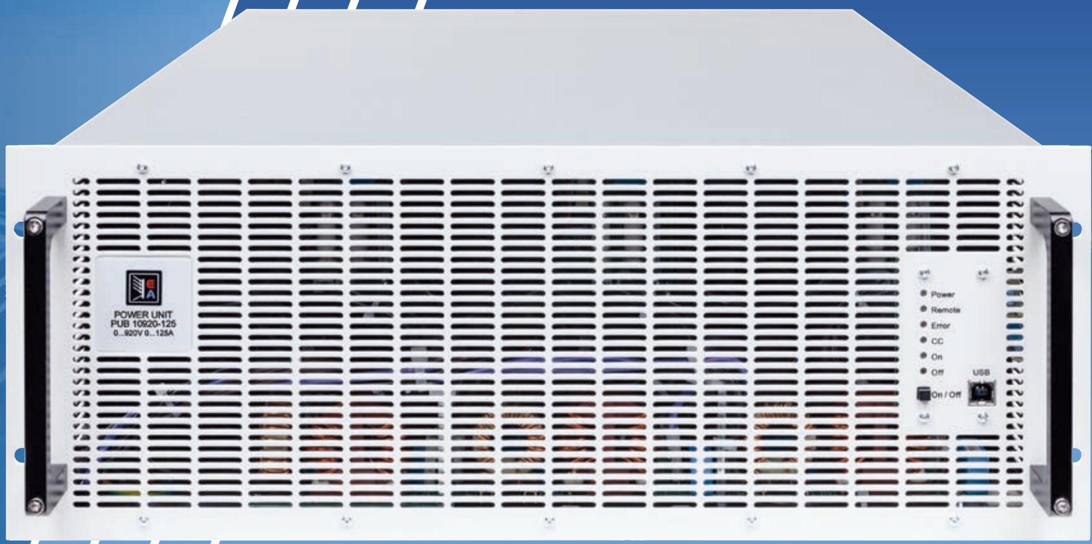

USER MANUAL

EA-PUB 10000 4U

Programmable bidirectional DC power units

Use, Remote Control

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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: 3.06”, “HMI: 3.04” and “DR: 1.0.2.20” or higher.

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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	Model	Model	Model
EA-PUB 10010-1000 4U	EA-PUB 10200-420 4U	EA-PUB 10750-120 4U	EA-PUB 11500-60 4U
EA-PUB 10060-1000 4U	EA-PUB 10360-240 4U	EA-PUB 10920-125 4U	EA-PUB 12000-40 4U
EA-PUB 10080-1000 4U	EA-PUB 10500-180 4U	EA-PUB 11000-80 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 Terms

A bidirectional device is a combination of a power supply and an electronic load. It can work alternately in one of two superior operation modes which are distinguished from each other in several parts of this document below:

- **Source / source mode:**
    - the device works as a power supply, generating and providing DC voltage to an external DC load
    - in this mode, the DC terminal is considered as DC output
- **Sink / sink mode:**
    - the device works as an electronic load, sinking DC energy from an external DC source
    - in this mode, the DC terminal is considered as DC input

2.2 Operating modes

A power supply is internally controlled by different control or regulation 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.

2.2.1 Voltage regulation / Constant voltage

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

The voltage on the DC terminal of the device is held constant on the adjusted value, unless the current or the power according to $P = U_{DC} * I$ 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 sink (in source mode) or rise (in sink mode) to a value resulting from Ohm's law.

CV is available for both, sink and source mode, and primarily depends on the relation between voltage set value and voltage level on the DC terminal. The device will switch between both modes seamless when adjusting voltage. In source mode, the output voltage in CV mode is equal to the setting while in sink mode the setting must always be lower than the input voltage in order to have the device draw current.

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.

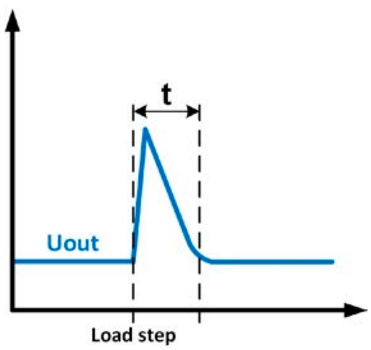
2.2.1.1 Voltage regulation peaks (source mode)

When working in constant voltage regulation (CV) and source mode 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 it takes to settle the voltage can be influenced by switching the voltage regulation speed between the settings **Slow, Normal and Fast, whereas Normal** is the default.

