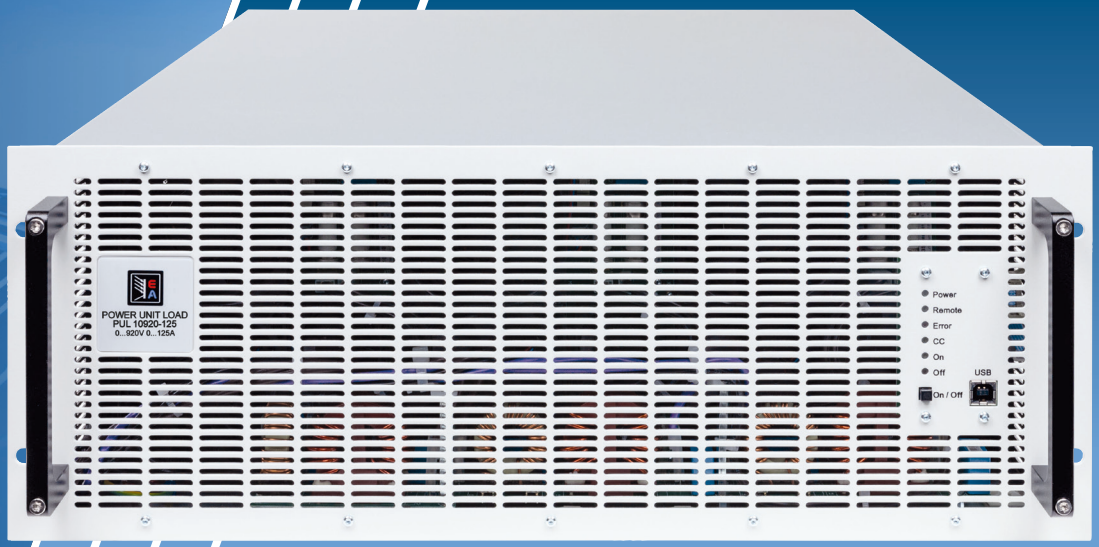
Elektro-Automatik



USER MANUAL

EA-PUL 10000 4U

Programmable electronic DC load units with energy recovery

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

Modification and partial or complete usage of this document for other purposes as intended are forbidden and breach may lead to legal consequences.

1.1.3 Validity

This document is valid for the following equipment and its variants:

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

1.1.4 Symbols and warnings in this document

Warning and safety notices as well as general notices in this document are shown in a box with a symbol as follows. The symbols are also valid, where placed, also to mark specific spots on the device:

	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 device like this is internally controlled by different control circuits, which shall bring 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. Every operating mode has its own characteristics which is explained below in short form.

2.1.1 Voltage control / Constant voltage

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

The voltage on the DC input of the device is held constant on the adjusted value, unless the current or the power according to $P = U_{DC} * I_{IN}$ 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 voltage can't be held constant anymore and will rise to a value resulting from Ohm's law.

While the DC input is switched on and constant voltage mode is active, then the status CV 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) and when the device has to react to a voltage change on the DC input, which is usually caused by the external source, the load requires a small transient time to settle the voltage. Positive voltage steps, i.e. lower to higher voltage, will cause the voltage to overshoot for a short time until compensated by the voltage regulator. The time it 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. This is done in the Settings app of **EA Power Control.**

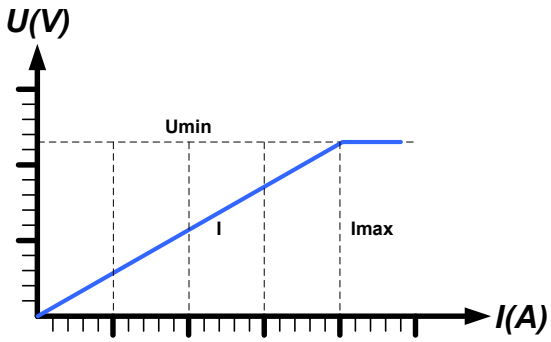
Setting Slow will result in a higher transient time and higher deviation from the set value, while Fast is vice versa and shortens the peaks. As a side effect and with the regulator being set to Fast, the load would react quicker to HF couplings and have a higher oscillation tendency, especially when using remote sensing. The choice of this setting thus depends on the situation. When using remote sensing, a typical recommendation would be to set Slow or, in case Fast is required for certain reasons, to disconnect the remote sensing terminals temporarily or permanently.

