (a.k.a. Modbus RTU over Ethernet). For the Modbus TCP protocol (which is not the same as Modbus over Ethernet), port 502 is used (and is not user adjustable).

The port and other network related parameters can be adjusted in the system's Settings menu, remotely via USB, or through the web interface.

A TCP/IP socket connection (IP:port) is intended for normal remote control access to the system when using an Ethernet interface.

> The TCP connection can be automatically disconnected by the system after a certain amount of time elapses with no data transmission. This is due to an adjustable timeout (default: 5 s). There is also another related option named **TCP keep-alive** which, if activated, makes the timeout ineffective, unless **TCP keep-alive** is not configured in the network.

10.4 Anybus Modules

This expansion slot accepts a number of field-replaceable Anybus Modules. These modules are described below.

Type / Name	Connectors	LED indication		Front view
CAN 2.0B / IF-AB-CAN	1x Sub-D 9pole, male	RUN	Indicates data traffic (green, flickering)	
		ERR	Will be lit (green) while a communication error is present.	
CANopen / IF-AB-CANO	1x Sub-D 9pole, male	RUN	Indicates status with flash sequences according to DR303-3 (CiA)	
		ERR	Indicates status with flash sequences according to DR303-3 (CiA)	
RS 232 / IF-AB-RS232	1x Sub-D 9pole, male, for null modem cable	PWR	Module is powered	
Profibus / IF-AB-PBUS	DP-V1 Slave, 1x Sub-D 9pole, female	OP	Operation mode: on (green) = Connection established flashing (green) = Ready flashing (red, 1x) = Parameter error flashing (red, 2x) = Profibus error	
		ST	Status off = Not Initialized on (green) = Initialized flashing (green) = Extended diagnosis on (red) = Exception error	
Ethernet / IF-AB-ETH1P	1x RJ45	NS	Network status: flashing (green) = default, can be ignored on (red) = Double IP, fatal error flashing (red) = Connection time-out	
		MS	Module status: flashing (green) = default, can be ignored on (red) = Exception error flashing (red) = Recoverable error	
Ethernet / IF-AB-ETH2P	2x RJ45	LINK	Connection status: on (green) = Connection established flashing (green) = Data traffic	

Type / Name	Connectors	LED indication		Front view
ProfiNET IO / IF-AB-PNET1P	1x RJ45	NS	Network status: on (green) = Online with controller in RUN flashing (green) = Controller in STOP	
		MS	Module status: on (green) = Everything OK on (red) = Exception error flashing (red, 1x) = Config error flashing (red, 2x) = IP address not set flashing (red, 3x) = Station name not set flashing (red, 4x) = Internal error	
ProfiNET IO / IF-AB-PNET2P	2x RJ45			
		LINK	Connection status: on (green) = Connection established flashing (green) = Data traffic	
EtherCAT Slave / IF-AB-ECT	2x RJ45	RUN	Indicates status with flash sequences according to DR303-3 (CiA)	
		ERR	Indicates status with flash sequences according to DR303-3 (CiA)	
Modbus TCP / IF-AB-MBUS1P	1x RJ45	NS	Network status: on (green) = Module active flashing (green) = Module waiting for connection on (red) = Double IP or fatal error flashing (red) = Process time-out	
		MS	Module status: on (green) = Everything OK on (red) = Primary error flashing (red) = Secondary error	
Modbus TCP / IF-AB-MBUS2P	2x RJ45	LINK	Connection status: on (green) = Connection established flashing (green) = Data traffic	

The CANopen module IF-AB-CANO does not feature an internal termination resistor. Thus the required bus termination resistor has to be applied by the user according to the CAN bus requirements.

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10.4.1 Anybus Startup Time

When integrating a unit with an Anybus interface into an existing network or field bus, please note:

- All modules, but especially the Ethernet types which provide a website, require some startup time each time the system is powered, which may delay their network readiness. Often, an interface module is ready for communication within the time the rest of the system needs to startup, but not always. The wait time before a system is ready will have to be determined empirically based on your product and module combination.
- A readiness for operation may be indicated by a module, which has an LED for that purpose, before the needed startup time has run out. If that happens, trying to contact an Ethernet module in order to access the website may result in a time-out error reported by the browser. Just wait a little longer, and try again.

For any automated scripting, a startup ready interval should be determined through testing. This time interval should be allowed to pass before sending commands to the unit.

10.4.2 Anybus Installation

The mechanical installation of the Anybus modules is described in the *mPower 311 Installation Guide*. This Guide provides details about the specific commands which mPower DC products make use of.

Broader background information about the protocols and inter-connectivity of field buses and networks supported by the modules (Modbus, CAN, ProfiNet, etc.) can be found in publicly available documentation and similar sources. Begin by trying to locate the web sites of the organizations which manage the standards.

10.4.3 Anybus Connection Topology

The Ethernet based modules for standard LAN, Modbus TCP and Profinet/IO are also available in a version with two ports. These provide the possibility to connect multiple systems in a linear topology and even to build a system level ring for extended safety against interruption. External switches can be eliminated, and the many long network cables, like when having a star-shaped topology, can be reduced to a minimum. These differences may or may not be advantagous to your setup, but might be worth considering when planning for module installation.

The EtherCAT module, however, has two ports by default, and always builds a ring because of the standard setup within EtherCAT systems. It is Ethernet based at the hardware layer, but cannot be considered a typical LAN port.

10.5 Remote Communication Sources

After connecting a power supply digital interface to a computer, remote software access can be gained in several ways.

- The control and monitoring software EA Power Control, available through Marway.
- LabView VIs, available through Marway.
- A custom programmed application created by the end user or contractor.
- General purpose third-party software, like a terminal program that can send text messages (suitable for SCPI).
- Standardised third-party software for CAN, CANopen, Profibus, or EtherCAT etc.

10.6 Remote Communication Protocols

All mPower DC 3 Series power supplies support two command protocols: Modbus and SCPI.

Some form of the Modbus command protocol can be used on every communication interface available on the mPower DC 3 Series systems. SCPI can be used on most, but not all interfaces. The exact compatibility between protocols and interfaces is listed in .

With Modbus, mPower DC uses the two standardized variations Modbus RTU and Modbus TCP, and then a subset form of the traditional Modbus RTU in conjunction with some of the other message protcols (CAN, Profibus, etc.). Each variation shares the same core register commands, but differs in its message format.

The mPower DC control system does not require that the remote protocol be declared. There is no "mode" for Modbus vs. SCPI as the remote protocol. Indeed, on interfaces which are compatible with both Modbus and SCPI, commands from either protocol could technically be arbitrarily intermixed.

10.6.1 Protocol Detection

On many interfaces, the mPower control system uses the first byte of the remote command message to automatically distinguish the message as being either Modbus RTU or SCPI. A Modbus RTU message begins with the slave address (which is a single byte). In all mPower DC 3 Series, this address is 0x00. The Modbus RTU protocol uses the address of 0x00 as a broadcast address. However, for mPower DC products, they will not be on a true "bus" (i.e. RS-485). Since communication will be over USB, some form of Ethernet, or RS232, the communication is always "point-to-point" from the remote control source to the power supply.

For the built-in USB and Ethernet (not on port 502), the internal system counts on the the first byte as 0x00 to indicate the message will be a Modbus RTU. A value between 0x01 and 0x29 in the first byte will cause a Modbus communication error, whereas starting with 0x2A (ASCII character *), the message will be considered a text message, and interpreted as a SCPI command.

For Anybus interfaces designed for specific protocols, they do not depend on this first byte distinction.

> ❗ The Modbus RTU slave address is always 0. This address cannot be changed.

As a result of mPower's auto-protocol-detection scheme, SCPI cannot be used on Ethernet TCP port 502. Since Modbus TCP requires a wrapper in which the first byte cannot be 0x00, the system cannot distinguish Modbus TCP from SCPI. Therefore, in the mPower system, port 502 (which is an IANA reserved port for Modbus TCP), is assumed to always be receiving Modbus TCP traffic. This applies also to the IF-AB-MBUS1P and IF-AB-MBUS2P Anybus mdules—even though these are Ethernet ports, SCPI cannot be used.

10.7 Control Location

Since the power supply can be controlled from the onboard controls, and from multiple remote control interfaces, there is the concept of control location—that is, the location, or source, of where control is being managed. The power supply software concerns itself with this concept by managing whether control is allowed from the local controls only, from remote controls only, or from either location. In order to run programmed sequences, remote control must be allowed.

See the discussion in .

10.8 Command Message Timing

Program code from a PC or PLC can send commands to a power supply faster than those commands can be processed. It is the responsibility of the program code to make sure that the power supply is ready for each command. This often involves creating arbitrary delays in the program code between commands. How long those delays need to be sometimes takes experimentation. However, there are some guidelines to help establish a starting point.

10.8.1 Reading response time

There are generally two methods of communicating with a port:

1) Open port > write query to port > read response from port > close port

2) Open port > write query to port > read response from port > repeat (write-read) X times > close port

Each method has advantages and disadvantages. The primary advantage of method 2 over method 1 is that writing and reading X times within one session is expected to take less time compared to a full session per cycle. The primary advantage of method 1 over method 2 is that closing the port also closes the connection which makes communication more stable—especially if the time between two write-read cycles is very long.

The values in the table below have been acquired using method 1.

Series	Protocol	Typical response times		
		USB	Ethernet	CAN/CANopen
mPower 311 Series	SCPI	< 5 ms	< 5 ms	—
	Modbus	< 5 ms	< 5 ms	< 3 ms

10.8.2 Writing response time

Unlike reading, there's not a predictable response time for write commands. Each command performs unique tasks in the power supply, and some take longer to accomplish than others. Timing is further complicated by the interface used as each operates at various speeds, with varying overhead.

When developing code to automate process sequences, it will be necessary to experiment with the product, computer, and communication bus together to acquire repeatable timing data.

10.8.3 Time between messages

The minimum time between two messages shown below, primarily depends on the typical read time as discussed above.

Series	Minimum delay between messages	Recommended delay between messages
mPower 311 Series	5 ms	USB / CAN / CANopen: 10-15 ms Everything else: 10 ms

10.9 Connection Timeout

Socket connection to systems which support an Ethernet port have a connection timeout. This variable and user-adjustable timeout (see Operating Guide for the system) closes the socket connection automatically on the system side if there was no communication going on between system and controlling unit (PC, PLC etc.) for the adjusted time. After the socket has been closed, connection can be established again anytime. The timeout becomes automatically ineffective if **TCP keep-alive** is activated, and supported in the network.

10.10 Fragmented Messages

With all communication interfaces, it is possible for the host computer (PC/PLC) to send partial messages, or messages with timing gaps between bytes. When this happens, what the power supply sees is a partial command, a delay, and the rest of the command is received. Since there is no requirement for a termination byte in Modbus or SCPI, the power supply could interpret these two data burts as two commands rather than one. Of course, neither would be recognizable, and the system will respond with errors.

How long of a delay between bytes is a problem? To help create some predictability in these scenarios, a variable timeout named **Com Timeout** is available. This timeout defines the maximum time delay tolerated between data burts. As long as gaps between bytes is less than this timeout, the power supply will continue to accept data as a single message.

If the communication between the host and power supply experiences communication errors, and fragmented messages are suspected, the timeout can be used. Increase the value a little at a time until reliable communications are restored. It's advised to keep the timeout setting as low as possible, because at the end of every message, the timeout has to elapse before the system can process the command.

When using SCPI, sending an additional termination character (LF, CR, or CRLF), which is not required but accepted, will terminate the timeout immediately and let the system consider the message as completely received, so it can process.

10.11 Resolution and Tolerances

When setting output and limit values for voltage, current, power, and resistance, the control system's resolution and tolerance have to be allowed for. Resolution affects the realistic incremental steps which values can be set to. Tolerance informs the amount of inaccuracy which can be expected.

In all mPower 311 systems, there is an internal resolution of 26,214. This means that a value such as the DC output volts has 26,214 possible values (or steps) between 0 volts and the maximum nominal rating of volts for the system. A system which has a nominal rating of 80 volts has 26,214 possible steps between 0 and 80. A system which has a nominal rating of 750 volts has 26,214 possible steps between 0 to 750. For the 80 V system, every "step" in value is an increment of 80 V ÷ 26214 steps, or 0.00305 V/step. For the 750 V system, each step is 750 ÷ 26214 steps, or 0.02861 V/step.

Let's say it was desired to set the output of each system to 10.00 Vdc. For the 80 V unit, 10.00 V ÷ 0.00305 V/step results in 3,278.68 steps. A fraction of a step is not possible. So, the system is capable of either 3,278 or 3,279 steps.

Multiplied back out, we end up with either 9.9979 Vdc or 10.00095 Vdc. For the 750 V unit, using the same math, the two possible results are 9.98489 Vdc or 10.0135 Vdc. Obviously these are very small differences, but differences nonetheless that you might see between setting and reading values.

Further, no control system is perfectly accurate, or perfectly repeatable. Every system has some plus or minus fluctuation of the actual result. The spec sheet for a given unit may indicate that the voltage tolerance is 0.1% (of nominal rating). This means that for an 80 Vdc system, setting any given output target can result in a value 0.1% x 80 V, or 80 mV. Therefore, setting a target of 24.00 Vdc means the actual measured value could be between 23.92 V and 24.08 V.

Both resolution and tolerance influence the final values, and explain why you will see small differences in set value targets and the actual measurements when reading values.

10.12 Function Generator Slope

With the arbitrary function generator, all sequence points have an AC part, which is used to generate sine waves, and a DC part with start and end values. When the DC start and end values are different, a slope is generated. That slope can be applied to voltage or to current.

The slope (ΔU/t or ΔI/t) must meet a specific minimum value.

> **!** Minimum slope = 0.000725 x Nominal Rated Voltage (or current) ÷ seconds

Before programming a sequence of points, the slope of those points should be calculated to make sure they meet the minumum slope. For the specific nominal values of the mPower unit to be used, perform the above calculation for minimum slope. Then, verify that the desired sequence of points is compatible.

Let's look at an example.

Using an mPower 311-54-0750-120-004 unit (750 V and 120 A rating), a rising ramp on the current is desired. The minimum slope calculates as: ΔI/t = 0.000725 * 120 A = 87.0 mA/s.

If we wanted to ramp 0–75 A in 60 seconds, we would take 75 amps ÷ 60 seconds which is 1.25 A/s or 125 mA/s. This is well above the mimum slope.

If we wanted to ramp 0–75 A in 20 minutes, we would take 75 amps ÷ (20 * 60) seconds which is 0.0625 A/s or 62.5 mA/s. This is less than our target of 87.0 mA/s for the mimum slope. This ramp would not be possible using the function generator.

Another way to calculate this, is to determine the maximum time for a certain ΔU or ΔI.

> **!** Maximum ramp time = Change in Voltage (or current) ÷ Minimum Slope

For our 75 amp slope above, we calculate 75 A ÷ 0.087 A/s which is 862.07 seconds. If we wanted a 1,000 second slope duration, we would know that's too long.

What this tells us is that long ramp times over many minutes or hours are not possible using the built-in calculations of the function generator. However there is another way—which is using software to programmatically generate a number of steps over time.

10.12.1 Programmatic Slope

In the section above, we established how to determine the limits of using the function generator to create a slope in voltage or current values over time. We also established that the function generator is not suitable for slopes lasting long periods of time (many minutes to hours). However, we can create long slopes by using programming to determine output values over any time span desired.

Here the effective resolution, as discussed in 10.11 Resolution and Tolerances (p 101), comes into play. The unit from the example above has an effective resolution of 26,214 steps which represents 0–100% = 0–120 A when working with current. For a ramp of 0–75 A, it would then be 16,384 steps. If we wanted to generate the 0–75 A ramp over 10 hours, we could set a new value every 10 h ÷ 16,384 = ~2.2 seconds, with the value increase every step of 75 A ÷ 16,384 = ~4.5 mA. This is a very small step which cannot be discerned from system tolerances. Therefore, it may be more reasonable to use a longer period per step, and a larger increment per step.

Whatever the numbers used, this approach is how to create long slope periods which are beyond the limits of the internal function generator.

10.13 Class Assignments

For distinction of different product series, a system class number is assigned to every series. It can be read from the system (Modbus register 0, or SCPI command `SYSTEM:DEVice:CLASS?`) and used to distinguish products when scanning a network for mPower units.

Class	Assigned to series
30	mPower 300 Series 1U models
33	mPower 310 Series 2U/3U models
45	mPower 320 Series
68	mPower 311 Series (before 10/2021)
82	mPower 311 Series (from 10/2021)

11 Modbus Protocol

11.1 Firmware Changes

> ❗ For those familiar with older mPower series, there has been an update to allow the mPower firmware to be more compliant with Modbus standards. This section details those changes.

11.1.1 Message First Byte

Prior to firmware releases starting in late 2020, the first byte of the Modbus message had to be 0x00. This is the Modbus address field, and while intended to allow multiple devices on a Modbus bus, the mPower units are always point-to-point with a remote host (computer of PLC). The address byte was required to be 0x00 to allow the software to perform automated protocol detection between Modbus and SCPI messages as discussed in 10.6.1 Protocol Detection (p 99).

This 0x00 requirement has changed.

A new configuration setting in register 10013 toggles a compliance mode between **Limited** and **Full**.

The mode **Limited** leaves the behavior of the software the same as it has been in the past. Therefore, this is the default setting to retain compatibility with programming written for previous systems. Modbus messages must start with 0x00.

The mode **Full** allows the first byte to be 0x00 or 0x01 (no other values are valid). Since we still do not need to support multiple addresses, we need only 0x01 to improve compatibility with the Modbus standard. When in **Full** mode, the address 0x00 or 0x01 can be used, and whichever one is used will be reflected in the Modbus response message.

11.1.2 Read/Write Coil

When compliance is set to **Full** there is an additional change in that the behavior of READ coil is standards compliant.

In previous versions, the read coil would always return 16 bits. Now it correctly returns a single bit. As a result, writing coils is also updated to use single bit data rather than the legacy 16-bit data type.

11.2 Modbus Overview

One advantage in using the Modbus command protocol is that some form of the commands can be used on every other communication interface available on the mPower DC 3 Series systems, except for the GPIB interface on the 310 Series. (GPIB uses only SCPI.) So, having learned Modbus, and its registers in particular, that knowledge is useful for almost all other interfaces, and all other mPower product series.

Keep in mind that for the mPower products, when we talk about Modbus, there are two types: Modbus RTU and Modbus TCP. Modbus RTU is the traditional standard. Modbus TCP is a modified form.

This section starts off with a number of topics which apply to all uses of Modbus before taking a closer look at the traditional Modbus RTU protocol, the Modbus TCP protocol, and some register-specific notes.

A detailed listing of all registers is included in a separate PDF document *mPower-311--Series-Modbus-Register-List* available on our website.

11.2.1 Modbus RTU

The traditional Modbus RTU message consists of hexadecimal bytes in three segments called the Address, the Protocol Data Unit (PDU), and the CRC Checksum. The PDU is made up of sub-elements starting with the function code (FC), and then varies depending on the message purpose.

For Modbus RTU, all of these traditional elements are used. For example, here's the Modbus RTU message format to write a single register. Details of the message format are covered in 11.7 Modbus RTU in Detail (p 109).

Review the table in 10.1 Remote Communication Interfaces (p 94) to identify which interfaces that Modbus RTU can be used with.

| Address | PDU (protocol data unit) | | | CRC |
	Func. Code	Start register	Data word	
0x00	0x06	0..65535	Value to write	Checksum Modbus-CRC16

For mPower DC products, the slave address (first byte) must always be 0x00. The mPower control system uses the first byte to auto-distinguish the message as being either Modbus or SCPI. A value between 0x01 and 0x29 in the first byte will cause a Modbus communication error, whereas starting with 0x2A (ASCII character *), the message will be considered a text message, and therefore a SCPI command. See 10.6.1 Protocol Detection (p 99) for additional details.

11.2.2 Modbus TCP

For Modbus TCP, the CRC checksum is removed, and an additional message header is added. This example shows an arbitrary transaction identification of 0x4711. The rest of the Modbus TCP message is the same as Modbus RTU, except for eliminating the checksum. Information about the header can be found in 11.8 Modbus TCP in detail (p 118).

Review the table in 10.1 Remote Communication Interfaces (p 94) to identify which interfaces that Modbus TCP can be used with.

| MBAP Header | Address | PDU (protocol data unit) | | |
		Func. Code	Start register	Data word
0x4711 0x0000 0x0006	0x00	0x06	0..65535	Value to write

11.2.3 Modbus for other Interfaces

While Modbus was developed for use with basic serial interfaces, the command set of the mPower Modbus protocol has been adapted to other field bus protocols. Elements of the Modbus PDU (described above), particularly the registers, are used in various ways with a distinct wrapping protocol. This still requires understanding the Modbus registers, and how data is defined and structured for Modbus messages.

The separate Registers List document, and section in this document explaining the Modbus protocol will be useful when using CAN-, Profibus-, and EtherCAT-based connectivity.

11.3 Set Value Resolution

When reading or writing set values, the numeric value is always a percent of the power supply's nominal rating (e.g. 80 V, 40A, 1000W). The percent is represented in hexadecimal where 0x0000 = 0% and 0xCCCC = 100%.

Note however, that some numeric values can be more than 100% of the nominal rating. For example, the voltage, current, and power set values can be up to 102% of the nominal rating. Therefore, for these registers, the acceptable maximum value is more than 0xCCCC (100%), and is actually 0xD0E5 (102%).

Similarly, the threshold alarms can be up to 110% of the ratings. Therefore, 0xE147 is the maximum acceptable value When reading the actual voltage, current, or power registers can be as high as 125% of the nominal rating (0xFFFF).

All numeric values have ranges, and many have ranges which exceed 100% nominal ratings. The register reference will detail the exact range and maximum hexadecimal value.

> **(!)** All set values are not only limited by the unit's nominal values, but are also limited by Limits settings. Just as they would be when manually entering values, set values sent to registers which exceed the Limits settings are rejected by the power supply. It is good practice to read back the value after setting Limits to verify that the value was accepted and stored.

11.3.1 Hex Percent and Decimal Value Conversion

Real values have to be translated to percent values before transmitting them to the system. Also, percent values read from the system are usually translated into real values in order to process them further (in the program code managing the power supply). As described in the section above, 0xCCCC (hex) = 52,428 (decimal) = 100% nominal value (U, I, P)

Translation is done by using these formulas in your software:

Percent hex value to decimal real value	Decimal real value to percent hex value
$$\text{Real value} = \frac{\text{Rated value} * \text{percent value}}{52428}$$ Example: The nominal voltage of your unit is 80 V and actual voltage was read as 0x2454 (decimal: 9300). According to the formula above, the real actual value will be (80 * 9300) / 52428 = 14,19 V.	$$\text{Percent value} = \frac{52428 * \text{real value}}{\text{Rated value}}$$ Example: the power set value shall be 3150 W, the power rating of your unit is 3500 W. According to the formula above we get a power set value of (52428 * 3150) / 3500 = 47185 = 0xB851.

11.4 USB Port Communications

Before a computer can be used to remote control the power supply through the USB port, whether through the EA Power Control software, LabView, or hand written scripts, the computer must have the PSI10000 USB driver.

See the *mPower 311 Installation Guide* for USB driver installation information.

After a successful USB driver installation in the PC/PLC, and connecting to the power supply, the system is ready for access. In Windows, the USB connection will be accessed as a COM port (which is visible in the System Manager control panel). The driver is based upon a standardized CDC driver (Communications System Class), and there's no need for configuration. The typical USB serial settings are not effective and are ignored.

To communicate using Modbus requires software on the PC side which is able to open a COM port, then both receive and send binary messages in hexadecimal format. This is generally done through end-user custom programming. There are also several general purpose packages which do this, and even some Modbus-aware software packages which can help with some message translation tasks. (Do an internet search for "Modbus rtu terminal software" to find options.)

> - In order to use remote control to change values, or switch the DC output on or off, remote control must first be activated—either with a remote command, or from the control panel **Menu**.
> - Remember that remote control may be blocked. See 9.2 Control Locations (p 86).

11.5 Ethernet / Anybus Communications

Except for RS-232 and USB (which use Modbus RTU), the core command payload is based on the Modbus registers. The specific field bus or network type (Modbus TCP, CAN, EtherCAT, Profibus, etc.) requires a message format unique to the interface protocol being used. To use these interfaces with Modbus-style commands, you will need to understand the Modbus PDU (not RTU) data structure, and then the distinct adaptations of the communication protocol you plan to use—each of which is described in a later sections of this Guide (Profibus, CAN, EtherCAT, etc).

Have a look again at 11.2.1 Modbus RTU (p 105) and 11.2.2 Modbus TCP (p 105), and notice how the PDU section of the message is the same in each. This PDU section is what is typically common on all interfaces even though there will be other details to the complete message format unique to each protocol.

11.6 Reading Register Lists

Along with this programming guide, there is a register list for the 311 Series as a separate PDF file. The list gives an overview of the features available to remote programming when using Modbus. The list is also a reference when controlling a unit using another field bus (CAN, CANopen, Profibus, Profinet, EtherCAT) or accessing it in programming environments like LabView or MatLab.

The list explains how the data in a binary message has to be interpreted or how a "register" with CANopen, or an "index" as it is called in EtherCAT, is specified. Even when not using pure Modbus RTU, the list is necessary to help implement remote communication within custom software applications. Programmers working with SCPI usually do not need these lists. Later in this document, the SCPI commands are referenced in a separate chapter.

11.6.1 Function Columns

The headers of the 5 columns next to the Modbus address column contain the names and codes of the supported Modbus functions. An x in these columns marks the assignment of a register to any of the functions. For example, the coil registers are usually writable and readable, so they're assigned to **Read Coils (0x01)** and **Write Single Coil (0x05)**.

11.6.2 Data type Column

Data type	Length	
char	1 Byte	Single byte, used for strings
uint(8)	1 Byte	Single byte
uint(16)	2 Bytes	Double byte, a word or 16bit integer
uint(32)	4 Bytes	Double word, a long or 32bit integer
float	4 Bytes	Floating point value according to IEEE745 standard

11.6.3 Access Column

This column defines whether the access is read only, write only, or read/write.

R = Register is read only

W = Register is write only, and would not return a reasonable value when read from

RW = Register can be read or written

> **!** Writing to a register which allows write access (W, RW) is only possible during remote control. In other words, there is no touch panel way to write values to the register.

11.6.4 Number of registers Column

With Modbus, a register always has a length of 2 bytes or a multiple of 2 bytes. This column tells how many 2-byte values are used by the register. The value is always half of the value in the **Data length in bytes** column.

11.6.5 Data Column

This column has additional information about the data which can be written to or read from the register. Two, four, or more bytes can be interpreted in different ways, depending on data type and content.

11.6.6 Profibus/Profinet Slot & Index Columns

These columns are needed by Profibus/Profinet programmers to link the registers in the register list via **slot** and **index** to data blocks (SFBs) in the PLC software. While **index** is a direct parameter for the data block, the **slot** value has to be used to find the address of a slot, which is variable, in order to get the parameter ID. There's more informatin about this in chapter 13 Profibus & Profinet (p 176).

11.6.7 EtherCAT SDO/PDO? Column

This column marks which of the Modbus registers can be accessed by the CANopen over Ethernet (CoE) protocol in the form of indexes. Some of the marked registers are connected to PDOs, the rest are connected as SDOs. Systems supporting the EtherCAT interface contain a downloadable data object list. Which of the registers are connected to PDOs is described in chaper 16 EtherCAT (p 193).

11.7 Modbus RTU in Detail

Modbus RTU can be used with the built-in USB interface, built-in Ethernet interface, and also with some of the optional Anybus modules (see 10.1 Remote Communication Interfaces (p 94)). The addressed object when using the Modbus protocol is called a register. This document uses the terms address, register, or register address to all mean the same thing—an addressable chunk of data with a specifically defined purpose.

> **!** When transferring Modbus RTU messages via any Ethernet interface it's called Modbus RTU over Ethernet, which is not the same as Modbus TCP. Modbus TCP is run on port 502, and Modbus RTU over Ethernet can run on a port other than 502.

11.7.1 Message types

The Modbus message system distinguishes between control messages, query messages, and response messages. Query messages will cause the power supply to send a response message. Control messages cause the power supply to reply with an echo of the message (in order to confirm reception).

11.7.2 Slave Address

mPower power supplies support Modbus binary messages and the text based SCPI language with automatic protocol detection. See 10.6.1 Protocol Detection (p 99) for more details. When using Modbus, the first byte of every message, known as the the slave address, has to be 0x00.

(In Modbus, the slave address is not related at all to the slave unit terminology used for multi-unit parallel setups.)

11.7.3 Functions

The second byte of a message contains a Modbus function code ("FC"), which determines whether the message is a READ or WRITE message. It also determines, whether one or multiple registers are accessed. mPower systems support the following Modbus functions:

Function		Function name		Description	Example of use
Hex	**Dec**	**Label**	**Abbrev.**		
0x01	1	READ Coils	RSC, RC	Returns only a single coil. mPower coils are not organized sequentially to allow reading multiple coils. See also 11.1.2 Read/Write Coil (p 104).	Query the output condition
0x03	3	READ Holding Registers	RHR	Used to read n subsequent registers. Results in n*2 bytes of data in the response message.	Read the model name string (1-40 bytes)
0x05	5	WRITE Single Coil	WSC	Used to write the coil (TRUE/FALSE) of a boolean register.	Switch system to remote control
0x06	6	WRITE Single Register	WSR	Used to write one register.	Set values (U, I, P etc.)
0x10	16	WRITE Multiple Registers	WMR	Used to write n subsequent registers. Can be used to write beyond the limits of a register block, for example when trying to write multiple set values (U, I, P) at once.	Write multiple values at once within a register block or write the user text

> - The register list defines which of the above functions may be used with every register.
> - The bytes in a Modbus message are read from left to right (big endian format), except for the 16 bit Modbus RTU checksum where the low byte and high byte are switched.

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11.7.4 Control Messages (Write)

When sending a status, a value, multiple values, or text, the data part of the message requires at least the target register and one value to write. The protocol validates the message, but only for maximum length of the register. After the data part, the checksum is expected.

If the data part contains the minimum two bytes, and thus the message would fulfill the protocol requirements for the selected function code, the checksum would be expected at the position of the 7th byte.

If there were incorrectly additional data bytes or zeros at that position, and thus the checksum would be at a different position in the message, the system would return an error. Therefore, the system will return an error, no matter if the message is too short or too long, because the checksum is wrong.

For message examples see

WRITE Single Register

Byte 0	Byte 1	Bytes 2+3	Bytes 4+5	Bytes 6+7
Addr	FC	Start reg.	Data word	CRC
0x00	0x06	0–65535	Value to write	Checksum Modbus-CRC16

WRITE Multiple Registers

Byte 0	Byte 1	Bytes 2+3	Bytes 4+5	Byte 6	Bytes 7-253	Last 2 Bytes
Addr	FC	Start reg.	Number	Count	Data bytes	CRC
0x00	0x10	0–65535	0–123	Number*2	n values to write	Checksum Modbus-CRC16

WRITE Single Coil

Byte 0	Byte 1	Bytes 2+3	Bytes 4+5		Bytes 6+7
Addr	FC	Register	Data word		CRC
0x00	0x05	0–65535	0x0000 (FALSE) or 0xFF00 (TRUE)		Checksum Modbus-CRC16

> The entire 16 bits of the data word represents 1 coil only, for writing and reading.

11.7.5 Query Messages (Read)

When querying something from the system, the response is expected to be immediate, and will be of varying length, but always of the same format. For the query, the start register and the number of registers or coils to read are required.

The foundation of the Modbus data format is a register, a 16-bit integer value. When querying one register with **READ Holding Registers**, the system will return two bytes, and when querying two registers it returns 4 bytes etc. For **READ Coils**, the response will always be two bytes.

For message examples see

READ Holding Registers

Byte 0	Byte 1	Bytes 2+3	Bytes 4+5	Bytes 6+7
Addr	FC	Start reg.	Number	CRC
0x00	0x03	0–65535	Number of regs to read (1–125)	Checksum Modbus-CRC16

READ Coils

Byte 0	Byte 1	Bytes 2+3	Bytes 4+5	Bytes 6+7
Addr	FC	Start reg.	Number	CRC
0x00	0x01	0–65535	Must always be 1	Checksum Modbus-CRC16

> ❗ Reading coils here is not according to the Modbus specification. Reading a coil always returns 16 coils, but all 16 are considered as one bit with either TRUE (0xFF00) or FALSE (0x0000).

11.7.6 Response Messages

A response from the power supply is usually expected after a query, or if something has been set and the system confirms the execution.

Expected response for WRITE Single Register:

Byte 0	Byte 1	Bytes 2+3	Bytes 4+5	Bytes 6+7
Addr	FC	Start reg.	Data	CRC
0x00	0x06	0–65535	Written value echoed	Checksum Modbus-CRC16

Expected response for WRITE Single Coil:

Byte 0	Byte 1	Bytes 2+3	Bytes 4+5	Bytes 6+7
Addr	FC	Start reg.	Data	CRC
0x00	0x05	0–65535	Written value echoed	Checksum Modbus-CRC16

Expected response for WRITE Multiple Registers:

Byte 0	Byte 1	Bytes 2+3	Bytes 4+5	Bytes 6+7
Addr	FC	Start reg.	Data	CRC
0x00	0x10	0–65535	Number of written registers	Checksum Modbus-CRC16

Expected response for READ Holding Registers:

Byte 0	Byte 1	Byte 2	Bytes 3-253	Last 2 Bytes
Addr	FC	Data length in bytes	Data	CRC
0x00	0x03	2–250	Queried registers content	Checksum Modbus-CRC16

Expected response for READ Coils:

Byte 0	Byte 1	Byte 2	Bytes 3+4	Bytes 5+6
Addr	FC	Data length in bytes	Data	CRC
0x00	0x01	2	Queried bit as 1 register (always 16 coils)	Checksum Modbus-CRC16

Unexpected response (communication error):

Byte 0	Byte 1	Byte 2	Last 2 Bytes
Addr	FC		CRC
0x00	Function code + 0x80	Error code	Checksum Modbus-CRC16

> ❗ Ccommunication errors may have several causes. For example a wrong checksum, or when attempting to switch a system to remote control that has been set to **Local** or if it's already remotely controlled by another interface. See the communication error code list in 11.7.8 Communication Errors (p 114).

11.7.7 The Modbus Checksum

The checksum at the end of Modbus RTU messages is a 16 bit checksum, but is not calculated as the usual CRC16 checksum. Furthermore, the byte order of the checksum in the message is reversed. Information about Modbus CRC16 and source code for implementation and calculation are available on the Internet, for example here:

http://www.Modbus.org/docs/Modbus_over_serial_line_V1_02.pdf , section 2.5.1.2.

11.7.8 Communication Errors

In this context. "communication errors" are those related to the digital communication with the system. This section is not about power supply alarms or events generated during the operation of the power supply.

The mPower software will return error messages in cases where the previously sent message is in wrong format, or if the function cannot be executed by some reason. For example, if the message to write a set value with **WRITE Single Register** were sent while the system is not in remote control. The message would not be accepted, and the system will return an error message instead of a confirmation message. Another example is that the message format would be wrong if the checksum is bad, or if you try to read a bit with function **READ Holding Registers** instead of **READ Coils**.

When there is an error like these, the response message contains the original function code summed with 0x80, in order to identify the response as an error message.

