Elektro-Automatik



USER MANUAL

EA-PU 10000 4U

Programmable DC power units

Use, Remote Control

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Revision: 02

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Attention! The part of this document that deals with remote control via a digital interface is only valid for devices with firmwares “KE: 3.10”, “HMI: 2.06” and “DR: 1.0.2.20” or higher.

1. General

1.1 About this document

1.1.1 Preamble

Together with the separate installation manual, this document builds the documentation for use and control of the devices as listed in section *«1.1.3 Validity»*. It explains manual operation and other control related features.

1.1.2 Copyright

Reprinting, copying, also partially, usage for other purposes as foreseen of this document are forbidden and breach may lead to legal consequences.

1.1.3 Validity

This document is valid for the following equipment including derived variants:

Model
EA-PU 10060-1000 4U
EA-PU 10080-1000 4U
EA-PU 10200-420 4U
EA-PU 10360-240 4U
EA-PU 10500-180 4U
EA-PU 10750-120 4U
EA-PU 10920-125 4U
EA-PU 11000-80 4U
EA-PU 11500-60 4U
EA-PU 12000-40 4U

1.1.4 Symbols and warnings

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

	Symbol for general safety notices (instructions and damage protection bans) or important information for operation
	*Symbol for general notices*

2. Operation and application (2)

2.1 Operating modes

A power supply is internally controlled by different control circuits, which shall regulate voltage, current and power to the adjusted values and hold them constant, if possible. These circuits follow typical laws of control systems engineering, resulting in different operating modes. Each operating mode has its own characteristics which are explained below in short form.

- *Unloaded operation isn't considered as a normal operation mode and can thus lead to false measurements, for example when calibrating the device*
- *The optimal working point of the device is between 50% and 100% voltage and current*
- *It's recommended to not run the device below 10% voltage and current, in order to meet technical values like ripple or transient times*

2.1.1 Voltage control / Constant voltage

Voltage control is also called constant voltage operation (short: CV).

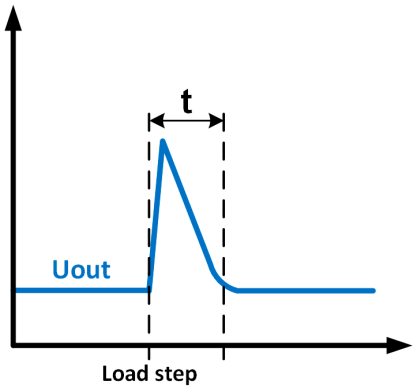
The DC output voltage of a power supply is held constant on the adjusted value, unless the output current or the output power according to $P = U_{OUT} * I_{OUT}$ reaches the adjusted current or power limit. In both cases the device will automatically change to constant current or constant power operation, whatever occurs first. Then the output voltage can't be held constant anymore and will sink to a value resulting from Ohm's law.

While the DC output is switched on and constant voltage mode is active, then the condition "CV mode active" will be indicated as signal on the analog interface and can also be read as status via the digital interfaces.

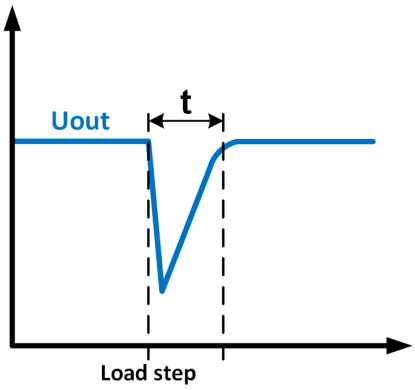
2.1.1.1 Voltage control peaks

When working in constant voltage control (CV), the device's internal voltage regulator requires a small transient time to settle the voltage after a load step. Negative load steps, i.e. high load to lower load, will cause the output voltage to overshoot for a short time until compensated by the voltage regulator. The time is takes to settle the voltage can be influenced by switching the voltage control speed between the settings **Slow**, **Normal** and **Fast**, whereas **Normal** is the default. Setting **Slow** will result in a higher transient time and higher voltage drop, but less overshooting, where **Fast** is vice versa. The control speed can be selected in the **Settings** app of **EA Power Control**.

Depictions:



Example for a neg. load step: the DC output will rise above the adjusted value for a short time. t = transient time to settle the output voltage.



Example for a pos. load step: the DC output will collapse below the adjusted value for a short time. t = transient time to settle the output voltage.

2.1.2 Current control / constant current / current limiting

Current control is also known as current limiting or constant current mode (short: CC).

The DC output current is held constant by the power supply, once the output current to the load reaches the adjusted limit. Then the power supply automatically switches to CC. The current flowing from the power supply is determined by the output voltage and the load's true resistance. As long as the output current is lower than the adjusted current limit, the device will be either in constant voltage or constant power mode. If, however, the power consumption reaches the adjusted power value, the device will switch automatically to power limiting and sets the output current according to $I_{MAX} = P_{SET} / U_{IN}$, even if the maximum current value is higher. The current set value, as determined by the user, is always an upper limit.

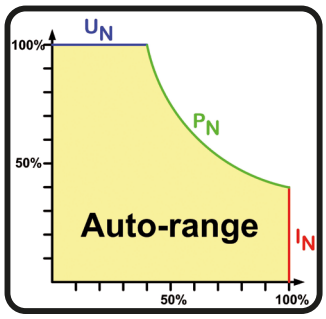
While the DC output is switched on and constant current mode is active, the condition "CC mode active" will be indicated on the front side control panel by LED "**CC**" and can also be read as status via the digital interfaces.

2.1.2.1 Voltage overshootings

In certain situations it's possible that the device generates a voltage overshooting. Such situations are when the device is in CC, with the actual voltage being unregulated, and either a jump in the current set value is initiated which would bring the device out of CC or when the load is suddenly cut from the power supply by an external means. Peak and duration of the overshooting aren't exactly defined, but as rule of thumb it shouldn't exceed a peak of 1-2% of the rated voltage (on top of the voltage setting) while the duration mainly depends on the charging state of the capacities on the DC output and also the capacity value.

2.1.3 Power control / constant power / power limiting

Power control, also known as power limiting or constant power (short: CP), keeps the DC output power of a power supply constant if the current flowing to the load, in relation to the output voltage and the resistance of the load, reaches the adjusted value according to P = U * I or P = U^2 / R_{LOAD}. The power limiting then regulates the output current according to I = sqr(P / R), where R is the load's true resistance.



Power limiting operates according to the auto-range principle such that at lower output voltages higher current flows and vice versa in order to maintain constant power within the range P_N (see diagram to the right).

While the DC output is switched on and constant power mode is active, the condition "CP mode active" can only be read as status via the digital interfaces.