2.1.1.2 Minimum input voltage for maximum current

Due to technical reasons, all models in this series have a minimum internal resistance that requires a specific minimum input voltage (U_{MIN}) in order for the device to be able to sink its rated current (I_{MAX}).

This minimum input voltage varies from model to model and is stated in the technical specification in the installation manual. If less voltage than U_{MIN} is supplied, the load proportionally draws less current, which can be calculated easily.

See the principle view to the right.



2.1.2 Current control / constant current / current limiting

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

The current in the DC input of the device is held constant once the current consumed from the source reaches the adjusted limit. Then the device automatically switches to CC. As long as the input 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 set maximum power value, the device will switch automatically to power limiting and set voltage and current according to $P = U * I$.

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

2.1.3 Power control / constant power / power limiting

Power control, also known as power limiting or constant power (short: CP), keeps the DC power constant if the DC input current, in relation to the DC input voltage, reaches the adjusted limit according to P = U * I.

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

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

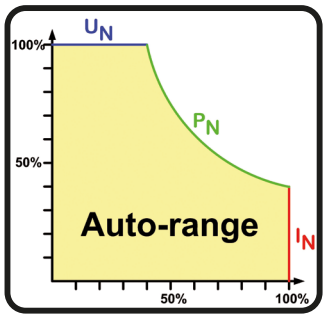


Figure 1 - Power range

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 devises 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 afterwards go up again, 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 PUL 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 Resistance control / constant resistance

Inside electronic loads, whose operating principle is based on a variable internal resistance, constant resistance mode (CR) is almost a natural characteristic. The load attempts to set the internal resistance to the user defined value by determining the input current depending on the input voltage according to Ohm's law $I_{IN} = U_{IN} / R_{SET}$. The internal resistance is naturally limited between almost zero and maximum (resolution of current control too inaccurate). As the internal resistance cannot have a value of zero, the lower limit is defined to an achievable minimum. This ensures that the electronic load, at very low input voltages, can consume a high input current from the source, up to the maximum.

While the DC input is switched on and constant resistance mode is active, the condition CR can only be read as status via the digital interfaces.

2.1.5 Dynamic characteristics and stability criteria

The device is an electronic load, characterized by short rise and fall times of the current, achieved by a high bandwidth of the internal control circuit.

In case of testing sources with own control circuits, like for example power supplies, a control instability may occur. This instability is caused if the complete system (feeding source and electronic load) has too little phase and gain margin at certain frequencies. 180° phase shift at > 0dB amplification fulfills the condition for an oscillation and results in instability. The same can occur when using sources without own control circuit, like batteries, and when the connection cables are highly inductive or inductive-capacitive.

The instability is not caused by a malfunction of the load, but by the behavior of the complete system. An improvement of the phase and gain margin can solve this. In practice, this is primarily done by switching the internal voltage regulator between dynamics modes called Slow, Fast and Normal. The switch is only found in the Settings app of **EA Power Control**. The user can only try the different settings to see if the desired effect is achieved. Should there be an improvement due to one of these settings, but the oscillation remains, an additional measure can be to install a capacitor directly at the DC input, perhaps alternatively to the remote sense input, if connected to the source. The capacitor's value to achieve the expected result is not defined and has to be found out. We recommend:

- 80 V models: 1000uF....4700uF
- 200/360 V models: 100uF...470uF
- 500 V models: 47uF...150uF
- 750/920/1000 V models: 22uF...100uF
- 1500/2000 V models: 4.7uF...22uF

2.1.6 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.

2.1.7 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 input 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 input when switched off.