Adding 0x80 to the function codes yields the following error message function codes:

FC error	Belongs to
0x81	READ Coils
0x83	READ Holding Registers
0x85	WRITE Single Coil
0x86	WRITE Single Register
0x90	WRITE Multiple Registers

Overview of the communication error codes which can be returned by the system:

Code		Error	Description
0x01	1	Wrong function code	The function code in byte 1 of the Modbus message is not supported. The error also occurs when trying to read or write a register with a function code for which the register is not defined.
0x02	2	Invalid address	The register address you were trying to access with read or write is not defined for your system. Every system series may have a different number of registers. Refer to the register list for the series your system belongs to.
0x03	3	Wrong data or data length	The length of data in the message is wrong, or the data itself is wrong. For example, a set value always requires two bytes of data. If the data part of the message would be one byte only or three bytes, then the data length would be wrong. Otherwise, when sending a set value of, for example, 0xE000 to a register for which the maximum value is defined as 0xCCCC, this would be wrong data.
0x04	4	Execution	Command could not be executed. This can result from multiple scenarios. Consider the run condition of the system and configuration to look for something not aligned with operating requirements.

Code		Error	Description
0x05	5	CRC	The CRC16 checksum at the end of the Modbus RTU message is wrong or has been transmitted in wrong byte order (high byte first instead of low byte).
0x07	7	Access denied	Access to a certain register is not allowed, or is read-only while trying to write, or vice versa. The error also occurs when trying to write to a writable address while the system is not in remote control, or in remote control from a different interface.
0x17	23	System in local	Indicates, that write access to the system is blocked by the **Local** condition, so only read access is possible. **Local** means that remote control is not allowed.

Here is an example of a an error message data stream. You attempted to switch the system to remote in order to control it from PC, but instead of an echo of your message, the system returned something like 0x00 0x85 0x07 0x52 0x92. This is an error message. The first byte is 0x00 as it should be. The function code contains the value 0x85. According to the first table above, this is related to the function **WRITE Single Coil**. The error code in the message is 0x7 which means, according to the second table above, the system has denied the access.

11.7.9 Examples of Modbus RTU messages

> The examples can also be used for Modbus TCP, but they need to be extended by the required Modbus TCP header, and stripped of the unused checksum. The green segment (FC, Start, Data) is the PDU which is consistent for RTU and TCP formats.

11.7.9.1 Writing a set value

> Set values are adjustable limits for the physical values Current, Voltage, Power, and Resistance (where available). They can only be written to a system if it has been switched to remote control before via a digital interface.

Example: You want to set the current to 50%. According to the register lists, **Set current value** is at address 501 (0x1F5) and the function is **WRITE Single Register**. Assuming the system is already in remote control mode, the message to build is this:

Message to send:

Addr	FC	Start	Data	CRC
0x00	0x06	0x01F5	0x6666	0x325F

► Expected response:

Addr	FC	Start	Data	CRC
0x00	0x06	0x01F5	0x6666	0x325F

In this case, the system is expected to return an echo of the original message—indicating successful execution of the command. The display of the system should now show 50% of the nominal current of your system. For a power supply with 510 A nominal current, it should show 255.0 A, or for a model with 170 A current rating, it should show 85 A.

11.7.9.2 Query all actual values at once

The system holds three readable actual values of voltage, current, and power. Actual values can be queried separately, or all at once. The advantage of a combined query is, that you gain a snapshot of the most recent actual values. When querying separately, values may have already changed while sending the next query.

According to the register list, the actual values start from register 507. Three registers shall be read:

Message to send:

Addr	FC	Start	Data	CRC
0x00	0x03	0x01FB	0x0003	0x7417

Example response:

Addr	FC	Len	Data			CRC
0x00	0x03	0x06	0x2620	0x0C9B	0x091B	0x9EC0

11.7.9.3 Read the nominal voltage of a system

The nominal voltage, like the other nominal values of current, power, or resistance, is an important value to read from a system. They're all referenced for translating set values and actual values. It's good programming practice to read them from the system right after opening the digital communication line and keep them as immutable values. They can then be used to validate values, and generate values based on capacity percentages.

According to the register list, the nominal voltage is a 4-byte float value in register 121.

Query message:

Addr	FC	Start	No.	CRC
0x00	0x03	0x0079	0x0002	0x1403

Example response:

Addr	FC	Len	Data	CRC
0x00	0x03	0x04	0x42A00000	0xFEA9

The response contains a float value according to IEEE754 format, which translates to 80.0.

11.7.9.4 Read system status

All mPower DC 3 Series systems report their system status in register 505.

Query message:

Addr	FC	Start	No.	CRC
0x00	0x03	0x01F9	0x0002	0x1417

Example response:

Addr	FC	Len	Data	CRC
0x00	0x03	0x04	0x00000483	0xA992

The response contains the value 0x483 which (according to the bit value map in the Register List) means that the system is in remote control via the USB port, that the DC output is switched on, and that CC (constant current) mode is active.

11.7.9.5 Switch between remote and manual control

Before you can control a system from remote, it's required to switch it to remote control. This is done by sending a certain command.

> ⓘ The system will never switch to remote control automatically, and cannot be remote controlled in this state, though reading from all readable registers is always possible.

> ⓘ The system will never exit remote control automatically, unless it's switched off, or the AC supply is cut. Remote control can be terminated by a command.

How to switch a system to remote control

1. If you are using the Modbus RTU protocol, you need to create and send a message according to the descriptions above. For example (in hex bytes): 00 05 01 92 FF 00 2D FA.
2. Once the switchover to remote control has been successful, the system should indicate the new condition in the display, as well as echoing the message as a confirmation.

If switching to remote control is denied by the system because setting **Allow remote control = No** is set, then the system will return an error message like 00 85 17 53 5E. According to Modbus specification, this is error 0x85 with error code 0x17.

Switching to remote control may be inhibited by several circumstances and is usually indicated by an error message:

- Condition **Local** is active (check the display on the front of your system or read the system status), which will prevent any remote control. See 9.2 Control Locations (p 86).
- The system is already remotely controlled by another interface.
- The system is in setup mode, meaning a user has accessed the setup menu, and not closed it yet.

How to exit remote control

Ending remote control can be done in two ways: using the remote command, or by switching the system to **Local**.

1. If you are using the Modbus RTU protocol, you need to build and send a message according to the description above, for example (in hex bytes): 00 05 01 92 00 00 6C 0A.

11.8 Modbus TCP in detail

This section is only about the differences to RTU. The core of a Modbus TCP message is Modbus RTU. Refer to 11.7 Modbus RTU in Detail (p 109) for more information.

The differences of Modbus TCP compared to Modbus RTU:

- The message requires an additional MBAP header (6 bytes).
- The checksum is omitted (2 bytes).
- Transmission is only via reserved port 502; any other port won't accept Modbus TCP frames.

The MBAP header is specified like this:

Bytes	Meaning	Explanation
0 + 1	Transaction identifier	This identifies the message. It's copied by the system in the response, and is used to identify a specific individual message. This is useful when a pool of incoming transmissions from multiple system are communicating with the PC. The identifier is an arbitrary value (select any value you want) between 0 and 65535.
2 + 3	Protocol identifier	Here always 0 = Modbus protocol
4 + 5	Length	Number of remaining bytes in the message, i.e. the length of the Modbus RTU core message minus 2.

11.8.1 Example for a Modbus TCP message

The example for READ Holding Registers from 11.7.9.3 Read the nominal voltage of a system (p 116), extended by the MBAP header using an arbitrary transaction identifier of 0x4711:

Query message:

MBAP Header	Addr	FC	Start	No.
0x4711 0x0000 0x0006	0x00	0x03	0x0079	0x0002

▶

Possible response:

MBAP Header	Addr	FC	Len	Data
0x4711 0x0000 0x0007	0x00	0x03	0x04	0x42A00000

The example is a query for reading the system's nominal voltage. The response contains a floating point value in Data, which translates to 80 (V).

11.9 Specific Register Notes

Many of the commands/registers are self-explainatory, but not all of them. Below are ones which likely need additional explanation.

11.9.1 Register 171

This allows writing and reading a user-defined string of up 40 characters. It's intended to be used as a system label or description which is meaningful to the end user.

11.9.2 Register 411

Described for SCPI in 12.16 Alarm Management Commands (p 168).

When using Modbus, this register is intended to reset alarm bits as represented in the system status (register 505, see below). Until these are reset, which is considered as an acknowledgement, the bits from previous alarms remain set, even if the alarms have subsided. Alarms which are still present while register 411 is used to reset the alarm bits will of course be excluded from resetting. There is an exception: the system alarm OT (bit 19, overtemperature). This will be cleared automatically once the unit has cooled down. After resetting the alarm bits, system alarms can only be read in form of an alarm counter (registers 520 - 524).

11.9.3 Registers 500–503 (Set Values)

These are the most important registers to work with, because they define the DC output values of voltage, current, power, and resistance. With Modbus, any set value is transmitted as a percent of the nominal system values (0–100%), whereas for SCPI, decimal values are used.

Generally, before you can use R mode with systems where internal resistance is featured, it has to be activated (register 409), otherwise the set value is ignored.

Units with the PV function active, the set value for current (register 501) is interpreted as the irradiation value, as long as the system is in PV mode. In other words, while the PV function is running, this register does not define the current limit for the system, but is a parameter called irradiation. In manual operation, irradiation can be adjusted in 1% steps between 0% and 100%. With the set value of current it's also 0–100%, according to definition of register 501, but it now has significantly higher resolution.

11.9.4 Register 505 (System Status)

This register represents the system condition in one 32-bit value. Some bits are grouped, and have to be interpreted as a set. According to the register list, bits 0-4 of register 505 are a group that represents the control location. By reading this register, you can detect if the system is already in remote control ("Remote mode = on" was executed by the system).

With SCPI, some but not all of these 32 bits of this register are represented in the status registers Questionable and Operation. See 12.4 Status Registers (p 134).

11.9.4.1 When running in parallel mode

During parallel operation, the status register uses bit 29 (MSS) to indicate the master-slave safety mode, which is activated every time the control unit detects any problem in the communication with the expansion units which can occur due to a connection failure or heavy electrical interferences. The control unit will then set this bit, and switch off all DC outputs of the expansion units still available to control. Expansion units will also put themselves into a similar state and switch off DC.

After correction of the problem cause, the M/S system has to be re-Initialized, which also clears this bit.

11.9.5 Registers 650–662 (Master-Slave config)

This block of registers are used to configure the parallel operation mode in a similar way as done with the control panel **Menu**. For remote control of a parallel setup, it's expected to be already fully wired. Before parallel operation, expansion units can be configured remotely, Once parallel mode is initialized, only the control unit should be controlled by remote commands. Expansion units can be monitored. Configuration and activation of parallel operation can also be done manually, and remote control initiated after the control unit has Initialized the system.

With the parallel mode not being set up yet, these registers have to be used in a certain order on all units:

1. Switch to remote control with register 402.

2. Activate parallel operation mode with register 653.

3. Select with register 650 whether the unit you are configuring will be Master or Slave.

Additional steps are performed on only the control unit:

4. Initialize the parallel setup with register 654.

5. Optional, but good programming: check register 655 whether the initialization has been successful.

6. Optional, but good programming: query the number of initialized expansion units with register 662. Validate that the returned number does matches expectations.

7. Optional, but good programming: read the nominal values (registers 656–660) of the Initialized system to acquire the summed values.

> The total ratings of voltage, current, power, and resistance are available from registers 121–129, so registers 656, 658, and 660 are actually obsolete. They can still be used, but without the option to read the max/min resistance of the parallel system which can be done by reading the rated values from the control unit and dividing it by the number of units.

8. Optional, but good programming: configure alarm thresholds, event thresholds, and set value limits.

During parallel operation, the remotely controlled control unit can be accessed like a single unit. Set values and actual values are always percent values related to certain nominal values. Access to those registers is described in the other sections.

11.9.6 Registers 850–6695 (Function Generator)

See 11.10 Remote Programming of Function Generator (p 123) for details.

11.9.7 Registers 9000–9009 (Adjustment Limits)

These are explained in 12.10 Adjustment Limit Commands (p 145) in the SCPI chapter. However, Modbus users should also read that section for the general handling of these settings. Apart from that, setting these parameters is like setting a set value (U, I, P, R).

11.9.8 Registers 10007–10900

These registers can be used to remotely configure the various built-in or optionally available digital interfaces. The registers are connected to the corresponding settings in the system's Settings menus.

Contrary to manual control, the settings for the pluggable interface modules can even be configured while the interface module is not yet installed.

11.9.9 Register 12000 (PV / 50530)

All Modbus registers which represent parameters related to this simulation, and which can be read or written are referenced in the EN 50530 standard document. The document is furthermore the reference for the user regarding setup and correct use of this simulation feature.

The procedure to set up and control the extended PV simulation using Modbus protocol is essentially the same as manual setup on the system's control panel, and as when using SCPI commands shown in 12.17.2 Programming Examples for PV 50530 (p 170). The step by step examples in the SCPI chapter have an extra column in the tables to show the related Modbus register number. Example #2 in that section is repeated below converted to Modbus RTU format (percental set values translated for a system with 80 V and 170 A rating):

Configuration (before starting the function)

Step	Command	Description
1	00 05 01 92 FF 00 2D FA	Activate remote control
2	00 06 2E E1 00 03 91 04	Activate PV simulation mode DAYET
3	00 06 2E F0 00 00 81 00	Select technology: Manual (all required parameters must be defined, here as with commands 4-10)
4	00 10 2F 02 00 02 04 3F 4C CC CD F7 ED	Fill factor voltage (FF_U): 0,8
5	00 10 2F 04 00 02 04 3F 47 AE 14 EE FF	Fill factor current (FF_I): 0,78
6	00 10 2F 06 00 02 04 39 9D 49 52 84 57	Temperature coefficient α for I_{SC}: 0,0003 /°C
7	00 10 2F 08 00 02 04 BB 44 9B A6 A1 7F	Temperature coefficient β for U_{OC}: -0,003 /°C
8	00 10 2F 0A 00 02 04 3D 94 7A E1 00 75	Scaling factor C_U for U_{OC}: 0,0725
9	00 10 2F 0C 00 02 04 39 66 AF CD 7F D1	Scaling factor C_R for U_{OC}: 0,00022 m²/W
10	00 10 2F 0E 00 02 04 3B 4E 70 3B A7 CE	Scaling factor C_G for U_{OC}: 0,00315 W/m²
11	00 05 2E F1 FF 00 D5 30	Select input mode: ULIK
12	00 06 2F 10 61 47 E8 A8	Set open circuit voltage: 38 V (=0x6147)
13	00 06 2F 11 08 6F 97 26	Set short-circuit current: 7 A (=0x086F)
14	00 05 2E F2 FF 00 25 30	Activate data recording
15	00 05 2E E5 00 00 D4 C4	Deactivate interpolation of day trend data
16	00 06 01 F4 61 47 A1 B7	Set global voltage limit: ≥Uoc (=0x6147)
17	00 06 01 F6 CC CC 3C 80	Set global power limit: 100% (=0xCCCC)

Write day trend data (before starting the function)

Step	Command	Description
18	00 05 2E E6 FF 00 65 34	Select access mode: write
19	00 05 2E E7 FF 00 34 F4	Delete former data (should be executed every time before loading new data)

Step	Command	Description
20	00 10 2E EA 00 06 0C 00 00 00 01 44 44 66 66 00 00 03 E8 88 8A	Write 1st day trend data set: Irradiation: 500 W/m² (=0x4444) Temperature: 20°C (=0x6666) Dwell time: 1000 ms (=0x000003E8)
	ⓘ The dwell time is defined to have a minimum of 500 ms. However, for the very first day trend data set it's expected to set 1000 ms or higher, otherwise the function run might fail.	
21	00 10 2E EA 00 06 0C 00 00 00 02 6D 3A 74 0D 00 00 05 DC E4 C3	Write 2nd day trend data set: Irradiation: 800 W/m² (0x6D3A) Temperature: 28°C (=0x740D) Dwell time: 1500 ms (=0x000005DC)
…		Write further data sets, a total of 500
519	00 10 2E EA 00 06 0C 00 00 01 F4 A3 D6 7F FF 00 00 4E 20 34 AF	Write 500. day trend data set: Irradiation: 1200 W/m² (=0xA3D6) Temperature: 35°C (=0x7FFF) Dwell time: 20000 ms (=0x000034AF)

Control, during simulation run

Step	Command	Description
520	00 05 2E E6 FF 00 65 34	Start simulation. The simulation will stop automatically after the time that results from the total of dwell times in all written data sets

ⓘ During the simulation, the index counter in register 12010 is updated with every next day trend point on the curve. It can be read and used to determine at which point the curve has been stopped due to an unexpected error, such as a system alarm.

Analysis after simulation end

Step	Command	Description
521	00 03 2E F4 00 02 8D 00	Read number (n) of recorded data sets. This number is not related to the number of day trend data sets in use. This feature records a new data set every 100 ms. Depending on the total simulation time, the record buffer could fill (max. 16 h record time) and overwrite existing data. It may become necessary to calculate the total simulation time from the day trend data sets and start reading the recorded data during simulation, then clearing the buffer and later read the rest of data.
522	00 10 2E F6 00 02 04 00 00 00 01 6C 5C	Select first data set (index 1) for reading
523	00 03 2E F8 00 08 CD 04	Read data from data set (index) 1
…		Read further n-1 data sets:

11.10 Remote Programming of Function Generator

Registers 850–6695

The integrated function generator is a complex feature. It's configured and loaded with a lot of registers. Before you can run a function, setup is required every time, and in a certain order.

Be aware that "the" function generator is actually two generators—the arbitrary function generator, and the XY function generator. Upon thses two foundations, the touch screen provides a number of facades which makes it easier to configure the two generators for various wave form types and simulations. When in remote control, those facades are not available. The programming is programming directly to either the arbitrary function generator, or the XY function generator.

So, the first step is to decide which one of the two basic function generators you want to use: arbitrary or XY.

> ❗ All function generator settings and loaded data (sequences, XY table) are not stored inside the system and have to be loaded into the system every time before you can use the function generator. These data and settings are completely separate from what you can setup and define for the function generator manually when using the control panel and touch display.

11.10.1 Programming the Arbitrary Generator

This generator is used to create wave functions like sine, square, triangle, or trapezoidal.

Step 1 — Select whether to apply the function to the voltage U (register 851) or the current I (register 852). Before you have made this selection, the system cannot accept sequence point data, because the sequence data is run through a validation check against the system's adjustment limits.

Step 2 — Define start sequence point (register 859), end sequence point (register 860) and number of cycles of that block to repeat (register 861).

Step 3 — Load data for n out of 99 sequence points (registers 900-2468, 8 values per sequence point).

Step 4 — Set global voltage limit (register 500), if the function is applied to the current. Else set global current limit (register 501), if the function is applied to voltage. Set global power limit (register 502) for both modes.

Step 5 — Control the function generator with start/stop (register 850).

Step 6 — When finished, exit the function generator by deselecting your former selection of either U (register 851) or I (register 852).

11.10.1.1 Arbitrary Generator Stop Behavior

Keep in mind that the arbitrary generator stops controlling the DC output state at the end of the function run unless you set the repetition to infinite (which loops the defined set of steps). After the function generator ends its run, the DC output remains switched on. Since the function generator is no longer providing values for the DC output, the system reverts to using the static set values of U, I, and P to whatever their adjustment level was when configured outside of the function. These static (or global) values also apply to the period after DC output is switched on but before the function is run.

This behavior needs to be taken into account when creating a run profile.

11.10.1.2 Programming example for the arbitrary generator

Let's consider creating a ramp function run. Before the arbitrary generator is programmed for a ramp, it's necessary to think about the best way to achieve the ramp generation.

In the case of a ramp, it is common to want a 0 beginning value, then maintain the ramp's maximum value for some

period of time. The default stop behavior, and the use of the static set values before and after the function runs, are a problem for a ramp function. Why? If you wanted to have a power supply generate a ramp starting from 0 V. The static set value for U (voltage) would then be set to 0. But after the function stops, the system would revert to that same 0 V set value, and the voltage would drop from whatever value had been set during the function run.

To solve this, the function has to consist of two parts: one for the rising or falling ramp, and the other for the sustained ending value. This can be done using two sequences of the arbitrary generator.

Let's assume we want the ramp to start from 0 V and rise to 50 V within 6 seconds. The end voltage shall remain constant for 3 minutes (the time can be varied at will). Sequences 1 and 2 (out of the 99) will be used. If remote control is already active, we only need to configure the sequences. Since the ramp will make the voltage rise linearly, using only the DC part of a sequence, the parameters for the AC part (indexes 0 - 4) should be set to zero in order to avoid remainders which could disturb the correct wave generation.

The first step is to activate function generator mode, in this case we select arbitrary generator for U:

Addr	FC	Start	Data	CRC
0x00	0x05	0x0353	0xFF00	0x7DBE

The next step is to create the Modbus message to configure sequence 1, the rising ramp. According to the register list start register 900 (WMR, function code 0x10) is assigned to sequence 1. In the table below, the data part doesn't fit as a single sequence in the page size, so the 8 float values are below each other:

Addr	FC	Start	Regs	Bytes	Data	CRC	Description
0x00	0x10	0x0384	0x10	0x20	0x00000000		Start value of AC part: 0 V
					0x00000000		End value of AC part: 0 V
					0x00000000		Start frequency of AC part: 0 Hz
					0x00000000		End frequency of AC part: 0 Hz
					0x00000000		Start angle of AC part: 0°
					0x00000000		Start value of DC part: 0V
					0x42480000		Start value of DC part: 50V
					0x4AB71B00	0x5A14	Rise time in µs: 6,000,000 (6 seconds)

After this, the Modbus message to configure sequence 2, the static voltage, would be next. The start register is 916:

Addr	FC	Start	Regs	Bytes	Data	CRC	Description
0x00	0x10	0x0394	0x10	0x20	0x00000000		Start value of AC part: 0 V
					0x00000000		End value of AC part: 0 V
					0x00000000		Start frequency of AC part: 0 Hz
					0x00000000		End frequency of AC part: 0 Hz
					0x00000000		Start angle of AC part: 0°
					0x42480000		Start value of DC part: 50V
					0x42480000		Start value of DC part: 50V
					0x4D2BA950	0x6AD7	Sequenz time in µs: 180,000,000 (180 seconds = 3 minutes)

The last step is the configuration of the arbitrary generator itself:

Addr	FC	Start	Data	CRC	Description
0x00	0x06	0x035B	0x0001	0x384C	Register 859, WSR, start sequence: 1
0x00	0x06	0x035C	0x0002	0xC98C	Register 860, WSR, end sequence: 2

0x00	0x06	0x035D	0x0001	0xD84D	Register 861, WSR, sequence cycles: 1
0x00	0x06	0x01F5	0xCCCC	0xCC80	Register 501, WSR, global current limit: 100%
0x00	0x06	0x01F6	0xCCCC	0x3C80	Register 502, WSR, global power limit: 100%

> ⓘ Setting the global values (current, power) to maximum or any other value that wouldn't interfere the ramp generation is necessary, especially when running multiple systems in parallel mode where those set values also limit the expansion unit's output.

The entire function setup is done, and the function can be started. If the DC output of the system was off when starting the function, it will automatically switch on. Alternatively, you could switch it on separately with the corresponding command, and before actually running the function. But it's not necessary here, because the voltage shall start to rise from 0 V. In other situations where the starting level is not zero, it would be required to switch on the DC output first and wait for the voltage to settle.

For the number of sequence cycles, 1 is sufficient, but it can be changed at will. The whole function would be repeated after 3 minutes and 6 seconds. The voltage would not instantly drop to 0 V at the end of the first function run, and before the second one starts. The drop rate depends on the load, and the voltage ramp down, when being graphically recorded on an oscilloscope, could look different than expected. This could be circumvented by adding a third sequence which only executes a time window with voltage at 0 to provide time for the voltage to go down.

Addr	FC	Start	Data	CRC	Description
0x00	0x05	0x0352	0xFF00	0x2C7E	Register 850, WSC, Run function

11.10.2 Procedure for the XY Generator

Below is the general procedure, without a specific example, for using the XY generator.

Step 1:

Select the XY function mode with following registers:

Mode	Register
UI	854
IU	855
Simple PV (only with power supplies)	426
FC (only with power supplies)	854 (as UI mode)

Step 2:

Load the XY table data in 256 blocks of 16 values (registers 2600–6695). This corresponds to a maximum of 4,096 values for a measurement range of 0-125% U_{Nom} or I_{Nom}. Less data can also be loaded, for instance 3,277 values for 0-100%. All values which are not set will be populated as 0 V or 0 A.

Step 3:

Set static values which are not affected by the table.

UI function: current (register 501) and power (register 502)

IU function: voltage (register 500) and power (register 502)

Step 4:

Run the function generator by switching the DC output of your system on (register 405).

For PV mode you may also want to control irradiation while the function is running. This is done by sending set values to register 501 (current), where 100% corresponds to a factor of 1 and 0% to a factor of 0. This factor is multiplied to the simulated current I_{MPP} of the MPP which usually is somewhere on the PV curve you loaded in step 2.

Step 5:

Exit the function generator by deselecting your former mode setting from step 1 using the same registers.

MARWAY
Power Solutions

Modbus address (dec)	Modbus address (hex)	Read code (0x01)	Read holding registers (0x03)	Write single coil (0x05)	Write single register (0x06)	Write multiple registers (0x10)	Description	Access	Data type	Data length in bytes	Number of registers	Data	Example	Profibus slot	Profibus Index	Profinet Index (hex)	EtherCAT SDO/PDO?
0	0x0000		x				Device class	R	uint16)	2	1		See programming guide in section "A"	1	0	0x0100	x
1	0x0001		x				Device type	R	char	40	20	ASCII	PSI 10080-1000	1	1	0x0101	x
21	0x0015		x				Manufacturer	R	char	40	20	ASCII		1	2	0x0102	x
41	0x0029		x				Manufacturer address	R	char	40	20	ASCII		1	3	0x0103	x
61	0x003D		x				Manufacturer ZIP code	R	char	40	20	ASCII		1	4	0x0104	x
81	0x0051		x				Manufacturer phone number	R	char	40	20	ASCII		1	5	0x0105	x
101	0x0065		x				Manufacturer website	R	char	40	20	ASCII		1	6	0x0106	x
121	0x0079		x				Nominal voltage	R	float	4	2	Floating point number IEEE754	80	1	7	0x0107	x
123	0x007B		x				Nominal current	R	float	4	2	Floating point number IEEE754	1000	1	8	0x0108	x
125	0x007D		x				Nominal power	R	float	4	2	Floating point number IEEE754	30000	1	9	0x0109	x
127	0x007F		x				Max. internal resistance	R	float	4	2	Floating point number IEEE754	5	1	10	0x010A	x
129	0x0081		x				Min. internal resistance	R	float	4	2	Floating point number IEEE754	0	1	11	0x010B	x
131	0x0083		x				Article no.	R	char	40	20	ASCII	06230801	1	12	0x010C	x
151	0x0097		x				Serial no.	R	char	40	20	ASCII	1234560001	1	13	0x010D	x
171	0x00AB		x			x	User text	RW	char	40	20	ASCII		1	14	0x010E	x
191	0x00BF		x				Firmware version (KE)	R	char	40	20	ASCII		1	15	0x010F	x
211	0x00D3		x				Firmware version (HMI)	R	char	40	20	ASCII		1	16	0x0110	x
231	0x00E7		x				Firmware version (DR)	R	char	40	20	ASCII		1	17	0x0111	x
402	0x0192	x	x	x			Remote mode	RW	uint16)	2	1	Coil : Remote	0x0000 = off; 0xFF00 = on	2	1	0x0200	x
405	0x0195	x	x	x			DC output/input	RW	uint16)	2	1	Coil : Output/input	0x0000 = off; 0xFF00 = on	2	4	0x0203	x
407	0x0197	x		x			Condition of DC output/input after power fail alarm	RW	uint16)	2	1	Coil : Auto-On	0x0000 = off; 0xFF00 = auto	2	30	0x031C	x
408	0x0198		x		x		Condition of DC output/input after powering the device	RW	uint16)	2	1	Reg. : Power-On	0xFFFF = off; 0xFFFE = restore	2	6	0x0205	x
409	0x0199	x	x	x			Operation mode (U/P/U/R)	RW	uint16)	2	1	Coil : Operation mode	0x0000 = U/P; 0xFF00 = U/R	2	7	0x0206	x
410	0x019A			x			Restart of the device (warm start)	W	uint16)	2	1	Coil : Restart	0xFF00 = execute	2	8	0x0207	x
411	0x019B			x			Acknowledge alarms	W	uint16)	2	1	Coil : Alarms	0xFF00 = acknowledge	2	9	0x0208	x
416	0x01A0	x		x			Analog interface: Reference voltage (pin VREF)	RW	uint16)	2	1	Coil : VREF	0x0000 = 10V; 0xFF00 = 5V	2	14	0x020D	x
417	0x01A1	x		x			Analog interface: REM-SB level	RW	uint16)	2	1	Coil : REM-SB Level	0x0000 = normal; 0xFF00 = inverted	2	12	0x020B	x
418	0x01A2			x			Analog interface: REM-SB action	W	uint16)	2	1	Coil : REM-SB Action	0x0000 = off; 0xFF00 = auto	2	13	0x020C	x
425	0x01A9	x		x			Condition of DC output/input after leaving remote	R	uint16)	2	1	Coil : Condition	0x0000 = off; 0xFF00 = unchanged	2	42	0x0229	
426	0x01AA		x	x			Function generator XY: Select simple PV mode	RW	uint16)	2	1	Coil : PV mode	0x0000 = off; 0xFF00 = on	5	13	0x0509	x
427	0x01AB		x		x		Voltage Controller Speed	RW	uint16)	2	1	Level	0x0000 = Normal (default); 0x0001 = Slow; 0x0002 = Fast;	2	60	0x023B	
428	0x01AC		x		x		SEMI F47	RW	uint16)	2	1	On/Off	0x0000 = off; 0x0001 = on;	2	61	0x023C	
432	0x01B0	x		x			Reset device to factory settings	RW	uint16)	2	1	Coil : Condition	0xFF00 = Trigger reset	2	43	0x022A	x
440	0x01B8		x		x		Analog interface: Pin 14 configuration	RW	uint16)	2	1	Alarms 1	0x0000 = OVP (default); 0x0001 = OCP; 0x0002 = OPP; 0x0003 = OVP + OCP; 0x0004 = OVP + OPP; 0x0005 = OCP + OPP; 0x0006 = OVP + OCP + OPP	2	44	0x022B	x
441	0x01B9		x		x		Analog interface: Pin 6 configuration	RW	uint16)	2	1	Alarms 2	0x0000 = OT + PF (default); 0x0001 = OT; 0x0002 = PF	2	45	0x022C	x
442	0x01BA		x		x		Analog interface: Pin 15 configuration	RW	uint16)	2	1	Status DC / reg. mode	0x0000 = CV; 0x0001 = DC output status	2	46	0x022D	x
500	0x01F4		x		x		Set voltage value	RW	uint16)	2	1	0x0000 - 0xD0E5 (0 - 102%)	Voltage value (for translation see programming guide)	2	23	0x0216	x
501	0x01F5		x		x		Set current value or irradiation (PV function)	RW	uint16)	2	1	0x0000 - 0xD0E5 (0 - 102%)	Current value (for translation see programming guide) / Irradiation	2	24	0x0217	x
502	0x01F6		x		x		Set power value	RW	uint16)	2	1	0x0000 - 0xD0E5 (0 - 102%)	Power value (for translation see programming guide)	2	25	0x0218	x
503	0x01F7		x		x		Set resistance value	RW	uint16)	2	1	0x0000 - 0xCCCC (0 - 100%)	Resistance value (for translation see programming guide)	2	26	0x0219	x
505	0x01F9		x				Device state	R	uint32)	4	2	Bit 0-4: Control location	0x00 = free; 0x01 = local; 0x03 = USB; 0x04 = analog; 0x05 = Profibus; 0x06 = Ethernet; 0x08 = Master/Slave; 0x09 = RS232; 0x10 = CANopen; 0x12 = Modbus TCP 1P; 0x13 = Profinet 1P; 0x14 = Ethernet 1P; 0x15 = Ethernet 2P; 0x16 = Modbus TCP 2P; 0x17 = Profinet 2P; 0x18 = GPIB; 0x19 = CAN; 0x1A = EtherCAT; 0x1C = free (due to communication timeout (CTO))	2	27	0x021A	x
												Bit 5 : Config mode					
												Bit 6 : Master-slave type	0 = Slave; 1 = Master				
												Bit 7 : Output state	0 = off; 1 = on				
												Bit 9-10 : Regulation mode	00 = CV; 01 = CR; 10 = CC; 11 = CP				
												Bit 11 : Remote	0 = off; 1 = on				
												Bit 13 : Function generator	0 = stopped; 1 = running				
												Bit 14 : External sense	0 = off; 1 = on				
												Bit 15 : Alarms	0 = none; 1 = active				
												Bit 16 : OVP	0 = none; 1 = active				
												Bit 17 : OCP	0 = none; 1 = active				
												Bit 18 : OPP	0 = none; 1 = active				
												Bit 19 : OT	0 = none; 1 = active				
												Bit 21 : Power fail	0 = none; 1 = active				
												Bit 24 : UVD	0 = none; 1 = active				
												Bit 25 : OVD	0 = none; 1 = active				
												Bit 26 : UCD	0 = none; 1 = active				
												Bit 27 : OCD	0 = none; 1 = active				
												Bit 28 : OPD	0 = none; 1 = active				
												Bit 29 : MSP	0 = none; 1 = active				
												Bit 30 : REM-SB	0 = DC enabled; 1 = REM-SB disables power output				
507	0x01FB		x				Actual voltage	R	uint16)	2	1	0x0000 - 0xFFFF (0 - 125%)	Actual voltage (for translation see programming guide)	2	28	0x021B	x
508	0x01FC		x				Actual current	R	uint16)	2	1	0x0000 - 0xFFFF (0 - 125%)	Actual current (for translation see programming guide)	2	29	0x021C	x
509	0x01FD		x				Actual power	R	uint16)	2	1	0x0000 - 0xFFFF (0 - 125%)	Actual power (for translation see programming guide)	2	30	0x021D	x
511	0x01FF		x				Device state 2	R	uint32)	4	2	Bit 1 : SF alarm	0 = none; 1 = active	2	19	0x0212	
												Bit 4 : Power derating	0 = none; 1 = active				
												Bit 5 : Semi F47	0 = none; 1 = active				
520	0x0208		x				Count of OV alarms since power up	R	uint16)	2	1	0x0000 - 0xFFFF	Count	3	20	0x0312	x
521	0x0209		x				Count of OC alarms since power up	R	uint16)	2	1	0x0000 - 0xFFFF	Count	3	21	0x0313	x
522	0x020A		x				Count of OP alarms since power up	R	uint16)	2	1	0x0000 - 0xFFFF	Count	3	22	0x0314	x
523	0x020B		x				Count of OT alarms since power up	R	uint16)	2	1	0x0000 - 0xFFFF	Count	3	23	0x0315	x
524	0x020C		x				Count of PF alarms since power up	R	uint16)	2	1	0x0000 - 0xFFFF	Count	3	24	0x0316	x
550	0x0226		x		x		Overvoltage protection threshold (OVP)	RW	uint16)	2	1	0x0000 - 0xE147 (0 - 110%)	OVP threshold (for translation see programming guide)	3	0	0x02FE	x
553	0x0229		x		x		Overcurrent protection threshold (OCP)	RW	uint16)	2	1	0x0000 - 0xE147 (0 - 110%)	OCP threshold (for translation see programming guide)	3	3	0x0301	x
556	0x022C		x		x		Overpower protection threshold (OPP)	RW	uint16)	2	1	0x0000 - 0xE147 (0 - 110%)	OPP threshold (for translation see programming guide)	3	6	0x0304	x
559	0x022F		x		x		Undervoltage detection (UVD)	RW	uint16)	2	1	0x0000 - 0xD0E5 (0 - 102%)	UVD threshold (for translation see programming guide)	3	9	0x0307	x
560	0x0230		x		x		Adjustable UVD notification	RW	uint16)	2	1	Adjustable UVD notification	0x0000 = nothing; 0x0001 = signal; 0x0002 = warning; 0x0003 = alarm	3	10	0x0308	x
561	0x0231		x		x		Overvoltage detection (OVD)	RW	uint16)	2	1	0x0000 - 0xD0E5 (0 - 102%)	OVD threshold (for translation see programming guide)	3	11	0x0309	x
562	0x0232		x		x		Adjustable OVD notification	RW	uint16)	2	1	Adjustable OVD notification	0x0000 = nothing; 0x0001 = signal; 0x0002 = warning; 0x0003 = alarm	3	12	0x030A	x
563	0x0233		x		x		Undercurrent detection (UCD)	RW	uint16)	2	1	0x0000 - 0xD0E5 (0 - 102%)	UCD threshold (for translation see programming guide)	3	13	0x030B	x
564	0x0234		x		x		Adjustable UCD notification	RW	uint16)	2	1	Adjustable UCD notification	0x0000 = nothing; 0x0001 = signal; 0x0002 = warning; 0x0003 = alarm	3	14	0x030C	x
565	0x0235		x		x		Overcurrent detection (OCD)	RW	uint16)	2	1	0x0000 - 0xD0E5 (0 - 102%)	OCD threshold (for translation see programming guide)	3	15	0x030D	x
566	0x0236		x		x		Adjustable OCD notification	RW	uint16)	2	1	Adjustable OCD notification	0x0000 = nothing; 0x0001 = signal; 0x0002 = warning; 0x0003 = alarm	3	16	0x030E	x
567	0x0237		x		x		Overpower detection (OPD)	RW	uint16)	2	1	0x0000 - 0xD0E5 (0 - 102%)	OPD threshold (for translation see programming guide)	3	17	0x030F	x
568	0x0238		x		x		Adjustable OPD notification	RW	uint16)	2	1	Adjustable OPD notification	0x0000 = nothing; 0x0001 = signal; 0x0002 = warning; 0x0003 = alarm	3	18	0x0310	x
577	0x0241		x		x		Condition of DC output/input after OT alarm	RW	uint16)	2	1	Reg. Condition	0x0000 = off; 0x0001 = restore (default)	3	37	0x0323	
650	0x028A	x		x			Master-slave: Link mode on MS bus	RW	uint16)	2	1	Coil: Mode	0x0000 = Slave; 0xFF00 = Master	4	0	0x03FD	x
653	0x028D	x		x			Master-slave: Enable MS	RW	uint16)	2	1	Coil MS on/off	0x0000 = off; 0xFF00 = on	4	3	0x0400	x
654	0x028E			x			Master-slave: Init MS	W	uint16)	2	1	Coil MS start init	0xFF00 = Start init	4	4	0x0401	x
655	0x028F	x		x			Master-slave: Condition	R	uint16)	2	1	Reg: MS status	0x0000 = not initialised; 0x0001 = init running; 0x0003 = set defaults; 0x0004 = setup interface; 0x0005 = assignment; 0xFFFC = disrupted; 0xFFFD = different models detected, init not OK; 0xFFFE = error; 0xFFFF = init OK; 0xFFFB = Termination not OK	4	5	0x0402	x
656	0x0290		x				Master-slave: Total voltage in V	R	float	4	2	Floating point number IEEE754	500	4	6	0x0403	x
658	0x0292		x				Master-slave: Total current in A	R	float	4	2	Floating point number IEEE754	900	4	7	0x0404	x
660	0x0294		x				Master-slave: Total power in W	R	float	4	2	Floating point number IEEE754	150000	4	8	0x0405	x
662	0x0296		x				Master-slave: Number of initialised slaves	R	uint16)	2	1		1...63	4	9	0x0406	x
666	0x029A		x				Master-slave: Bus termination	R	uint16)	2	1	Coil : Termination	0x0000 = off; 0xFF00 = on	4	10	0x0407	x
667	0x029B		x				Master-slave: Bus bias	R	uint16)	2	1	Coil : BIAS	0x0000 = off; 0xFF00 = on	4	11	0x0408	x
850	0x0352	x	x	x			Function generator Arbitrary: Start/stop	RW	uint16)	2	1	Coil : Start/Stop	0x0000 = Stop; 0xFF00 = Start	5	0	0x04FC	x
851	0x0353	x	x	x			Function generator Arbitrary: Select U	RW	uint16)	2	1	Coil : U	0x0000 = not assigned; 0xFF00 = Assign function to voltage	5	1	0x04FD	x
852	0x0354	x	x	x			Function generator Arbitrary: Select I	RW	uint16)	2	1	Coil : I	0x0000 = not assigned; 0xFF00 = Assign function to current	5	2	0x04FE	x
854	0x0356	x	x	x			Function generator XY: Select U-I mode	RW	uint16)	2	1	Coil : U-I	0x0000 = not assigned; 0xFF00 = Assign function to U-I curve	5	4	0x0500	x
855	0x0357	x		x			Function generator XY: Select I-U mode	RW	uint16)	2	1	Coil : I-U	0x0000 = not assigned; 0xFF00 = Assign function to I-U curve	5	5	0x0501	x
856	0x0358		x				Function generator XY: Select mode	RW	uint16)	2	1	Reg: Mode	0x0000 = deactivated; 0x0001 = IU; 0x0004 = Fuel cell; 0x0005 = PV	5	14	0x050A	x
859	0x035B		x		x		Function generator Arbitrary: Start sequence	RW	uint16)	2	1	0x0001...0x0063		5	9	0x0505	x
860	0x035C		x		x		Function generator Arbitrary: End sequence	RW	uint16)	2	1	0x0001...0x0063		5	10	0x0506	x
861	0x035D		x		x		Function generator Arbitrary: Sequence cycles	RW	uint16)	2	1	0x0000...0x03E7	0x0000 = infinite	5	11	0x0507	x
862	0x035E			x			Function generator Arbitrary: Submit settings (only required for CAN, CANopen, EtherCAT CoE)	W	uint16)	2	1	Coil : Submit Arbitrary	0xFF00 = Submit settings				
900	0x0384		x			x	Function generator Arbitrary: Setup for sequence 1	RW	float	32	16	Bytes 0-3: Us/Is(AC) in V or A; Bytes 4-7: Ue/Ie(AC) in V or A; Bytes 8-11: fs(1/T) in Hz; Bytes 12-15: fe(1/T) in Hz; Bytes 16-19: Angle in degrees; Bytes 20-23: Us/Is(DC) in V or A; Bytes 24-27: Ue/Ie(DC) in V or A; Bytes 28-31: Sequence time in µs	Floating point number in IEEE754 format, see device manual for value range, chapter about function generator; Integer in IEEE754 format: 0...10000 Hz; Integer in IEEE754 format: 0...10000 Hz; Integer in IEEE754 format: 0°...359°; Floating point number in IEEE754 format, see device manual for value range, chapter about function generator; Floating point number in IEEE754 format: 100 µs...36,000,000.000 µs	6	0	0x05FB	x
2468	0x09A4		x			x	Function generatorArbitrary: Setup for sequence 99	RW	float	32	16	Bytes 0-3: Us/Is(AC) in V or A; Bytes 4-7: Ue/Ie(AC) in V or A; Bytes 8-11: fs(1/T) in Hz; Bytes 12-15: fe(1/T) in Hz; Bytes 16-19: Angle in degrees; Bytes 20-23: Us/Is(DC) in V or A; Bytes 24-27: Ue/Ie(DC) in V or A; Bytes 28-31: Sequence time in µs	Floating point number in IEEE754 format, see device manual for value range, chapter about function generator; Integer in IEEE754 format: 0...10000 Hz; Integer in IEEE754 format: 0...10000 Hz; Integer in IEEE754 format: 0°...359°; Floating point number in IEEE754 format, see device manual for value range, chapter about function generator; Floating point number in IEEE754 format: 100 µs...36,000,000.000 µs	6	99	0x065E	x
2600	0x0A28		x			x	Function generator: X/Y table, block 0	RW	uint16)	32	16	U mode: set voltage value / IU mode: set current value (16 values block)	value = real set value of voltage * 0.8 / Unom * 32768 or value = real set value of current * 0.8 / Inom * 32768	7	0	0x06FA	x
6680	0x1A18		x			x	Function generator: X/Y table, block 255	RW	uint16)	32	16	U mode: set voltage value / IU mode: set current value (16 values block)	value = real set value of voltage * 0.8 / Unom * 32768 or value = real set value of current * 0.8 / Inom * 32768	7	255	0x07F9	x
9000	0x2328		x		x		Upper limit of voltage set value (U-max)	RW	uint16)	2	1	0x0000 - 0xD0E5 (0 - 102%)	Voltage value (for translation see programming guide)	2	31	0x021E	x
9001	0x2329		x		x		Lower limit of voltage set value (U-min)	RW	uint16)	2	1	0x0000 - 0xD0E5 (0 - 102%)	Voltage value (for translation see programming guide)	2	32	0x021F	x
9002	0x232A		x		x		Upper limit of current set value (I-max)	RW	uint16)	2	1	0x0000 - 0xD0E5 (0 - 102%)	Current value (for translation see programming guide)	2	33	0x0220	x
9003	0x232B		x		x		Lower limit of current set value (I-min)	RW	uint16)	2	1	0x0000 - 0xD0E5 (0 - 102%)	Current value (for translation see programming guide)	2	34	0x0221	x
9004	0x232C		x		x		Upper limit of power set value (P-max)	RW	uint16)	2	1	0x0000 - 0xD0E5 (0 - 102%)	Power value (for translation see programming guide)	2	35	0x0222	x
9006	0x232E		x		x		Upper limit of resistance set value (R-max)	RW	uint16)	2	1	ELR variable - 0xD0E5 (x - 102%); Minimum value needs to be calculated, refer to programming guide; PS: 0x0000 - 0xD0E5 (0 - 102%)	Resistance value (for translation see programming guide)	2	37	0x0224	x