2.1.3.1 Power derating

Primarily, the models in this series are designed for 400 V AC supply , but can also operate on a three-phase supply with 208 V (USA, Japan). In order to limit the AC current when running on the low input voltage, the devices would automatically switch into a derating mode that reduces the available DC power to a maximum of 18 kW.

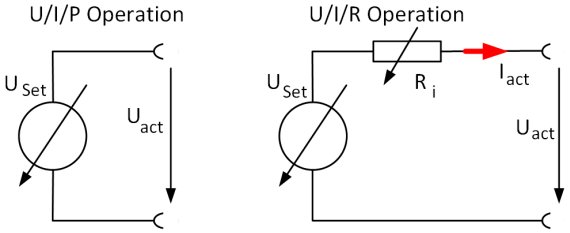
The switchover is determined once when the device is powered and it depends on the AC supply voltage being present in that moment. Should the voltage go up again later, the device would remain in derating mode as long as it's powered, because the switchover into and out of derating mode isn't dynamic. The full rated power is thus only available with AC voltages from 380 V.

The derated condition isn't signaled in any form on the outside of a PU 10000 device. It can only be queried as status via digital interface. However, the device would in this mode automatically adapt all values related to the reduced power. This also applies to master-slave operation of derated units.

2.1.4 Internal resistance control

Internal resistance control (short: 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 adjusted output voltage and the actual output voltage. This will also work in CC or CP mode whereas the actual output voltage will differ even more from the adjusted voltage, because both modes additionally limit the output voltage. CR mode is actually running in CV, but will be indicated as status "CR" (via the digital interfaces only) once the adjusted resistance value is reached.

The available resistance range of a particular model is given in the technical specifications. The voltage control, in dependency of the resistance set value and the output current, is done by calculation in a fast FPGA controller, being only a little slower than other controllers inside the main control circuit. Clarification:



$$U_{Act} = U_{Set} - I_{Act} * R_{Set} \quad \Big| P_{Set}, I_{Set}$$

$$P_{Ri} = (U_{Set} - U_{Act}) * I_{Act}$$

2.1.5 Actual value filter

From a certain set of firmware, particularly HMI 4.05 and KE 3.08, the device supports a user-configurable filtering feature. Its purpose is to periodically smoothen the actual values as they are shown on the screen or put out as digital or analog values. The filtering, if activated, is working in a way that it read an adjustable number of samples, i. e. measured actual values of voltage, current and power into an internal buffer, then calculates an average and exports the result as the next new set of actual values.

The mode selection is done, similar to other configuration of a device from this series, either in direct remote control using ModBus or SCPI protocol, or using **EA Power Control** and its Settings app in **General->Actual value filter mode**. The user can select between the modes **Fixed** and **Moving**, which differ as follows:

- **Fixed**: the selected number of samples is used to calculate the average, then the internal temporary sample buffer is purged and x new values are sampled
- **Moving**: the average is always calculated over the last x samples while the internal buffer isn't purged, but every new sample pushes all previous ones up so the values in the buffer move. This also means, that several subsequent average calculations are done with partially the same samples

Additionally to the mode, the user can select the size of the internal buffer, in **EA Power Control** called **Actual value filter buffer size** (alternative term: filtering stage), between 2 and 24. Together with the general fact that the device can deliver a new set of actual values every 20 ms, at least when the filtering is turned off, the filter delays every next new set pf values by this factor. It means, with the highest setting of 24 new actual values are only put out on the interfaces and screen approximately every 480 ms.

2.1.6 Fast discharge

All models in this series are bidirectional and due to their built-in sink capability they can discharge their own output capacities and also those of a possibly connected, external source by sinking a high current, up the rated one. This way of ramping the output voltage down quickly is only designed to work while the DC terminal remains switched on.

After switching it off, the main power stage would stop sinking energy, but a smaller, internal electronic load would take over and ensure to discharge the voltage in under 10 seconds to below 60 V, as part of a safety requirement. After reaching the threshold of 60 V, the voltage would continue to sink towards 0 V, but slower.

The feature **Fast discharge**, as available from firmware KE 3.10 for all 10000 power supply series, is a new functionality aiming to discharge the output voltage even quicker. It can be activated if needed (see ModBus register list, registers 30101-30104). Three adjustable parameters belong to it, the **Fast discharge voltage**, the **Fast discharge current** and the F**ast discharge duration**. The voltage value will determine to down what level of voltage the fast discharge action is performed, together with the current, which has a primary impact. The device would, in the moment of the action, overwrite the currently adjusted set value of sink current by the fast discharge current and the one of the sink power to 102% P_{Rated}.

The actual duration of the discharge action also depends on the maximum current a particular device model can sink, as well as the model specific output capacity, and therefore isn't defined. The parameter of **Fast discharge time** allows to extend the duration wide enough for the feature to work correctly, as well as narrow it down to the necessary minimum. The maximum of 5 seconds is supposed to be enough to always discharge the output voltage even to 0 V, except a connected external source would prevent that.

As side effect of the activated feature, the DC terminal status would remain as "on" as long as the discharge action runs after the user commanded to switch the DC terminal off manually by button On/Off or per remote control command, no matter what stop condition occurs first, the reached voltage threshold or the elapsed duration. It's expected that the output voltage would jump down to the adjusted threshold (**Fast discharge voltage**) in a split second, given the **Fast discharge current** is high enough, and, in case the threshold isn't set to 0 V, continue to sink, but as slow as when **Fast discharge** is deactivated.

Clarification:

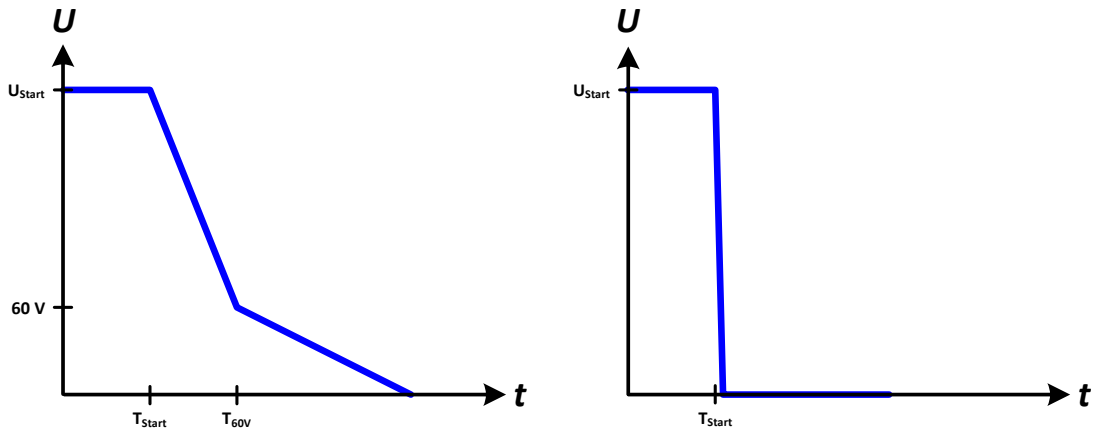


Figure 1 - Comparison of the voltage run after switching DC off without (left diagram) and with Fast discharge (to 0 V, right diagram) being activated

Since this a software feature, it won't work if the DC terminal is switched by other reasons, such as all alarms which would also switch DC off. That includes the moment when switching the device off.