Due to technical reasons, the display actual voltage and the true voltage on the DC input 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 input is below the threshold of 3 V. Since the device continuously measure the voltage on its DC input, 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 an ELR 10000 series device, which is considered to a standard device with its display and knobs. When accessing the PUL 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_PUL10000_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 input 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:]POWer[:DC]?
*CLS	MEASure:[SCALar:]VOLTage[:DC]?
*RST	[SOURce:]CURRent
*ESE	[SOURce:]CURRent?
*ESE?	[SOURce:]CURRent:LIMit:HIGH
*ESR	[SOURce:]CURRent:LIMit:HIGH?
*STB?	[SOURce:]CURRent:LIMit:LOW
INPut[:STATe]	[SOURce:]CURRent:LIMit:LOW?
INPut[:STATe]?	[SOURce:]CURRent:PROTection[:LEVel]
MEASure:[SCALar:]CURRent[:DC]?	[SOURce:]CURRent:PROTection[:LEVel]?

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

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

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

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 input.

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 it's 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
- 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 is not used for adjustment, it can be tied to a defined level or connected to pin VREF, so it gives 100%

2.2.4.2 Acknowledging device alarms

In case of a device alarm occurring during remote control via analog interface, the DC input 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 input 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**.

2.2.4.3 Analog interface specification

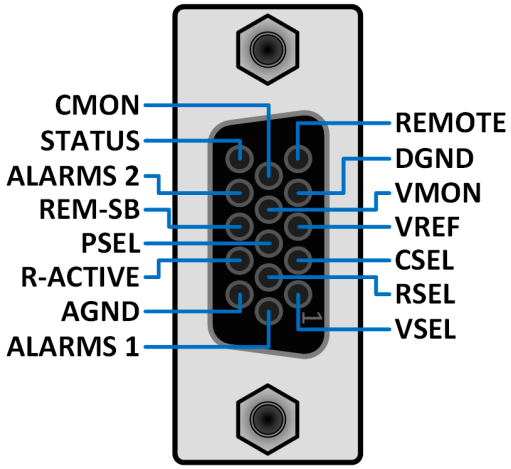
Pin	Name	Type (1	Description	Default levels	Electrical specifications
1	**VSEL**	AI	Voltage set value	0…10 V or 0…5 V correspond to 0..100% of U_{Nom}	Accuracy 0-5 V range: < 0.4% (5 Accuracy 0-10 V range: < 0.2% (5 Input impedance R_i >40 k...100 k
2	**CSEL**	AI	Current set value (source & sink)	0…10 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	Ground for all digital signals		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 /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	Resistance value (source & sink)	0…10 V or 0…5 V correspond to R_{Min}...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	Power set value (source & sink)	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} (5	Accuracy 0-5 V range: < 0.4% (5 Accuracy 0-10 V range: < 0.2% (5 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} (5	
11	**AGND**	POT	Ground for all analog signals		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 at 5 V $U_{LOW\ to\ HIGH\ typ.}$ = 3 V Rec'd sender: Open collector against DGND
13	**REM-SB**	DI	DC input OFF (DC input 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 input	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 a set value input adds to the general error of the related value on the DC input of the device

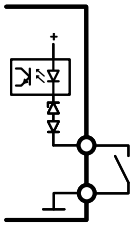
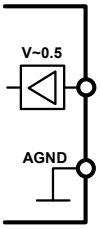
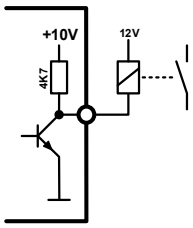
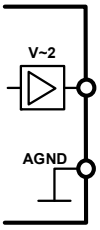
2.2.4.4 Resolution

The analog interface is internally sampled and processed by a digital micro-controller. This causes a limited resolution of analog steps. The effective resolution is the same for set values (VSEL etc.) and actual values (VMON/CMON). It's 26214 steps for 0...100% of a value when working in 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 D-sub socket

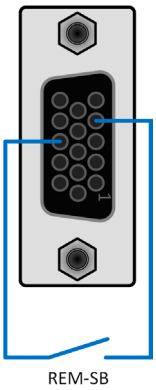


2.2.4.6 Simplified diagram of the pins

	**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".		**Analog Input (AI)** High resistance input (impedance >40 kΩ) for an operation amplifier circuit.
	**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 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 input 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 sufficiently low resistance. Check the specification of the controlling application. Also see pin diagrams above.*