Modbus address (dec)	Modbus address (hex)	Read code (0x01)	Read holding registers (0x03)	Write single coil (0x05)	Write single register (0x06)	Write multiple registers (0x10)	Description	Access	Data type	Data length in bytes	Number of registers	Data	Example	Profibus slot	Profibus index	Profinet Index (hex)	EtherCAT SDO/PDO?
10007	0x2717	x		x			Ethernet: TCP keep-alive timeout	RW	uint(16)	2	1	Coil: Keep-alive on/off	0x0000 = off; 0xFF00 = on				
10008	0x2718	x		x			Ethernet/Profinet/Modbus TCP: DHCP	RW	uint(16)	2	1	Coil: DHCP on/off	0x0000 = off; 0xFF00 = on				
10010	0x271A	x		x			Protocol: Modbus	RW	uint(16)	2	1	Coil: MODBUS on/off	0x0000 = off; 0xFF00 = on				
10011	0x271B	x		x			Protocol: SCPI	RW	uint(16)	2	1	Coil: SCPI on/off	0x0000 = off; 0xFF00 = on				
10012	0x271C	x		x			Restart interface card	RW	uint(16)	2	1	Coil: Restart	0xFF00 = Trigger restart				
10013	0x271D	x		x			Modbus specification compliance	RW	uint(16)	2	1	Coil: Mode	0x0000 = Limited (default); 0xFF00 = Full				
10020	0x2724		x				AnyBus module: Type	R	uint(16)	2	1	Reg: Type	0x0005 = Profibus 0x0009 = RS232 0x0010 = CANopen 0x0011 = Devicenet 0x0012 = Modbus-TCP 1P 0x0013 = Profinet 1P 0x0014 = Ethernet 1P 0x0015 = Ethernet 2P 0x0016 = Modbus-TCP 2P 0x0017 = Profinet 2P 0x0019 = CAN 0x001A = EtherCAT 0x00FF = no or unknown module plugged				
10021	0x2725		x				AnyBus module: Interface type	R	char	40	20	ASCII	"Profibus DPV1"				
10041	0x2739		x				AnyBus module: Version number	R	uint(8)	4	2						
10043	0x273B		x				AnyBus module: Serial number	R	uint(32)	4	2						
10251	0x280B		x		x		Profibus: Ident number	RW	uint(16)	2	1		0xA001	8	0	0x07F9	
10252	0x280C		x		x		Profibus/CANopen: Node address	RW	uint(16)	2	1		Profibus: 0-125 ; CANopen: 0-127	8	1	0x07FA	
10253	0x280D		x		x		Profibus/Profinet: User-defineable "Function tag"	RW	char	32	16	ASCII	"Test"	8	2	0x07FB	
10269	0x281D		x		x		Profibus/Profinet: User-defineable "Location tag"	RW	char	22	11	ASCII	"Test"	8	3	0x07FC	
10280	0x2828		x		x		Profibus/Profinet: User-defineable installation date	RW	char	40	20	ASCII	"13.01.2012 09:59:00"	8	4	0x07FD	
10300	0x283C		x		x		Profibus/Profinet: User-defineable description	RW	char	54	27	ASCII	"www.webpage.de"	8	5	0x07FE	
10354	0x2872		x		x		Profinet: User-defineable "Station name"	RW	char	200	100	ASCII	"Test"	8	6	0x07FF	
10502	0x2906		x		x		Ethernet/Modbus TCP: IP address	RW	uint(8)	4	2	Bytes 0-3: 0..255	192.168.0.2 (default)				
10504	0x2908		x		x		Ethernet/Modbus TCP: Subnet mask	RW	uint(8)	4	2	Bytes 0-3: 0..255	255.255.255.0 (default)				
10506	0x290A		x		x		Ethernet/Modbus TCP: Gateway	RW	uint(8)	4	2	Bytes 0-3: 0..255	192.168.0.1 (default)				
10508	0x290C		x		x		Ethernet/Profinet/Modbus TCP: Host name	RW	char	54	27	ASCII	"Client" (default)				
10535	0x2927		x		x		Ethernet/Profinet/Modbus TCP: Domain name	RW	char	54	27	ASCII	"Workgroup" (default)				
10562	0x2942		x		x		Ethernet/Modbus TCP: DNS 1	RW	uint(8)	4	2	Bytes 0-3: 0..255	0.0.0.0 (default)				
10564	0x2944		x		x		Ethernet/Modbus TCP: DNS 2	RW	uint(8)	4	2	Bytes 0-3: 0..255	0.0.0.0 (default)				
10566	0x2946		x			x	RS232/USB: Connection timeout in milliseconds	RW	uint(16)	2	1	5..65535	Default: 5ms				
10567	0x2947		x				Ethernet/Profinet/Modbus TCP: MAC	R	uint(8)	6	3	Bytes 0-5: 0..255	00:50:C2:C3:12:34 or 00-50-C2-C3-12-34				
10570	0x294A		x			x	Ethernet/Modbus TCP: Connection speed Port 1 (1 & 2 port modules)	RW	uint(16)	2	1	Connection speed	0x0000 = Auto; 0x0001 = 10Mbit half duplex; 0x0002 = 10Mbit full duplex; 0x0003 = 100Mbit half duplex; 0x0004 = 100Mbit full duplex				
10571	0x294B		x			x	Ethernet/Modbus TCP: Connection speed Port 2 (2 port module)	RW	uint(16)	2	1	Connection speed	0x0000 = Auto; 0x0001 = 10Mbit half duplex; 0x0002 = 10Mbit full duplex; 0x0003 = 100Mbit half duplex; 0x0004 = 100Mbit full duplex				
10572	0x294C		x		x		Ethernet (except for Modbus TCP): Port	RW	uint(16)	2	1	0..65535	5025 (default), except port 80				
10573	0x294D		x		x		Ethernet: TCP Socket timeout (in seconds)	RW	uint(16)	2	1	5..65535	0 = timeout inactive; 5 = 5 s (default)				
10700	0x29CC		x		x		RS232/CANopen/CAN: Baud rate	RW	uint(16)	2	1	Baud rate	CAN CANopen RS232 0x00: 10kbps 10kbps 2400 Bd 0x01: 20kbps 20kbps 4800 Bd 0x02: 50kbps 50kbps 9600 Bd 0x03: 100kbps 100kbps 19200 Bd 0x04: 125kbps 125kbps 38400 Bd 0x05: 250kbps 250kbps 57600 Bd 0x06: 500kbps 500kbps 115200 Bd 0x07: 1Mbps 800kbps - 0x08: - 1Mbps - 0x09: - Autobaud -				
10701	0x29CD	x		x			CAN: ID format	RW	uint(16)	2	1	Coil: Base/Extended	0x0000 = Base (11 Bit); 0xFF00 = Extended (29 Bit)				
10702	0x29CE	x		x			CAN: Termination	RW	uint(16)	2	1	Coil: Bus termination	0x0000 = off; 0xFF00 = on				
10704	0x29D0		x			x	CAN: Base ID	RW	uint(32)	4	2	0x0000...0x07FF or 0x0000...0x1FFFFFFF	Default: 0x000				
10706	0x29D2		x			x	CAN: Broadcast ID	RW	uint(32)	4	2	0x0000...0x07FF or 0x0000...0x1FFFFFFF	Default: 0x7FF				
10709	0x29D5	x		x			CAN: Data length	RW	uint(16)	2	1	Coil: Data length	0x0000 = Auto; 0xFF00 = Always 8 bytes				
10710	0x29D6		x			x	CAN: Cyclic read: Base ID	RW	uint(32)	4	2	0x0000...0x07FF or 0x0000...0x1FFFFFFF	Default: 0x100				
10712	0x29D8		x			x	CAN: Cyclic send: Base ID	RW	uint(32)	4	2	0x0000...0x07FF or 0x0000...0x1FFFFFFF	Default: 0x200				
10714	0x29DA	x		x		x	CAN: Cyclic read time (in ms): Status	RW	uint(16)	2	1	20...5000; 0 == off	Default: off				
10715	0x29DB	x		x		x	CAN: Cyclic read time (in ms): Set value (U, I, P, R)	RW	uint(16)	2	1	20...5000; 0 == off	Default: off				
10716	0x29DC	x		x		x	CAN: Cyclic read time (in ms): Limits 2 (P, R)	RW	uint(16)	2	1	20...5000; 0 == off	Default: off				
10717	0x29DD	x		x		x	CAN: Cyclic read time (in ms): Limits 1 (U, I)	RW	uint(16)	2	1	20...5000; 0 == off	Default: off				
10718	0x29DE	x		x		x	CAN: Cyclic read time (in ms): Actual values U, I, P	RW	uint(16)	2	1	20...5000; 0 == off	Default: off				
10820	0x2A44		x				Internal Ethernet interface: Status	R	uint(16)	2		Bits 0-5: - Bit 6: Keep-Alive Bit 7: DHCP 1 Bit 8: DHCP 2	0 = inactiv; 1 = activ 0 = DHCP deactivated; 1 = DHCP activated 0 = DHCP is not running, IP has been not assigned; 1 = DHCP is running, IP has been assigned				
10821	0x2A45	x		x			Internal Ethernet interface: TCP keep-alive timeout	RW	uint(16)	2	1	Coil: Keep-alive on/off	0x0000 = off; 0xFF00 = on				
10822	0x2A46	x		x			Internal Ethernet interface: DHCP	RW	uint(16)	2	1	Coil: DHCP on/off	0x0000 = off; 0xFF00 = on				
10823	0x2A47		x		x		Internal Ethernet interface: IP address	RW	uint(8)	4	2	Bytes 0-3: 0..255	192.168.0.2 (default)				
10825	0x2A49		x		x		Internal Ethernet interface: Subnet mask	RW	uint(8)	4	2	Bytes 0-3: 0..255	255.255.255.0 (default)				
10827	0x2A4B		x		x		Internal Ethernet interface: Gateway	RW	uint(8)	4	2	Bytes 0-3: 0..255	192.168.0.1 (default)				
10829	0x2A4D		x		x		Internal Ethernet interface: Host name	RW	char	54	27	ASCII	"Client" (default)				
10856	0x2A68		x		x		Internal Ethernet interface: Domain name	RW	char	54	27	ASCII	"Workgroup" (default)				
10883	0x2A83		x		x		Internal Ethernet interface: DNS	RW	uint(8)	4	2	Bytes 0-3: 0..255	0.0.0.0 (default)				
10885	0x2A85		x				Internal Ethernet interface: MAC	R	uint(8)	6	3	Bytes 0-5: 0..255	00:50:C2:C3:12:34 or 00-50-C2-C3-12-34				
10888	0x2A88		x		x	x	Internal Ethernet interface: Port	RW	uint(16)	2	1	0..65535	5025 (default), except port 80				
10889	0x2A89		x		x	x	Internal Ethernet interface: TCP Socket timeout (in seconds)	RW	uint(16)	2	1	5..65535 (0 = timeout inactive)	Default: 5				
12000	0x2EE0	x		x		x	Function generator PV: Start/Stop	RW	uint(16)	2	1	Coil: Start/Stop	0x0000 = Stop; 0xFF00 = Start	10	0	0x09F7	x
12001	0x2EE1		x			x	Function generator PV: Simulation mode	RW	uint(16)	2	1	Mode	0x0000 = off; 0x0001 = Irradiation/temperature; 0x0002 = Umpp/Impp; 0x0003 = Daily trend irradiation/temp.; 0x0004 = Daily trend Umpp/Impp	10	1	0x09F8	x
12002	0x2EE2		x				Function generator PV: MPP Voltage	R	uint(16)	2	1	0x0000 - 0xCCCC	MPP voltage (for translation see programming guide)	10	2	0x09F9	x
12003	0x2EE3		x				Function generator PV: MPP Current	R	uint(16)	2	1	0x0000 - 0xCCCC	MPP current (for translation see programming guide)	10	3	0x09FA	x
12004	0x2EE4		x				Function generator PV: MPP Power	R	uint(16)	2	1	0x0000 - 0xCCCC	MPP power (for translation see programming guide)	10	4	0x09FB	x
12005	0x2EE5	x		x			Function generator PV: Interpolation	RW	uint(16)	2	1	Coil: on/off	0x0000 = off; 0xFF00 = on	10	5	0x09FC	x
12006	0x2EE6	x		x			Function generator PV: Day trend mode	RW	uint(16)	2	1	Coil: Mode	0x0000 = read only; 0xFF00 = write	10	6	0x09FD	x
12007	0x2EE7		x				Function generator PV: Day trend (clear completely)	W	uint(16)	2	1	Coil: Clear	0xFF00 = clear	10	7	0x09FE	x
12008	0x2EE8		x			x	Function generator PV: Day trend index	RW	uint(32)	4	2	1...100000	0x0001 = Index 1	10	8	0x09FF	x
12010	0x2EEA		x			x	Function generator PV: Day trend index data	RW			12	6	Byte 0-3: Index [0x00000001...0x000186A0] Byte 4-5: E or U-MPP [0x0000...0xCCCC] Byte 6-7: Temp. 8 or I-MPP [0x0000...0xCCCC] Byte 8-11: ∆t in [ms] 500...1800000	Currently selected index Irradiation or U-MPP (for translation see register 12053) or U-MPP (for translation see programming guide) Module temperature (for translation see register 12052) or I-MPP (for translation see programming guide) Dwelltime of index	10	9	0x0A00	x
12016	0x2EF0		x			x	Function generator PV: Technology	RW	uint(16)	2	1	Technology	0x0000 = Manual; 0x0001 = cSI technology; 0x0002 = Thin film technology	10	10	0x0A01	x
12017	0x2EF1	x		x		x	Function generator PV: Input mode	RW	uint(16)	2	1	Coil: Mode	0x0000 = MPP; 0xFF00 = ULIK	10	11	0x0A02	x
12018	0x2EF2	x		x		x	Function generator PV: Activate data recording	RW	uint(16)	2	1	Coil: Record	0x0000 = halt; 0xFF00 = continue	10	12	0x0A03	x
12019	0x2EF3		x				Function generator PV: Clear recorded data	W	uint(16)	2	1	Coil: Clear	0xFF00 = clear	10	13	0x0A04	x
12020	0x2EF4		x				Function generator PV: Actual record count	R	uint(32)	4	2	0x00000000...0x0008CA00	0x0000000F = 15 recorded values	10	14	0x0A05	x
12022	0x2EF6		x			x	Function generator PV: Record index	RW	uint(32)	4	2	0x00000001...0x0008CA00	0x0008CA00 = Index 576,000 (highest possible index)	10	15	0x0A06	x
12024	0x2EF8		x				Function generator PV: Data set	R			16	8	Byte 0-3: Actual index [0x00000001...0x0008CA00] Byte 4-5: U_ist [0x0000...0xCCCC] Byte 6-7: I_ist [0x0000...0xCCCC] Byte 8-9: P_ist [0x0000...0xCCCC] Byte 10-11: U_mpp [0x0000...0xCCCC] Byte 12-13: I_mpp [0x0000...0xCCCC] Byte 14-15: P_mpp [0x0000...0xCCCC]	Actual index Actual voltage Actual current Actual power MPP voltage MPP current MPP power	10	16	0x0A07	x
12032	0x2F00		x				Function generator PV: Open-circuit voltage	R	uint(16)	2	1	0x0000...0xCCCC	Open-circuit voltage (for translation see programming guide)	10	17	0x0A08	x
12033	0x2F01		x				Function generator PV: Short-circuit current	R	uint(16)	2	1	0x0000...0xCCCC	Short-circuit current (for translation see programming guide)	10	18	0x0A09	x
12034	0x2F02		x			x	Function generator PV: Fill factor (voltage)	RW	float	4	2	FFu: >0...1	Floating point number in IEEE754 format	10	19	0x0A0A	x
12036	0x2F04		x			x	Function generator PV: Fill factor (current)	RW	float	4	2	FFi: >0...1	Floating point number in IEEE754 format	10	20	0x0A0B	x
12038	0x2F06		x			x	Function generator PV: Temperature coefficient for Isc (Technology parameter)	RW	float	4	2	a in 1/°C; values >0....1	Floating point number in IEEE754 format	10	23	0x0A0E	x
12040	0x2F08		x			x	Function generator PV: Temperature coefficient for Uoc (Technology parameter)	RW	float	4	2	b in 1/°C; values <0....-1	Floating point number in IEEE754 format	10	24	0x0A0F	x
12042	0x2F0A		x			x	Function generator PV: Conection factor Cu(Technology parameter)	RW	float	4	2	Cu without unit; values > 0....1	Floating point number in IEEE754 format	10	25	0x0A11	x
12044	0x2F0C		x			x	Function generator PV: Conection factor Cr (Technology parameter)	RW	float	4	2	Cr in m²/W; values >0....1	Floating point number in IEEE754 format	10	28	0x0A13	x
12046	0x2F0E		x			x	Function generator PV: Conection factor Cg/Es (Technology parameter)	RW	float	4	2	Cg in W/m²; values >0....1	Floating point number in IEEE754 format	10	30	0x0A15	x
12048	0x2F10		x			x	Function generator PV: Open-circuit voltage STC (Standard Test condition)	RW	uint(16)	2	1	0x0000 - 0xCCCC	Open-circuit voltage (for translation see programming guide)	10	31	0x0A16	x
12049	0x2F11		x			x	Function generator PV: Short-circuit current STC	RW	uint(16)	2	1	0x0000 - 0xCCCC	Short-circuit current (for translation see programming guide)	10	32	0x0A17	x
12050	0x2F12		x			x	Function generator PV: MPP Voltage STC	RW	uint(16)	2	1	0x0000 - 0xCCCC	MPP voltage (for translation see programming guide)	10	33	0x0A18	x
12051	0x2F13		x			x	Function generator PV: MPP current STC	RW	uint(16)	2	1	0x0000 - 0xCCCC	MPP current (for translation see programming guide)	10	34	0x0A19	x
12052	0x2F14		x			x	Function generator PV: Module temperature	RW	uint(16)	2	1	∆module in °C; 0x0000...0xCCCC coresponds to -40...80 °C	Module temperature (translation: value = [real value+40]/120*52428)	10	35	0x0A1A	x
12053	0x2F15		x			x	Function generator PV: Irradiation	RW	uint(16)	2	1	E in W/m²; 0x0000...0xCCCC coresponds to 0-1500 W/m²	Irradiation (translation: value = real value/1500*52428)	10	36	0x0A1B	x
12054	0x2F16		x				Function generator PV: Status	R	uint(16)	2	1	Status code of PV simulation	0x0000 = Stop; 0x0001 = Run; 0x0002 = Stopped, mode fault; 0x0003 = Stopped, day trend fault; 0x0004 = Stopped, alarm; 0x0005 = Stopped, interpolation fault; 0xFFFF = PV not activ	10	37	0x0A1C	x
12055	0x2F17		x				Function generator PV: Actual day data count	R	uint(32)	4	2	0x00000000...0x000186A0	0x0000000F = 15 data samples written	10	38	0x0A1D	x
21000	0x5208		x				Operation counter: total time	R	uint(16)	6	3	DDDDD:HH:MM	Word 0 = Days (0-65535) Word 1 = Hours (0-23) Word 2 = Minutes (0-59)	2	53	0x0234	_
21003	0x520B		x				Operation counter: DC on time	R	uint(16)	6	3	DDDDD:HH:MM	Word 0 = Days (0-65535) Word 1 = Hours (0-23) Word 2 = Minutes (0-59)	2	54	0x0235	_
21006	0x520E		x				Operation counter: DC off time	R	uint(16)	6	3	DDDDD:HH:MM	Word 0 = Days (0-65535) Word 1 = Hours (0-23) Word 2 = Minutes (0-59)	2	55	0x0236	_
21009	0x5211		x				Operation counter: Energy in kWh (PSB/PSBE: source mode)	R	float	4	2	Floating point number IEEE754		2	56	0x0237	_
21011	0x5213		x				Operation counter: Capacity in Ah (PSB/PSBE: source mode)	R	float	4	2	Floating point number IEEE755		2	57	0x0238	_
21013	0x5215		x				Operation counter: Secondary energy in kWh (PSB/PSBE sink mode only)	R	float	4	2	Floating point number IEEE756		2	58	0x0239	_
21015	0x5217		x				Operation counter: Secondary capacity in Ah (PSB/PSBE sink mode only)	R	float	4	2	Floating point number IEEE757		2	59	0x023A	_

12 SCPI protocol

SCPI is an international standard for a plain text based command language. Details about the standard itself can be found on the internet.

12.1 Syntax

The following syntax formats can occur in commands and/or responses.

Values	This numeric value corresponds to the value in the display of the system and depends on the nominal values of the system. Rules: - The value must be sent after the command and separated by a space - Instead of a numeric value you can also use the literal labels:	
	MIN	corresponds to the minimum value of the parameter
	MAX	corresponds to the maximum value of the parameter
<NR1>	Numeric values without decimal place	
<NR2>	Numeric values with decimal place (floating point)	
<NR3>	Like <NR2>, but with multiplier (kilo, milli etc.)	
<NRf>	<NR1> or <NR2> or <NR3>, negative values supported	
Unit	V (Volt), A (Ampere), W (Watt), OHM, s (Seconds)	
<CHAR>	0..255: Decimal value	
<+INT>	0..32768: Positive integer value (output from system)	
<B0>	1 or ON: Function is/will be activated	
	0 or OFF: Function is/will be deactivated	
<B1>	NONE: manual operation active, switching to remote control possible	
	LOCal: local (manual) operation only, reading of data possible	
	REMote: system is in remote control	
<ERR>	Error with number (-800 to 399) and description	
<SRD>	String data, various formats: - IP address as number string with dots as separator, for example "192.168.0.2" - Key words, for example AUTO or OFF	
<Time>	[s]s.s[s][s][s][s][s][s] / Default format is seconds (s.s)	
;	The semicolon is used separate multiple commands within one message	
:	The colon separates the SCPI keywords (main system, subsystems)	
[ ]	Lowercase letters and the content of square brackets are optional	
?	The question mark identifies a message as query. A query can be combined with a control message (command concatenation). Note, that it's required to wait for the response of the query before the next control message can be sent.	
->	Response from system	

12.1.1 Concatenated Commands

It's possible to concatenate up to 5 commands in one message. Each command must be separated by a semicolon (;).

Example:

```
VOLT 80;CURR 20;POW 3kW
```

The commands in the string are processed from left to right, so the order of commands is important to achieve correct results. When querying multiple values or parameters at once, the returned string is also in concatenated format, with the queried returns separated by semicolons.

12.1.2 Upper and Lower Case

SCPI uses upper case commands by convention, though the mPower control system also accepts lower case.

12.1.3 Long Form and Short Form

SCPI commands have a long form and a short form. The short form (e.g. SOUR) and the long form (e.g. SOURCE) can be used arbitrarily. To distinguish both forms, the commands as described in the following sections are written partly in upper case to indicate the short form, and partly in lower case to indicate the rest of the long form (e.g. SOURce).

12.1.4 Termination Character

Some interfaces (GPIB is one) require a termination character to the message, but others don't (such as USB). When not required, the termination character is optional, but often used anyway in order to maintain software compatibility between several different interfaces.

The termination character to use is **0xA** (LF, line feed).

12.1.5 Errors

Errors in terms of SCPI are only communication errors. According to the standard, systems using SCPI do not return errors immediately. They have to be queried from the system. The query can occur directly with the error command or by first reading the signal bit **err** from the STB register (see 12.4 Status Registers (p 134)).

The error format is defined by the standard, and is made of a string containing a number (the error code) and a descriptive text. The following are error strings generated by mPower systems:

Error Code, Text	Description
0, "No error"	No error
-100, "Command error"	Command unknown
-102, "Syntax error"	Command syntax wrong
-108, "Parameter not allowed"	A command was sent with a parameter though the command doesn't use parameters
-200, "Execution error"	Command could not be executed
-201, "Invalid while in local"	Control command could not be executed, because system is in LOCAL mode
-220, "Parameter error"	Wrong parameter used
-221, "Settings conflict"	Command could not be executed because of the condition of the system (being in MENU etc.)
-222, "Data out of range"	Parameter could not be set because it exceeded a limit

-223, "Too much data"	Too many parameters per command or too many commands at once
-224, "Illegal parameter value"	A parameter not specified for the command has been sent
-999, "Safety OVP"	Alarm Safety OVP (only available with specific models) has been triggered (see system manual). It requires to power cycle the system.

12.1.6 Value Format

In the SCPI command language, real values are used in their decimal numeric text form, with or without unit identification. For example, if you wanted to set a current of 177.5 A you would use the simple command CURR 177.5 or, with units, CURR 177.5 A. Likewise, values returned in responses are also in the decimal numeric text form.

12.2 Getting Started

12.2.1 Ping

It's always recommended to ping a system first, in order to test if it responds at all. With SCPI, this is usually done by querying the identification string:

Command
`*IDN?`

As an immediate response, the system might send something like below which is Company Name, Part No., Serial No., HMI version, KE version, DR version, User Text (none shown):

Response
Marway Power Solutions, MPW 310-12-0080-120, 1960140001, V2.18 30.08.2019 V2.28 12.08.2019 V1.6.6,

12.2.2 Enable and Disable Remote Control

> - The system does not switch to remote control automatically, and cannot be remotely controlled without being explicitly in remote control mode. However, *reading* status and values is always possible.
> - The system does not exit remote control automatically (when a remote command completes). The system must be switched off (or lose AC supply), or commanded to switch back to manual control (through control panel, or remote command).