2.1.7 STBY zero stabilization

This feature, as available from firmware KE 3.10 for all models of the 10000 series, is deactivated by default and be activated in the settings menu (see ModBus register list, register 30100), if needed. The goal is to stabilize the actual voltage value after the DC terminal has been switched off and after the voltage has sunken below a certain threshold (here: 3 V, model independent). The **STBY** in the name stand for stand-by and refers to the status of the DC terminal when switched off.

Due to technical reasons, the display actual voltage and the true voltage on the DC terminal can fluctuate and also remain slightly over 0 V. Those reasons are the switching power supply design, parasitic capacities and measurement errors. This feature, when activated, would set the actual voltage values to 0 V as long as the measured value on the DC terminal is below the threshold of 3 V. Since the device continuously measure the voltage on its DC terminal, also when DC is switched off, it would measure the voltage of a connected, external source as well. In both situations, voltage leaps between 3 V and 0 V in both directions are expected and normal. This suppresses the small voltage fluctuations around the zero point.

2.2 Remote control

2.2.1 General

Remote control is essential when operating devices of this series, for example during master-slave. It's furthermore possible to take over remote via any of the built-in control interfaces (USB, analog, Anybus). One of the digital interfaces is the master-slave bus. Important here is the fact that the device can either be under remote via one of the directly accessible interfaces for users or a master unit. It means that if, for example, an attempt were to be made to switch to remote control via the digital interface whilst master-slave mode is running the device would report an error via the digital interface. In the opposite direction, the master unit could not initialize a Slave unit being in USB remote control. In both cases, however, status monitoring and reading of values via any of the USB ports is always possible.

2.2.2 Remote control via digital interface

2.2.2.1 Selecting an interface

In addition to the built-in USB and Ethernet ports, all models of this series support the following optionally available interface modules:

Short ID	Type	Ports	Description*
IF-AB-CANO	CANopen	1	CANopen slave with generic EDS
IF-AB-RS232	RS232	1	Standard RS232, serial
IF-AB-PBUS	Profibus	1	Profibus DP-V1 slave
IF-AB-PNET1P	ProfiNet	1	Profinet DP-V1 slave
IF-AB-PNET2P	ProfiNet	2	Profinet DP-V1 slave, with switch
IF-AB-CAN	CAN	1	CAN 2.0 A / 2.0 B
IF-AB-ECT	EtherCAT	2	Standard EtherCAT slave with CoE
IF-AB-MBUS1P	ModBus TCP	1	ModBus TCP protocol via Ethernet
IF-AB-MBUS2P	ModBus TCP	2	ModBus TCP protocol via Ethernet

* For technical details of the various modules see the extra documentation "Programming Guide Modbus & SCPI"

2.2.2.2 Rear USB

The rear USB port offers the same set of commands as a PS 10000 series device, which is considered to a standard device with its display and knobs. When accessing the PU 10000 series device via this USB port, every feature specified for the series is available, including the option to use the device as master for any other compatible slave device. Regarding programming and remote control the documentation "Programming guide SCPI & ModBus" is valid for the user, as well as the connected ModBus register list "Modbus_Register_PU10000_KEx.xx+_EN.pdf".

2.2.2.3 Front USB

The main purpose of the front USB port is quick access to the most important DC output related parameters, such as set values and protections. Reading values and status is always possible, setting them only while the device isn't in control by a master device or any of the other interfaces.

Outside of master-slave, the device could be controlled remotely with software **EA Power Control** or from custom applications. In order to do so, a programming documentation is delivered with the device on USB stick. The number of available commands is restricted on this USB port, but it supports both, SCPI and ModBus RTU communication protocols. As part of the programming documentation, there is an extra ModBus register list named Modbus_Register_PUx10000_Front_HMIx.xx+_EN.pdf.

In the programming guide there is a section for all SCPI commands supported by the various series, as supported via the rear USB port. The front USB port has a reduced set of commands, as shown below. Details about the commands and their use can be found in the programming guide.

*IDN?	MEASure:[SCALar:]VOLTage[:DC]?
*CLS	OUTPut[:STATe]
*RST	OUTPut[:STATe]?
*ESE	[SOURce:]CURRent
*ESE?	[SOURce:]CURRent?
*ESR	[SOURce:]CURRent:LIMit:HIGH
*STB?	[SOURce:]CURRent:LIMit:HIGH?
MEASure:[SCALar:]CURRent[:DC]?	[SOURce:]CURRent:LIMit:LOW
MEASure:[SCALar:]POWer[:DC]?	[SOURce:]CURRent:LIMit:LOW?