In analog remote control, pin REM-SB is be used to switch the DC input of the device on and off. This function is also available without analog remote control being active and can on the one hand block the DC input from being switched on in manual or digital remote control and on the other hand the pin can switch the DC input 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 input 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 input, 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 input on. So when activating remote control, the DC input will instantly switch on.*

- **Remote control has not been activated**

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

DC terminal	+	Level on pin REM-SB	+	Parameter „REM-SB level“ (1	→	Behavior
is off	+	HIGH	+	**Normal**	→	The DC input 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 input 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 input is already switched on, toggling the pin will switch the DC input off, similar to what it does in analog remote control:

DC terminal	+	Level on pin REM-SB	+	Parameter „REM-SB level“ (1	→	Behavior
is on	+	HIGH	+	**Normal**	→	The DC input remains on, nothing is locked. It can be switched on or off by pushbutton or digital command.
		LOW	+	**Inverted**		
	+	HIGH	+	**Inverted**	→	The DC input 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

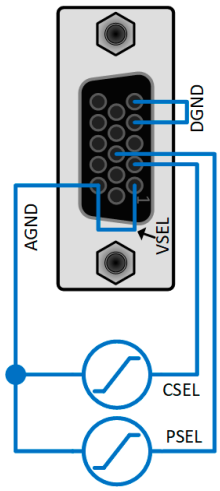
Requires remote control to be activated (pin REMOTE = LOW)

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.

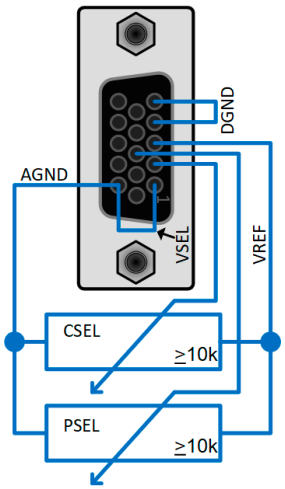
The voltage set value VSEL is directly connected to AGND and will thus not interfere with the constant current or constant power operation.

If the control voltages are fed in from an external source it's necessary to consider the input voltage ranges for set values (0...5 V oder 0...10 V).

!	*When using the voltage range 0...5 V the effective resolution of set values and actual values halves.*



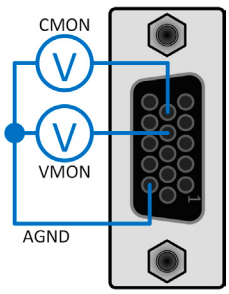
Example with external voltage source



Example with potentiometers

c) Reading actual values

The AI provides the DC input values as current and voltage monitor. These can be read using a standard multimeter or similar.



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 input 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 input 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)

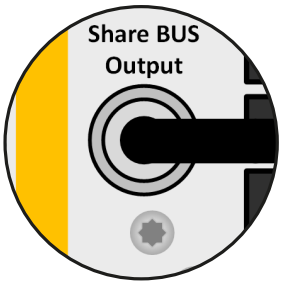
The primary and intended form of operation for device of this series is master-slave, specifically as slave.

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.

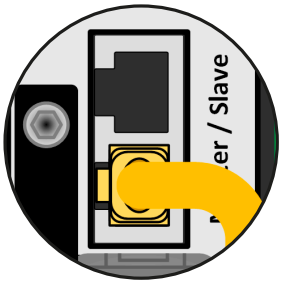
The Share-Bus is intended to balance the units dynamically in their voltage on the DC input, i.e. in CV mode which isn't the primary operation for an electronic load. The Share-Bus is primarily useful if the master runs a function. In order for this bus to work correctly, at least the DC minus poles of all units have to be connected, because DC minus is the reference for the Share-Bus.