Before you can remotely control a system, you need to switch it to remote control by sending a command. Switching to remote control may be inhibited by several circumstances and is usually indicated by an error message:

- Condition **Local** is active (check the display or control panel on the front of your system), which will prevent any remote control (see 9.2 Control Locations (p 86)).
- The system is already remotely controlled by another interface.
- The system is in setup mode, meaning the user has accessed the Menu and not closed it yet.

How to switch a system to remote control

> Send a text command (the space is required):
> `SYST:LOCK 1 —or— SYST:LOCK ON`

How to exit remote control

> Send a text command (the space is required):
> `SYST:LOCK 0 —or— SYST:LOCK OFF`

12.3 Standard IEEE Commands

To support the legacy interface standards of GPIB and IEEE 488, some of the traditional commands have been implemented.

*CLS

Clears the error queue and the status byte (STB).

*IDN?

Returns the system identification string, which contains following information, separated by commas.

1. Manufacturer
2. Model name
3. Serial number
4. Firmware version(s) (in case there are several, these are separated by a space)
5. User text (arbitrary user-definable text, as definable with SYST:CONFIG:USER:TEXT)

*RST

Sets the system to a defined state:

1. Switch to remote control (same as SYST:LOCK 1)
2. Set DC output to off
3. Clear alarm buffer
4. Clear status registers to default condition (QUEStionable Event, OPERation Event, STB)

*STB?

Reads the STatus Byte register. The signal run of the various system conditions and events is illustrated in the register model below. The STB bits in particular:

- Bit 0: sec_ques, Second Questionable Status Register is active (one or more events have occurred)
- Bit 1: not used
- Bit 2: err, Error Queue --> one or more errors in the error buffer. By reading the error buffer or sending *CLS it's flushed and the bit err is reset
- Bit 3: ques, Questionable Status Register is active (one or more events have occurred)
- Bit 4: not used
- Bit 5: not used
- Bit 6: not used
- Bit 7: oper, Operation Status Register is active (one or more events have occurred)

12.4 Status Registers

Not all system conditions and alarms can be read with dedicated SCPI commands. As an alternative, the remaining system-related information are grouped in status registers. Using regular polling, the status byte (STB) can be a starting point for reading the system status. It tells which status register has recorded at least one event. Apart from that, the other status registers could also be polled directly. The difference would be that the user would have to determine which bits in the register have changed by comparing the most recent value with an older value. The bits in the status byte register will do that job for you. If they remain 0, nothing has happened.

Once a bit in the STB indicates (value 1) that there was an event recorded in the QUES or OPER register, you could read the corresponding event register of OPER and QUES in order to find out which bits have changed in the COND register.
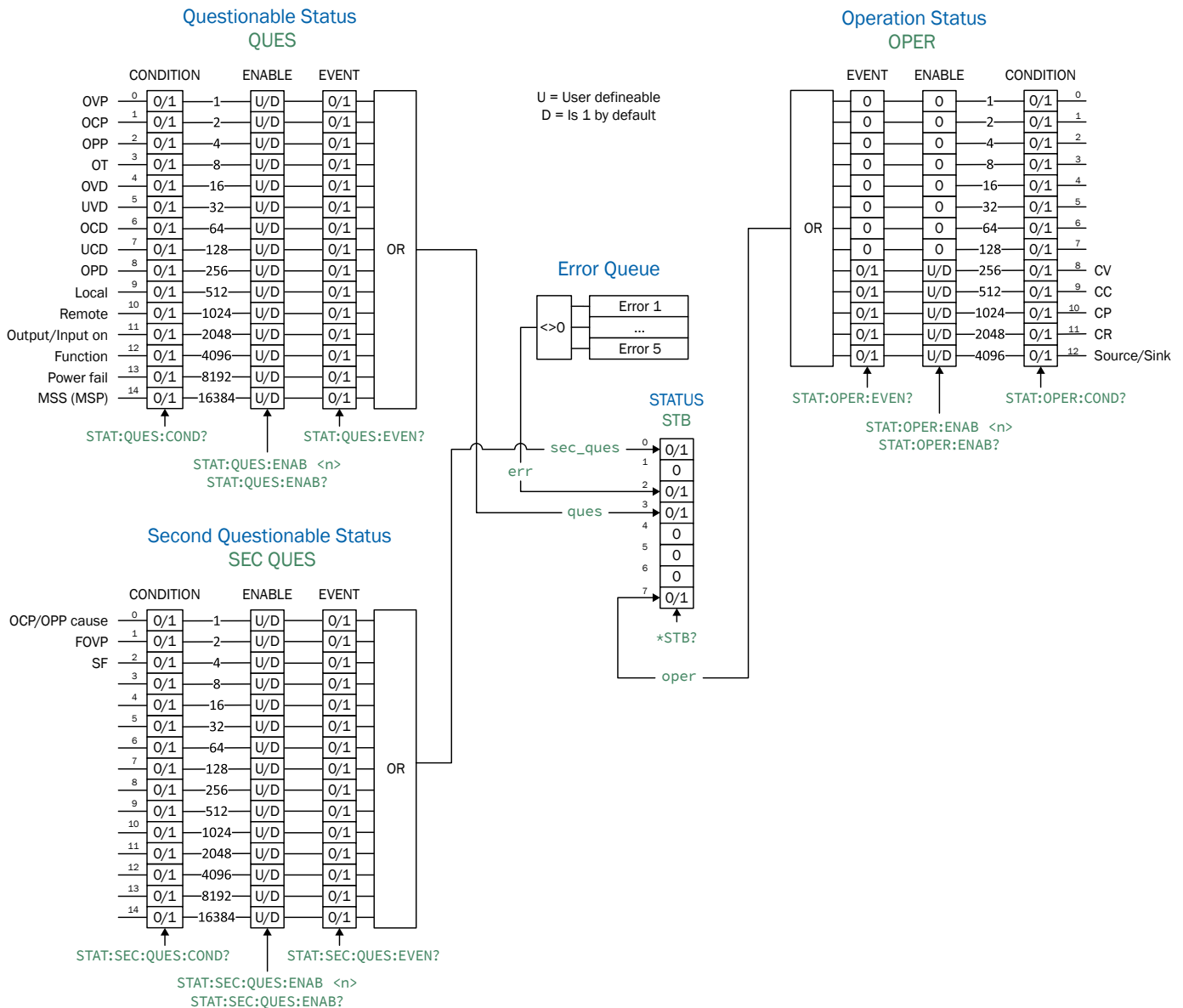
Events recorded in the event registers `STAT:QUES:EVENT` and `STAT:OPER:EVENT` only record positive transitions (changes from 0 to 1).

System alarms like OVP are signaled in the subregisters `CONDITION` and `EVENT`. Each has to be acknowledged separately using commands `SYST:ERR?` and `SYST:ERR:ALL?`, These commands are considered alarm acknowledgement, and will clear the corresponding bit in CONDITION, but only if the alarm condition has subsided. Alarms which have been acknowledged can be determined from the system in the form of an alarm counter. It's recommended to regularly poll alarms from the system and to query `STAT:QUES?` prior to `SYST:ERR?`.

STATus:QUEStionable?

Reads the Questionable status CONDITION or EVENT register.

Returns a 16 bit value representing system information from the register model in 12.4 Status Registers (p 134).

Query Forms:

STATus:QUEStionable:CONDition?
STATus:QUEStionable:EVENt?
STATus:QUEStionable?

Examples:

STAT:QUES? -> 3072   Reads the event register. This example reveals that bits 10 and 11 are set which identifies that **Remote = active** and **Output on = on**.

STAT:QUES:COND?   Reads the condition register of the questionable status register. The value contains the current snapshot of a number of status bits.

STATus:QUEStionable:ENABle <NR1>

Sets or reads the ENABLE register of the Questionable status register. The ENABLE register is a filter that enables all or single bits to signal an event to the status byte STB. By default, all bits of the ENABLE register are set. In case you want to ignore certain bits, you just need to add the values of the remaining bits and send the value to the ENABLE register.

Returns the sum of the decimal-valued bits in the register.

Query Forms:

STATus:QUEStionable:ENABle? <0–32767>

Example:

STAT:QUES:ENAB 3081   Sets the enable register of the questionable status registers to 3072 and enables the bits **OVP** (1), **OT** (8), **Remote** (1024), and **Output on** (2048) for event reporting to STB. (Note that 1 + 8 + 1024 + 2048 = 3081.)

STATus:OPERation?

Reads the Operation status EVENT or CONDITION register.

Returns a 16 bit value representing system information from the register model in 12.4 Status Registers (p 134).

Query Forms:

STATus:OPERation:CONDition?

STATus:OPERation:EVENt?

STATus:OPERation?

Examples:

STAT:OPER? -> 256	Reads the operation register (identical to :EVENt?). A possible response would be a value of 256, which tells, that bit 8 is set and according to the register model bit 8 signals, that CV (constant voltage regulation) is active.
STAT:OPER:COND?	Reads the condition register of the operation status registers.

STATus:OPERation:ENABle <NR1>

Sets or reads the Enable register of the Questionable status register. The Enable register is a filter. It enables single or all bits of the condition registers to change the corresponding bit in the event register. This also impacts the summary bit in the status byte STB. By default, all bits of the Enable register are set to 1. If you want to use only some specific bits, add the bit values (see register model) and send the total to the Enable register.

Returns a value which represents the bits set to 1 in the Enable register (as seen in 12.4 Status Registers (p 134)).

Query form:

STATus:OPERation:ENABle?

Value range:

<NR1> = 0, 256–3840	Since bits 0–7 are not used, the minimum value other than 0 starts with 256. Also, bit 12 is always zero, therefore the maximum sum of the bits is 3840.

Example:

STAT:OPER:ENAB 1792	Sets the Enable register of the Operation register to value 1792 and enables bits CV, CC and CP for reporting events to the STB.

12.5 Status Commands

Status commands are used to alter the status of the system in terms of activating remote control or switching the DC output, or to query the current status.

SYSTem:LOCK <B0>

This command is used to activate remote control of a system. Remote control has to be activated first before you can send any command which change system status or values. Once remote control has been activated via one of the digital interfaces, only that interface is in charge.

The activation of remote control can be refused by the system due to several reasons. It's usually replied in form of a SCPI error which is put into the SCPI error buffer. This buffer can be read with the error command.

Query form:

SYSTem:LOCK:OWNer?

Value range for set:

ON, OFF

Value range for query:

REMOTE, NONE, LOCAL

Examples:

SYST:LOCK ON	Absolute short form. Requests the system to switch to remote control. The system then usually indicates activated remote control either by a LED or a status text in the display.
SYSTEM:LOCK:OWNER?	-> REMOTE
	Queries the lock owner regarding remote control. This can be used to verify whether the system has accepted the request to switch to remote control or not. It will return one of three different values:
	REMOTE = System is in remote control via any of the available interfaces
	NONE = System is not in remote control
	LOCAL = System is in LOCAL condition, which denies or interrupts remote control.

OUTPut <B0>

This command is used to switch the DC output on or off.

Query form:

OUTPut?

Value range:

ON, OFF

Examples:

OUTP 1	Absolute short form. Switches the DC output on if remote control is active.
OUTPUT?	-> ON
	Queries the condition of the DC output, which will be returned as ON or OFF. Output state cannot be assumed as the output might be switched off due to a system alarm.

SYSTem:ERRor?

This command is used to read a single error, or all errors, from the system's internal SCPI error queue. This queue only contains errors in relation to commands (e.g. wrong syntax, too high values, etc.). It cannot return any system alarm. Those are usually queried from the system by reading bits of the status registers. You can choose either to query the next error multiple times until it returns "No error," or generally query all at once. After all errors have been read from the buffer, it will be purged.

The queue is of type FIFO (first in, first out), so the first error event is returned first when querying.

> Querying errors with SYST:ERR? also clears bits related to system alarms in register QUEStionable, but only if the alarm condition has already receded. The query is considered as an acknowledgement by the user. Alarms which have been acknowledged this way can then not be read from the register anymore.

Query forms:

SYSTem:ERRor?	Queries the last or next error
SYSTem:ERRor:NEXT?	Queries the last or next error
SYSTem:ERRor:ALL?	Queries all errors in the buffer (up to 5)

Example:

SYST:ERR?	-> 0,No error
	Absolute short form. The system replies to this query with a string that first contains an error code (see error code list) and second an error description. This is returned every time no error is present, or after all errors have been returned.
SYSTEM:ERROR:ALL?	This query will let the system return up to 5 concatenated errors in one string, separated by comma plus space.

12.6 Set Value Commands

> All set values (U, I, P, R) are not only limited by the maximum nominal values of the unit, but are additionally limited by the adjustment **Limits** just as they would be in manual operation.

`[SOURce:]VOLTage <NRf>[Unit]`

Sets the output voltage limit of the system within a certain range, which is either defined by adjustment limits, or is 0–102% nominal value. When queried, this reads the last setting. Alternatively, parameters MIN or MAX can be used to instantly set the voltage to the adjustable MINimum or MAXimum.

Returns a numeric value of the voltage limit setting.

Query form:

`[SOURce:]VOLTage?`

Value range:

`<NRf> = 0–1.02 * nominal V`	102% of nominal value for the model.

Examples:

`VOLT 12`	Absolute short form. Sets 12 V.
`SOUR:VOLTAGE 24.5V`	Mixed form short/long, with unit. Sets 24.5 V, unless the voltage adjustment range has been limited otherwise.
`SOURCE:VOLTAGE MIN`	Sets the voltage to the defined minimum, usually 0 V.

`[SOURce:]CURRent <NRf>[Unit]`

Sets the output current limit of the system within a certain range, which is either defined by adjustment limits, or is 0–102% nominal value. When queried, this reads the last setting. Alternatively, parameters MIN or MAX can be used to instantly set the current to the adjustable MINimum or MAXimum.

Returns a numeric value of the current limit setting.

Query form:

`[SOURce:]CURRent?`

Value range:

`<NRf> = 0–1.02 * nominal V`	102% of nominal value for the model.

Example:

`CURR 170`	Absolute short form. Sets 170 A.
`SOUR:CURRENT 45.3A`	Mixed form short/long, with unit. Sets 45.3 A, unless the adjustment range of the current has been limited otherwise.
`SOURCE:CURRENT MAX`	Sets the current to the defined maximum, which is either 102% of the rated current of the system, or to the value of adjustment limit **I-max** (also see 12.10 Adjustment Limit Commands (p 145)).

[SOURce:]POWer <NRf>[Unit]

Sets the output power limit of the system within a certain range, which is either defined by adjustment limits, or is 0–102% nominal value. When queried, this reads the last setting. Alternatively, parameters MIN or MAX can be used to instantly set the current to the adjustable MINimum or MAXimum.

Returns a numeric value of the current limit setting.

Query form:

`[SOURce:]POWer?`

Value range:

<NRf> = 0–1.02 * nominal V	102% of nominal value for the model.

Examples:

`POW 3000`	Absolute short form. Sets 3000 W, unless the power adjustment range has been limited otherwise.
`SOUR:POWER 3.5kW`	Mixed form short/long, with unit and magnitude Kilo. Sets 3.5 kW (3500 W), unless the adjustment range of the power has been limited otherwise.
`SOURCE:POWER MIN`	Sets the power to the defined minimum, which is usually 0 W.

[SOURce:]RESistance <NRf>[Unit]

This command will set the input resistance value in Ohms within a defined range, as it can be adjusted on the front panel. The mPower 311 units use this value to simulate an internal resistor in series to the output, where the output voltage differs from the adjusted value by an amount that calculates from the adjusted resistance value and actual output current. The way of setting the resistance value on both system types is identical. The adjustable range can be limited with an upper adjustment limit. Alternatively, parameters MIN or MAX can be used to instantly set the resistance to the adjustable MINimum or MAXimum.

Returns a numeric value of the current limit setting.

Query form:

`[SOURce:]RESistance?`

Value range:

<NRf> = Min. resistance to max. resistance, according to technical specs of the model

Examples:

RES?	Absolute short form. Queries the currently set resistance value.
SOUR:RESISTANCE 10	Mixed form short/long. Sets 10 Ω.
SOURCE:RES MIN	Sets the resistance to the minimum defined for the particular system model.

12.7 Measure Commands

Actual values, as returned by the measuring commands, are the DC output values as they are present at the moment they are queried. They are not necessarily identical to the corresponding set values. The system constantly measures the actual values, and returns the last snapshot when queried.

The number of decimal places in the returned value will be identical to the value format in the system display and varies from model to model. (There's more about decimal places in the Operating Guides.)

MEASure:[SCALar:]VOLTage[:DC]?

Queries the system to return the last measured DC output voltage value in Volts.

Example:

MEAS:VOLT?   -> 43.50 V

Absolute short form. Queries the actual voltage. A response, which should be instant, will return a value between 0% and 125% of nominal system voltage.

MEASure:[SCALar:]CURRent[:DC]?

Queries the system to return the last measured DC output current value in Amperes.

Example:

MEASURE:CURRENT?   -> 100.1 A

Queries the actual current only. A response, which should be instant, will return a value between 0% and 125% of nominal system current.

MEASure:[SCALar:]POWer[:DC]?

Queries the system to return the last calculated DC output power value in Watts.

Example:

MEAS:POW?   -> 2534 W

Absolute short form. Queries the consumed supplied power. A response, which should be instant, will return a value between 0% and 125% of nominal system power. No matter how the actual power format is in the system's display, here it will always be returned in Watts.

MEASure:[SCALar:]ARRay?

Queries the system to return the last measured actual values of voltage, current, and power (in that sequence) , separated by commas, and with units.

Example:

```
MEAS:ARR?                 -> 12.5 V, 33.3 A, 420 W
```
Absolute short form. A response, which should be instant, will return three values between 0% and 125% of nominal system values.

12.8 Protective Feature Commands

mPower systems feature a set of system alarms, partly for self-protection, partly for the protection of connected equipment. Additionally, there is a supervision feature which can monitor DC output attributes like voltage, current, or power for exceeding user-defined limits, and trigger user-definable actions like an acoustic alarm or shutdown of the DC output. Configuration of the supervision features can be done manually in the user profile, or by remote commands.

[SOURce:]VOLTage:PROTection[:LEVel] <NRf>[Unit]

This command is connected to the adjustable value OVP (overvoltage protection). The value is adjustable between 0 and 110% nominal system voltage. It defines a threshold where the system switches the DC output off whether the system has generated a voltage higher than this threshold, or the excess is coming from an outside source. When controlling a source, this feature usually serves to protect the connected load from overvoltage and thus damage. This can occur if the output voltage is accidentally adjusted to a dangerous level.

Query form:

```
[SOURce:]VOLTage:PROTection[:LEVel]?
```

Value range:

0–1.1 * nominal voltage of the system

Examples:

```
VOLT:PROT 88
```
Absolute short form. Sets the OVP threshold to 88 V. At a model with 80 V nominal voltage, this is 110% of the maximum voltage and the maximum OVP value.

[SOURce:]CURRent:PROTection[:LEVel] <NRf>[Unit]

This command is connected to the adjustable value OCP (overcurrent protection). The value is adjustable between 0 and 110% nominal system current. It defines a threshold where the system switches the DC output off. Once the output current reaches the threshold, the system will instantly switch the DC output off. The threshold is only effective if it's adjusted to a lower value than the output current, because otherwise the system would just limit the current, but not switch off. If current value and overcurrent protection are adjusted to the same value, the OCP has priority and will switch off rather than limit.

Query form:

```
[SOURce:]CURRent:PROTection[:LEVel]?
```

Value range:

0–1.1 * nominal current of the system

Example:

CURR:PROT 100   Absolute short form. Sets the OCP threshold to 100 A.

[SOURce:]POWer:PROTection[:LEVel] <NRf>[Unit]

This command is connected to the adjustable value OPP (overpower protection). The value is adjustable between 0 and 110% nominal system power. It defines a threshold where the system switches the DC output off. This feature helps to protect equipment from exceeding a certain power load. Once the output power reaches the threshold, the system will instantly switch the DC output off. The threshold is only effective if it's adjusted to a lower value than the output power, otherwise the system will just limit the power, but not switch off. If power value and overpower protection are adjusted to the same value, the OPP has priority and will switch off rather than limit.

Query form:

[SOURce:]POWer:PROTection[:LEVel]?

Value range:

0–1.1 * nominal power of the system

Example:

POW:PROT 1.5kW   Absolute short form. Sets the OPP threshold to 1.5 kW.

12.9 User Events Commands

These commands provide remote configuration of user event features related to voltage, current, or power on the DC output. Reference 5.1.3 User Defined Events (p 37) and 12.4 Status Registers (p 134).

The `:ACTion` can have following parameters (also see the system's operation guide):

NONE = Event inactive, no supervision

SIGNAL = As soon as the event occurs, text is presented in the status field of the system display, and a bit in the Questionable Register (`STAT:QUES?`) is set. The bit indicates that a specific event has occurred. This can be used to record the event.

WARNING = As soon as the event occurs, a warning pop-up is presented in the system display, and a bit in the Questionable Register (`STAT:QUES?`) is set. The bit indicates that a specific event has occurred. This can be used to record the event.

ALARM = As soon as the event occurs, a warning pop-up is presented in the system display, as well as an acoustic alarm is initiated, the DC output is switched off, and a bit in the Questionable Register (`STAT:QUES?`) is set. The bit indicates, that a specific event has occurred. This can be used to record the event.

> ❗ The action ALARM lets the system act similar to when a system alarm occurs. However, system alarms have priority. This means that if, for example, OVP and OVD were equal, and the output voltage reached that level, the system would initiate an OV alarm rather than an OVD event.

```
SYSTem:CONFig:UVD[?] <NRf>[Unit]
SYSTem:CONFig:UVD:ACTion[?] {NONE|SIGNAL|WARNING|ALARM}
```

Identical to event UVD, as configurable in the system menu.

```
SYSTem:CONFig:UCD[?] <NRf>[Unit]
SYSTem:CONFig:UCD:ACTion[?] {NONE|SIGNAL|WARNING|ALARM}
```

Identical to event UCD, as configurable in the system menu

```
SYSTem:CONFig:OVD[?] <NRf>[Unit]
SYSTem:CONFig:OVD:ACTion[?] {NONE|SIGNAL|WARNING|ALARM}
```

Identical to event OVD, as configurable in the system menu

```
SYSTem:CONFig:OCD[?] <NRf>[Unit]
SYSTem:CONFig:OCD:ACTion[?] {NONE|SIGNAL|WARNING|ALARM}
```

Identical to event OCD as configurable uin the system menu

```
SYSTem:CONFig:OPD[?] <NRf>[Unit]
SYSTem:CONFig:OPD:ACTion[?] {NONE|SIGNAL|WARNING|ALARM}
```

Identical to event OPD, as configurable in the system menu

12.10 Adjustment Limit Commands

As explained in 4.8 Set Value Limits (p 29), adjustment limits give the operator a way to set lower and upper bounds on U, I, P, R set values to prevent, for example, accidently setting too high a voltage for the connected equipment.

When a set value is sent to the system that would exceed an adjustment limit, whether too high or too low, the system will ignore it, and put an error into the error queue. At the same time, it's impossible to set the lower adjustment limit (:LOW) higher than the related set value or, vice versa, the upper adjustment limit.

These commands are connected to the **Limits** settings, the same as you can adjust them with the touch pad controls.

```
[SOURce:]VOLTage:LIMit:LOW[?] <NRf>[Unit]
```

Identical to value U-min, as configurable at the system

```
[SOURce:]VOLTage:LIMit:HIGH[?] <NRf>[Unit]
```

Identical to value U-max, as configurable at the system

```
[SOURce:]CURRent:LIMit:LOW[?] <NRf>[Unit]
```

Identical to value I-min, as configurable at the system

```
[SOURce:]CURRent:LIMit:HIGH[?] <NRf>[Unit]
```

Identical to value I-max, as configurable at the system

```
[SOURce:]POWer:LIMit:HIGH[?] <NRf>[Unit]
```

Identical to value P-max, as configurable at the system

```
[SOURce:]RESistance:LIMit:HIGH[?] <NRf>[Unit]
```

Identical to value R-max, as configurable at the system

12.11 Parallel Operation Commands

The commands are used to remotely configure and control the master-slave mode. The commands are connected to the related settings in the system setup menu.

Configuration and control require a specific procedure. Configuration should always be first, but this can be done either by remote control or manual control on the system's front panel. Doing the latter allows parallel operation to instantly start after activating remote control.

The commands in the table below are listed in the sequence they should be used (top to bottom). The configuration steps can be skipped if already done manually at the system's control panel or previously in remote control, and nothing has changed.

```
SYSTem:MS:ENABle {ON|OFF}
```

Enables (ON) or disables (OFF) master-slave (MS) mode

```
SYSTem:MS:ENABle?
```

Queries, whether the MS is enabled or not

```
SYSTem:MS:LINK {MASTER|SLAVE}
SYSTem:MS:LINK?
```

Defines or queries the role of the system in the MS system:

MASTER = System will be master unit

SLAVE = System will be slave unit

```
SYSTem:MS:Initialization
```

Starts the MS initialization with the given settings. Also refer to the systems's operating manual. After a successful initialization, the MS mode can be controlled with further commands. To test if the init has been successful, the next command can be used:

```
SYSTem:MS:CONDition?
```

Queries the result of a former MS init. Possible return values:

INIT = Init was successful

NO INIT = Init was not successful

An init is also successful if there is only a master. In order to find out whether you have a complete MS system available or not, you would have to query the number of Initialized units from the master with command SYST:MS:UNITS? (see below). Any value other than 0 means, the MS system is Initialized and available for control.

```
SYSTem:MS:UNITs?
```

Queries the number of units that have been Initialized successfully. The number can differ from the expected value, if the master did not Initialize one or multiple slaves due to any reason. If only the master has Initialized itself, the command will return a 1.

12.12 General Query Commands

These commands are used to query other information from the system.

`SYSTem:NOMinal:VOLTage?`

Queries the nominal, i.e. rated input/output voltage of a single system or an Initialized master-slave system

`SYSTem:NOMinal:CURRent?`

Queries the nominal, i.e. rated input/output current of a single system or an Initialized master-slave system

`SYSTem:NOMinal:POWer?`

Queries the nominal, i.e. rated input/output power of a single system or an Initialized master-slave system

`SYSTem:NOMinal:RESistance:MINimum?`

Queries the minimum internal resistance value of a single system or an Initialized master-slave system. This value is usually not zero with electronic loads.

`SYSTem:NOMinal:RESistance:MAXimum?`

Queries the maximum internal resistance value of a single system or an Initialized master-slave system

`SYSTem:System:CLAss?`

Queries the system class and returns a value which defines to what series the system belongs to. This is an easy way to distinguish different system series. See 10.13 Class Assignments (p 103).

12.13 System Configuration Commands

The commands as listed below are used to modify settings of the system configuration. The settings can be part of the current user profile (see system's operating manual). Any modification on the configuration requires activated remote control. These settings are automatically stored.

12.13.1 General Configuration Commands

```
POWer:STAGe:AFTer:REMote { AUTO|OFF }
POWer:STAGe:AFTer:REMote?
```

Defines, how the DC output of the system shall be after leaving remote control.

- AUTO = Last condition remains
- OFF = DC output will be switched off

```
SYSTem:CONFig:INPut:RESTore[?] {AUTO|OFF}
SYSTem:CONFig:OUTPut:RESTore[?] {AUTO|OFF}
```

Defines the condition of DC output after the system is powered. This is connected to the system setting "DC input after power on" resp. "DC output after power on".

- AUTO = DC output will be restored to the condition it had when switching the system off the last time
- OFF = DC output will always be off

```
SYSTem:CONFig:USER:TEXT <SRD>
SYSTem:CONFig:USER:TEXT?
```

Writes or queries a user-definable text of up to 40 characters permanently to the system. This string can be used to add custom information to the unit, in order to distinguish it from other, identical models, alternatively to the serial number.

```
SYSTem:CONFig:ANAlog:PIN6 {OT|PF|ALL}
SYSTem:CONFig:ANAlog:PIN6?
```

Defines what system alarms are signaled on pin 6.

- OT = Pin 6 only signals OverTemperature
- PF = Pin 6 only signals Power Fail
- All = Pin 6 signals both (default)

```
SYSTem:CONFig:ANAlog:PIN14 {OVP|OCP|OPP|OVP/OCP|OVP/OPP|OCP/OPP|ALL}
SYSTem:CONFig:ANAlog:PIN14?
```

Defines what system alarms are signaled on pin 14. There are options to signal the three system alarms OVP, OCP and OPP separately or as combination of two or signal all (logical OR)..

```
SYSTem:CONFig:ANAlog:PIN15 {CONT|POW}
SYSTem:CONFig:ANAlog:PIN15?
```

Defines what status is signaled on pin 15.

- CONT = Regulation mode CV (default)
- POW = DC terminal on/off

```
SYSTem:CONFig:ANAlog:REFerence {5|10}
SYSTem:CONFig:ANAlog:REFerence?
```

Selects the voltage range for analog inputs and outputs of the analog interface. This has no effect on anything concerning digital remote control.

- 5 = 0–5 V range
- 10 = 0–10 V range (factory setting)

```
SYSTem:CONFig:ANAlog:REMSB:LEVel {NORMAL|INVERTED}
SYSTem:CONFig:ANAlog:REMSB:LEVel?
```

Determines how pin REM-SB of the analog interface (see system manual) shall be interpreted by the system:

- NORMAL = level and conditions as described in the manual (factory setting)
- INVERTED = level and conditions are interpreted as inverted

```
SYSTem:CONFig:ANAlog:REMSB:ACTion {OFF|AUTO}
SYSTem:CONFig:ANAlog:REMSB:ACTion?
```

Determines the action that is caused by using pin REM-SB of the analog interface in connection with DC output of the system:

- OFF = pin can only be used to switch the DC output off
- AUTO = pin can be used to switch off and on again, if the DC output was at least switched on once by pushbutton on the control panel or digital command

```
SYSTem:CONFig:MODE {UIP|UIR}
SYSTem:CONFig:MODE?
```

Selects the operation mode between U/I/P and U/I/R. Both modes are available for electronic loads and also on select power supplies. By selecting U/I/R, the adjustable resistance value (command [SOURce:]RESistance resp. SINK:RESistance) is unlocked. Activated U/I/R mode can only be detected in the display from the resistance value being shown.

```
SYSTem:COMMunicate:PROTocol:Modbus {ENABLE|DISABLE}
SYSTem:COMMunicate:PROTocol:Modbus?
```

Enables or disables Modbus protocol on the system. This setting is stored. After disabling Modbus with this command, further Modbus messages are ignored, so that only SCPI commands are accepted. Only one of both protocols can be deactivated at the same time.

```
SYSTem:COMMunicate:TIMeout {5-65535}
SYSTem:COMMunicate:TIMeout?
```

Defines a timeout in milliseconds (factory setting: 5 ms), a max. time that can elapse between two consecutive bytes, before the system considers the message as "completely received". For details refer to section 10.10.

Note: this only applies for serial interfaces (USB, RS232)

```
SYSTem:ALARm:ACTion:PFAil { AUTO|OFF }
SYSTem:ALARm:ACTion:PFAil?
```

Defines, how the DC output of the system shall be after a power fail (PF) alarm, which could be a mains blackout or similar and after which the system could continue its work automatically.

- AUTO = DC output condition before PF is restored
- OFF = DC output will be switched off (default setting)

```
SYSTem:ALARm:ACTion:OTEMperature { AUTO|OFF }
```

```
SYSTem:ALARm:ACTion:OTEMperature?
```

Defines, how the DC output of the system shall be after the system has recovered, i. e. cooled down after an overtemperature (OT) alarm.

- AUTO = DC output condition before OT is restored (default setting)
- OFF = DC output will be switched off

12.13.2 Anybus Configuration Commands

Most of the Anybus interface modules can also be remotely configured using SCPI commands, either via USB port or even via the Anybus interface itself. These settings are always saved automatically.

```
SYSTem:COMMunicate:INTerface:CODE?
```

Returns a value, representing a model code for the installed Anybus interface module:

- 5 = Profibus
- 9 = RS232
- 16 = CANopen
- 18 = Modbus TCP 1P
- 19 = Profinet/IO 1P
- 20 = Ethernet 1P

- 21 = Ethernet 2P
- 22 = Modbus TCP 2P
- 23 = Profinet/IO 2P
- 25 = CAN
- 26 = EtherCAT

```
SYSTem:COMMunicate:INTerface:SERial?
```

Queries the serial number of the installed Anybus interface module.

```
SYSTem:COMMunicate:INTerface:ADDRess <NR1>
SYSTem:COMMunicate:INTerface:ADDRess?
```

Sets the Profibus address of the Profibus module IF-AB-PBUS or queries it. Allowed range: 0–125

```
SYSTem:COMMunicate:PROFibus:ID?
```

Queries the Profibus ID of the system manufacturer.

```
SYSTem:COMMunicate:PROFibus:FTAG <SRD>
SYSTem:COMMunicate:PROFibus:FTAG?
```

Sets or queries the Profibus/Profinet specific "function tag", a string of up to 32 characters

```
SYSTem:COMMunicate:PROFibus:LTAG <SRD>
SYSTem:COMMunicate:PROFibus:LTAG?
```

Sets or queries the Profibus/Profinet specific "location tag", a string of up to 22 characters

```
SYSTem:COMMunicate:PROFibus:DATE <SRD>
SYSTem:COMMunicate:PROFibus:DATE?
```

Sets or queries the Profibus/Profinet specific "date tag", a date/time string of up to 40 characters

```
SYSTem:COMMunicate:PROFibus:DESCription <SRD>
SYSTem:COMMunicate:PROFibus:DESCription?
```

Sets or queries the Profibus/Profinet specific "description" tag, a string of up to 54 characters

```
SYSTem:COMMunicate:PROFibus:NAME <SRD>
SYSTem:COMMunicate:PROFibus:NAME?
```

Sets or queries the Profinet specific "station name", a string of up to 200 characters

```
SYSTem:COMMunicate:INTerface:BAUD <NR1>
SYSTem:COMMunicate:INTerface:BAUD?
```

Queries or sets the bus speed, i.e. baud rate of a CANopen or RS232 interface module. The system will only save the value. This means, with value 3 being saved and CANopen installed, it will run at 100 kbps and with RS232 installed, with 19200 Baud.

Value	CANopen	CAN	RS232
0	10 kbps	10 kbps	2400 Baud
1	20 kbps	20 kbps	4800 Baud
2	50 kbps	50 kbps	9600 Baud
3	100 kbps	100 kbps	19200 Baud
4	125 kbps	125 kbps	38400 Baud
5	250 kbps	250 kbps	57600 Baud
6	500 kbps	500 kbps	115200 Baud
7	800 kbps	1 Mbps	-
8	1 Mbps	-	-
9	Auto	-	-

```
SYSTem:COMMunicate:CAN:BROadcast <NR1>
SYSTem:COMMunicate:CAN:BROadcast?
```

Sets the CAN broadcast ID for normal CAN communication. Allowed range:

- 0–2047 (11 bit)
- 0–536870911 (29 bit)

```
SYSTem:COMMunicate:CAN:DLC {AUTO|FILL}
SYSTem:COMMunicate:CAN:DLC?
```

CAN data length setting for response messages from the system.

- AUTO = the number of data bytes in a CAN message from the system (response) varies according to the used command/register (default)
- FILL = the number of data bytes in a CAN message is always 8, filled with zeros

```
SYSTem:COMMunicate:CAN:FORMat {BASE|EXT}
SYSTem:COMMunicate:CAN:FORMat?
```

Selects the CAN address format.