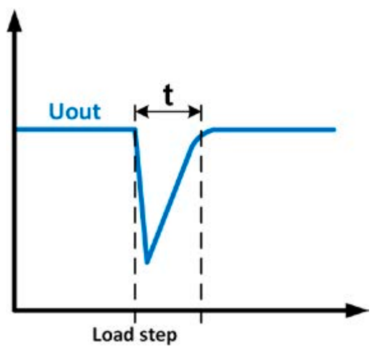
This is done in the Settings app of **EA Power Control.** Setting **Slow** will result in a higher transient time and higher voltage drop, but less overshooting, while **Fast** is vice versa.

The same occurs with a positive load step, i.e. low load to high load. There the output collapses for a moment. The amplitude of the overshoot resp. collapse depends on the device model, the currently adjusted output voltage and the capacity on the DC output and can thus not be stated with a specific value.

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.



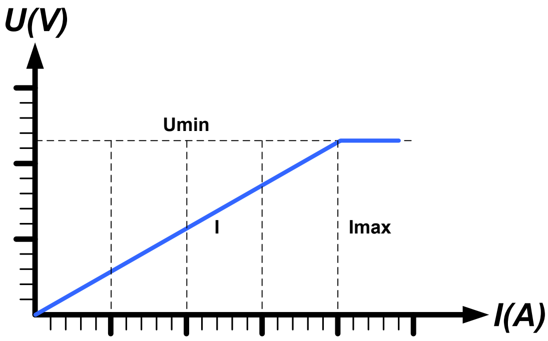
Example for a pos. load step: the DC output will collapse below the adjusted value for a short time. t = transient time to settle the output voltage.

2.2.1.2 Minimum input voltage for maximum current (sink mode)

Due to technical reasons, all models in this series have a minimum internal resistance that requires to provide 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 section *1.8.3* of the installation manual. If less voltage than U_{MIN} is supplied, the load proportionally draws less current, which can be calculated easily.

See principle view to the right.



2.2.2 Current regulation / constant current / current limiting

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

The current in the DC terminal of the device is held constant once the output current (source mode) to the load resp. the current consumed from the load (sink mode) reaches the adjusted limit. Then the device automatically switches to CC. In source mode, the current flowing from the power supply is only 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 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 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.

2.2.2.1 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 could 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.

2.2.3 Power regulation / constant power / power limiting

Power regulation, also known as power limiting or constant power (CP), keeps the DC power constant if the current flowing to the load (source mode) resp. the current from the source (sink mode) in relation to the voltage reaches the adjusted limit according to P = U * I (sink mode) resp. P = U² / R (source mode).

In source mode, the power limiter then regulates the output current according to I = sqr(P / R), where R is the load's resistance.

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).

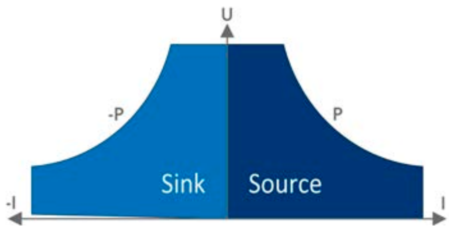


Figure 1 - Power range visualization

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.

2.2.3.1 Power derating

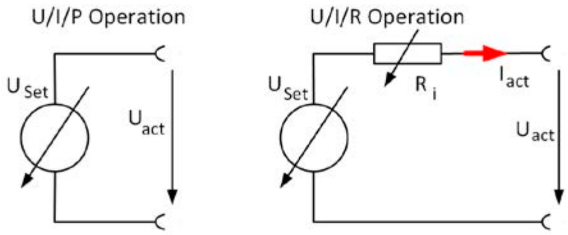
All models in this series can also operate on a three-phase supply of 208 V (USA, Japan). In order to limit the AC current when running on this low input voltage, they would switch to a derating mode which reduces the available DC power to 18 kW. The switchover is determined once when the device is powered and depends on the currently present AC supply voltage. It means that it cannot switch back and forth between derated and not derated mode during operation. The full power is thus only available with AC voltages from 380 V or higher.

Since the devices don't feature a display, the state of derating isn't indicated on the device and can only be determined by reading the rated power from the device which then would not be returned as 30000 W, but as 18000 W.

2.2.4 Internal resistance regulation (source mode)

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 limit the output voltage additionally. 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 regulation 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:



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

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

With resistance mode being activated the function generator will be unavailable and the actual power value provided by the device does not include the simulated power dissipation of Ri.

2.2.5 Resistance regulation / constant resistance (sink mode)

In sink mode, when the device is working as electronic load, the 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 formula $I_{IN} = U_{IN} / R_{SET}$, which is derived from Ohm's law.

With series PUB 10000, the difference between an external voltage supplied to the device and the set value of voltage determines the true current. There are two situations:

a) The voltage on the DC terminal is higher than the voltage set value

In this situation, the above formula extends to $\mathbf{I_{IN} = (U_{IN} - U_{SET}) / R_{SET}}$.