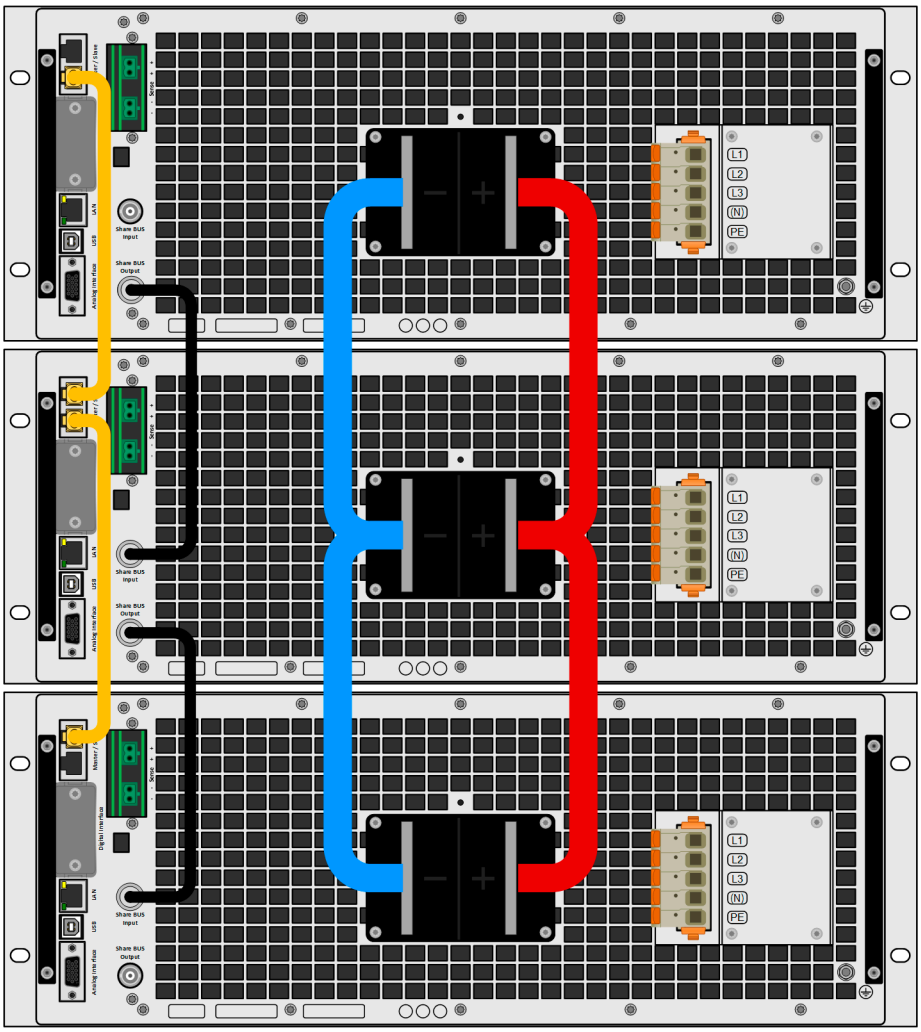
Principle view (without source):

Share-Bus connection



Master-slave bus





3.1.1 Restrictions

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

- 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 ELR 10000 series

3.1.2 Wiring the DC inputs

The DC input 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 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 sockets are internally connected 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 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. electronic load to electronic load; connection of different power classes is allowed and supported, but with some restrictions (see section *3.1.5* below)
- 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 <u>not</u> 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 PUL 10000 series in connection with ELR 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

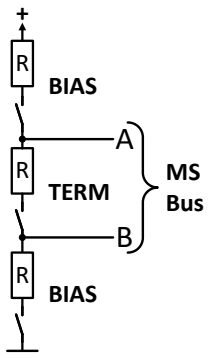
3.1.6 Configuring the master-slave operation

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 system, represented by the master, 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.) and event settings (UCD, OVD 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 or an event 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 inputs 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 inputs 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 inputs using the pin REM-SB of the analog interface. This can be used as some kind of "emergency off", here 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 input. The slaves will fall back to single operation mode, but also switch off their DC input. 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 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.

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 directly be solved, 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

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

Phone: +49 2162 3785 - 0
Fax: +49 2162 16230
ea1974@elektroautomatik.com

www.elektroautomatik.com
www.tek.com

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