- BASE = 11 Bit (CAN 2.0A) (default)
- EXT = 29 Bit (CAN 2.0B)

```
SYSTem:COMMunicate:CAN:NODe <NR1>
SYSTem:COMMunicate:CAN:NODe?
```

Sets the CAN base ID for normal CAN communication. Allowed range:

- 0–2047 (11 bit)
- 0–536870911 (29 bit)

```
SYSTem:COMMunicate:CAN:READ:NODe <NR1>
SYSTem:COMMunicate:CAN:READ:NODe?
```

Sets the CAN base ID for cyclic. Also see section . Allowed range:

- 0–2047 (11 bit)
- 0–536870911 (29 bit)

```
SYSTem:COMMunicate:CAN:READ:ACTual <NR1>
SYSTem:COMMunicate:CAN:READ:ACTual?
```

Defines the interval (in milliseconds) for the cyclic read of the system's actual values (U, I, P) over CAN interface IF-AB-CAN. Allowed parameter range: 0 or 20–5000. (0 = cyclic read for this object is deactivated)

```
SYSTem:COMMunicate:CAN:READ:ALIMits <NR1>
SYSTem:COMMunicate:CAN:READ:ALIMits?
```

Defines the interval (in milliseconds) for the cyclic read of the system's adjustment limits for U and I over CAN interface IF-AB-CAN. Allowed parameter range: 0 or 20–5000. (0 = cyclic read for this object is deactivated)

```
SYSTem:COMMunicate:CAN:READ:BLIMits <NR1>
SYSTem:COMMunicate:CAN:READ:BLIMits?
```

Defines the interval (in milliseconds) for the cyclic read of the system's adjustment limits for P and R over CAN interface IF-AB-CAN. Allowed parameter range: 0 or 20–5000. (0 = cyclic read for this object is deactivated)

```
SYSTem:COMMunicate:CAN:READ:SETS <NR1>
SYSTem:COMMunicate:CAN:READ:SETS?
```

Defines the interval (in milliseconds) for the cyclic read of the system's set values (U, I, P, R) over CAN interface IF-AB-CAN. Allowed parameter range: 0 or 20–5000. (0 = cyclic read for this object is deactivated)

```
SYSTem:COMMunicate:CAN:READ:STAT <NR1>
SYSTem:COMMunicate:CAN:READ:STAT?
```

Defines the interval (in milliseconds) for the cyclic read of the system's status over CAN interface IF-AB-CAN. Allowed parameter range: 0 or 20–5000. (0 = cyclic read for this object is deactivated)

```
SYSTem:COMMunicate:CAN:SEND:NODe <NR1>
SYSTem:COMMunicate:CAN:SEND:NODe?
```

Sets the CAN base ID for cyclic send. Also see section 5.5.7. Allowed range:

- 0–2047 (11 bit)
- 0–536870911 (29 bit)

```
SYSTem:COMMunicate:CAN:TERMination {ON|OFF}
SYSTem:COMMunicate:CAN:TERMination?
```

Switches the integrated CAN bus termination resistor ON or OFF

12.13.3 Ethernet Configuration Commands

The commands below are related to any Ethernet interface port, no matter if built-in or Anybus module. Some commands are only supported when an Anybus interface module is used.

```
SYSTem:COMMunicate:LAN:1SPEed[?] {AUTO|10HALF|10FULL|100HALF|100FULL
SYSTem:COMMunicate:LAN:2SPEed[?] {AUTO|10HALF|10FULL|100HALF|100FULL
```

Only for IF-AB Ethernet modules (ETH, MBUS). Sets the communication speed of the network port(s) of Anybus Ethernet interfaces with one port (P1) or two ports (P1, P2):

- AUTO = Auto negotiation
- 10HALF = 10MBit, half duplex
- 10FULL = 10MBit, full duplex
- 100HALF = 100MBit, half duplex
- 100FULL = 100MBit, full duplex

```
SYSTem:COMMunicate:LAN:ADDRess[?] <SRD>
```

Queries or sets the IP address of the selected Ethernet interface. When setting the IP, the string has to be in the typical IP format like this: 192.168.0.2

```
SYSTem:COMMunicate:LAN:CONTrol[?] {0-65535}
```

Queries or sets the TCP port of the selected Ethernet interface. Default is 5025, used for Modbus RTU or SCPI communication. Systems supporting Modbus TCP have port 502 activated and reserved by default, so 502 is illegal to be set with this command.

```
SYSTem:COMMunicate:LAN:DHCP[?] {ON|OFF}
```

Activates (=ON) or deactivates (=OFF) the DHCP functionality for the selected Ethernet interface. Default is OFF, so the IP as set with :ADDR command above is used.

```
SYSTem:COMMunicate:LAN:DNS1[?] <SRD>
SYSTem:COMMunicate:LAN:DNS2[?] <SRD>
```

Queries or sets the network address of the first DNS1 of the selected Ethernet interface, plus also for the second DNS2 (only with Anybus modules).

```
SYSTem:COMMunicate:LAN:DOMain[?] <SRD>
```

Queries or sets the domain name (refer to network terminology for details). This is a simple ASCII string of up to 54 characters.

```
SYSTem:COMMunicate:LAN:GATeway[?] <SRD>
```

Queries or sets the gateway address of the selected Ethernet interface. Format is the same as with the IP. This address is often not used and can thus be left at the default setting.

```
SYSTem:COMMunicate:LAN:HOSTname[?] <SRD>
```

Queries or set the host name (refer to network terminology for details). This is a simple ASCII string of up to 54 characters.

```
SYSTem:COMMunicate:LAN:KEEPalive[?] {ON|OFF}
```

Enables / disables the "TCP keep-alive" for the selected Ethernet interface. Also see "10.9. Connection Timeout". Default setting: OFF

```
SYSTem:COMMunicate:LAN:MAC?
```

Queries the MAC address of the selected Ethernet interface, when physically present.

```
SYSTem:COMMunicate:LAN:SMASk[?] <SRD>
```

Queries or sets the subnet mask of the selected Ethernet interface. Format is the same as with the IP.

```
SYSTem:COMMunicate:LAN:TIMeout[?] {0|5-65535}
```

Defines a socket connection timeout for the selected Ethernet interface. Also see "10.9. Connection Timeout". Setting this to 0 disables the timeout. Default setting: 5 seconds

```
SYSTem:COMMunicate:LAN:INDex {1|2}
SYSTem:COMMunicate:LAN:INDex?
```

Temporary switch between internal port (2) and the additional port (1, default after power-up).

12.14 Function Generator Commands

> 🛈 Sequence data or table data written via SCPI commands are <u>not stored</u> in the system.

The function generator is a complex part of the whole control options of the system. It can be remotely configured and controlled by SCPI commands. When operating the function generator on the touch panel of the system, a certain procedure of setup is required before getting to the starting point. Using the display, it is not possible to skip steps. When using SCPI commands, it is up to the programmer to ensure a correct setup sequence.

1) Select the type of generator

Configure the function generator at least once after the system has been powered. The first step is to select the type of function generator between XY and arbitrary.

2) Configure the function generator Part 1

When using the arbitrary generator — select which DC output value the function is assigned: either voltage (U) or current (I). After that, define the number of sequences to run (1-99).

When using the XY generator — select what sort of XY curve it shall run. Depending on that selection, values written to the table are validated.

3) Configure the function generator Part 2

When using the arbitrary generator — Fill the function generator with data. With the arbitrary generator this is done by setting up X out of 99 possible sequences. The number of effective sequences to run is variable, but at least 1.

When using the XY generator — The XY generator is filled with 1–4096 values.

> 🛈 XY data and sequence data are submitted by a dedicated command which requires waiting some time before proceeding with additional commands. We recommend to wait at least 2 seconds after submitting the data before sending the next command.

4) Use the function generator

After this, the function generator is completely configured and can be started.

> 🛈 Switching to a different function generator mode requires to first exit the function generator by sending `[SOURce:]FUNCtion:GENerator:SELect OFF`. Only then will the system allow changing modes. Previously loaded table or sequence data will be erased when existing the function generator.

12.14.1 XY Type Mode Selection

```
[SOURce:]FUNCtion:GENerator:SELect {UI|IU|PV|NONE}
[SOURce:]FUNCtion:GENerator:SELect?
```

Selects the run mode of XY function generator:

- UI = UI curve and FC curve
- IU = IU curve
- PV = Standard PV curve (for the extended EN 50530 PV curve commands refer to section 12.10 Adjustment Limit Commands (p 145))
- NONE = Exit function generator

12.14.2 XY type: Load Table Data

The XY generator is based on a table with up to 4096 values. Before actually filling the table with data, the kind of table to run must be selected so the system can interpret and validate the data after it is loaded.

The sequence data is loaded into the system with three commands and in a specific order like this:

```
[SOURce:]FUNCtion:GENerator:XY:LEVel {0-4095}
```

Select one out of 4096 table entries for writing or returns the currently selected entry number.

```
[SOURce:]FUNCtion:GENerator:XY:DATA <NRf>
[SOURce:]FUNCtion:GENerator:XY:DATA?
```

Writes a value, for example a voltage value, to the previously with :LEVel selected table entry or returns the value.

```
[SOURce:]FUNCtion:GENerator:XY:SUBmit
```

Submit the data which has been written so far. Can be any number out of the max. 4096 entries. The rest would then be 0. After this the function can be started

12.14.3 XY Type Control

After the configuration of the XY generator, and after all table data has been loaded, the function generator can be started by switching the DC output of the system on. The function will continue to run, and stops only due to system alarms, or user abort (switching DC output off).

12.14.4 Arbitrary Type Mode and Configuration

```
[SOURce:]FUNCtion:GENerator:SELect {VOLTAGE|CURRENT|UI|IU|PV|NONE}
[SOURce:]FUNCtion:GENerator:SELect?
```

Select the type of function generator:

- VOLTage = Arbitrary generator for U
- CURRent = Arbitrary generator for I
- NONE = Exit function generator

```
[SOURce:]FUNCtion:GENerator:WAVE:STARt {1..99}
[SOURce:]FUNCtion:GENerator:WAVE:STARt?
```

Defines the start, i.e. first sequence (1–99), or queries the last setting. If only one sequence is used, then the start and end values will be the same. Sequences to be used should also be written with data before submitting them.

```
[SOURce:]FUNCtion:GENerator:WAVE:END {1..99}
[SOURce:]FUNCtion:GENerator:WAVE:END?
```

Defines the end, i.e. last sequence (1–99) or queries the last setting. If only one sequence is used, then the start and end values will be the same.

```
[SOURce:]FUNCtion:GENerator:WAVE:NUMber {0..999}
[SOURce:]FUNCtion:GENerator:WAVE:NUMber?
```

Defines, how often the sequence block from :STARt to :END is cycled through, or queries the last setting.

- 0 = infinite cycles
- 1–999 = number of cycles

12.14.5 Arbitrary Type Load Sequence Data

Sequence data should only be sent to the system after it was switched to function generator mode, which also sets the assignment of the arbitrary generator to U or I.

A function can consist of 1 to 99 sequences, where one sequence is either a complete function on its own, or just a part of it. When started, the function generator will execute the sequences in order from :STARt sequence to :END sequence. The sequence data is loaded into the system with four commands, and in a specific order like this:

```
[SOURce:]FUNCtion:GENerator:WAVE:LEVel {1–99}
[SOURce:]FUNCtion:GENerator:WAVE:LEVel?
```

Selects a sequence (similar to HMI access) to write, or queries the currently selected sequence number

```
[SOURce:]FUNCtion:GENerator:WAVE:INDex {0–7}
[SOURce:]FUNCtion:GENerator:WAVE:INDex?
```

For the selected sequence, a set of parameters can be configured. This command selects the parameter between 0 and 7 with value INDex. The next command (:DATA), is then used to write a value. The indexes are explained below. Can also be used to query the current index.

```
[SOURce:]FUNCtion:GENerator:WAVE:DATA <NRf>
[SOURce:]FUNCtion:GENerator:WAVE:DATA?
```

This will write a value, for example a frequency, to the previously selected parameter, as part of the sequence. Can also be used to query the last value.

```
[SOURce:]FUNCtion:GENerator:WAVE:SUBmit
```

Submits all data. Without sending this command, the FG can be started, but will run with all values being zero

> ⓘ
> - The AC and DC start and end values have a dependency on each other. Rule of thumb: use of the AC part requires to set DC values first, otherwise the AC values are not accepted by the system and an error is put into the SCPI error buffer. The DC values (start, end) must not be smaller than the related AC values (start, end).
> - It can be useful to read back a value that was just written to the system, in order to verify whether it has been accepted or not. Alternatively, you may read the error queue.

When adjusting parameters for the arbitrary function generator manually on the system's control panel, they are limited so the resulting signal will work as expected. But, in remote control, there will be no validation check, so it's up to the programmer to write correct values.

For example, index 0 is connected to index 5, as the DC value is the baseline of the AC amplitude. For example, if you want to achieve a sine wave with 5 A amplitude on the DC input current of an electronic load, the baseline of the resulting sine wave has to be at minimum 5 A, otherwise the negative wave will be clipped at 0. Indexes 5 and 6 are adjustable DC offsets which move the AC wave's baseline on the Y axis. So the values in indexes 5 and 6 should at least be as high as index 0 or 1 (whichever is bigger), but they can also be higher. See figures below.

In relation to the adjustments for a function, the following indexes are selectable and readable/writable with sub command :DATA.

Index	Parameter	Data type	Unit	Value range	Note
0	Start value (amplitude)	Float	A, V	0–Nominal value (U or I)	For AC part only
1	End value (amplitude)	Float	A, V	0–Nominal value (U or I)	For AC part only
2	Start frequency in Hz	Integer	Hz	0–10000	For AC part only
3	End frequency in Hz	Integer	Hz	0–10000	For AC part only
4	Start angle in °	Integer	—	0–359	For AC part only
5	Start level (offset)	Float	A, V	0–Nominal value (U or I)	For AC and DC part
6	End level (offset)	Float	A, V	0–Nominal value (U or I)	For AC and DC part
7	Sequence time	Float	s	0.0001–36000	

> ⓘ
> - When start and end values (indexes 0+1 and indexes 5+6) are not equal, the system expects a certain minimum change of ±0.058%/s of ±9.3 Hz/s for the start and end frequency (indexes 2+3) over the sequence time. Therefore, it is not possible to let the input current rise by 1 A over 1 h, because this exceeds the internal set value resolution.
> - Another example: with the sequence time being set to 2 s, a start frequency of 1 Hz and end frequency of 10 Hz would not be accepted, because the difference is only 9 Hz/s, but start frequency of 30 Hz and end frequency of 5 Hz would.

Parameter assignment illustrated by an example curve:

respectively
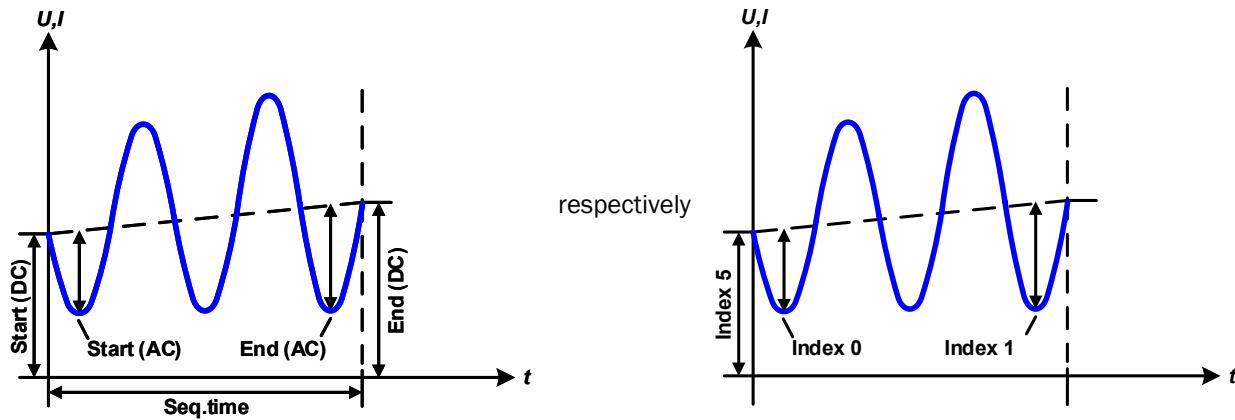
12.14.6 Arbitrary Type Control

Contrary to the XY generator where the curve is immediately active when switching on the DC output, the arbitrary generator requires run control by command. The run cannot be paused. This means, once the function is stopped, no matter by what reason, the next start will run from the beginning.

```
[SOURce:]FUNCtion:GENerator:WAVE:STATe {RUN|STOP}
[SOURce:]FUNCtion:GENerator:WAVE:STATe?
```

Starts/stops the arbitrary function generator or queries the STATe.

12.14.7 Special Function: Simple PV

The photovoltaics function (PV), is based on the XY function generator. When programming a PV function using the control panel, you only have to set up 4 parameters, and the system calculates the table. However, in remote control mode, it's necessary to load a complete, precalculated table with 4,096 values into the system.

There are a few options to get the table data calculated and entered.

- Use the control panel, enter four PV simulation parameters, then let the system calculate and load the table.
- Use external tools to create a CSV file. Load that file using a thumb drive into the system from the control panel.
- Create a custom software script using SCPI, and directly enter the PV table using remote control.

Regardless of which method is used, once a table is loaded in the system, the control panel can be used to save the table to a thumb drive in the front USB port. (If you're using custom remote control scripting, saving the table to the thumb drive isn't necessary, as you would just reload the table by remote control. Still, it might be useful for archiving and using manually later.)

Assuming the system is already in remote control, and the XY table for the PV function is already calculated and ready to be loaded, use the procedure in the sections below.

12.14.7.1 Loading data for the simple PV function

Step	Command	Description
1	`FUNC:GEN:SEL PV`	Select the PV function for the XY generator. By sending this command the system will switch to function generator mode.
2	`FUNC:GEN:XY:LEVEL 0`	
3	`FUNC:GEN:XY:DATA 150`	
...		Sequentially write all XY table values for the PV curve into the system.
8192	`FUNC:GEN:XY:LEVEL 4095`	
8193	`FUNC:GEN:XY:DATA 0`	
8194	`FUNC:GEN:XY:SUB`	Submit the written data.

12.14.7.2 Setting limits

After submitting all data, it's necessary to wait some time (≈2 s) before starting the simulation. Optionally, and if not already done, set additional global limits like voltage and power, either to maximum or any value that does not interfere with the simulation. The voltage here should be set to the open circuit voltage (Uoc), or to unit nominal value.

No.	Command	Description
8195	`VOLT MAX`	Set voltage to maximum regardless of the nominal value.
8196	`POW MAX`	Set power to maximum regardless of the nominal value.

12.14.7.3 Controlling the system during the PV function run

After all is set, you can run the function and control the simulation and irradiation.

No.	Command	Description
8197	OUTP ON	Switch the DC output of your system on to make the function start
8198	IRR 85	Set irradiation to 85% (example) or any other value between 0 and 100
8199	OUTP OFF	Switch the DC output of your system off to make the function stop
8200	FUNC:GEN:SEL NONE	Parameter NONE selects no function generator type and leaves the function generator mode

As indicated above, During function run, the irradiation value can be adjusted.

```
[SOURce:]IRRadiation <NR1>
[SOURce:]IRRadiation?
```

Adjust or query the irradiation value during the solar panel simulation in a range of {0–100} percent, which affects the DC current and shifts the MPP on the Y axis.

12.14.8 Special Function FC

The fuel cell function (FC) is based on the XY function generator. In remote control mode, it's only possible to load a complete, precalculated table with 4096 values into the system. A fuel cell curve is essentially a voltage-current (UI) curve—so, using the control panel you would select XY Table, then UI Table. Using SCPI command you would select UI mode.

When programming a fule cell function using the control panel, you only have to set up 4 parameters, and the system calculates the table. However, in remote control mode, it's necessary to load a complete, precalculated table with 4096 values into the system (using scripted SCPI commands).

There are a few options to get the table data calculated and entered:

• Use the control panel, enter four PV simulation parameters, then let the system calculate and load the table.
• Use external tools to create a CSV file. Load that file using a thumb drive into the system from the control panel.
• Create a custom software script using SCPI and directly enter the PV table using remote control.

Regardless of which method is used, once a table is loaded in the system, the control panel can be used to save the table to a thumb drive in th front USB port. (If you're using custom remote control scripting, saving the table to the thumb drive isn't necessary, as you would just reload the table by remote control. Still, it might be useful for archiving and using manually later.)

Use the same command set as listed for .

12.15 Extended PV Commands

12.15.1 General Configuration

Command	Description
FUNCtion:PHOTovoltaics:MODe { OFF|ET|UI|DAYET|DAYUI} FUNCtion:PHOTovoltaics:MODe?	General mode selection for the PV simulation OFF = simulation mode off (default) ET = Continuous mode, temperature and irradiation can be varied during simulation UI = Continuous mode, voltage and current of the MPP can be varied during simulation DAYET = Day trend mode, no values can be varied, the data set consists of an index, a temperature value, an irradiation value and a dwell time DAYUI = Day trend mode, no values can be varied, the data set consists of an index, MPP voltage and current values and a dwell time
FUNCtion:PHOTovoltaics:IMODe {MPP|ULIK} FUNCtion:PHOTovoltaics:IMODe?	Input mode (applies to all modes selectable with :MODe command) MPP = The base values to calculate the PV curve from are entered as Umpp and Impp. These values are adjustable simulation mode UI (default) ULIK = The base values to calculate the PV curve from are entered as U_{oc} (open circuit voltage) and I_{sc} (short-circuit current). These values are adjustable in simulation mode ET

12.15.2 Day Trend Configuration

The below listed commands can only be used if any of the day trend modes DAYET or DAYUI (see above) has been set before and will else return an error.

It's recommended to clear the old day data with :DAY CLEAR command before loading a new set, especially if the new set is shorter.

Commands	Description
FUNCtion:PHOTovoltaics:DAY:INTerpolate {ON|OFF} FUNCtion:PHOTovoltaics:DAY:INTerpolate?	Only for modes DAYET and DAYUI: ON = Interpolation on OFF = Interpolation off (default)
FUNCtion:PHOTovoltaics:DAY:MODe {READ|WRITE} FUNCtion:PHOTovoltaics:DAY:MODe?	Only for modes DAYET and DAYUI: Day trend mode data access type READ = Read only (default) WRITE = Write only
FUNCtion:PHOTovoltaics:DAY {CLEar}	Only for modes DAYET and DAYUI: Clear all data
FUNCtion:PHOTovoltaics:DAY:INDex {1–100000} FUNCtion:PHOTovoltaics:DAY:INDex?	Only for modes DAYET and DAYUI: Select the data index before re-reading day trend data. For writing day trend data, this index values is ignored. Use the index in FUNC:-PHOT:DAY:DATA command instead.
FUNCtion:PHOTovoltaics:DAY:DATA {<NR1>, <NRf>, <NRf>, <NR1>} FUNCtion:PHOTovoltaics:DAY:DATA?	Only for modes DAYET and DAYUI: Write one set of day trend data (4 values) or read them back from it, which requires prior index selection. Depending on the selected day trend mode, different data is returned upon read or must be provided when writing.
	Mode DAYET:
	1. value = index, range: 1- 100000
	2. value = irradiation in W/m², range: 0-1500
	3. value = temperature in °C, range: -40...+80
	4. value = Dwell time of index in ms, range: 500–1800000 (^=0,5s...0,5h)
	Mode DAYUI:
	1. value = index, range: 1-100000
	2. value = Umpp in V, range: 0...rated voltage
	3. value = Impp in A, range: 0...rated current
	4. value = Dwell time of index in ms, range: 500–1800000 (^=0,5s...0,5h)
FUNCtion:PHOTovoltaics:TECHnology {MAN|CSI|THIN} FUNCtion:PHOTovoltaics:TECHnology?	Panel technology preselection. Determines if some simulation parameters are fixed or accessible MAN = Manual mode (all parameters unlocked) CSI = cSi technology panel (default) THIN = thin film technology panel

12.15.3 Data Recording

The system can record data while the PV simulation is running in any mode. It records up to 576,000 data sets with 6 values each (actual values of U, I, P and MPP values U, I, P). The recording can be started with the simulation or while it runs. Once the internal memory is filled, it overwrites from the beginning and the number of recorded data sets (:REC:NUM?) is reset to 0 . There is one new data set recorded every 100 ms, so that it covers a total time of exactly 16 hours.

The recording is either stopped at the end of the simulation or on purpose by the user. After the stop, the recorded data can be read set by set. In case they are need to be saved, they should be read as long as the unit is powered, because the internal memory data is not stored.

Command	Description
FUNCtion:PHOTovoltaics:RECord:ACTive {ENABle|DISable} FUNCtion:PHOTovoltaics:RECord:ACTive?	Data recording ENABle = activated DISable = deactivated (default)
FUNCtion:PHOTovoltaics:RECord {CLEar}	Clear recorded data
FUNCtion:PHOTovoltaics:RECord:NUMBer?	Number of already recorded data sets (1-576000)
FUNCtion:PHOTovoltaics:RECord:INDex {1–576000} FUNCtion:PHOTovoltaics:RECord:INDex?	Set or read the index number prior to read a data set with :DATa? command
FUNCtion:PHOTovoltaics:RECord:DATa?	Read data set X from the previously selected index. The system will then return following values separated by commas, representing a snapshot from a certain time: 1. value = Index number 2. value = Actual voltage on the DC output 3. value = Actual current on the DC output 4. value = Actual power on the DC output 5. value = Umpp (voltage in the MPP) 6. value = Impp (current in the MPP) 7. value = Pmpp (power in the MPP)

> **!** After selecting the index with FUNC:PHOT:REC:IND, prior to reading the data set, it requires some time (<5 ms) to pass before the system can return the true data of the index from an internal buffer. Being too early with the request command will cause the system to write an error into the error queue. After data reception the correct data can be verified by comparing the index number in the data set with the index you selected with FUNC:PHOT:REC:IND.

> **!** After simulation start the system will calculate the first PV curve. This takes about 500 ms. But the first data set is already recorded 100 ms after simulation start, so the first 3-4 data set are erroneous. This won't be the case if the recording is started at least 500 ms after the simulation start.

12.15.4 Status Commands

Status commands and those which read result values from the simulation can be used at any time, but it's recommend to carefully chose the moment and order of use.

Command	Description
FUNCtion:PHOTovoltaics:MPP:VOLTage?	Voltage in the MPP, in V. The MPP results from the PV simulation curve, which is calculated by the given simulation settings. The voltage can be between 0 and the rated system voltage.
FUNCtion:PHOTovoltaics:MPP:CURRent?	Current in the MPP, in A. Can be between 0 and rated current.
FUNCtion:PHOTovoltaics:MPP:POWer?	Power in the MPP, in A. Can be between 0 and rated power.
FUNCtion:PHOTovoltaics:STATe?	PV simulation status
	STOP = Simulation has stopped normally, either due to user action or end of day trend
	RUN = Simulation running
	ERROR MODE = Simulation didn't start due to and error during PC curve calculation in simulation modes ET or UI
	ERROR DAY = Simulation didn't due to and error during PC curve calculation in simulation modes DAYET or DAYUI
	ERROR ALARM = Simulation has stopped due to a system alarm
	ERROR INTERPOLATION = Simulation not started due to a wrong dwell time value in day trend data index 1
FUNCtion:PHOTovoltaics:DAY:NUMBer?	Number of accepted day trend indexes. When transferring day trend data to the system, this counter counts up every time an index is successfully transferred and accepted. Can ve used to verify written data.
FUNCtion:PHOTovoltaics:OCVoltage?	Open circuit voltage of the simulated solar panel, calculated with a formula according to the standard. The values is affected by the selected simulation mode, the standard panel parameters (see below) and the calculation factors (also see below).
FUNCtion:PHOTovoltaics:SCCurrent?	Short-circuit current of the simulated solar panel, calculated with a formula according to the standard. The values is affected by the selected simulation mode, the standard panel parameters (see below) and the calculation factors (also see below).

12.15.5 Parameter Commands

The commands listed below are used to set or read all the values required for the different PV simulation modes and the PV curve calculation. Not all commands can be written. When trying to write values it's important what simulation mode (ET, UI, DAYET, DAYUI) and what input mode (MPP, ULIK) is currently set. The matrix below indicates what command are supported in what mode. A third setting, the technology (MAN, CSI, THIN) also determines if a specific parameter is locked from writing, but instead is internally setup with a value according to the DIN EN 50530 standard. Reading the parameters is possible anytime and in every mode.

Command	Writable in modes:				
	MPP	ULIK	MAN	CSI	THIN

`FUNCtion:PHOTovoltaics:FACTor:FFU <NRf>`
`FUNCtion:PHOTovoltaics:FACTor:FFU?`
Fill factor for voltage (FF_U). Only writable in technology selection MAN. Has impact on the PV curve calculation with formula according to standard. Range: >0–1
	Y	Y	Y	—	—

`FUNCtion:PHOTovoltaics:FACTor:FFI <NRf>`
`FUNCtion:PHOTovoltaics:FACTor:FFI?`
Fill factor for current (FF_I). Only writable in technology selection MAN. Has impact on the PV curve calculation with formula according to standard. Range: >0–1
	Y	Y	Y	—	—

`FUNCtion:PHOTovoltaics:FACTor:ALPHa <NRf>`
`FUNCtion:PHOTovoltaics:FACTor:ALPHa?`
Temperature coefficient α (in 1/°C) for the short-circuit current. Only writable in technology selection MAN. Has impact on the PV curve calculation with formula according to standard. Range: >0–1
	Y	Y	Y	—	—

`FUNCtion:PHOTovoltaics:FACTor:BETA <NRf>`
`FUNCtion:PHOTovoltaics:FACTor:BETA?`
Temperature coefficient β (in 1/°C) for the open circuit voltage. Only writable in technology selection MAN. Has impact on the PV curve calculation with formula according to standard. Range: -1...<0
	Y	Y	Y	—	—

`FUNCtion:PHOTovoltaics:FACTor:CU <NRf>`
`FUNCtion:PHOTovoltaics:FACTor:CU?`
Scaling factor C_U for the open circuit voltage. Only writable in technology selection MAN. Has impact on the PV curve calculation with formula according to standard. Range: >0–1
	Y	Y	Y	—	—

`FUNCtion:PHOTovoltaics:FACTor:CR <NRf>`
`FUNCtion:PHOTovoltaics:FACTor:CR?`
Scaling factor C_R in m²/W or the open circuit voltage. Only writable in technology selection MAN. Has impact on the PV curve calculation with formula according to standard. Range: >0–1
	Y	Y	Y	—	—

`FUNCtion:PHOTovoltaics:FACTor:CG <NRf>`
`FUNCtion:PHOTovoltaics:FACTor:CG?`
Scaling factor C_G in W/m² for the open circuit voltage. Only writable in technology selection MAN. Has impact on the PV curve calculation with formula according to standard. Range: >0–1
	Y	Y	Y	—	—

`FUNCtion:PHOTovoltaics:STANdard:OCVoltage <NRf>`
`FUNCtion:PHOTovoltaics:STANdard:OCVoltage?`
U_{OC} (open circuit voltage) of the simulated solar panel in V. Range: 0 - rated voltage
	—	Y	Y	Y	Y

`FUNCtion:PHOTovoltaics:STANdard:SCCurrent <NRf>`
`FUNCtion:PHOTovoltaics:STANdard:SCCurrent?`
I_{SC} (short-circuit current) of the simulated solar panel in A. Range: 0 - rated current
	—	Y	Y	Y	Y

`FUNCtion:PHOTovoltaics:STANdard:MPP:VOLTage <NRf>`
`FUNCtion:PHOTovoltaics:STANdard:MPP:VOLTage?`
Voltage in the MPP of the simulated solar panel, in V. Range: 0 - rated voltage
	Y	—	Y	Y	Y

Command	Writable in modes:				
	MPP	ULIK	MAN	CSI	THIN

`FUNCtion:PHOTovoltaics:STANdard:MPP:CURRent <NRf>`
`FUNCtion:PHOTovoltaics:STANdard:MPP:CURRent?`
Current in the MPP of the simulated solar panel, in A. Range: 0 - rated current
	Y	—	Y	Y	Y

12.15.6 Control Commands

These commands are to control the PV simulation, usually after the successful configuration. In some modes, one or two parameters are adjustable while the simulation is running. Any change of parameter requires to calculate the PV curve again, overwriting the former curve. Depending on what point on the curve the simulation currently is , the point will shift after a certain calculation and response time.

Command	Description
`FUNCtion:PHOTovoltaics:STATe {RUN|STOP}` `FUNCtion:PHOTovoltaics:STATe?`	Start/stop simulation RUN = Triggers PV curve calculation and succeeding simulation start, if there is no error occurring. If data recording is activated, it will also start STOP = Simulation and possibly running data recording are stopped
`FUNCtion:PHOTovoltaics:TEMPerature <NR1>` `FUNCtion:PHOTovoltaics:TEMPerature?`	Only available in mode ET: Solar module temperature in °C. Range: -40...+80
`FUNCtion:PHOTovoltaics:IRRaditation <NR1>` `FUNCtion:PHOTovoltaics:IRRaditation?`	Only available in mode ET: Irradiation in W/m². Range: 0-1500

12.15.7 Error Situations

An error situation occurs when the configured simulation can't be started or it has started already and was running for a while, but then unexpectedly stopped. Command `FUNCtion:PHOTovoltaics:STATe?` can help in both cases to identify the cause of the error.

The following generally applies:

- Once stopped for any reason, the simulation cannot be continued.
- Data from the data recording feature can be read during the simulation or after the stop, as long as the system remains powered.
- All configuration parameters are not stored and are reset when power-cycling the system.

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12.16 Alarm Management Commands

In remote control operation it's important to manage alarms correctly. This can be done the same way as in manual control. When using the SCPI command language, system alarms are indicated through a status register which can be polled. Polling for errors should be performance after making changes to settings. Furthermore, most alarms have to be acknowledged.

12.16.1 Reading System Alarms

Reading system alarms should happen in certain intervals, by querying the Questionable status register by either the subregister CONDITION or EVENT. The commands `STAT:QUES:COND?`, `STAT:QUES?`, or `STAT:QUES:EVEN?` return a value that represents certain bits, indicating various conditions. When a bit is set, it means a certain alarm is present. Refer to the system's operating manual for details about system alarms. See 12.4 Status Registers (p 134).

12.16.2 Acknowledging System Alarms

In order to make the user take notice of system alarms, they have to be acknowledged after they occurred and vanished again. This will delete those alarms from the status register and should be only be done after they have been recorded. To delete/acknowledge an alarm, the command `SYST:ERR?` resp. `SYST:ERR:ALL?` is used, which also serves to query other errors.

If one or multiple alarms are still present, they won't be cleared from the register.

There is one exception in handling, the OT (overtemperature) error. This doesn't require extra acknowledgement and thus won't be indicated anymore in CONDITION once it's gone.

12.16.3 Alarm Counters

These counters count alarm occurrences since the last time the system was powered. They can be read by command anytime, are not stored when the system is switched off and are purged by reading.

`SYSTem:ALARm:COUNt:OVOLtage?`

Counts overvoltage alarms (OVP, adjustable threshold)

`SYSTem:ALARm:COUNt:OTEMperature?`

Counts overtemperature alarms (OT, not adjustable)

`SYSTem:ALARm:COUNt:OPOWer?`

Counts overpower alarms (OPP, adjustable threshold)

`SYSTem:ALARm:COUNt:OCURrent?`

Counts overcurrent alarms (OCP, adjustable threshold)

`SYSTem:ALARm:COUNt:PFAil?`

Counts power fail alarms (PF, not adjustable)

12.16.4 Alarm Example

You are running the system in remote control, and poll the alarm status with STAT:QUES:COND? at a certain interval, and you always receive value 3072. This is the sum of the bit values of bits 10 (remote) and 11 (output on). It tells you that remote control is active and the DC output is switched on. Then a system alarm occurs caused by the unit overheating. When reading the register the next time, bit 3 should indicate the OT alarm for you to take notice. Additionally, the DC output might be indicated as switched off. Thus the returned value could be 1032 or 3080.