[SOURce:]CURRent:PROTection[:LEVel]	SYSTem:CONFig:OCD:ACTion
[SOURce:]CURRent:PROTection[:LEVel]?	SYSTem:CONFig:OCD:ACTion?
[SOURce:]POWer	SYSTem:CONFig:OPD
[SOURce:]POWer?	SYSTem:CONFig:OPD?
[SOURce:]POWer:LIMit:HIGH	SYSTem:CONFig:OPD:ACTion
[SOURce:]POWer:LIMit:HIGH?	SYSTem:CONFig:OPD:ACTion?
[SOURce:]POWer:PROTection[:LEVel]	SYSTem:CONFig:OUTPut:RESTore
[SOURce:]POWer:PROTection[:LEVel]?	SYSTem:CONFig:OUTPut:RESTore?
[SOURce:]RESistance	SYSTem:CONFig:OVD
[SOURce:]RESistance?	SYSTem:CONFig:OVD?
[SOURce:]RESistance:LIMit:HIGH	SYSTem:CONFig:OVD:ACTion
[SOURce:]RESistance:LIMit:HIGH?	SYSTem:CONFig:OVD:ACTion?
[SOURce:]VOLTage	SYSTem:CONFig:UCD
[SOURce:]VOLTage?	SYSTem:CONFig:UCD?
[SOURce:]VOLTage:LIMit:HIGH	SYSTem:CONFig:UCD:ACTion
[SOURce:]VOLTage:LIMit:HIGH?	SYSTem:CONFig:UCD:ACTion?
[SOURce:]VOLTage:LIMit:LOW	SYSTem:CONFig:USER:TEXT
[SOURce:]VOLTage:LIMit:LOW?	SYSTem:CONFig:USER:TEXT?
[SOURce:]VOLTage:PROTection[:LEVel]	SYSTem:CONFig:UVD
[SOURce:]VOLTage:PROTection[:LEVel]?	SYSTem:CONFig:UVD?
STATus:OPERation?	SYSTem:CONFig:UVD:ACTion
STATus:QUEStionable?	SYSTem:CONFig:UVD:ACTion?
SYSTem:ALARm:COUNt:OCURrent?	SYSTem:DEVice:CLAss?
SYSTem:ALARm:COUNt:OPOWer?	SYSTem:ERRor:ALL?
SYSTem:ALARm:COUNt:OTEMperature?	SYSTem:ERRor:NEXT?
SYSTem:ALARm:COUNt:OVOLtage?	SYSTem:ERRor?
SYSTem:ALARm:COUNt:PFAil?	SYSTem:LOCK
SYSTem:ALARm:ACTion:PFAil	SYSTem:LOCK?
SYSTem:ALARm:ACTion:PFAil?	SYSTem:LOCK:OWNer?
SYSTem:COMMunicate:TIMeout?	SYSTem:NOMinal:CURRent?
SYSTem:CONFig:MODE	SYSTem:NOMinal:POWer?
SYSTem:CONFig:MODE?	SYSTem:NOMinal:RESistance:MAXimum?
SYSTem:CONFig:OCD	SYSTem:NOMinal:RESistance:MINimum?
SYSTem:CONFig:OCD?	SYSTem:NOMinal:VOLTage?

2.2.2.4 Programming

Programming details about the communication protocols etc. are to be found in the documentation “Programming Guide ModBus & SCPI“ which is supplied on the included USB stick or is available as download from the manufacturer’s website.

2.2.3 Interface monitoring

Interface monitoring is a functionality with the goal to monitor (or supervise) the digital communication line between the device and a superior control unit, such as a PC or PLC, and to ensure that the device wouldn't continue working uncontrolled in case the communication line fails. A failing line can mean that it's either physically interrupted (damaged cable, bad contact, cable pulled) or the interface port inside the device hangs. The monitoring can only be configured via the Settings app of **EA Power Control**.

While monitoring is activated, it would only be valid for the one interface being used for remote control, except for the situation when the device is a slave unit within a master-slave system. Then only the master has active interface monitoring. However, the connection between master and slaves is also supervised and in case of interruption on that particular connection line or other malfunctions, the device would go into the alarm state of MSP (master-slave protection).

The monitoring is based on a user-definable timeout which would run out if not at least one message is sent to the device within the given time frame. After every message, the timeout would start again and reset with the next incoming message.

In case it runs out, the following reaction of the device is defined:

- Exit remote control
- Should the DC output be switched on, it either switches it off or remains on, depending on what's determined by the **EA Power Control** setting **Other-> DC input/output state after remote**

Notes for the operation:

- The timeout of the monitoring can be changed anytime via remote control; the new value would only be valid after the current timeout has elapsed
- The interface monitoring doesn't deactivate the Ethernet connection timeout, so these two timeouts can overlap

2.2.4 Remote control via the analog interface

2.2.4.1 General

The built-in, galvanically isolated, 15-pole analog interface (below referenced in short form as **AI**) is located on the rear side of the device and provides the following possibilities:

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

Setting the set values of voltage, current and power via the analog interface must always be done concurrently. It means, that for example the voltage can't be adjusted via the AI and current and power set by digital line, or vice versa. The internal resistance set value can additionally be adjusted.

The OVP set value and other alarm thresholds can't be set via the AI and therefore must be adapted to the given situation before the AI is taking over control. Analog set values can be supplied from an external voltage source or can be derived from the reference voltage on pin 3.

The AI can be operated in the common voltage ranges 0...5 V and 0...10 V, both representing 0...100% of the rated value. The selection of the voltage range can be done via a few settings available as ModBus register, SCPI command or in the Settings app of **EA Power Control**. The reference voltage sent out from pin 3 (VREF) will be adapted accordingly:

Selected setting **5 V**: Reference voltage = 5 V, 0...5 V set value signal for VSEL, CSEL, PSEL and RSEL correspond to 0...100% nominal value, 0...100% actual values correspond to 0...5 V at the actual value outputs CMON and VMON.

Selected setting **10 V**: Reference voltage = 10 V, 0...10 V set value signal for VSEL, CSEL, PSEL and RSEL correspond to 0...100% nominal values, 0...100% actual values correspond to 0...10 V at the actual value outputs CMON and VMON.

All set values are always additionally limited to the corresponding adjustment limits (U-max, I-max etc.), which would clip setting excess values for the DC output.

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

	*After powering the device and during the start phase the AI signals undefined statuses on the output pins. Those must be ignored until is ready to work.*

- Analog remote control of the device must be activated by switching pin REMOTE (5) first. Only exception is pin REM-SB, which can be used independently
- Before the hardware is connected that will control the analog interface, it shall be checked that it can't provide voltage to the pins higher than specified (table in section *2.2.4.3*)
- Set value inputs, such as VSEL, CSEL, PSEL and RSEL, if R mode is activated, must not be left unconnected (i.e. floating) during analog remote control. In case any of the set values isn't used for adjustment, it can be tied to a defined level or connected to pin VREF (solder bridge or different)

2.2.4.2 Acknowledging device alarms

In case of a device alarm occurring during remote control via analog interface, the DC output will be switched off the same way as in digital remote control. The device would indicate an alarm (see section *3.5* in the installation manual) on the front with LED "Error" and also signal it on the analog interface. Which alarms are eventually signaled can be set up in the device configuration via remote control (commands or **EA Power Control**).

The alarms MSP, OVP, OCP and OPP have to be acknowledged (also see *«3.5.2 Device alarm and event handling»* in the installation manual*)*. Acknowledgment is done with pin REM-SB switching the DC output off and on again, thats means a HIGH-LOW-HIGH edge (min. 50ms for LOW), given the default logical level is set for REM-SB.

The same is required for PF and OT in case the related **EA Power Control** settings **Other -> DC input/output state after PF alarm** or **Other -> DC input/output 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. It can't be acknowledged and requires to power-cycle the device. It can be monitored via the analog interface and would be indicated by the alarms PF and OVP being signaled at the same time, so it would require to select the alarm indication on pin 6 to at least signal PF and for pin 14 to signal OVP in any of the combinations.