12.17   Example applications

12.17.1 Configure and Control Master-Slave with SCPI

In a paralle mode setup, usually only the control unit is remotely controlled, while the expansion units are usually not connected to the PC, except for when being configured remotely to switch to Slave mode. It's therefore recommended to configure the expansion units with the control panels, and put only the control unit into remote control via software. Even if you would configure all units manually on the control panel, the remote control software could later read the status of the initialization from the control unit. The initialization of the system is done automatically every time the control unit is powered, but can be triggered and repeated by command.

Let's assume for an example configuration that we have five power supplies (80 V, 510 A, 15 kW) in parallel. The control unit has to exhibit itself as an 80V, 2550 A , 75 kW and 1 Ω unit after successful configuration and initialization. These values are also the temporary new ratings of the parallel system. The same way as with manual control, the Limits and Set Values can be adjusted in 0–102% of the rated value, while protection values have range of 0–110%.

Part 1a: Configure the control unit

1. Activate remote control: `SYST:LOCK ON`

2. Activate master-slave mode: `SYST:MS:ENABLE ON`

3. Define the unit as master: `SYST:MS:LINK MASTER`

Part 1b: Configure the expansion unit(s), if they're connected to the control unit (PC, PLC etc.)

4. Activate remote control: `SYST:LOCK ON`

5. Activate master-slave mode: `SYST:MS:ENABLE ON`

6. Define the unit as slave: `SYST:MS:LINK SLAVE`

If there is more than one expansion unit, repeat these steps for each unit with their own addresses.

Part 2: Initialize the parallel system

7. Ensure remote contol is activated: `SYST:LOCK ON`

8. Trigger initialization, then wait a few seconds: `SYST:MS:INIT`

Part 3: Additional optional steps

9. Query the initialization status from the control unit, in order to analyse it: `SYST:MS:COND?`

10. Query the number of units Initialized for the system (should be 5 with this example): `SYST:MS:UNIT?`

11. Query the nominal current of the system: `SYST:NOM:CURR?`

12. Query the nominal power of the system: `SYST:NOM:POW?`

13. Query the maximum resistance of the system: `SYST:NOM:RES:MAX?`

14. Query the minimum resistance of the system: `SYST:NOM:RES:MIN?`

15. Configure protection values, for example OCP: `CURR:PROT 400`

16. Configure events, for example,

    a) set OCD to 2100 A: `SYST:CONF:OCD 2100`

    b) then define the alarm type for OCD to "warning": `SYST:CONF:OCD:ACT WARNING`

The adjustment limits (**Limits**) require extra treatment, because they are tied to the set values. With the set values being reset to the higher summed value during the prallal mode initialization, the set value of current would be at maximum, and thus the related adjustment limit I_{Max} can't be set lower than this without prior changing the set value.

17. Narrow the adjustable range of values, for example limit the maximum current set value to 2200 A

    c) First, set the current value down to anything lower than the desired limit, like the minimum: `CURR MIN`

    d) Second, set the adjustment limit to the value translated for the master unit: `CURR:LIM:HIGH 2200`

With these settings applied, the current should be at 0, because the lower adjust limit has not yet been changed. The current will me monitored for the threshold of 2100 A by the event system and since it's adjustable up to 2200 A, the true current might exceed the threshold and cause an OCD event, which would only generate a warning on screen, but not switch off the DC output.

18. To start working with the full parallel system, switch the DC output on: `OUTP ON`

The system will remain configured and keep the settings after power-cycling it. However, the control unit unit has to initialize MS mode and the expansion units at least one time after power-up. The status of the first automatic initialization can be read from the control unit by custom software and depending on the result, the software could trigger further steps like the ones above.

12.17.2 Programming Examples for PV 50530

Additional information about this extended PV function can be found in the function generator section of the manual. The user manuals also have information about the connection between simulation mode, input mode, and panel technology.

> ! Important: after the simulation start, the system will calculate the first PV curve table. This takes about 500 ms, so the actual simulation begins ~ 500 ms after the start.

Overview (an "x" marks a possible combination):

Simulation mode Options	Input mode ULIK	Input mode MPP
ET	X	X — Example 1
UI		X — Example 3
DAY ET	X — Example 2	x
DAY UI		X — Example 4

12.17.2.1 Example 1

- Technology: cSi
- Input mode: MPP values
- Simulation mode: Continuous, with adjustable temperature and irradiation
- Recording: activated

Configuration

Nr.	Command	Description	Register
1	SYST:LOCK ON	Activate remote control	402
2	FUNC:PHOT:MODE ET	Activate PV simulation mode ET	12001
3	FUNC:PHOT:TECH CSI	Select technology: cSi	12016
4	FUNC:PHOT:IMOD MPP	Select input mode: MPP	12017
5	FUNC:PHOT:STAN:MPP:VOLT 20	Set MPP voltage: 20 V	12050
6	FUNC:PHOT:STAN:MPP:CURR 5	Set MPP current: 5 A	12051
7	FUNC:PHOT:REC:ACT ENABLE	Activate data recording	12018
8	POW MAX	Set global power set value to maximum	502
9	VOLT 30	Set the global voltage limit (should be higher than Uoc)	500

> - The values for the standard test condition (STC), as set in steps 5 and 6, are only used to calculate the first PV curve. The MPP values (:STAN:MPP) are linked to the solar panel specs Uoc (:STAN:OCV) and Isc (:STAN:SCC) via the factors FFi and FFu. They overwrite each other. This means that setting :STAN:MPP:VOLT overwrites the value in :STAN:OCV and vice versa.
> - Voltage and current in the MPP are connected via factors FFi and FFu to the open circuit voltage (Uoc) and the short-circuit current (Isc). Depending on the selected technology, these factors are not adjustable.
> - The first curve after function start is calculated with the default values T = 25°C and E = 1000 W/m² (E = from German Einstrahlung meaning Irradiation).

Control (also during simulation run)

Nr.	Command	Description	Register
10	FUNC:PHOT:STAT RUN	Start simulation	12000
11	FUNC:PHOT:TEMP 40	Adjust temperature value: 40 °C	12052
12	FUNC:PHOT:IRR 800	Adjust irradiation: 800 W/m²	12053
13	FUNC:PHOT:STAT STOP	Stop simulation after an arbitrary time	12000

Analysis after simulation end

Nr.	Command	Description	Register
14	FUNC:PHOT:REC:NUMB?	Read number (n) of recorded data sets	12020
15	FUNC:PHOT:REC:IND 1	Select first data set (index 1) for reading	12022

Nr.	Command	Description	Register
16	`FUNC:PHOT:REC:DATA?`	Read data from data set (index) 1	12024
…	`...`	Read further n-1 data sets:	…
x	`FUNC:PHOT:REC:IND n`	Select data set n (index n) for reading	12022
y	`FUNC:PHOT:REC:DATA?`	Read data from data set (index) n	12024

12.17.2.2 Example 2

- Technology: Manual
- Input mode: Open circuit voltage and short-circuit current
- Simulation mode: Day trend with adjustable temperature and irradiation
- Interpolation: deactivated
- Data recording: activated

Configuration

Nr.	Command	Description	Register
1	`SYST:LOCK ON`	Activate remote control	402
2	`FUNC:PHOT:MODE DAYET`	Activate PV simulation mode DAY ET	12001
3	`FUNC:PHOT:TECH MAN`	Select technology: Manual (all required parameters must be defined, here as with commands 4-10)	12016
4	`FUNC:PHOT:FACT:FFU 0.8`	Fill factor voltage (FF_U): 0,8	12034
5	`FUNC:PHOT:FACT:FFI 0.78`	Fill factor current (FF_I): 0,78	12036
6	`FUNC:PHOT:FACT:ALPH 0.0003`	Temperature coefficient α for I_{SC}: 0,0003 / °C	12038
7	`FUNC:PHOT:FACT:BETA −0.003`	Temperature coefficient β for U_{OC}: -0,003 / °C	12040
8	`FUNC:PHOT:FACT:CU 0.0725`	Scaling factor C_U for U_{OC}: 0,0725	12042
9	`FUNC:PHOT:FACT:CR 0.00022`	Scaling factor C_R for U_{OC}: 0,00022 m²/W	12044
10	`FUNC:PHOT:FACT:CG 0.00315`	Scaling factor C_G for U_{OC}: 0,00315 W/m²	12046
11	`FUNC:PHOT:IMOD ULIK`	Select input mode: ULIK	12017
12	`FUNC:PHOT:STAN:OCV 38`	Set open circuit voltage: 38 V	12048
13	`FUNC:PHOT:STAN:SCC 7`	Set short-circuit current: 7 A	12049
14	`FUNC:PHOT:REC:ACT ENABLE`	Activate data recording	12018
15	`FUNC:PHOT:DAY:INT OFF`	Deactivate interpolation of day trend data	12005
16	`POW MAX`	Set global power set value to maximum	502
17	`VOLT 38`	Set the global voltage limit (should be ≥Uoc)	500

> - The values for the standard test condition (STC), as set in steps 5 and 6, are only used to calculate the first PV curve. Every change of parameter that would shift the MPP causes the system to calculate the PV anew.
> - Voltage and current in the MPP are connected via factors FFi and FFu to the open circuit voltage (Uoc) and the short-circuit current (Isc), which are both given in this example, other than in Example 1. Depending on the selected technology, these factors are not adjustable

Write day trend data (only possible before the function start)

Nr.	Command	Description	Register
18	FUNC:PHOT:DAY:MODE WRITE	Select access mode: write	12006
19	FUNC:PHOT:DAY CLEAR	Delete former data (should be executed every time before loading new data)	12007
20	FUNC:PHOT:DAY:DATA 1, 500, 20, 1500	Write 1st day trend data set: Irradiation: 500 W/m² Temperature: 20°C Dwell time: 1500 ms ! The dwell time is defined to have a minimum of 500 ms. However, when setting up the very first day trend data set it's expected to set 1000 ms or higher for this one, because else the function run might fail.	12010
21	FUNC:PHOT:DAY:DATA 2, 800, 28, 1500	Write 2nd day trend data set: Irradiation: 800 W/m² Temperature: 28°C Dwell time: 1500 ms	12010
…	…	Write further data sets, a total of 500	…
519	FUNC:PHOT:DAY:DATA 500, 1200, 35, 20000	Write 500. day trend data set: Irradiation: 1200 W/m² Temperature: 35°C Dwell time: 20000 ms	12010

Control

Nr.	Command	Description	Register
520	FUNC:PHOT:STAT RUN	Start simulation. The simulation will stop automatically after the time that results from the total of dwell times in all written data sets	12000

Analysis (after simulation end)

Nr.	Command	Description	Register
521	FUNC:PHOT:REC:NUMB?	Read number (n) of recorded data sets. This number is not related to the number of day trend data sets in use. This feature records a new data set every 100 ms. Depending on the total simulation time, the record buffer could fill (max. 16 h record time) and overwrite existing data. It may become necessary to calculate the total simulation time from the day trend data sets and start reading the recorded data during simulation, then clearing the buffer and later read the rest of data.	12020
522	FUNC:PHOT:REC:IND 1	Select first data set (index 1) for reading	12022
523	FUNC:PHOT:REC:DATA?	Read data from data set (index) 1	12024
…	…	Read further n-1 data sets:	…
x	FUNC:PHOT:REC:IND n	Select data set n (index n) for reading	12022

Nr.	Command	Description	Register
y	FUNC:PHOT:REC:DATA?	Read data from data set (index) n	12024

12.17.2.3 Example 3

- Technology: thin film
- Input mode: MPP values
- Simulation mode: Continuous, with adjustable MPP (voltage and current)
- Recording: deactivated

Configuration

Nr.	Command	Description	Register
1	SYST:LOCK ON	Activate remote control	402
2	FUNC:PHOT:MODE UI	Activate PV simulation mode UI	12001
3	FUNC:PHOT:TECH THIN	Select technology: Thin film	12016
4	FUNC:PHOT:IMOD MPP	Select input mode: MPP	12017
5	FUNC:PHOT:STAN:MPP:VOLT 45	Set MPP voltage: 45 V	12050
6	FUNC:PHOT:STAN:MPP:CURR 10	Set MPP current: 10 A	12051
7	FUNC:PHOT:REC:ACT DISABLE	Deactivate data recording	12018
8	POW MAX	Set global power set value to maximum	502
9	VOLT 57	Set the global voltage limit (should be ≥Uoc)	500

Control (also during simulation run)

Nr.	Command	Description	Register
10	FUNC:PHOT:STAT RUN	Start simulation	12000
11	FUNC:PHOT:STAN:MPP:VOLT 40	Shift MPP: 40 V	12050
12	FUNC:PHOT:STAN:MPP:CURR 9	Shift MPP: 9 A	12051
13	FUNC:PHOT:STAT STOP	Stop simulation after an arbitrary time	12000

12.17.2.4 Example 4

- Technology: cSi
- Input mode: MPP values
- Simulation mode: Day trend with shiftable MPP (voltage and current)
- Interpolation: activated
- Data recording: deactivated

Configuration

Nr.	Command	Description	Register
1	SYST:LOCK ON	Activate remote control	402
2	FUNC:PHOT:MODE DAYUI	Activate PV simulation mode DAY UI	12001
3	FUNC:PHOT:TECH CSI	Select technology: cSi	12016
4	FUNC:PHOT:IMOD MPP	Select input mode: MPP	12017
5	FUNC:PHOT:STAN:MPP:VOLT 36	Set open circuit voltage: 36 V	12050
6	FUNC:PHOT:STAN:MPP:CURR 12	Set short-circuit current: 12 A	12051
7	FUNC:PHOT:REC:ACT DISABLE	Deactivate data recording	12018
8	FUNC:PHOT:DAY:INT ON	Activate interpolation of day trend data	12005
9	POW MAX	Set global power set value to maximum	502
10	VOLT 57	Set the global voltage limit (should be ≥Uoc)	500

Load day trend data (only possible before the function start)

Nr.	Command	Description	Register
11	FUNC:PHOT:DAY:MODE WRITE	Select access mode: write	12006
12	FUNC:PHOT:DAY CLEAR	Delete former data (should be executed every time before loading new data)	12007
13	FUNC:PHOT:DAY:DATA 1, 1, 1, 300000	Write 1st day trend data set: MPP voltage: 1 V MPP current: 1 A Dwell time: 300 seconds -> 5 minutes	12010
14	FUNC:PHOT:DAY:DATA 2, 2, 2, 500	Write 2nd day trend data set: MPP voltage: 2 V MPP current: 2 A	12010
...	...	Write further data set, a total of 1000	...
1012	FUNC:PHOT:DAY:DATA 1000, 30, 9, 500	Write 1000th day trend data set: MPP voltage: 30 V MPP current: 9 A	12010

Due to the dwell time of 5 minutes in the very first day trend data set, all 1000 data sets use the same dwell time, so the total simulation time results as 5000 minutes.

Control

Nr.	Command	Description	Register
1013	FUNC:PHOT:STAT RUN	Start simulation. The simulation will stop automatically after the time that results from the total of dwell times in all written data sets	12000

13 Profibus & Profinet

13.1 General

Connection to Profibus and Profinet are possible only through the Anybus modules IF-AB-PBUS (Profibus) or IF-AB-PNET (Profinet, 1 or 2 ports).

The Profinet/IO module (1 or 2 ports) can be used to control and monitor a system using a network system, usually combined with an integrated PLC and proper software. For Profinet, the software selects the necessary Ethernet port, because this port cannot be adjusted on the system. The standard Profinet communication is handled by the field bus protocol via special software.

On the system side, the interface module simplifies the necessary configuration. When using Profibus, the user only has to set a slave address (0–125), while Profinet's network settings are usually configured through remote control, often using the Siemens Primary Setup Tool (PST) or somethig similar. Optional parameters like tags can be defined in the system's setup menu or via command.

This part of the document covers how to use the Modbus register lists (PDF) with your system in order to access indexes and slots via acyclic communication. The interface modules present the system as a DP-V1 slave to the network, capable of cyclic and acyclic data transmission.

13.2 Preparation

For the implementation of a system into Profibus or Profinet, and the enumeration at the master (PLC or similar), a fully configured and wired unit is presumed. The next thing you will usually need is a system description file called GSD (Generic Station System) for Profibus, or a GSDML for Profinet, which is available as a download from our website.

This GSD/GSDML file enables building a specific slot configuration for cyclic process data, such as actual values or status. Those slots are also used to access other data objects of the system via acyclic read/write. See more below.

13.3 Slot Configuration for Profibus

The slot configuration for users of the interface module IF-AB-PBUS is done by loading the GSD/GSE file in the configuration dialogue (with Siemens STEP7: HWCONFIG) and by arranging the slots in a specific order:

Slot	Slot name	Description
1	System status & acyclic slot 1	Cyclic: System status (see register list) Acyclic: all registers (indexes) assigned to slot 1
2	Act. voltage & acyclic slot 2	Cyclic: Actual voltage of DC output Acyclic: all registers (indexes) assigned to slot 2
3	Act. current & acyclic slot 3	Cyclic: Actual current of DC output Acyclic: all registers (indexes) assigned to slot 3
4	Act. power & acyclic slot 4	Cyclic: Actual power of DC output Acyclic: all registers (indexes) assigned to slot 4
5	Acyclic slot 5	Acyclic: all registers (indexes) assigned to slot 5
...	...	...
12	Acyclic slot 12	Acyclic: all registers (indexes) assigned to slot 12

Example view of the HW CONFIG in Siemens Simatic, with 8 slots:

Steckplatz	DP-Kennung	Bestellnummer / Bezeichnung	E-Adresse	A-Adresse
1	209	Status and acyclic slot 1	256...259	
2	208	Act. voltage & acyclic slot 2	260...261	
3	208	Act. current & acyclic slot 3	262...263	
4	208	Act. power & acyclic slot 4	264...265	
5	208	Acyclic slot 5	266...267	
6	208	Acyclic slot 6	268...269	
7	208	Acyclic slot 7	270...271	
8	208	Acyclic slot 8	272...273	

The address ranges can of course be re-arranged as required. The slots for acyclic access don't need an output address range, because the input address range already reserves memory space for both directions.

13.4 Slot Configuration for Profinet

The GSDML file does not offer automatic slot configuration. When loading the file, the correct version for the Profinet interface module in use, 1 port or 2 port, must be selected. After that, the slot placement can be set up like this:

Slot	Slot name	Description
1	Input 2 words	Cyclic: System status (register 505, see register list) Acyclic: all registers (indexes) assigned to slot 1
2	Input 1 word	Cyclic: Actual voltage of DC output (register 507, see register list) Acyclic: all registers (indexes) assigned to slot 2
3	Input 1 word	Cyclic: Actual current of DC output (register 508, see register list) Acyclic: all registers (indexes) assigned to slot 3
4	Input 1 word	Cyclic: Actual power of DC output (register 509, see register list) Acyclic: all registers (indexes) assigned to slot 4
5	Input 1 word	Acyclic: all registers (indexes) assigned to slot 5
...	...	...
12	Input 1 word	Acyclic: all registers (indexes) assigned to slot 12

Example view of the HW CONFIG in Siemens Simatic, with 8 slots:

Steckplatz	Baugruppe	Bestellnummer	E-Adresse	A-Adresse	Diagnoseadresse
0	Default	ABCC-PRT (2-Port)			2043*
1	Input 2 word		256...259		
2	Input 1 word		260...261		
3	Input 1 word		262...263		
4	Input 1 word		268...269		
5	Input 1 word		270...271		
6	Input 1 word		272...273		
7	Input 1 word		274...275		
8	Input 1 word		264...265		
9					

The address ranges can of course be re-arranged as required. The slots for acyclic access don't need an output address range, because the input address range already reserves memory space for both directions.

13.5 Cyclic Communication via Profibus/Profinet

The Profibus / Profinet slave cyclically transfers process data to certain input addresses of the master, as defined by the user for Profibus or Profinet during slot configuration. Also see sections 13.3 Slot Configuration for Profibus (p 176) resp. 13.4 Slot Configuration for Profinet (p 177).

Actual values coming from the system have to be translated to real values according to the formula described in section 11.3.1 Hex Percent and Decimal Value Conversion (p 106), while any other data are referenced in those register lists which usually should come along with this document. The slot names are partially connected to corresponding registers in the lists. For instance, one slot is named "Actual current", a name which can be found in the register list at position 508. This is also where the register is enabled for use with Profibus/Profinet use by having a slot/index number assigned.

According to sections 13.3 and 13.4 there are up to 12 slots for acyclic system access, which carry a varying number of indexes (see register lists). By using appropriate blocks/functions (SFB52, SFB53), the user can acyclically access the IDs (slot addresses) and indexes by write and read. The slots for acyclic transfer are only defined to reserve slot addresses and memory space, so it doesn't matter that they are only inputs.

> ! Set values, settable status and most other registers are not transferred cyclically for several reasons. One is the high number ot available registers which cannot be covered by only 16 available slots and the max. data size per slot.

13.6 Acyclic Communication via Profibus/Profinet

Acyclic communication with the target system is done by using slots 1-12, precisely their resulting ID, and indexes, which are accessed by system function blocks for read or write. The SFBs to use here are usually SFB52 and SFB53 when using Siemens software. Other PLC control softwares offer similar options.

The SFBs require an ID, an index and a parameter as input. The parameter can be a status or a set value, translated to a hexadecimal value according to 11.3.1 Hex Percent and Decimal Value Conversion (p 106).

For starters there are example projects (on the included USB stick or as download), one each for Profibus and Profinet, which can be opened with Siemens STEP7 and which shall demonstrate the access to the system with preconfigured data blocks.

The register list for your system series has two extra columns for Profibus/Profinet use only. These define slot and index number for a particular command. The necessary parameter is defined in the register lists respectively, also in 11.3.1 Hex Percent and Decimal Value Conversion (p 106). Rule of thumb:

• Registers where no slot/index is given are not supported via Profibus or Profinet

The general procedure to control a system remotely is like this:

1. Activate remote control with the appropriate command (may be denied by the system, see 9.2 Control Locations (p 86))

2. Control and monitor your system remotely, via cyclic (DP-V0) and/or acyclic (DP-V1) access.

3. Deactivate, i.e. leave remote control

If you just want to record data by reading values from the system, activation of remote control is not necessary. You can send query commands to the system at anytime and the system will respond immediately, if its current situation allows to respond at all. After querying something from the system, the function block will put out the data returned from the

system to an output buffer for further processing.

The field bus ensures that the command is transmitted to the system, otherwise it will generate an error. However, it can't verify that the system really accepted the command or already has set the desired value. This can only be verified by reading the value from the system and comparing. Whether a value has been truly transferred to the system's DC output can't be determined definitely.

In order to send a command from with a typical Profibus/Profinet software, following applies in general:

1. Select the desired register from the register list and read its assigned slot/index values.

2. Determine the I/Q address which is assigned to the particular slot in HWCONFIG. The use of ID, index, slot and subslot are not just different between Profibus and Profinet, but also between the different PLC systems and softwares. The examples below demonstrate the use with Siemens software.

3. Set ID, index and parameter (set value, status or something else) in decimal or hexadecimal form in the SFB and execute.

4. Process the data returned from the system, if the last message was a query.

13.7 Examples for Acyclic Access

13.7.1 Activate/Deactivate Remote Control

Remote control is a system state and not the default one. It has to be activated, i.e. requested by the user before the system can be controlled remotely. Depending the settings and on the state the system is currently in when trying to switch to remote control, the system can deny the request.

Activating or deactivating remote control of your system via Profibus

1. Use the register list and find the proper command, here: Register 402 - Remote mode.
2. Find the slot and index values for this command in the dedicated columns, here slot 2 and index 1.
3. From the slot configuration read the I/Q address for slot 2 to have the value for parameter "ID", for example 260 (like in the example configs in 13.3 and 13.4) or DW#16#104
4. The value "Index" from the register list is submitted to the parameter INDEX like this:
   Profibus: INDEX = Index = 1
   Profinet: INDEX = Slot number * 255 + 1 + Index = 510 + 1 + 1 = 512
5. Use a suitable function block in your automation software, for example SFB53.
6. Define the control value to use for this command, as described in the columns "Data" and "Example":
   0xFF00 = Activate remote control
   0x0000 = Deactivate remote control
7. Configure the function block with ID, INDEX and control value and execute the block. If not somehow inhibited by the system, it should either switch to remote control or back to manual control.

13.7.2 Send a set value

Any command that sets something in the system, no matter if value or status, requires activated remote control status. Also see 13.7.1 Activate/Deactivate Remote Control (p 179) and 9.2 Control Locations (p 86).

Before you send a value, you first need to select which one you want to set and you also might need to translate it, because via Profibus/Profinet set values are transferred as percent of the nominal values. Read sections   (p 105) and 11.3.1 Hex Percent and Decimal Value Conversion (p 106) for more information.

Setting the DC output current value

1. Use the register list and find the proper command, here: Register 501 - Set current value.
2. Find the slot and index values for this command in the dedicated columns, here slot 2 and index 24.
3. From the slot configuration read the I/Q address for slot 2 to have the value for parameter "ID", for example 260 (like in the example configs in 13.3 and 13.4) or DW#16#104
4. The value "Index" from the register list is submitted to the parameter INDEX like this:

   Profibus: INDEX = Index = 25

   Profinet: INDEX = Slot number * 255 + 1 + Index = 510 + 1 + 24 = 535
5. Use a suitable function block in your automation software, for example SFB53.
6. Define the control value to use for this command, as described in the columns "Data" and "Example". First, read the value range: 0x0000–0xCCCC (decimal: 52428) = Current 0–100%. Second, calculate the set value. For a model with, for example, 170 A nominal current and a desired current of 10 A, this would be 52428/17 = 3084 --> 0x0C0C.
7. Put the conrol value 0x0C0C together with ID and INDEX into the function block and execute the block. The system should instantly set 10 A as current limit. This can be verified in the display of the system where it shows the set value of current.

13.7.3 Read Something

Reading something from the system is always possible, it means that no remote control is required. Apart from the cyclically transferred data, any other available information can be read via acyclic transfer.

Reading the actuals values of voltage and current

1. Use the register list and find the proper register. The registers of voltage and current are next to each other, the one of voltage is the lower number, thus it will be: Register 507 - Actual voltage
2. Find the slot and index values for this command in the dedicated columns, here slot 2 and index 28
3. From the slot configuration read the I/Q address for slot 2 to have the value for parameter "ID", for example 260 (like in the example configs in 13.3 and 13.4) or DW#16#104.
4. The value "Index" from the register list is submitted to the parameter INDEX like this:

   Profibus: INDEX = Index = 28

   Profinet: INDEX = Slot number * 255 + 1 + Index = 510 + 1 + 28 = 539
5. Read the length of bytes from the column "Data length in bytes" to determine how many bytes to read. In this case there are two registers with length 2 bytes to read, so it's 4 bytes.
6. Use a suitable function block in your automation software, for example SFB52.
7. Configure the function block with ID, INDEX and data length (4 bytes or 2 words of 16 bit, depending in the way the software defines the input).
8. Execute the function block. The data buffer of the block should return the requested data in form of 4 bytes.

The returned 4 bytes will contain the actual voltage value in the first two bytes which is represented as percent value (for translation see 11.3.1 Hex Percent and Decimal Value Conversion (p 106)). The actual current value will be in the last two bytes.

By varying the data length to 6 you could also include the actual power value. Alternatively, you can query each actual value separately. To do this, you need to use the corresponding register number to calculate the INDEX and a data length of 2.

13.8 Data Interpretation

Data returned from queries, but cyclically transferred data in the first place, have to be interpreted. Let's use an example from a Profibus master simulator where the cyclic data is comfortably displayed. Also see section 11.3.1 Hex Percent and Decimal Value Conversion (p 106).


```
Eingangsdaten
            76543210

 1:   00   00000000   .    0
 2:   00   00000000   .    0
 3:   04   00000100   .    4
 4:   C0   11000000   .   192
---------------------------------
 5:   26   00100110        38
 6:   3A   00111010   :    58
---------------------------------
 7:   0C   00001100   .    12
 8:   9B   10011011   .   155
---------------------------------
 9:   09   00001001   .    9
10:   25   00100101   %    37
---------------------------------
11:   00   00000000   .    0
12:   00   00000000   .    0
---------------------------------
13:   00   00000000   .    0
14:   00   00000000   .    0
---------------------------------
15:   00   00000000   .    0
16:   00   00000000   .    0
---------------------------------
17:   00   00000000   .    0
18:   00   00000000   .    0
```

The figure shows the transferred data of a configuration with 8 slots. Because only slots 1-4 are used for cyclic transfer, the rest remains empty.

Slot 1: System status (connected to register 505). The value 0x000004C0 says that bits 6, 7 and 10 are set. It means, the system is configured as master (for master-slave), the input/output is on and regulation mode is CC.

Slot 2: Actual voltage (connected to register 507). With a 250 V model, for instance, the value 0x263A translates to 250 V*0x263A/52428=46.7 V.

Slot 3: Actual current (connected to register 508). With a 510 A model, for instance, the value 0x0C9B translates to 510 A*0xC9B/52428=31.4 A.

Slot 4: Actual power (connected to register 509). For a 5 kW power supply, for instance, the value 0x0925 translates to 5000 W*0x925/52428=223 W or 0.22 kW.

Slot 5: not used for cyclic data

Slot 6: not used for cyclic data

Slot 7: not used for cyclic data

Slot 8: not used for cyclic data

14 CANopen

The available communication objects (ADIs) in an Electronic Data Sheet file (EDS/XDD) are available from from our website. This EDS can be integrated in CANopen related software. The EDS indexes are not separately explained, because their definition and use is identical to the Modbus register list. Examples from the Modbus part of this document can be used, and applied for CANopen as well, but would be reduced to the core data, because CANopen users are not confronted with checksums and function codes as with Modbus.

> **!** The CANopen module IF-AB-CANO does not feature an internal termination resistor. Thus the bus termination has to be applied by the user according to the CAN bus requirements.

14.1 Preparation

For the communication with the system via CANopen interface IF-AB-CANO, a few things are required:

1. A suitable CAN cable, preferably with switchable termination resistor, which has to be activated always if the system is at the end of the bus, like when directly connecting the PC to a single unit.

2. EDS/XDD (included with the system on USB stick).

3. CANopen software for the PC (not included, any available software for CANopen should suffice).

4. Documentation about how to use the supported indexes as well as the Modbus register list.

14.2 User Objects (Indexes)

The message format used via CANopen communication is related to Modbus. A specific index is connected to a specific Modbus register. The CANopen standard defines that user objects are enumerated from index 0x2001. With Modbus, the registers are counted from 0. This means, that index 0x2001 corresponds to register 0, and index 21F5 corresponds to register 0x01F4 (decimal 500) etc.

The EDS/XDD contains fewer indexes than mPower supports for Modbus registers, but the available indexes still cover most functions needed for remote control of an mPower system. Users can edit the EDS/XDD anytime, and add indexes.

Along with this document, there are Modbus register lists. These can also be used to CANopen, as they also define data type and value range of the indexes. Examples in other sections of this documents can be applied to CANopen as well.

14.2.1 Translation ADI > Register

The translation of an CANopen index, as listed in the EDS file, to a register address is quite easy due to the fixed offset of 0x2001. For example, if you pick the index "207A Nominal voltage" from the EDS, it translates like this:

Index number – Offset = register address → 0x207A – 0x2001 = 0x79 (hex) = 121 (dec). According to the register list for an mPower 311 Series, this represents the nominal system voltage as a FLOAT value. Since CANopen does not support the data type FLOAT, the EDS uses REAL32 here. The user just has to translate the 32 bit value according to IEEE 754 specification.

14.3 Specific Examples

14.3.1 Switching to Remote Control

As described in 11.7.9.5 Switch between remote and manual control (p 117), it's required to switch the system to remote control before you can control it. In order to do this, you first need to find the proper command in the register list relative to the dedicated index in the EDS. In this case, it's register 402 which is index 0x2193. The register list defines that the value 0xFF00 has to be sent to switch to remote or value 0x0000 to leave remote control.

14.3.2 Setting a Set Value

After remote control has been accepted by the system, you are allowed to send set values. Those values usually represent a percent value. From the definition in the register list, 100% of a value translated to the hexadecimal value 0xCCCC and 0% to 0x0000. There are 52429 possible values between 0% and 100%. It has to be pointed out here, that this is not the true resolution values like voltage or current actually achieve at the DC output. The effective resolution of output values is 26214 steps. More details are available in 11.7.9.1 Writing a set value (p 115).

14.4 CANopen to Modbus Differences

14.4.1 When Using the Arbitrary Generator

Due to CANopen only being able to transport a maximum of 4 effective user data bytes per message, the 8 values of data defining a sequence point of the arbitrary generator cannot be transferred at once. Instead, they are sent in 8 separate messages. The system checks every single value for plausibility upon reception, but once all sequence points are set without any error, an additional submit command is needed (index 235F). This will transfer all sequence point data and load the function into the function generator, and enable start/stop action. Without sending the submit command, the function generator would either run with all data being zero or using old data.

The steps to perform, as described in section 11.10.1 Programming the Arbitrary Generator (p 123), are the same for CANopen, except for the additional step 3.1:

Step 1:

Select, whether to apply the function to the voltage U (index 2354) or the current I (index 2355). Before making this selection, the system cannot accept sequence point data, because the data is run through a plausibility check against the system's nominal values.

Step 2:

Define start sequence point (index 235C), end sequence point (index 235D) and number of cycles of that sequence point block to repeat (index 861).

Step 3:

Load data for all required sequence points (x out of 99, indexes 2385 - 29A5, 8 values per sequence point in sub indexes).

Step 3.1:

Submit the data by writing 0xFF00 to index 235F (register 862, undocumented for Modbus, because not required there)

Step 4:

Set global voltage limit (index 21F5), if the function is applied to the current. Otherwise, set global current limit (index 21F6), if the function is applied to voltage. Set global power limit (index 21F7) for both modes.

Step 5:

Control the function generator with start/stop (index 2353).

Step 6:

When finished, leave the function generator by deselecting your former selection of either U (index 2354) or I (index 2355) again by writing 0x0000.

14.5 Error Codes

Following error codes, as part of the CANopen standard, are supported by the CANopen interface module:

Code	Description
0x06020000	Object does not exist in the object dictionary (Modbus register list)
0x06040043	Command not supported
0x06099911	Sub-Index does not exist
0x06010002	Attempt to write a read only object
0x06010002	Attempt to read a write only object
0x06070012	Too much data
0x06070013	Not enough data
0x06090030	Value range of parameter exceeded
0x08000022	Data could not be transferred or stored to the application because of the present system state
0x05040005	Out of memory
0x08000000	General error

15 CAN

This section is specific to the communication with a system via the CAN Anybus module IF-AB-CAN. Configuration of the interface itself is done on the control panel (HMI) of the system.

15.1 Preparation

Requirements for communication with the system via CAN module IF-AB-CAN.

1. A suitable CAN cable. It's not required to have one with integrated bus termination switch and resistor, because the interface module has an electronically switched resistor for bus termination. In case the cable also has one, it's important to take care to activate only one of both, otherwise there can be bus errors.

2. When using Vector™ or similar software which can make use of database files (DBC), a dedicated DBC for the particular system model is needed. If not available, it can be created by the user, for example by modifying a similar one.

3. CAN software for the PC (not included, any available software for CAN should suffice).

4. Documentation about how to use the supported CAN objects. See below and sections 1. - 4., as well as the register list for the series.

15.2 Introduction

The data format is derived from Modbus RTU. In relation to a database file (DBC) a mux value (Vector terminology) represents a specific Modbus register or object/command. Objects in the database are selected by the muxer, and when programming the CAN message buffer directly (CAPL), the first two bytes of data in a CAN message define the register (object, command) to access. The selection between writing and reading objects is done by the CAN ID.

Each system will be assigned at least three CAN IDs, which are defined via the Base ID in the system's CAN settings. The Base ID is used write to objects (message type: Send_Object), while querying objects (message type: Query_Object) is done with Base ID+1 and responses (message type: Read_Object) coming from the system use Base ID+2. Responses from the system are expected after a query, but can also be received unexpectedly in case of communication or access error. When adjusting the Base ID of a system, the other related IDs will shift automatically.

There is another adjustable ID, the Broadcast ID. It's separate from all others and can be used to address multiple systems at once by one command when using the same broadcast ID on these system. This ID is for write access (Send_ Object) only. Queries to multiple systems at once with one message are not possible.

Apart from the Base ID and Broadcast ID for acyclic access, some series support further adjustable IDs for cyclic status data which is sent permanently by the system once activated and after the CAN connection has been established. Refer to the system manual for setup, particularly the section for the communication settings, and also further below.

15.3 Message formats

15.3.1 Normal Sending (Writing)

Writing to the system always used the base ID or the broadcast ID. It requires defining the first register/object to write to in the CAN data, as well as the number of registers to write and a specific number of parameter bytes which can represent different data types.

Access: Base ID, broadcast ID

Connected Modbus functions: Write Single Coil (WSC), Write Single Register (WSR)

Bytes 0+1	Byte 2	Bytes 3+4
Register	Nr. of regs to write	Data
0–65534	Always 1	Value (16 bit)

Access: Base ID, broadcast ID

Connected Modbus function: Write Multiple Registers (WMR)

Bytes 0+1	Byte 2	Byte 3	Bytes 4-7
Start reg.	Nr. of regs to write	Marker	Data bytes
0–65534	2–123	0xFF, 0xFE…	Four bytes or two 16 bit values or one 32 bit value

Start register: always the register number from the register list, i. e. start register, even for WMR.

Nr. of regs to write: refer to the register list. An object defined with 40 bytes occupies 20 registers, so when writing to such an object the value here would have to be 20.

Marker: is used to distinguish single messages from split messages and to detect the correct sequence of data. For example, a string like the user text can be up to 40 characters long and when writing it has to be split across multiple messages. Every message can transport 4 characters of the string. The marker always starts with 0xFF and is counted down (0xFF, 0xFE…) with every next split message belonging to a transmission. The marker is required, because on CAN bus it's not guaranteed that messages are received in the same order they were sent.

Data bytes: the number of bytes in this type of message is always 4, no matter if all bytes are filled with information from the actual data to transmit or are 0. An example: an user text with a length of 15 characters would require to send at least 4 messages. The object for the user text is defined to have 20 registers, means 10 messages. Since you would write to less registers than defined you would only have to reduce the number of Nr. of regs to write. In this example it would be 8, resulting in 4 messages containing 16 bytes (15 bytes of string + termination character).

15.3.2 Cyclic Sending (Writing)

Cyclic sending (or writing) is intended for compact and time efficient transmission of often used set values and status in form of a block of data. It uses separate CAN IDs. The user defines the interval of cyclic send via timing in the CAN software, though we recommend to stick to timing recommendations as described in 9.2 Control Locations (p 86).

It's strongly recommended to send the block **Control** after the other data blocks, especially when remote control has not yet been activated. This means you should write the set values first, and as the last step write the status to **Base ID Send**. This will submit all data internally and since block `Control` would contain **remote control = on**, the set values in the other blocks would be accepted without error.

In order to use this feature, the user only has to define the separately adjustable **Base ID Cyclic Send** and can then send two different messages with following format:

Access: Base ID Cyclic Send (Control)

Bytes 0-1
Control word

Control word definition:

Bit	Name	Related register	Meaning
0	Remote control	402	Activates remote control of the system with 1 or deactivates it with 0
1	Input/Output	405	Switches the DC output of the system on with 1 or off with 0
2	UIP / UIR	409	Activates resistance control mode (UIR, where featured) with 1, while with 0 mode UIP will be active
3	(not applicable)	422	—
4	Alarm	411	The value 1 acknowledges all currently acknowledgeable alarms

This control word requires special attention, as the 5 bits can trigger several actions at once which don't have a certain priority of processing. This means that if you would try to activate remote control together with switching on the DC output (bits 0 and 1 both TRUE), you may receive a settings conflict error, because the system would possibly process bit 1 before bit 0.

Access: Base ID Cyclic Send + 1 (Set values 1)

Bytes 0-1	Bytes 2-3	Bytes 4-5	Bytes 6-7
Register 500	Register 501	Register 502	Register 503
Set value of voltage	Set value of current	Set value of power	Set value of resistance

15.3.3 Querying

Querying an object is the first part of a read action. It's always done via Base ID + 1. The system should then respond via Base ID + 2 (Read_Object) and with the expected data. Only after reading the response, the read action is finished. In order to query an object via the Query ID (Base ID +1) it's sufficient to send the start register number. The system will respond with the correct length of data, but in different. See *Normal Reading* below.

Access: Base ID + 1

Connected Modbus functions: Read Coils (RC), Read Holding Registers (RHR)

Bytes 0+1
Start reg.
0–65534

15.3.4 Normal Reading

Data coming from the system can be a single message (expected data or error) or can be split messages forming a response. The information is either in a buffer or, when using Vector software, automatically sorted into signals. The data of split messages has to be combined again according to the marker. Even the Vector database cannot do this automatically. But there are only a few objects like the user text which require this treatment and these are usually not accessed very often.

Access: Base ID + 2

Response with one message (number of queried registers 1-3):

Bytes 0+1	Bytes 2-7
Register	Data
0–65534	1-3 registers

Response with multiple messages (number of queried registers >3):

Bytes 0+1	Byte 2	Bytes 3-7
Register	Marker	Data
0–65534	0xFF, 0xFE...	5 bytes

Response as error message:

Bytes 0+1	Byte 2
65535	Error code

The error codes used here are the same as with Modbus. See 11.7.8 Communication Errors (p 114).

15.3.5 Cyclic Reading

The cyclic read feature is an extended function where the system can automatically send specific objects to specific IDs and in a specific interval. Cyclic read messages differ from those of normal read actions.

In order to activate and use cyclic read, the user has to

1. Set the extra **Base ID Cyclic Read** on the system (HMI, CAN settings).

2. Define which of the 5 available objects for cyclic read are going to be used and activate them by setting the interval time to a value other than zero.

3. Process the received data separately and differently, because the data format is different here (see below).

The interval times for the cyclic objects can be set separately and arbitrarily. In case they match or overlap, the system will send the corresponding messages subsequently and as fast as possible.

> (!) The minimum interval is 20 ms. When using a very low CAN bus speed, for example 10-50 kbps, CAN bus errors may occur when multiple cyclic read items are active, because of too much traffic.

Once cyclic read is activated by setting the interval time of at least one item and as soon as a CAN connection is established, the system will start to automatically and permanently send messages to the defined IDs. The cyclic read feature can be turned off or on anytime using the CAN settings on the control panel or the corresponding commands sent as acyclic CAN message.

There are up to 6 CAN IDs reserved for cyclic read. Starting at the adjustable **Base ID Cyclic Read** (see control panel of the system) the data in the messages is defined as follows:

Access: Base ID Cyclic Read (Status)

Bytes 0-3
System status (32 Bit)

Bit layout of the system status value:

Bit	Name	Meaning		Bit	Name	Meaning
31	Remote control	1 = on		15	-	
30	Input / output	1 = on (req., register 405)		14	Alarm OVD	1 = alarm active
29	Volt. reg. speed	1 = fast (register 422)		13	Alarm OVP	1 = alarm active
28	Operation mode	0 = UIR, 1 = UIP		12		
27	Alarms	1 = at least 1 alarm active		11	Alarm PF	1 = alarm active
26	Alarm MSS	1 = alarm active		10		
25	Alarm OCD	1 = alarm active		9	REM-SB	1 = on (register 505, bit 30)
24	Alarm OCP	1 = alarm active		8	Alarm UCD	1 = alarm active
23				7	Alarm UVD	1 = alarm active
22				6	Remote sensing	1 = external, 0 = internal
21	Interface in access	register 505, bits 4-0		5	Function gen.	1 = FG active
20				4	MS type	1 = master, 0 = slave
19				3	Input / output	1 = on (register 505, bit 7)
18	Alarm OPD	1 = alarm active		2	Reg. mode	register 505, bits 10-9
17	Alarm OPP	1 = alarm active		1		
16	Alarm OT	1 = alarm active		0	DC mode	0 = source

Access: Base ID Cyclic Read + 1 ("Actual values")

Bytes 0-1	Bytes 2-3	Bytes 4-5
Register 507	Register 508	Register 509
Actual voltage	Actual current	Actual power

Access: Base ID Cyclic Read + 2 ("Set values 1")

Bytes 0-1	Bytes 2-3	Bytes 4-5	Bytes 6-7
Register 500	Register 501	Register 502	Register 503
Set value of voltage	Set value of current	Set value of power	Set value of resistance

Access: Base ID Cyclic Read + 3 ("Limits 1" or "Limits 1 [PS]")

Bytes 0-1	Bytes 2-3	Bytes 4-5	Bytes 6-7
Register 9002	Register 9003	Register 9000	Register 9001
I-max	I-min	U-max	U-min

Access: Base ID Cyclic Read + 4 ("Limits 2" or "Limits 2 [PS]")

Bytes 0-1	Bytes 2-3
Register 9004	Register 9006
P-max	R-max

15.3.6 Message Examples

15.3.6.1 Switching to remote control

As described in 11.7.9.5 Switch between remote and manual control (p 117), it's required to switch the system to remote control before you can control it. In order to do this, you first need to find the proper command, i.e. register in the register list resp. the dedicated index in the EDS. In this case, it's register 402 (hex: 0x192). The register list defines that the value 0xFF00 has to be sent to switch to remote or value 0x0000 to leave remote control.

Assuming the system has been set to Base ID 0x20, the data to be sent according to 15.3.1 Normal Sending (Writing) (p 186) would be:

0x01 0x92	0x01	0xFF 0x00
Register / object	Nr. of regs	Bit (coil) for TRUE

The system should switch to remote control immediately after reception, if not inhibited somehow. The status of remote control can be read from the display or by reading another object.

15.3.6.2 Write and read back a set value

After remote control has been accepted by the system, you are allowed to send set values. Those values usually represent a percent value. From the definition in the register list, the hexadecimal value 0xCCCC translates to 100% and 0x0000 to 0%. It means, there are 52428 possible values between 0% and 100%. It has to be pointed out here, that this is not the resolution a system value like voltage or current can have at the DC output. The effective resolution of output values is 26214 steps. An example for set value translation is in 11.7.9.1 Writing a set value (p 115).

Power supply model PSI 9080-170 3U has a nominal current of 170 A. If you wanted to set it to 35 A, the set value according to the formula in 11.3.1 Hex Percent and Decimal Value Conversion (p 106) calculates as: 35 A * 52428 / 170 A = 10794 = 0x2A2A. The current is set with register 501. Assuming the system would have been set to Base ID 0x88 the data to be sent to this ID, according to 15.3.1 Normal Sending (Writing) (p 186), would be:

0x01	0xF5	0x01	0x2A	0x2A
Register / object		Nr. of regs	Bit (coil) for TRUE	

Soon after the system received and accepted the value, it's set, and could be read from the display or also by reading it back using the same object. With the same base ID, the query message would be

0x01	0xF5
Register / object	

and would have to be sent to the query ID of the system, here 0x89. Shortly after this, the system should respond the requested value on the read ID 0x8A:

0x01	0xF5	0x2A	0x2A
Register / object		Set value current	

In case the values has not been accepted when sending it, for example because the adjustment limit for current (I-max) has been set to 30 A, the system may have responded with an error message (see 15.3.4 Normal Reading (p 188)) instead of the expected one:

0xFF	0xFF	0x03
Error		Error Code

The Modbus error code 0x3 indicates wrong data. In this case, the set value was too high.

16 EtherCAT

16.1 Overview

This section is specific to the communication with a system via the Anybus module IF-AB-ECT.

The EtherCAT data communication is based on CANopen. All documentation for EtherCAT and CANopen is provided by the Beckhoff company and the CAN in Automation (CiA) organization. In the documentation below, certain software examples refer to Beckhoff's TwinCAT.

16.2 Integrating the System in TwinCAT

To use EtherCAT, you will need an ESI file (an EtherCAT system description in XML format) from our website. The file is to be put into a dedicated folder in the TwinCAT installation. Default path on Windows system:

c:\TwinCAT\<twincat_version>\Config\Io\EtherCAT\

After installing that file and restarting the TwinCAT IDE, mPower EtherCAT units can be integrated into the setup with the Insert EtherCAT System dialog and by selecting the system name IF-AB-ECT.
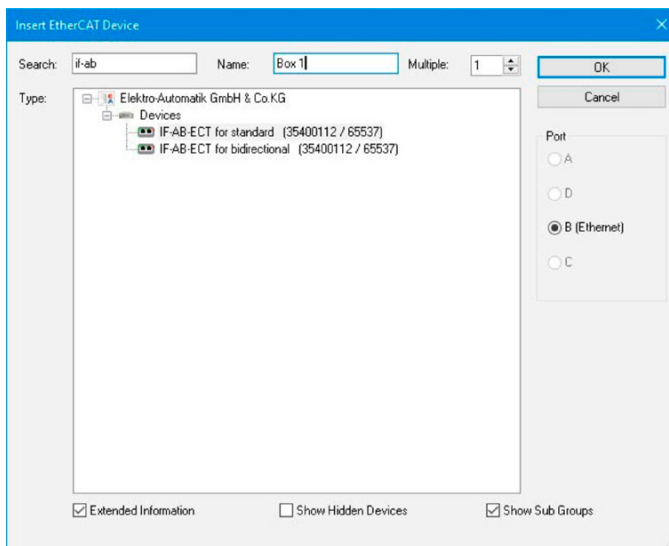
16.3 Data Objects

The systems internally use Modbus protocol and for CANopen over Ethernet communication. This is why the reference for all cyclic data (PDOs) and acyclic data (SDOs) is the Modbus register lists (11.6 Reading Register Lists (p 108)). The acyclic objects are downloaded from the system when accessing an online EtherCAT slave in tab "CoE" in TwinCAT. Offline objects in form of an EDS file are not available.

Together with the PDOs defined in the ESI file the complete list of indexes then becomes accessible and enable the user to completely control the system.

There is a connection between the CoE indexes and the Modbus register numbers in the lists. You can translate both back and forth.

Translating Modbus register to CANopen index

Modbus register number in decimal + 8193 => convert to hexadecimal = index

Example: you want to set the system into remote control mode and want to find the corresponding CoE index. In the register list you have register number 402 for this task. The calculation is: 402 + 8193 = 8595 => converted to hexadecimal is 0x2193, and thus the index is 2193.

Translating CANopen index to Modbus register

CANopen index in hexadecimal – 0x2001 => convert to decimal = register

Example: you need know the meaning of the bits in the "Status" PDO. Find the corresponding CoE index in the index list. In this case, it's 21FA. The calculation is: 0x21FA – 0x2001 = 0x1F9 => converted to decimal is 505. In the register list you will find register number 505 and the layout of the 32 bit value.

16.3.1 PDO Object

The system description file defines for mPower EtherCAT slaves the same set of object in the one PDO:

Name	EtherCAT data type	Length in bytes	Modbus register	Short description
Status	UDINT	4	505	System status
Voltage Monitor	UINT	2	507	Actual voltage on DC output (in percent)
Current Monitor	UINT	2	508	Actual current on DC output (in percent)
Voltage select	UINT	2	500	Set value of voltage (in percent)
Current select	UINT	2	501	Set value of current (in percent)
Power select	UINT	2	502	Set value of power (in percent)
Resistance select	UINT	2	503	Set value of resistance (in percent)

16.3.2 SDOs

The acyclic data objects for use in the EtherCAT system are defined in your system and can be downloaded from it. It requires the system to be online with the EtherCAT system. There is no separate documentation for the downloadable data objects. Like with CANopen (see 14 CANopen (p 182)), the register lists which are part of the programming documentation are the reference for the SDOs to explain data content and function, as well the section of this document dealing with the Modbus protocol and its examples.

16.3.3 Use of the Data Objects

Please refer to 14.2 User Objects (Indexes) (p 182).

17 Service and maintenance

17.1 Maintenance / cleaning

The unit needs no maintenance. Cleaning may be needed for the internal fans, the frequency depending on the ambient conditions. The fans serve to cool the components which are heated by the inherent power loss. Heavily dirt filled fans can lead to insufficient airflow and therefore the DC output would switch off due to overheating or possibly lead to defects.

In case there is requirement for such a maintenance, please contact Marway.

17.2 Fault finding / diagnosis / repair

If the equipment suddenly performs in an unexpected way, which indicates a fault, or it has an obvious defect, this can't and must not be repaired by the user.

It will usually be necessary to return the unit to Marway (in or out of warranty). If a return for checking or repair is to be carried out, ensure that:

- Marway has been contacted, and that you have obtained an RMA.
- The unit is in fully assembled state, and in suitable transport packaging, ideally the original packaging.
- Optional extras such as an interface module is included if this is in any way connected to the problem.
- A fault description in as much detail as possible is attached.
- If shipping destination is abroad, the necessary customs papers are attached.

17.2.1 Firmware updates

There are three firmware systems, one for the control panel (HMI), the communication unit (KE) and the digital controller (DR). These can be updated using the rear USB port. For this, the EA Power Control software for Windows® is needed which is available as a download from our website. Firmware files are available upon request.

Note that we recommend to install updates only if:

- An imminent problem with your unit can be solved directly, especially if we suggested to install an update during a support case.
- A new feature has been added which you definitely want to use. In this case, the full responsibility is transferred to you.

Any firmware update with any piece of equipment come with the risk that the system could be rendered unusable if the update process goes wrong.

After making an update, you may need updated documentation, new drivers, new software for LabView, new files for the protocols supported by the Anybus modules, and you may need to modify your own custom software if you have any.

> ⚠️ Firmware updates should only be installed when they can eliminate existing bugs in the firmware in the system or contain needed new features.

17.3 Calibration

17.3.1 Preface

The units of the 311 Series don't have a built- in feature to re-adjust the most important DC output related values, but they can still be readjusted using the Power Control software. The required calibration app is included in the free version of this software. In order to use the feature is may be necessary to install an update of this software if you already have an older version in use for other mPower series.

Re-adjustment is intended to compensate small deviations of the output related values of voltage and current in a range of up to 1% or 2% of the rated value. There are several reasons which could make it necessary to re-adjust a unit: component aging, component deterioration, extreme ambient conditions, high frequent use.

In order to determine if a value is out of tolerance, the parameter must first be verified with measurement tools of high accuracy and with at least half the error of the system. Only then a comparison between values displayed on the power supply and true DC output values is possible.

For example, if you want to verify and possibly readjust the output current of model MPW 311-54-080-1000-004 which has 1000 A maximum current, stated with a max. error of 0.1%, you can only do that by using a high current shunt or current transducer with max. 0.1% error or less. Also, when measuring such high currents, it's recommended to keep the process short, in order to avoid the shunt heating up too much. It's furthermore recommended to use a shunt with at least 25% reserve.

When measuring the current with a shunt, the measurement error of the multimeter on the shunt adds to the error of the shunt and the sum of both must not exceed the max. error of the unit under calibration.

17.3.2 Preparation

For a successful calibration and readjustment, a few tools and certain ambient conditions are required:

- A measurement device (multimeter) for voltage, with a max. error of half the system's voltage error. That measurement device can also be used to measure the shunt voltage when readjusting the current.
- If the current is also going to be calibrated: a suitable DC current shunt, ideally specified for at least 1.25 times the max. output current of the system and with a maximum error that is half or less than the maximum current error of the system to calibrate.
- Normal ambient temperature of approx. 20-25°C.
- Warmed up system, which has been run for at least 10 minutes under 50% power.
- One or two adjustable loads, preferably electronic ones, which are capable of consuming at least 102% of the max. voltage and current of the system and which are calibrated and precise.

Before you can start calibrating, a few measures have to be taken:

- Let the system warm up for at least 10 minutes under 50% load, in connection with the voltage / current source.
- In case the remote sensing input is going to be calibrated, prepare a cable for the remote sensing connector to DC output, but leave it yet unconnected.
- Abort any form of remote control, deactivate master-slave mode, deactivate resistance mode.
- Install the shunt between system and load, and make sure the shunt is cooled somehow.
- Connect external measurement devices to the DC output and/or to the shunt/transducer, depending on whether the voltage is going to be calibrated first or the current.

17.3.3 Calibration procedure

The re-adjustment is done in the graphical user interface of Power Control. The software will guide through the process with instructions, as far as possible.

18 Contact and Support

18.1 Repairs

If not otherwise arranged between Marway and the customer, repairs must be carried out by Marway. The unit must be returned to Marway clearly labeled with a Return Materials Authorization (RMA) number. Contact Marway Support to obtain an RMA. Package the equipment adequately and send it, together with a detailed description of the problem, and if still under warranty, a copy of the invoice, to the address below.

18.2 Contact Options

Problems with or questions about operation of the unit, use of optional components, with the documentation or software, can be addressed to technical support either by telephone or email.

Address	Email	Telephone
Marway Power Solutions 1721 S. Grand Ave. Santa Ana, CA 92705	Technical support: support@marway.com All other issues: info@marway.com	714-917-6200

18.3 Two Year Warranty

Marway Power Solutions warrants each of its manufactured units to be as described in its specifications, made with quality materials and good workmanship, but also limited by this warranty and no other.

Two Year Warranty — For a period of two years following the date of shipment, Marway will repair or exchange, at Marway's sole discretion, any unit purchased shown to be defective in materials or workmanship when used for its intended purpose. This will be done at no charge to the purchaser. Purchaser will return unit(s) at its own expense and only with prior autorization from the factory. Instructions will be given by an authorized factory representative at the time an inquiry is made. All repairs will be made at Marway Power Solutions' corporate headquarters.

Transferability — This warranty is fully transferable to the end user if the purchaser is an original equipment manufacturer and the Marway unit is a component of their product or system sold to an end user.

Further Limitations — Marway's liability under the terms of this warrenty and the purchase and sale of its units is limited to the repair or replacement of its units. Marway shall in no situation be liable for any special, consequential damages or other damages of any kind or nature. Marway's warranty does not cover units damaged by accident, abuse, misuse, unauthorized repair and such-the-like occurences out of Marway's control.

Exclusion of all Implied Warranties — **There are no warranties which extend beyond description on the face hereof. There are no warranties that any unit is fit for any particular purpose nor that they are merchantable.**

19 Appendix: Model Specifications

19.1 Approved Operating Conditions

- Use only inside dry buildings
- Ambient temperature 0-50 °C (32-122 °F)
- Operational altitude: max. 2000 m (1.242 mi) above sea level
- Max. 80% relative humidity, non-condensing

19.2 Model Data-Table Footnotes

Note that throughout the specs, U_{nom} (nominal voltage), I_{nom} (nominal current), and P_{nom} (nominal power) all refer to the product's rated values. Therefore, a unit rated for 200 V, 420 A, and 30 kW has a U_{nom} of 200, an I_{nom} of 420, and a P_{nom} of 30 or 30000 depending on whether the specification calls out kW or W.

For the model-specific data tables on the following pages, these are the referenced footnotes.

1. Related to the nominal values, the accuracy defines the maximum deviation between an adjusted values and the true (actual) value.

    - Example: a 1,000 A model has min. 0.2% current accuracy, which is 2 A. When adjusting the current to 300 A, the actual value is allowed to differ up to 2 A from the set value, which means it might be between 292 A and 302 A.

2. The display error adds to the error of the related actual value on the DC output.

3. RMS value: LF 0–300 kHz, PP value: HF 0–20MHz.

4. Typical value at 100% output voltage and 100% power.

5. Allowed float (potential shift) on the DC output.

19.3 MPW 311-54 : 4U, 30,000 Watt, 380–480 Vac 3ph

4U 30,000 W
380–480 Vac (a)

All 311-54 Models

AC Supply	
Voltage requirements	380–480 Vac, 3-phase Delta, ±10% Optional 208 Vac, 3-phase Delta, ±10%, with power derating to 18 kW
Frequency	45–66 Hz
Power factor	≈ 0.99
Leak current	≤ 10 mA

DC Output (static)	
Load regulation (CV mode)	≤ 0.05% FS • 0–100% load, constant input voltage, constant temperature
Line regulation (CV)	≤ 0.01% FS • 208–480 Vac +10% input voltage, constant load, constant temperature
Stability (CV)	≤ 0.02% FS • 8 hrs period after 30 min warm-up, constant input voltage, load, temperature
Temperature coefficient (CV)	≤ 30 ppm/°C • After 30 minutes warm up
Remote sense compensation	≤ 5% $U_{Nominal}$
Load regulation (CC mode)	≤ 0.1% FS • 0–100% load, constant input voltage, constant temperature
Line regulation (CC)	≤ 0.01% FS • 208–480 Vac +10% input voltage, constant load, constant temperature
Stability (CC)	≤ 0.02% FS • 8 hrs period after 30 min warm-up, constant input voltage, load, temperature
Temperature coefficient (CC)	≤ 50 ppm/°C • After 30 minutes warm up
Load regulation (CP mode)	≤ 0.3% FS • 0–100% load, constant input voltage, constant temperature
Load regulation (CR mode)	≤ 0.3% FS + 0.1% FS current • 0–100% load, constant input voltage, constant temperature

Protective Alarms	
OVP	Over voltage protection adjustable, 0–110% $U_{Nominal}$
OCP	Over current protection adjustable, 0–110% $I_{Nominal}$
OPP	Over power protection adjustable, 0–110% $P_{Nominal}$
OT	Over temperature protection, internally automated

DC Output (dynamic)	
Rise time 10–90% (CV)	≤ 20 ms
Fall time 90–10% (CV)	≤ 20 ms
Rise time 10–90% (CC)	≤ 10 ms
Fall time 90–10% (CC)	≤ 10 ms

Display Accuracy	
Voltage	≤ 0.05% FS
Current	≤ 0.1% FS

Insulation	
AC Input to DC Output	3750 Vrms (1 Minute), creepage distance >8 mm
AC Input to case (PE)	2500 Vrms
DC Output to case (PE)	Depending on the model, see model table
DC Output to Interfaces	1000 V DC for models up to 360 V output 1500 V DC for models from 500 V output

4U 30,000 W
380–480 Vac (b)

Interfaces, Digital

Built-in, galvanically isolated	USB Type B, Ethernet (100 MBit) for communication USB Type A Host for data acquisition
Optional, galvanically isolated	CAN, CANopen, RS232, ModBus TCP, Profinet, Profibus, EtherCAT, Ethernet

Interfaces, Analog

Built-in, galvanically isolated	15-pin D-Sub
Signal range	0–10 V or 0–5 V (switchable)
Inputs	U, I, P, R, remote control on/off, DC output on/off, resistance mode on/off
Outputs	Monitor U and I, alarms, reference voltage, status DC output, status CV/CC
Accuracy U / I / P / R	0–10 V ≤ 0.2% • 0–5 V ≤ 0.4%

Parallel Confgurability

Unit count	Up to 64 units total, 1 controller, 63 expansion units
Unit types	Any 311-54 model (voltage and current limited by the lowest rating of the group)

Safety and EMC

Safety	EN 61010-1 IEC 61010-1 UL 61010-1 CSA C22.2 No 61010-1 BS EN 61010-1
EMC	EN 55011, class B CISPR 11, class B FCC 47 CFR Part 15B, Unintentional Radiator, class B EN 61326-1 include tests according to: - EN 61000-4-2 - EN 61000-4-3 - EN 61000-4-4 - EN 61000-4-5 - EN 61000-4-6
Ingress Rating	IP20

Environmental Conditions

Operating temperature	32–122 °F • 0–50 °C
Storage temperature	-4–158 °F • -20–70 °C
Humidity	≤ 80% RH, non-condensing
Altitude	≤ 6600 ft • ≤ 2000 m

Mechanical Construction

Cooling	Forced air flow from front to rear, temperature controlled fans
Dimensions	19" rack width • 4U height • approx 27" chassis depth
Weight	Approx. 110 lbs • 50 kg

4U 30,000 W
380–480 Vac

	60 V • 1000 A 311-54-0060-1000-004	80 V • 1000 A 311-54-0080-1000-004	200 V • 420 A 311-54-0200-420-004	360 V • 240 A 311-54-0360-240-004
DC Output				
Voltage range	0–60 V	0–80 V	0–200 V	0–360 V
Ripple RMS (CV)	≤ 25 mV BW 300 kHz	≤ 25 mV BW 300 kHz	≤ 40 mV BW 300 kHz	≤ 55 mV BW 300 kHz
Ripple and noise p-p (CV)	≤ 320 mV BW 20 MHz	≤ 320 mV BW 20 MHz	≤ 300 mV BW 20 MHz	≤ 320 mV BW 20 MHz
Current range	0–1,000 A	0–1,000 A	0–420 A	0–240 A
Power range	0–30,000 W	0–30,000 W	0–30,000 W	0–30,000 W
Resistence range	0.003–5 Ω	0.003–5 Ω	0.0165–25 Ω	0.05–90 Ω
Output capacitance	25,380 µF	25,380 µF	5,400 µF	1,800 µF
Efficiency up to (At 100% power and 100% output voltage)	95.1%	95.1%	95.3%	95.8%
Insulation				
Negative DC pole to PE	±600 Vdc	±600 Vdc	±1,000 Vdc	±1,000 Vdc
Positive DC pole to PE	+600 Vdc	+600 Vdc	+1,000 Vdc	+1,000 Vdc

4U 30,000 W
380–480 Vac

	500 V • 180 A 311-54-0500-180-004	750 V • 120 A 311-54-0750-120-004	920 V • 125 A 311-54-0920-125-004	1000 V • 80 A 311-54-1000-080-004
DC Output				
Voltage range	0–500 V	0–750 V	0–920 V	0–1,000 V
Ripple RMS (CV)	≤ 70 mV BW 300 kHz	≤ 200 mV BW 300 kHz	≤ 200 mV BW 300 kHz	≤ 300 mV BW 300 kHz
Ripple and noise p-p (CV)	≤ 350 mV BW 20 MHz	≤ 800 mV BW 20 MHz	≤ 800 mV BW 20 MHz	≤ 1600 mV BW 20 MHz
Current range	0–180 A	0–120 A	0–125 A	0–80 A
Power range	0–30,000 W	0–30,000 W	0–30,000 W	0–30,000 W
Resistence range	0.08–170 Ω	0.2–370 Ω	0.25–550 Ω	0.4–650 Ω
Output capacitance	675 µF	450 µF	100 µF	200 µF
Efficiency up to (At 100% power and 100% output voltage)	96.5%	96.5%	96.5%	95.8%
Insulation				
Negative DC pole to PE	±1,500 Vdc	±1,500 Vdc	±1,500 Vdc	±1,500 Vdc
Positive DC pole to PE	+2.000 Vdc	+2.000 Vdc	+2.000 Vdc	+2.000 Vdc

4U 30,000 W
380–480 Vac

1500 V • 60 A
311-54-1500-060-004

2000 V • 40 A
311-54-2000-040-004

DC Output

Voltage range	0–1,500 V	0–2,000 V
Ripple RMS (CV)	≤ 400 mV BW 300 kHz	≤ 400 mV BW 300 kHz
Ripple and noise p-p (CV)	≤ 2400 mV BW 20 MHz	≤ 2400 mV BW 20 MHz
Current range	0–60 A	0–40 A
Power range	0–30,000 W	0–30,000 W
Resistence range	0.8–1500 Ω	1.7–2700 Ω
Output capacitance	75 µF	50 µF
Efficiency up to (At 100% power and 100% output voltage)	96.5%	96.5%

Insulation

Negative DC pole to PE	±1,500 Vdc	±1,500 Vdc
Positive DC pole to PE	+2.000 Vdc	+2.000 Vdc

19.4 MPW 311-53 : 3U, 15,000 Watt, 380–480 Vac 3ph

3U 15,000 W
380–480 Vac (a)

All 311-53 15 KW Models

AC Supply

Voltage requirements	380–480 Vac, 3-phase Delta, ±10% Optional 208 Vac, 3-phase Delta, ±10%, with power derating to 9 kW
Frequency	45–66 Hz
Power factor	≈ 0.99
Leak current	≤ 5 mA

DC Output (static)

Load regulation (CV mode)	$\leq 0.05\%$ FS • 0–100% load, constant input voltage, constant temperature
Line regulation (CV)	$\leq 0.01\%$ FS • 208–480 Vac +10% input voltage, constant load, constant temperature
Stability (CV)	$\leq 0.02\%$ FS • 8 hrs period after 30 min warm-up, constant input voltage, load, temperature
Temperature coefficient (CV)	≤ 30 ppm/°C • After 30 minutes warm up
Remote sense compensation	$\leq 5\%$ $U_{Nominal}$
Load regulation (CC mode)	$\leq 0.1\%$ FS • 0–100% load, constant input voltage, constant temperature
Line regulation (CC)	$\leq 0.01\%$ FS • 208–480 Vac +10% input voltage, constant load, constant temperature
Stability (CC)	$\leq 0.02\%$ FS • 8 hrs period after 30 min warm-up, constant input voltage, load, temperature
Temperature coefficient (CC)	≤ 50 ppm/°C • After 30 minutes warm up
Load regulation (CP mode)	$\leq 0.3\%$ FS • 0–100% load, constant input voltage, constant temperature
Load regulation (CR mode)	$\leq 0.3\%$ FS + 0.1% FS current • 0–100% load, constant input voltage, constant temperature

Protective Alarms

OVP	Over voltage protection adjustable, 0–110% $U_{Nominal}$
OCP	Over current protection adjustable, 0–110% $I_{Nominal}$
OPP	Over power protection adjustable, 0–110% $P_{Nominal}$
OT	Over temperature protection, internally automated

DC Output (dynamic)

Rise time 10–90% (CV)	≤ 20 ms
Fall time 90–10% (CV)	≤ 20 ms
Rise time 10–90% (CC)	≤ 10 ms
Fall time 90–10% (CC)	≤ 10 ms

Display Accuracy

Voltage	$\leq 0.05\%$ FS
Current	$\leq 0.1\%$ FS

Insulation

AC Input to DC Output	3750 Vrms (1 Minute), creepage distance >8 mm
AC Input to case (PE)	2500 Vrms
DC Output to case (PE)	Depending on the model, see model table
DC Output to Interfaces	1000 V DC for models up to 360 V output 1500 V DC for models from 500 V output

3U 15,000 W
380–480 Vac (b)

Interfaces, Digital

Built-in, galvanically isolated	USB Type B, Ethernet (100 MBit) for communication USB Type A Host for data acquisition
Optional, galvanically isolated	CAN, CANopen, RS232, ModBus TCP, Profinet, Profibus, EtherCAT, Ethernet

Interfaces, Analog

Built-in, galvanically isolated	15-pin D-Sub
Signal range	0–10 V or 0–5 V (switchable)
Inputs	U, I, P, R, remote control on/off, DC output on/off, resistance mode on/off
Outputs	Monitor U and I, alarms, reference voltage, status DC output, status CV/CC
Accuracy U / I / P / R	0–10 V ≤ 0.2% • 0–5 V ≤ 0.4%

Parallel Confgurability

Unit count	Up to 64 units total, 1 controller, 63 expansion units
Unit types	Any 311-54 model (voltage and current limited by the lowest rating of the group)