2.2.4.3 Analog interface specification

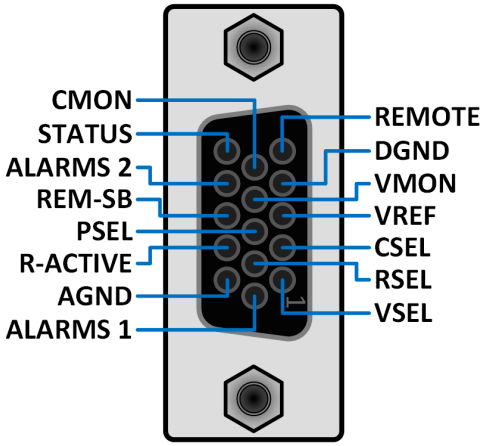
Pin	Name	Type [1]	Description	Default levels	Electrical specifications
1	**VSEL**	AI	Set voltage value	0...10 V or. 0...5 V correspond to 0..100% of U_{Nom}	Accuracy 0-5 V range: < 0.4% [5] Accuracy 0-10 V range: < 0.2% [5] Input impedance R_i >40 k...100 k
2	**CSEL**	AI	Set current value	0...10 V or. 0...5 V correspond to 0..100% of I_{Nom}	
3	**VREF**	AO	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	Switches between manual and remote control	Remote = LOW, U_{Low} <1 V Manual = HIGH, U_{High} >4 V Manual, if pin not wired	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**	AI	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**	AI	Set power value	0...10 V or. 0...5 V correspond to 0..100% of P_{Nom}	
9	**VMON**	AO	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**	AO	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	On = LOW, U_{Low} <1 V Off = HIGH, U_{High} >4 V Off, if pin not wired	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, if pin not wired	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 control 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 AI = Analog Input, AO = 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 device

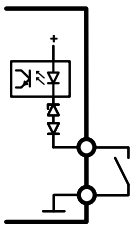
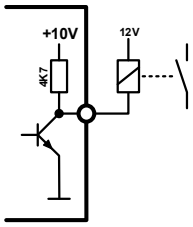
2.2.4.4 Resolution

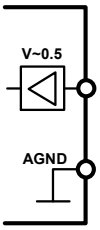
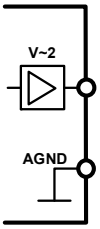
The analog interface is internally sampled and processed by a digital microcontroller. This causes a limited resolution of analog steps. The resolution is the same for set values (VSEL etc.) and actual values (VMON/CMON) and is 26214 steps for 0...100% when working with the 10 V range. In the 5 V range this resolution halves. Due to tolerances, the truly achievable resolution can be slightly lower.

2.2.4.5 Overview of the Sub-D Socket



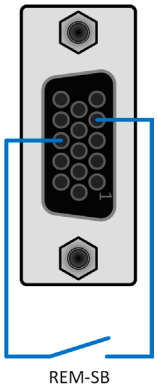
2.2.4.6 Simplified diagram of the pins

	**Digital Input (DI)** It requires to use a switch with low resistance (relay, switch, circuit breaker etc.) in order to send a clean signal to the DGND. A digital output of an IC or PLC my not be able to pull the input down , if not of type "open collector".
	**Digital Output (DO)** A quasi open collector, realized as high resistance pull-up against the internal supply. In condition LOW it can't drive any load, only sink small current, as shown in the diagram with a relay as example.

	**Analog Input (AI)** High resistance input (impedance >40 kΩ) for an operation amplifier circuit.
	**Analog Output (AO)** Output from an operation amplifier circuit, low impedance. See the specifications table above.

2.2.4.7 Application examples

a) Switching the DC output with pin REM-SB



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 controlling application. Also see pin diagrams above.

In remote control, pin REM-SB is used to switch the DC output of the device on and off. This function is also available without remote control being active and can on the one hand block the DC output from being switched on in manual or digital remote control and on the other hand the pin can switch the DC output on or off, but not standalone. See below at **Remote control has not been activated**.

REM-SB cannot serve as a safety stop switch to securely deactivate the DC output in case of emergency! For that an external emergency stop system is required.

It's recommended that a low resistance contact such as a switch, relay or transistor is used to switch the pin to ground (DGND).

Following situations can occur:

- **Remote control has been activated**

During remote control via analog interface, only pin REM-SB determines the states of the DC output, according to the level definitions in section *2.2.4.3*. The logical function and the default levels can be inverted by a setting **Analog interface > REM-SB level** in the Settings app of **EA Power Control,** via ModBus register or SCPI command.

If the pin is unconnected or the connected contact is open, the pin will be HIGH. With the setting "Analog interface -> REM-SB level" being set to "Normal", it requests to switch the DC output on. So when activating remote control, the DC output will instantly switch on.

- **Remote control isn't active**

In this mode of operation pin REM-SB can serve as lock, preventing the DC output from being switched on by any means. This results in following possible situations:

DC output	+	Level on pin REM-SB	+	Parameter „REM-SB level“ (1	→	Behavior
is off	+	HIGH	+	**Normal**	→	The DC output isn't locked. It can be switched on by pushbutton "On/Off" (front panel) or via command from digital interface.
		LOW	+	**Inverted**		
	+	HIGH	+	**Inverted**	→	The DC output is locked. It can't be switched on by pushbutton "On/Off" (front panel) or via command from digital interface. When trying to switch on the device would simply not react, but in remote control, it would return a communication error.
		LOW	+	**Normal**		

In case 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 „REM-SB level“ (1	→	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 pin REM-SB.
		LOW	+	**Normal**		

b) Remote control of current and power

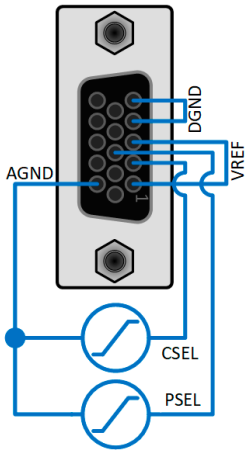
Requires remote control to be activated (Pin REMOTE = LOW)

The set values PSEL and CSEL are generated from, for example, 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 max. 5 mA load for the VREF output, potentiometers of at least 10 kΩ must be used.

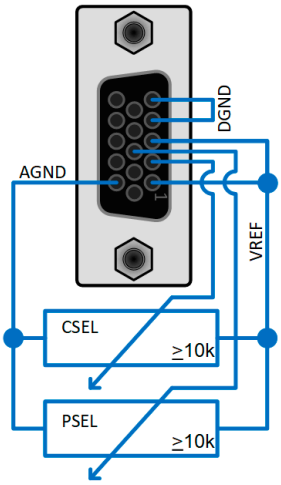
The voltage set value VSEL is directly connected to VREF and will thus be permanently 100%.

If the control voltage is fed in from an external source it's necessary to mind the input voltage range for set values (0...5 V or 0...10 V).

Use of the input voltage range 0...5 V for 0...100% set value halves the effective resolution.



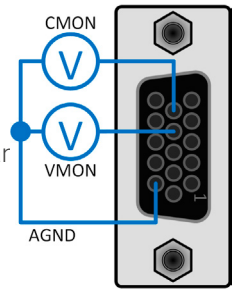
Example with external voltage source



Example with potentiometers

c) Reading actual values

The AI provides the actual values on the DC output as current and voltage monitor. These can be read using a standard multimeter or an analog input of a PLC etc.



1) The parameter can either be set per ModBus register 417, SCPI command or in EA Power Control. The name here is taken from EA Power Control

2.2.4.8 Analog interface priority

A new functionality, available for all PUx 10000 series devices with analog interface and from firmware KE 3.10, allows the user to prioritize the analog interface over other remote control interfaces. The rule was and is that no interface, analog or digital, is superior to another in regard of the remote control state. It means, that when a device would be in remote control by any digital interface and the remote control is going to be switched over to analog interface, it would require to leave the digital remote control state first via a specific command sent via the interface in control.

With this feature, when activated (see Modbus register list, register 444), the analog interface can take over remote control anytime. In the moment of the switchover, the set values and the DC terminal status, as given by the pins of the analog interface, would become effective immediately. In the contrary, leaving analog remote control (pin: REMOTE) would neither return the device into the prior state of digital remote control, nor restore the set values and DC condition as they were before. Leaving remote control always keeps the last set of set values, while the DC terminal condition is determined by the parameter **Condition of DC output/input after leaving remote** (see ModBus register list, register 425) or SCPI command.

3. Other applications (2)

3.1 Parallel operation in master-slave (MS)

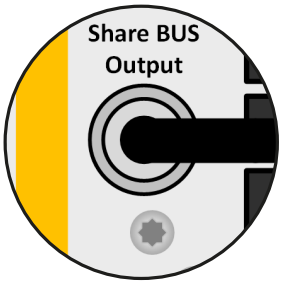
The primary and intended form of operation for device of this series is master-slave, specifically as slave.

Multiple devices of same kind can be connected in parallel in order to create a system with higher total current and also higher power. For parallel operation in master-slave mode the units are usually connected on their DC terminals, their Share-Bus and their master-slave bus, which is a digital bus that makes the system work as one big unit regarding adjusted values, actual values and status.

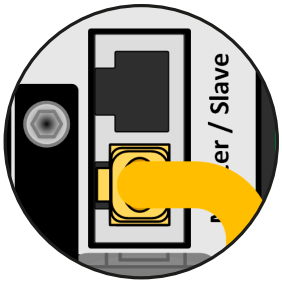
The Share-Bus is intended to balance the units dynamically in their voltage on the DC output, i.e. in CV mode, especially if the master unit runs a function generator, if featured there. In order for this bus to work correctly, at least the DC minus poles of all units have to be connected, because DC minus is the reference for the Share-Bus.

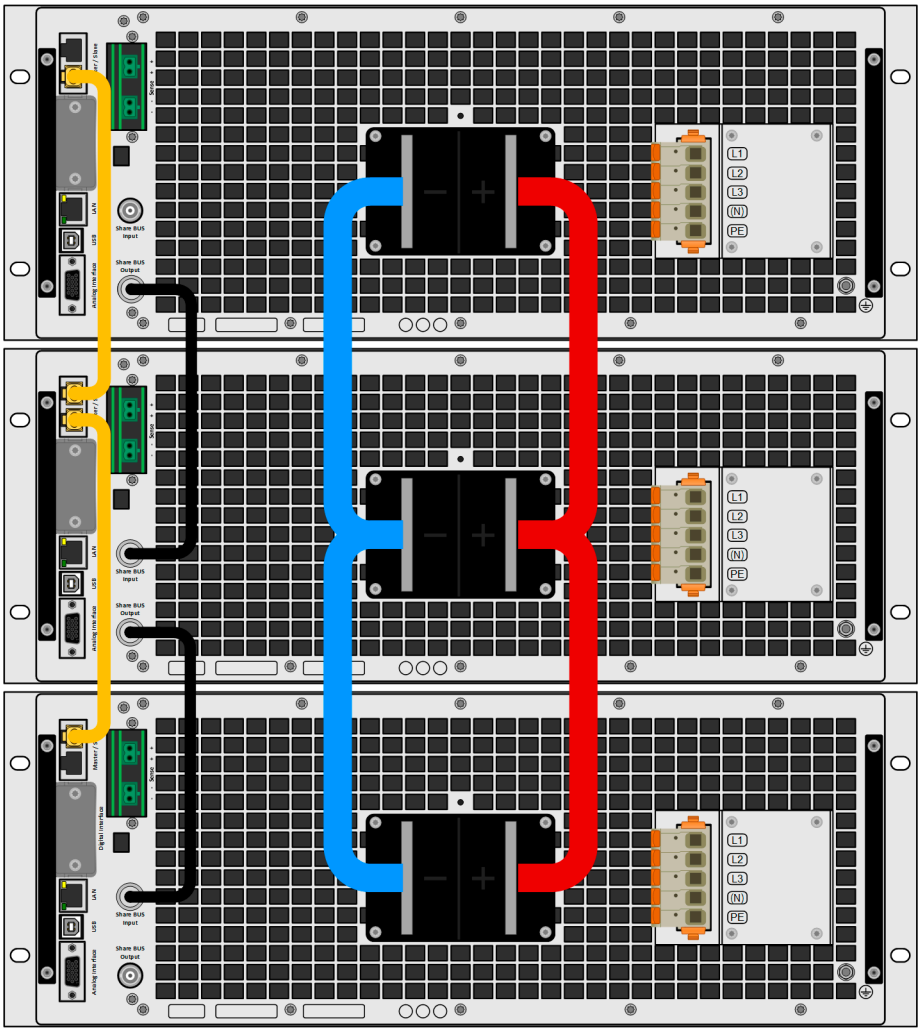
Principle view (without load):

Share-Bus connection



Master-slave bus





3.1.1 Restrictions & requirements

Compared to normal operation of a single device, master-slave operation has some restrictions and requirements:

- The MS system reacts partially different in alarm situations (see below in section *3.1.8*)
- Though the Share-Bus makes the system react as dynamic as possible, it's still not as dynamic as single unit operation
- Connection to identical models from other series is supported, but limited to PSI 10000 and PS 10000 series

3.1.2 Wiring the DC outputs

The DC output of every unit in the parallel operation is connected with correct polarity to the next unit, using cables or copper bars with a cross section according to the total system current and with short as possible length, so their inductance is as low as possible.