Safety and EMC

Safety	EN 61010-1 IEC 61010-1 UL 61010-1 CSA C22.2 No 61010-1 BS EN 61010-1
EMC	EN 55011, class B CISPR 11, class B FCC 47 CFR Part 15B, Unintentional Radiator, class B EN 61326-1 include tests according to: - EN 61000-4-2 - EN 61000-4-3 - EN 61000-4-4 - EN 61000-4-5 - EN 61000-4-6
Ingress Rating	IP20

Environmental Conditions

Operating temperature	32–122 °F • 0–50 °C
Storage temperature	-4–158 °F • -20–70 °C
Humidity	≤ 80% RH, non-condensing
Altitude	≤ 6600 ft • ≤ 2000 m

Mechanical Construction

Cooling	Forced air flow from front to rear, temperature controlled fans
Dimensions	19" rack width • 3U height • approx 27" chassis depth
Weight	Approx. 72 lbs • 32.8 kg

3U 15,000 W
380–480 Vac

	60 V • 510 A 311-53-0060-510-004	80 V • 510 A 311-53-0080-510-004	200 V • 210 A 311-53-0200-210-004
DC Output			
Voltage range	0–60 V	0–80 V	0–200 V
Ripple RMS (CV)	≤ 10 mV BW 300 kHz	≤ 10 mV BW 300 kHz	≤ 40 mV BW 300 kHz
Ripple and noise p-p (CV)	≤ 100 mV BW 20 MHz	≤ 100 mV BW 20 MHz	≤ 300 mV BW 20 MHz
Current range	0–510 A	0–510 A	0–210 A
Power range	0–15,000 W	0–15,000 W	0–15,000 W
Resistence range	0.006–9 Ω	0.006–9 Ω	0.03–50 Ω
Output capacitance	23,970 µF	23,970 µF	7,560 µF
Efficiency up to (At 100% power and 100% output voltage)	94.5%	94.5%	94.5%
Insulation			
Negative DC pole to PE	±600 Vdc	±600 Vdc	±1,000 Vdc
Positive DC pole to PE	+600 Vdc	+600 Vdc	+1,000 Vdc

3U 15,000 W
380–480 Vac

	360 V • 120 A 311-53-0360-120-004	500 V • 90 A 311-53-0500-090-004	750 V • 60 A 311-53-0750-060-004
DC Output			
Voltage range	0–360 V	0–500 V	0–750 V
Ripple RMS (CV)	≤ 55 mV BW 300 kHz	≤ 70 mV BW 300 kHz	≤ 200 mV BW 300 kHz
Ripple and noise p-p (CV)	≤ 320 mV BW 20 MHz	≤ 350 mV BW 20 MHz	≤ 800 mV BW 20 MHz
Current range	0–120 A	0–90 A	0–60 A
Power range	0–15,000 W	0–15,000 W	0–15,000 W
Resistence range	0.1–180 Ω	0.2–330 Ω	0.4–750 Ω
Output capacitance	1,179 µF	540 µF	540 µF
Efficiency up to (At 100% power and 100% output voltage)	95.5%	95.5%	95.5%
Insulation			
Negative DC pole to PE	±1,000 Vdc	±1,500 Vdc	±1,500 Vdc
Positive DC pole to PE	+1,000 Vdc	+2,000 Vdc	+2,000 Vdc

3U 15,000 W
380–480 Vac

	1000 V • 40 A 311-53-1000-040-004	1500 V • 30 A 311-53-1500-030-004	2000 V • 20 A 311-53-2000-020-004
DC Output			
Voltage range	0–1,000 V	0–1,500 V	0–2,000 V
Ripple RMS (CV)	≤ 300 mV BW 300 kHz	≤ 400 mV BW 300 kHz	≤ 400 mV BW 300 kHz
Ripple and noise p-p (CV)	≤ 1600 mV BW 20 MHz	≤ 2400 mV BW 20 MHz	≤ 2400 mV BW 20 MHz
Current range	0–40 A	0–30 A	0–20 A
Power range	0–15,000 W	0–15,000 W	0–15,000 W
Resistence range	0.8–1,300 Ω	1.7–3,000 Ω	3.5–5,300 Ω
Output capacitance	131 µF	60 µF	60 µF
Efficiency up to (At 100% power and 100% output voltage)	95.5%	95.5%	95.5%
Insulation			
Negative DC pole to PE	±1,500 Vdc	±1,500 Vdc	±1,500 Vdc
Positive DC pole to PE	+2,000 Vdc	+2,000 Vdc	+2,000 Vdc

19.5 MPW 311-53 : 3U, 10,000 Watt, 380–480 Vac 3ph

3U 10,000 W 380–480 Vac (a)

All 311-53 10 KW Models

AC Supply

Voltage requirements	380–480 Vac, 3-phase Delta, ±10% Optional 208 Vac, 3-phase Delta, ±10%, with power derating to 6 kW
Frequency	45–66 Hz
Power factor	≈ 0.99
Leak current	≤ 5 mA

DC Output (static)

Load regulation (CV mode)	≤ 0.05% FS • 0–100% load, constant input voltage, constant temperature
Line regulation (CV)	≤ 0.01% FS • 208–480 Vac +10% input voltage, constant load, constant temperature
Stability (CV)	≤ 0.02% FS • 8 hrs period after 30 min warm-up, constant input voltage, load, temperature
Temperature coefficient (CV)	≤ 30 ppm/°C • After 30 minutes warm up
Remote sense compensation	≤ 5% $U_{Nominal}$
Load regulation (CC mode)	≤ 0.1% FS • 0–100% load, constant input voltage, constant temperature
Line regulation (CC)	≤ 0.01% FS • 208–480 Vac +10% input voltage, constant load, constant temperature
Stability (CC)	≤ 0.02% FS • 8 hrs period after 30 min warm-up, constant input voltage, load, temperature
Temperature coefficient (CC)	≤ 50 ppm/°C • After 30 minutes warm up
Load regulation (CP mode)	≤ 0.3% FS • 0–100% load, constant input voltage, constant temperature
Load regulation (CR mode)	≤ 0.3% FS + 0.1% FS current • 0–100% load, constant input voltage, constant temperature

Protective Alarms

OVP	Over voltage protection adjustable, 0–110% $U_{Nominal}$
OCP	Over current protection adjustable, 0–110% $I_{Nominal}$
OPP	Over power protection adjustable, 0–110% $P_{Nominal}$
OT	Over temperature protection, internally automated

DC Output (dynamic)

Rise time 10–90% (CV)	≤ 20 ms
Fall time 90–10% (CV)	≤ 20 ms
Rise time 10–90% (CC)	≤ 10 ms
Fall time 90–10% (CC)	≤ 10 ms

Display Accuracy

Voltage	≤ 0.05% FS
Current	≤ 0.1% FS

Insulation

AC Input to DC Output	3750 Vrms (1 Minute), creepage distance >8 mm
AC Input to case (PE)	2500 Vrms
DC Output to case (PE)	Depending on the model, see model table
DC Output to Interfaces	1000 V DC for models up to 360 V output 1500 V DC for models from 500 V output

3U 10,000 W
380–480 Vac (b)

Interfaces, Digital

Built-in, galvanically isolated	USB Type B, Ethernet (100 MBit) for communication USB Type A Host for data acquisition
Optional, galvanically isolated	CAN, CANopen, RS232, ModBus TCP, Profinet, Profibus, EtherCAT, Ethernet

Interfaces, Analog

Built-in, galvanically isolated	15-pin D-Sub
Signal range	0–10 V or 0–5 V (switchable)
Inputs	U, I, P, R, remote control on/off, DC output on/off, resistance mode on/off
Outputs	Monitor U and I, alarms, reference voltage, status DC output, status CV/CC
Accuracy U / I / P / R	0–10 V ≤ 0.2% • 0–5 V ≤ 0.4%

Parallel Confgurability

Unit count	Up to 64 units total, 1 controller, 63 expansion units
Unit types	Any 311-54 model (voltage and current limited by the lowest rating of the group)

Safety and EMC

Safety	EN 61010-1 IEC 61010-1 UL 61010-1 CSA C22.2 No 61010-1 BS EN 61010-1
EMC	EN 55011, class B CISPR 11, class B FCC 47 CFR Part 15B, Unintentional Radiator, class B EN 61326-1 include tests according to: - EN 61000-4-2 - EN 61000-4-3 - EN 61000-4-4 - EN 61000-4-5 - EN 61000-4-6
Ingress Rating	IP20

Environmental Conditions

Operating temperature	32–122 °F • 0–50 °C
Storage temperature	-4–158 °F • -20–70 °C
Humidity	≤ 80% RH, non-condensing
Altitude	≤ 6600 ft • ≤ 2000 m

Mechanical Construction

Cooling	Forced air flow from front to rear, temperature controlled fans
Dimensions	19" rack width • 3U height • approx 27" chassis depth
Weight	Approx. 56 lbs • 25.4 kg

3U 10,000 W 380–480 Vac

	60 V • 340 A 311-53-0060-340-004	80 V • 340 A 311-53-0080-340-004	200 V • 140 A 311-53-0200-210-004
DC Output			
Voltage range	0–60 V	0–80 V	0–200 V
Ripple RMS (CV)	≤ 10 mV BW 300 kHz	≤ 10 mV BW 300 kHz	≤ 40 mV BW 300 kHz
Ripple and noise p-p (CV)	≤ 100 mV BW 20 MHz	≤ 100 mV BW 20 MHz	≤ 300 mV BW 20 MHz
Current range	0–340 A	0–340 A	0–140 A
Power range	0–10,000 W	0–10,000 W	0–10,000 W
Resistence range	0.008–13 Ω	0.008–13 Ω	0.05–80 Ω
Output capacitance	15,980 µF	15,980 µF	5,04 0µF
Efficiency up to (At 100% power and 100% output voltage)	94.5%	94.5%	94.5%
Insulation			
Negative DC pole to PE	±600 Vdc	±600 Vdc	±1,000 Vdc
Positive DC pole to PE	+600 Vdc	+600 Vdc	+1,000 Vdc

3U 10,000 W 380–480 Vac

	360 V • 80 A 311-53-0360-080-004	500 V • 60 A 311-53-0500-060-004	750 V • 40 A 311-53-0750-040-004
DC Output			
Voltage range	0–360 V	0–500 V	0–750 V
Ripple RMS (CV)	≤ 55 mV BW 300 kHz	≤ 70 mV BW 300 kHz	≤ 200 mV BW 300 kHz
Ripple and noise p-p (CV)	≤ 320 mV BW 20 MHz	≤ 350 mV BW 20 MHz	≤ 800 mV BW 20 MHz
Current range	0–120 A	0–60 A	0–40 A
Power range	0–10,000 W	0–10,000 W	0–10,000 W
Resistence range	0.15–260 Ω	0.3–500 Ω	0.6–1,100 Ω
Output capacitance	786 µF	360 µF	360 µF
Efficiency up to (At 100% power and 100% output voltage)	95.5%	95.5%	95.5%
Insulation			
Negative DC pole to PE	±1,000 Vdc	±1,500 Vdc	±1,500 Vdc
Positive DC pole to PE	+1,000 Vdc	+2,000 Vdc	+2,000 Vdc

3U 10,000 W
380–480 Vac

	1000 V • 30 A 311-53-1000-030-004	**1500 V • 20 A** 311-53-1500-020-004
DC Output		
Voltage range	0–1,000 V	0–1,500 V
Ripple RMS (CV)	≤ 200 mV BW 300 kHz	≤ 400 mV BW 300 kHz
Ripple and noise p-p (CV)	≤ 1000 mV BW 20 MHz	≤ 2000 mV BW 20 MHz
Current range	0–30 A	0–20 A
Power range	0–10,000 W	0–10,000 W
Resistence range	1.2–2,000 Ω	2.6–4,500 Ω
Output capacitance	90 µF	90 µF
Efficiency up to (At 100% power and 100% output voltage)	95.5%	95.5%
Insulation		
Negative DC pole to PE	±1,500 Vdc	±1,500 Vdc
Positive DC pole to PE	+2,000 Vdc	+2,000 Vdc

3U 5,000 W
380–480 Vac (a)

All 311-53 5 KW Models

AC Supply	
Voltage requirements	380–480 Vac, 3-phase Delta, ±10% Optional 208 Vac, 3-phase Delta, ±10%, with power derating to 3 kW
Frequency	45–66 Hz
Power factor	≈ 0.99
Leak current	≤ 5 mA

DC Output (static)	
Load regulation (CV mode)	≤ 0.05% FS • 0–100% load, constant input voltage, constant temperature
Line regulation (CV)	≤ 0.01% FS • 208–480 Vac +10% input voltage, constant load, constant temperature
Stability (CV)	≤ 0.02% FS • 8 hrs period after 30 min warm-up, constant input voltage, load, temperature
Temperature coefficient (CV)	≤ 30 ppm/°C • After 30 minutes warm up
Remote sense compensation	≤ 5% $U_{Nominal}$
Load regulation (CC mode)	≤ 0.1% FS • 0–100% load, constant input voltage, constant temperature
Line regulation (CC)	≤ 0.01% FS • 208–480 Vac +10% input voltage, constant load, constant temperature
Stability (CC)	≤ 0.02% FS • 8 hrs period after 30 min warm-up, constant input voltage, load, temperature
Temperature coefficient (CC)	≤ 50 ppm/°C • After 30 minutes warm up
Load regulation (CP mode)	≤ 0.3% FS • 0–100% load, constant input voltage, constant temperature
Load regulation (CR mode)	≤ 0.3% FS + 0.1% FS current • 0–100% load, constant input voltage, constant temperature

Protective Alarms	
OVP	Over voltage protection adjustable, 0–110% $U_{Nominal}$
OCP	Over current protection adjustable, 0–110% $I_{Nominal}$
OPP	Over power protection adjustable, 0–110% $P_{Nominal}$
OT	Over temperature protection, internally automated

DC Output (dynamic)	
Rise time 10–90% (CV)	≤ 20 ms
Fall time 90–10% (CV)	≤ 20 ms
Rise time 10–90% (CC)	≤ 10 ms
Fall time 90–10% (CC)	≤ 10 ms

Display Accuracy	
Voltage	≤ 0.05% FS
Current	≤ 0.1% FS

Insulation	
AC Input to DC Output	3750 Vrms (1 Minute), creepage distance >8 mm
AC Input to case (PE)	2500 Vrms
DC Output to case (PE)	Depending on the model, see model table
DC Output to Interfaces	1000 V DC for models up to 360 V output 1500 V DC for models from 500 V output

3U 5,000 W
380–480 Vac (b)

Interfaces, Digital

Built-in, galvanically isolated	USB Type B, Ethernet (100 MBit) for communication USB Type A Host for data acquisition
Optional, galvanically isolated	CAN, CANopen, RS232, ModBus TCP, Profinet, Profibus, EtherCAT, Ethernet

Interfaces, Analog

Built-in, galvanically isolated	15-pin D-Sub
Signal range	0–10 V or 0–5 V (switchable)
Inputs	U, I, P, R, remote control on/off, DC output on/off, resistance mode on/off
Outputs	Monitor U and I, alarms, reference voltage, status DC output, status CV/CC
Accuracy U / I / P / R	0–10 V ≤ 0.2% • 0–5 V ≤ 0.4%

Parallel Confgurability

Unit count	Up to 64 units total, 1 controller, 63 expansion units
Unit types	Any 311-54 model (voltage and current limited by the lowest rating of the group)

Safety and EMC

Safety	EN 61010-1 IEC 61010-1 UL 61010-1 CSA C22.2 No 61010-1 BS EN 61010-1
EMC	EN 55011, class B CISPR 11, class B FCC 47 CFR Part 15B, Unintentional Radiator, class B EN 61326-1 include tests according to: - EN 61000-4-2 - EN 61000-4-3 - EN 61000-4-4 - EN 61000-4-5 - EN 61000-4-6
Ingress Rating	IP20

Environmental Conditions

Operating temperature	32–122 °F • 0–50 °C
Storage temperature	-4–158 °F • -20–70 °C
Humidity	≤ 80% RH, non-condensing
Altitude	≤ 6600 ft • ≤ 2000 m

Mechanical Construction

Cooling	Forced air flow from front to rear, temperature controlled fans
Dimensions	19" rack width • 3U height • approx 27" chassis depth
Weight	Approx. 40 lbs • 18 kg

3U 5,000 W 380–480 Vac

	60 V • 170 A 311-53-0060-170-004	80 V • 170 A 311-53-0080-170-004	200 V • 70 A 311-53-0200-070-004
DC Output			
Voltage range	0–60 V	0–80 V	0–200 V
Ripple RMS (CV)	≤ 10 mV BW 300 kHz	≤ 10 mV BW 300 kHz	≤ 40 mV BW 300 kHz
Ripple and noise p-p (CV)	≤ 100 mV BW 20 MHz	≤ 100 mV BW 20 MHz	≤ 300 mV BW 20 MHz
Current range	0–170 A	0–170 A	0–70 A
Power range	0–5,000 W	0–5,000 W	0–5,000 W
Resistence range	0.016–26 Ω	0.016–26 Ω	0.1–160 Ω
Output capacitance	7,790 µF	7,790 µF	2,520 µF
Efficiency up to (At 100% power and 100% output voltage)	94.5%	94.5%	94.5%
Insulation			
Negative DC pole to PE	±600 Vdc	±600 Vdc	±1,000 Vdc
Positive DC pole to PE	+600 Vdc	+600 Vdc	+1,000 Vdc

3U 5,000 W 380–480 Vac

	360 V • 40 A 311-53-0360-040-004	500 V • 30 A 311-53-0500-030-004	750 V • 20 A 311-53-0750-020-004
DC Output			
Voltage range	0–360 V	0–500 V	0–750 V
Ripple RMS (CV)	≤ 55 mV BW 300 kHz	≤ 70 mV BW 300 kHz	≤ 200 mV BW 300 kHz
Ripple and noise p-p (CV)	≤ 320 mV BW 20 MHz	≤ 350 mV BW 20 MHz	≤ 800 mV BW 20 MHz
Current range	0–40 A	0–30 A	0–20 A
Power range	0–5,000 W	0–5,000 W	0–5,000 W
Resistence range	0.3–520 Ω	0.6–1,000 Ω	1.2–2,200 Ω
Output capacitance	393 µF	180 µF	180 µF
Efficiency up to (At 100% power and 100% output voltage)	95.5%	95.5%	95.5%
Insulation			
Negative DC pole to PE	±1,000 Vdc	±1,500 Vdc	±1,500 Vdc
Positive DC pole to PE	+1,000 Vdc	+2,000 Vdc	+2,000 Vdc

2U 3,000 W
208–240 Vac (a)

All 311-62 3 KW Models

AC Supply	
Voltage requirements	208–240 Vac, 1-phase, ±10% Optional 120 Vac, 1-phase, ±10%, with power derating to 1,500 W
Frequency	45–66 Hz
Power factor	≈ 0.99
Leak current	≤ 3.5 mA

DC Output (static)	
Load regulation (CV mode)	≤ 0.05% FS • 0–100% load, constant input voltage, constant temperature
Line regulation (CV)	≤ 0.01% FS • 208–480 Vac +10% input voltage, constant load, constant temperature
Stability (CV)	≤ 0.02% FS • 8 hrs period after 30 min warm-up, constant input voltage, load, temperature
Temperature coefficient (CV)	≤ 30 ppm/°C • After 30 minutes warm up
Remote sense compensation	≤ 5% $U_{Nominal}$
Load regulation (CC mode)	≤ 0.1% FS • 0–100% load, constant input voltage, constant temperature
Line regulation (CC)	≤ 0.01% FS • 208–480 Vac +10% input voltage, constant load, constant temperature
Stability (CC)	≤ 0.02% FS • 8 hrs period after 30 min warm-up, constant input voltage, load, temperature
Temperature coefficient (CC)	≤ 50 ppm/°C • After 30 minutes warm up
Load regulation (CP mode)	≤ 0.3% FS • 0–100% load, constant input voltage, constant temperature
Load regulation (CR mode)	≤ 0.3% FS + 0.1% FS current • 0–100% load, constant input voltage, constant temperature

Protective Alarms	
OVP	Over voltage protection adjustable, 0–110% $U_{Nominal}$
OCP	Over current protection adjustable, 0–110% $I_{Nominal}$
OPP	Over power protection adjustable, 0–110% $P_{Nominal}$
OT	Over temperature protection, internally automated

DC Output (dynamic)	
Rise time 10–90% (CV)	≤ 20 ms
Fall time 90–10% (CV)	≤ 20 ms
Rise time 10–90% (CC)	≤ 10 ms
Fall time 90–10% (CC)	≤ 10 ms

Display Accuracy	
Voltage	≤ 0.05% FS
Current	≤ 0.1% FS

Insulation	
AC Input to DC Output	3750 Vrms (1 Minute), creepage distance >8 mm
AC Input to case (PE)	2500 Vrms
DC Output to case (PE)	Depending on the model, see model table
DC Output to Interfaces	1000 V DC for models up to 360 V output 1500 V DC for models from 500 V output

2U 3,000 W
208–240 Vac (b)

Interfaces, Digital

Built-in, galvanically isolated	USB Type B, Ethernet (100 MBit) for communication USB Type A Host for data acquisition
Optional, galvanically isolated	CAN, CANopen, RS232, ModBus TCP, Profinet, Profibus, EtherCAT, Ethernet

Interfaces, Analog

Built-in, galvanically isolated	15-pin D-Sub
Signal range	0–10 V or 0–5 V (switchable)
Inputs	U, I, P, R, remote control on/off, DC output on/off, resistance mode on/off
Outputs	Monitor U and I, alarms, reference voltage, status DC output, status CV/CC
Accuracy U / I / P / R	0–10 V ≤ 0.2% • 0–5 V ≤ 0.4%

Parallel Confgurability

Unit count	Up to 64 units total, 1 controller, 63 expansion units
Unit types	Any 311-54 model (voltage and current limited by the lowest rating of the group)

Safety and EMC

Safety	EN 61010-1 IEC 61010-1 UL 61010-1 CSA C22.2 No 61010-1 BS EN 61010-1
EMC	EN 55011, class B CISPR 11, class B FCC 47 CFR Part 15B, Unintentional Radiator, class B EN 61326-1 include tests according to: - EN 61000-4-2 - EN 61000-4-3 - EN 61000-4-4 - EN 61000-4-5 - EN 61000-4-6
Ingress Rating	IP20

Environmental Conditions

Operating temperature	32–122 °F • 0–50 °C
Storage temperature	-4–158 °F • -20–70 °C
Humidity	≤ 80% RH, non-condensing
Altitude	≤ 6600 ft • ≤ 2000 m

Mechanical Construction

Cooling	Forced air flow from front to rear, temperature controlled fans
Dimensions	19" rack width • 2U height • approx 18.2" chassis depth
Weight	Approx. 28 lbs • 12.7 kg

2U 3,000 W 208–240 Vac	60 V • 120 A 311-62-0060-120-004	80 V • 120 A 311-62-0080-120-004	200 V • 50 A 311-62-0200-050-004
DC Output			
Voltage range	0–60 V	0–80 V	0–200 V
Ripple RMS (CV)	≤ 10 mV BW 300 kHz	≤ 10 mV BW 300 kHz	≤ 30 mV BW 300 kHz
Ripple and noise p-p (CV)	≤ 100 mV BW 20 MHz	≤ 100 mV BW 20 MHz	≤ 300 mV BW 20 MHz
Current range	0–120 A	0–120 A	0–50 A
Power range	0–3,000 W	0–3,000 W	0–3,000 W
Resistence range	0.02–40 Ω	0.02–40 Ω	0.12–250 Ω
Output capacitance	17,280 µF	17,280 µF	1,600 µF
Efficiency up to (At 100% power and 100% output voltage)	94.0%	94.0%	94.5%
Insulation			
Negative DC pole to PE	±600 Vdc	±600 Vdc	±1,000 Vdc
Positive DC pole to PE	+600 Vdc	+600 Vdc	+1,000 Vdc

2U 3,000 W 208–240 Vac	360 V • 30 A 311-62-0360-030-004	500 V • 20 A 311-62-0500-020-004	750 V • 12 A 311-62-0750-012-004
DC Output			
Voltage range	0–360 V	0–500 V	0–750 V
Ripple RMS (CV)	≤ 30 mV BW 300 kHz	≤ 40 mV BW 300 kHz	≤ 50 mV BW 300 kHz
Ripple and noise p-p (CV)	≤ 300 mV BW 20 MHz	≤ 500 mV BW 20 MHz	≤ 500 mV BW 20 MHz
Current range	0–30 A	0–20 A	0–12 A
Power range	0–3,000 W	0–3,000 W	0–3,000 W
Resistence range	0.4–800 Ω	1–1,500 Ω	2–3,000 Ω
Output capacitance	660 µF	240 µF	80 µF
Efficiency up to (At 100% power and 100% output voltage)	94.5%	95.0%	95.0%
Insulation			
Negative DC pole to PE	±1,000 Vdc	±1,500 Vdc	±1,500 Vdc
Positive DC pole to PE	+1,000 Vdc	+2,000 Vdc	+2,000 Vdc

2U 3,000 W
208–240 Vac

	1000 V • 10 A 311-62-1000-010-004	1500 V • 6 A 311-62-1500-006-004
DC Output		
Voltage range	0–1000 V	0–1500 V
Ripple RMS (CV)	≤ 100 mV BW 300 kHz	≤ 15 mV BW 300 kHz
Ripple and noise p-p (CV)	≤ 2000 mV BW 20 MHz	≤ 6500 mV BW 20 MHz
Current range	0–10 A	0–6 A
Power range	0–3,000 W	0–3,000 W
Resistence range	3–6,000 Ω	8–6,000 Ω
Output capacitance	60 µF	20 µF
Efficiency up to (At 100% power and 100% output voltage)	95.0%	95.0%
Insulation		
Negative DC pole to PE	±1,500 Vdc	±1,500 Vdc
Positive DC pole to PE	+2,000 Vdc	+2,000 Vdc

2U 1,500 W
208–240 Vac (a)

All 311-62 1.5 W Models

AC Supply	
Voltage requirements	208–240 Vac, 1-phase, ±10% Optional 120 Vac, 1-phase, ±10%, with power derating to 1,200 W
Frequency	45–66 Hz
Power factor	≈ 0.99
Leak current	≤ 3.5 mA
DC Output (static)	
Load regulation (CV mode)	≤ 0.05% FS • 0–100% load, constant input voltage, constant temperature
Line regulation (CV)	≤ 0.01% FS • 208–480 Vac +10% input voltage, constant load, constant temperature
Stability (CV)	≤ 0.02% FS • 8 hrs period after 30 min warm-up, constant input voltage, load, temperature
Temperature coefficient (CV)	≤ 30 ppm/°C • After 30 minutes warm up
Remote sense compensation	≤ 5% $U_{Nominal}$
Load regulation (CC mode)	≤ 0.1% FS • 0–100% load, constant input voltage, constant temperature
Line regulation (CC)	≤ 0.01% FS • 208–480 Vac +10% input voltage, constant load, constant temperature
Stability (CC)	≤ 0.02% FS • 8 hrs period after 30 min warm-up, constant input voltage, load, temperature
Temperature coefficient (CC)	≤ 50 ppm/°C • After 30 minutes warm up
Load regulation (CP mode)	≤ 0.3% FS • 0–100% load, constant input voltage, constant temperature
Load regulation (CR mode)	≤ 0.3% FS + 0.1% FS current • 0–100% load, constant input voltage, constant temperature
Protective Alarms	
OVP	Over voltage protection adjustable, 0–110% $U_{Nominal}$
OCP	Over current protection adjustable, 0–110% $I_{Nominal}$
OPP	Over power protection adjustable, 0–110% $P_{Nominal}$
OT	Over temperature protection, internally automated
DC Output (dynamic)	
Rise time 10–90% (CV)	≤ 20 ms
Fall time 90–10% (CV)	≤ 20 ms
Rise time 10–90% (CC)	≤ 10 ms
Fall time 90–10% (CC)	≤ 10 ms
Display Accuracy	
Voltage	≤ 0.05% FS
Current	≤ 0.1% FS
Insulation	
AC Input to DC Output	3750 Vrms (1 Minute), creepage distance >8 mm
AC Input to case (PE)	2500 Vrms
DC Output to case (PE)	Depending on the model, see model table
DC Output to Interfaces	1000 V DC for models up to 360 V output 1500 V DC for models from 500 V output

2U 1,500 W
208–240 Vac (b)

Interfaces, Digital

Built-in, galvanically isolated	USB Type B, Ethernet (100 MBit) for communication USB Type A Host for data acquisition
Optional, galvanically isolated	CAN, CANopen, RS232, ModBus TCP, Profinet, Profibus, EtherCAT, Ethernet

Interfaces, Analog

Built-in, galvanically isolated	15-pin D-Sub
Signal range	0–10 V or 0–5 V (switchable)
Inputs	U, I, P, R, remote control on/off, DC output on/off, resistance mode on/off
Outputs	Monitor U and I, alarms, reference voltage, status DC output, status CV/CC
Accuracy U / I / P / R	0–10 V ≤ 0.2% • 0–5 V ≤ 0.4%

Parallel Confgurability

Unit count	Up to 64 units total, 1 controller, 63 expansion units
Unit types	Any 311-54 model (voltage and current limited by the lowest rating of the group)

Safety and EMC

Safety	EN 61010-1 IEC 61010-1 UL 61010-1 CSA C22.2 No 61010-1 BS EN 61010-1
EMC	EN 55011, class B CISPR 11, class B FCC 47 CFR Part 15B, Unintentional Radiator, class B EN 61326-1 include tests according to: - EN 61000-4-2 - EN 61000-4-3 - EN 61000-4-4 - EN 61000-4-5 - EN 61000-4-6
Ingress Rating	IP20

Environmental Conditions

Operating temperature	32–122 °F • 0–50 °C
Storage temperature	-4–158 °F • -20–70 °C
Humidity	≤ 80% RH, non-condensing
Altitude	≤ 6600 ft • ≤ 2000 m

Mechanical Construction

Cooling	Forced air flow from front to rear, temperature controlled fans
Dimensions	19" rack width • 2U height • approx 18.2" chassis depth
Weight	Approx. 21 lbs • 9.5 kg

2U 1,500 W
208–240 Vac

	60 V • 60 A 311-62-0060-060-004	80 V • 60 A 311-62-0080-060-004	200 V • 25 A 311-62-0200-025-004
DC Output			
Voltage range	0–60 V	0–80 V	0–200 V
Ripple RMS (CV)	≤ 10 mV BW 300 kHz	≤ 10 mV BW 300 kHz	≤ 30 mV BW 300 kHz
Ripple and noise p-p (CV)	≤ 100 mV BW 20 MHz	≤ 100 mV BW 20 MHz	≤ 300 mV BW 20 MHz
Current range	0–60 A	0–60 A	0–25 A
Power range	0–1,500 W	0–1,500 W	0–1,500 W
Resistence range	0.04–80 Ω	0.04–80 Ω	0.25–500 Ω
Output capacitance	8,640 µF	8,640 µF	800 µF
Efficiency up to (At 100% power and 100% output voltage)	94.0%	94.0%	94.5%
Insulation			
Negative DC pole to PE	±600 Vdc	±600 Vdc	±1,000 Vdc
Positive DC pole to PE	+600 Vdc	+600 Vdc	+1,000 Vdc

2U 1,500 W
208–240 Vac

|	360 V • 15 A 311-62-0360-015-004	500 V • 10 A 311-62-0500-010-004	750 V • 6 A 311-62-0750-006-004
DC Output			
Voltage range	0–360 V	0–500 V	0–750 V
Ripple RMS (CV)	≤ 30 mV BW 300 kHz	≤ 40 mV BW 300 kHz	≤ 50 mV BW 300 kHz
Ripple and noise p-p (CV)	≤ 300 mV BW 20 MHz	≤ 500 mV BW 20 MHz	≤ 500 mV BW 20 MHz
Current range	0–15 A	0–10 A	0–6 A
Power range	0–1,500 W	0–1,500 W	0–1,500 W
Resistence range	0.8–1,600 Ω	2.0–3,000 Ω	4.0–6,000 Ω
Output capacitance	330 µF	120 µF	40 µF
Efficiency up to (At 100% power and 100% output voltage)	94.5%	95.0%	95.0%
Insulation			
Negative DC pole to PE	±1,000 Vdc	±1,500 Vdc	±1,500 Vdc
Positive DC pole to PE	+1,000 Vdc	+2,000 Vdc	+2,000 Vdc

20 Appendix: Control Software

20.1 EA Power Control

In addition to using the built-in control panel to manage the power supply, there is software from Elektro-Automatik available for Windows® computers which can be used to monitor, configure, and program the power supply.

With the standard units, configuration, and setup for various applicatiopns can be accomplished using the built-in user interface controls. However, using the EA Power Control software (for Windows 7 and Windows 10), a number of these tasks are easier to accpomplish and manage.

- Use for a single unit and for multiple units.
- Use on standard models and slave models.
- Monitor actual values.
- Modify set values.
- Adjust all configuration settings.
- Send Modbus/SCPI commands.
- Manage Modbus/SCPI script files.
- Program the function generator.

The software can be downloaded from Marway's web site.
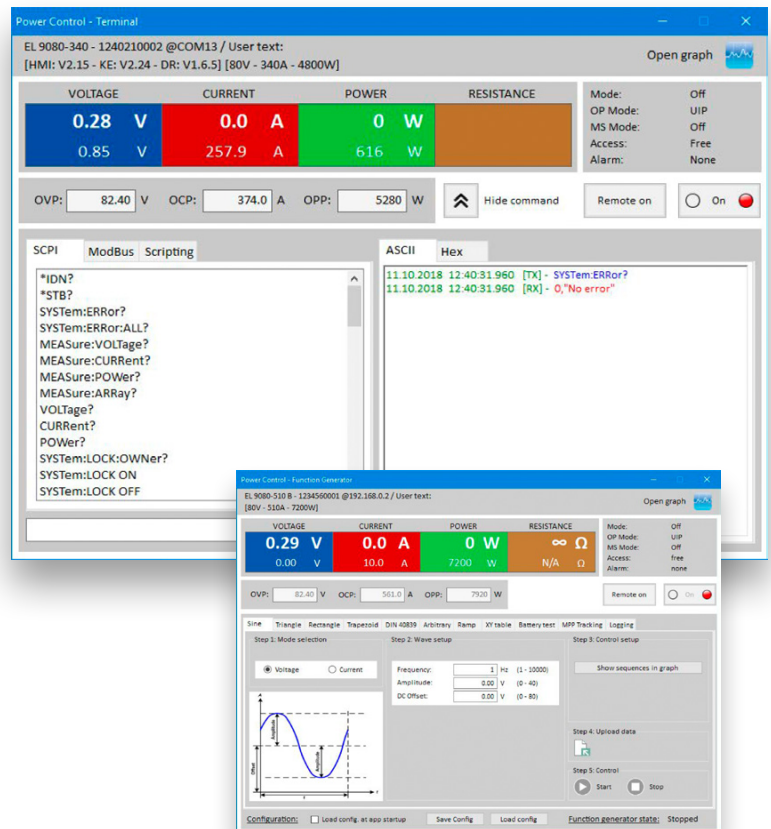
21 Appendix: Change Log

B — October 17, 2023

- Updated the SCPI Status Registers on pg 134 to include registers missing from previous diagram.
- Minor text corrections (not significant to operational details).
- Removal of some programming information relevent only to 411 Series.

A — October, 2022

- Initial Release

mPower™ DC Power Supplies 311 Series

Operating Guide P/N: 501046-311-OP-B

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