3.1.3 Wiring the Share-Bus

The Share-Bus is essential for master-slave operation. It's wired from unit to unit with standard BNC cables (coaxial, 50 Ω type), with a length of 0.5 m (1.64 ft) or similar. Both BNC sockets are internally wired and are not specifically input or output. The labeling is only for orientation.

- *A max. of 64 units can be connected via Share-Bus.*
- *When connecting the Share-Bus before a device had been configured as Master or Slave, an SF alarm will occur*

3.1.4 Wiring of the master-slave bus

The master-slave connectors are built-in and can be connected via network cables (≥CAT3, patch cable). After this, MS can be configured manually (recommended) or by remote control. The following applies:

- A maximum of 64 units can be connected via the bus: 1 master and up to 63 slaves.
- Connection only between devices of same kind, i.e. like power supply to power supply; connection of different power classes is allowed and supported, see below in section *3.1.5*
- Units at the end of the bus must be terminated (see below for more information), else the master-slave initialization will fail

The master-slave bus must not be wired using crossover cables!

Later operation of the MS system implies:

- The master unit provides summed up actual values and status of the entire system via remote control query, but not over every interface. It means, as an example, only when using SCPI a 300 kW system is capable of returning the queried actual power as "300.0kW", but on all other interfaces this value would be a per cent value of the system's total power and would have to be correctly translated by remote control software.
- The ranges for setting the values, adjustment limits, protections (OVP etc.) of the master are adapted to the total number of units
- Slaves are not operable as long as being controlled by the master
- Slaves which haven't yet been initialized by the master will show the MSP alarm with LED "Error". The same alarm is signaled upon MS bus errors.

3.1.5 Mixed systems

As mixed systems following is understood:

- Different power classes like 5 kW, 15 kW or 30 kW within one master-slave system (requires at least firmware KE 3.02)
- Different series, specifically PS 10000 series in connection with PU 10000 series (requires at least firmware KE 3.02)

When connecting devices with different feature sets it makes sense to select the one with the best configuration as master. Combining different power classes can have an unexpected side effect, such that the resulting total power after initialization isn't the expected one, but lower. This depends on what unit with what power class has been picked as master. In such a situation the golden rule is: always select the master from within the units with the highest power rating.

Example: you want to connect a 30 kW unit and a 3kW unit in order to achieve 33 kW. Generally, the voltage rating must match, but current and power rating can be different. The power rating then is decisive. When using the 3 kW unit as master, the total system power will only be 28 kW, which is even less than the single 30 kW unit can provide. However, when switching to the 30 kW unit as master, the system will result in 33 kW total power.

Compatibility of 10000 series to each other, no matter what power class (date 03-2023):

	PS	PSI	PU	ELR	PUL	PSB	PSBE	PUB
PS	x	x	x (*	-	-	-	-	-
PSI	x	x	x (*	-	-	-	-	-
PU	x (*	x (*	x (*	-	-	-	-	-
ELR	-	-	-	x	x (*	-	-	-
PUL	-	-	-	x (*	x (*	-	-	-
PSB	-	-	-	-	-	x	x	x (*
PSBE	-	-	-	-	-	x	x	x (*
PUB	-	-	-	-	-	x (*	x (*	x (*

(* Requires at least firmware KE 3.06 on all involved units

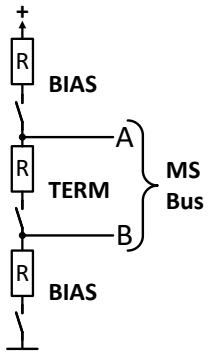
3.1.6 Configuring the master-slave operation

Master-slave configuration for a system that shall not be changed anymore afterwards, has to be done only once. The devices will store their settings and after every start the master will automatically try to initialize all slaves. Should the master be one with a display, configuration and initialization can be done manually, using the touch screen.

Otherwise, the setup is done either via custom software and ModBus/SCPI commands or **EA Power Control**. Given that the master-slave system is already properly wired and all units are running, the last step is master-slave configuration.

► How to configure a unit as slave or master for master-slave operation using EA Power Control

1. Connect the device to the PC using either the front USB or rear USB port
2. Start **EA Power Control** and let it find the device. In case, several devices are connected to the PC, select the proper one and drag its symbol onto the **Settings** app.
3. In the Settings app, navigate to group **Master-slave** and set **Master-slave mode** to **Slave** or **Master**.
4. Correctly set termination. The actual bus termination is done with internal electronic switches which are controlled via commands. This can be done as part of setting up every unit as master or slave, but should be done before the master is going to be set as such, because doing so immediately triggers a bus initialization. In the settings group **Master-slave** the termination resistors for BIAS and for the bus itself (TERM, see figure to the right) can be set separately. Termination setting for the units on the MS bus:



Device position	Termination setting(s)
Master (at end of bus)	Bias resistor = On + Termination resistor = On
Master (central in bus)	Bias resistor = On
Slave (at end of bus)	Termination resistor = On
Slave (central in bus)	Bias resistor = Off + Termination resistor = Off

5. Save settings and leave the app.

As long as MS mode remains activated, the initialization process of the master-slave system will be repeated each time the master unit is powered. The initialization can also be repeated manually anytime via the Settings app in EA Power Control, in group "Master-Slave", or custom software using master-slave operation related commands.

3.1.7 Operating the master-slave system

After successful configuration and initialization of the master and slave units, the focus is on the master. In case the master is a model from this series, it cannot show its master status on the front via LEDs, but the status of the MS operation can be queried anytime from the master using **EA Power Control** or custom software. Masters with display can show all status on the display as well.

From now on the slaves can no longer be controlled manually or remotely, neither via the analog nor via any digital interface. If needed, the could be monitored via these interfaces by reading actual values and status.

The master unit will reconfigure after initialization and all set values are reset. Towards a controlling software, the master can represent all its values in readable form and adapted to what the system now is defined for, but only when using SCPI or perhaps LabVIEW, which limits the choice of interfaces to LAN or USB. Depending on the number of units, the adjustable current and power range will multiply, while the resistance range will decrease. With any of the other available interfaces, the translation of values is to be done by the software.

The following generally applies:

- The master-slave system can be treated like a standalone unit
- The master shares the set values etc. across the slaves and controls them
- The master is remotely controllable via the analog or digital interfaces
- All settings for the set values U,I, P and R on the master, plus also all related values from supervision, limits etc. should be adapted to the new total values
- All initialized slaves will reset any limits (U_{Min}, I_{Max} etc.), supervision thresholds (OVP, OPP etc.) to default values, so these don't interfere the control by the master. As soon as these values are modified on the master, they are transferred 1:1 to the slaves. Later, during operation, it might occur that a slave causes an alarm earlier than the master, due to imbalanced current or slightly faster reaction.
- If one or more slaves report a device alarm, it will also be signaled on the master via LED "Error" and must be acknowledged on the master, no matter with what of the available ways, so that the slave(s) can continue operation. Since an alarm usually causes the DC outputs to switch off and can only reinstate the on/off condition automatically after PF or OT alarms, where the reaction to the alarms is configurable, action from an operator or a remote control software may become necessary in such a situation.
- Loss of connection to any slave will result in shutdown of all DC outputs as a safety measure and the units will report this situation on their front panels by the LED "Error" lighting up, as well as master will provide a readable alarm status MSP ("master-slave protection"). Then the MS system has to be re-initialized, either with or without prior re-establishment of the connection to the disconnected unit(s).
- All units, even the slaves, can be externally shut down on their DC outputs using the REM-SB pin of the analog interface. This can be used as some kind of "emergency off" where usually a contact (maker or breaker) is wired to this pin on all units in parallel.

3.1.8 Alarms and other problem situations

Master-slave operation, due to the connection of multiple units and their interaction, can cause additional problem situations which wouldn't occur when operating individual units. For such occurrences the following regulations have been defined:

- Generally, if the master loses connection to any slave, it will generate an MSP (master-slave protection) alarm, pop up a message on the screen (if the master is one with display) and switch off its DC output. The slaves will fall back to single operation mode, but also switch off their DC output. The MSP alarm can be deleted by either initializing the master-slave system again or deactivating master-slave mode which requires to connect to every single slave. Re-initialization can either be done in the MSP alarm requester (if the master is with display) or in the MENU of the master (if the master is with display) or via remote control.
- If one or more slave units are cut from AC supply (blackout, supply undervoltage) and come back later, they're not automatically initialized and included again in the MS system. Then the init has to be repeated.
- If the master unit is cut from AC supply (fuse tripped, blackout) and comes back later, it will automatically try to initialize the MS system again, finding and integrating all active slaves. In such a case, MS can be restored automatically.
- If multiple units are defined as master the master-slave system can't be initialized.
- Should the master report the initialization status as failed and the status message says "Different firmwares or models detected" (if the master is with display), then at least one unit in the MS system either has an older hardware version or there are different firmware versions installed in the units. The latter can be fixed by checking what's installed on the units and then adapt.

In situations where one or multiple units generate a device alarm like OVP etc. following applies:

- Any alarm of a slave is indicated on the slave's front panel and on the master's front panel (with or without display)
- If multiple alarms happen simultaneously, the master only indicates the most recent one. In this case, the particular alarms could be read from the slave units via digital interface.
- All units in the MS system supervise their own values regarding overvoltage, overcurrent and overpower and in case of alarm they report the alarm to the master. In situations where the output current is probably not balanced well between the units, it could occur that one unit generates an OCP alarm though the global OCP limit of the MS system was not reached. The same could occur with the OPP alarm.

3.2 SEMI F47

SEMI F47 (the SEMI comes from semiconductor) is a specification that demands a device to continue working without interruption in case of a power failure in form of an AC supply undervoltage (here: sag) of max. -50% of the rated line voltage with a max. duration of 1.7 seconds. PU 10000 4U series devices have this feature by default, but when running in connection with older units with display being the master of a master-slave system, perhaps a PSI 10000, it may not yet have this feature. It also cannot be retrofitted.

SEMI F47 specifies a voltage sag in steps with increasing voltage:

Sag of	Duration at 50 Hz	Duration at 60 Hz	Duration in seconds
50%	10 cycles	12 cycles	0.2
30%	25 cycles	30 cycles	0.5
20%	50 cycles	60 cycles	1 s

3.2.1 Restrictions

- The feature will be disabled automatically and also locked if the device boots with low AC supply voltage present, i. e. 208 V (L-L) instead of the default 400 V (L-L), because then the device couldn't bridge the 1.7 s duration of the F47 pulse anymore. It means that SEMI F47 isn't available while derating is active.
- It requires a decreased max. output power (21000 W or 70%), compared to the actual power of the particular model, thus SEMI F47 is also a sort of derating, but not automatically activated by AC voltage detection. The reduced power rating is activated and deactivated together with SEMI F47 which can be switched on or off during runtime.

3.2.2 Adjustments

SEMI F47 can only be activated/deactivated via digital interface, either by remote control command or by using our software **EA Power Control** with its **Settings** app in tab **"Other"**, unless blocked due to the current device state.

3.2.3 Application

The feature can be activated at any time, unless blocked due to the situation, for example when low voltage derating is already active (see section *2.1.3.1*). With the release of firmware KE 3.10, the mode **Dynamic** has been added. When just activating SEMI F47 as before, the device will instantly reduce the max. available power, as well as adjust the power set value, should the currently adjusted one be higher than the new maximum. When deactivating the feature, it acts vice versa, only the power set value remains unaltered. Due to the fact that the activation of SEMI F47 is stored beyond shutting down the device, it would directly boot into SEMI F47 mode during the next start. When using the new mode **Dynamic**, the available maximum power isn't reduced permanently, as with mode **Enabled**, but temporarily, for the duration of the sag.

If later a voltage sag occurs, the level of sag or the duration decides whether the device continues its operation without switching the DC output off or if it would indicate a **PF** alarm via LED "Error". Without SEMI F47 being activated, the PF alarm would appear immediately while with activated SEMI F47 it's delayed for at least 2 seconds or will never occur. In this case, the device wouldn't show any reaction to the sag, nor register the occurrence in any form.

4. Service and maintenance (2)

4.1 Firmware updates



Firmware updates should only be installed when they can eliminate existing bugs in the firmware in the device or contain new features.

The firmware of the control panel (HMI), of the communication unit (KE) and the digital controller (DR), if necessary, is updated via the rear USB port. For this the software **EA Power Control** is needed, which is included with the device or available as download from our website together with the firmware update, or upon request.

However, it's advisable not to install updates promptly. Every update includes the risk of an inoperable device or system. We recommend to install updates only if...

- an imminent problem with your device 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.

The following additionally applies in connection with firmware updates:

- Simple changes in firmwares can have crucial effects on the application the devices are used in. We recommend to study the list of changes in the firmware history very thoroughly.
- Newly implemented features may require an updated documentation (user manual and/or programming guide, as well as LabView VIs), which is often delivered only later, sometimes significantly later

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