An example: the supplied voltage on the DC terminal is 200 V, the resistance R_{SET} is adjusted to 10 Ω and the voltage set value U_{SET} is set to 0 V. When switching the DC terminal on, the current should rise to 20 A and the actual resistance R_{MON} should show approx. as 10 Ω. When adjusting the voltage set value U_{SET} to 100 V now, the current would lower to 10 A while the actual resistance R_{MON} should remain at 10 Ω.

b) The voltage on the DC terminal is equal to or lower than the voltage set value

The PUB 10000 would not draw any current and enter CV mode. In a situation where the supplied input voltage is approx. equal to or oscillating around the voltage set value, the sink mode would permanently toggle between CV and CR. It's thus not advised to adjust the voltage set value to the same level as the external source.

The internal resistance is naturally limited between almost zero and maximum, where the resolution of current regulation becomes very inaccurate. Because the internal resistance can't have a value of zero, the lower limit is defined to an achievable minimum. This ensures that the internal electronic load, at very low input voltages, can consume a high input current from the source, up to the adjusted current set value.

While the DC terminal is switched on and constant resistance mode is active, the condition "CR mode active" can only be read via digital interface.

2.2.6 Sink-source mode switching

The switchover between sink and source mode happens automatically and only depends on the device's voltage setting and actual value on the DC terminal or the remote sense connector, if in use.

It means, that when connecting an external voltage source to the DC terminal, only the voltage set value determines the operation mode. When connecting an external load which can't generate a voltage, only source mode can be run.

Rules for applications with external voltage source connected:

- If the voltage set value is higher than the actual voltage of the external source, the device will run in source mode
- If the voltage set value is lower, it will run in sink mode

To run one of both modes explicitly, i.e. without automatic switchover, it would require following:

- for "source only mode" adjust the current set value for the sink mode to 0
- for "sink only mode" adjust the voltage set value to 0

2.2.7 Dynamic characteristics and stability criteria

When working in sink mode, the device becomes an electronic load which is characterized by short rise and fall times of the current, which are achieved by a high bandwidth of the internal regulation circuit.

In case of testing sources with own regulation circuits at the load, like for example power supplies, a regulation 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 regulation 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,** configured using remote control and SCPI or ModBus command or 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 capacity directly to the DC terminal, perhaps alternatively to the remote sense input, if connected to the source. The value to achieve the expected result is not defined and has to be found out. We recommend:

- 10/60/80 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

2.3 Remote control

2.3.1 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.

2.3.2 Remote control via digital interface

2.3.2.1 Rear USB

The rear USB port offers the same set of commands as a PSB 10000 series device, which is considered to a standard device with its display and knobs. When accessing the PUB 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_PUB10000_KEx.xx+_EN.pdf".

2.3.2.2 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?	SINK:POWer:LIMit:HIGH?
*CLS	SINK:POWer:PROTection[:LEVel]
*RST	SINK:POWer:PROTection[:LEVel]?
*ESE	SINK:RESistance
*ESE?	SINK:RESistance?
*ESR	SINK:RESistance:LIMit:HIGH
*STB?	SINK:RESistance:LIMit:HIGH?
MEASure:[SCALar:]CURRent[:DC]?	[SOURce:]CURRent
MEASure:[SCALar:]POWer[:DC]?	[SOURce:]CURRent?
MEASure:[SCALar:]VOLTage[:DC]?	[SOURce:]CURRent:LIMit:HIGH
OUTPut[:STATe]	[SOURce:]CURRent:LIMit:HIGH?
OUTPut[:STATe]?	[SOURce:]CURRent:LIMit:LOW
SINK:CURRent	[SOURce:]CURRent:LIMit:LOW?
SINK:CURRent?	[SOURce:]CURRent:PROTection[:LEVel]
SINK:CURRent:LIMit:HIGH	[SOURce:]CURRent:PROTection[:LEVel]?
SINK:CURRent:LIMit:HIGH?	[SOURce:]POWer
SINK:CURRent:LIMit:LOW	[SOURce:]POWer?
SINK:CURRent:LIMit:LOW?	[SOURce:]POWer:LIMit:HIGH
SINK:CURRent:PROTection[:LEVel]	[SOURce:]POWer:LIMit:HIGH?
SINK:CURRent:PROTection[:LEVel]?	[SOURce:]POWer:PROTection[:LEVel]
SINK:POWer	[SOURce:]POWer:PROTection[:LEVel]?
SINK:POWer?	[SOURce:]RESistance
SINK:POWer:LIMit:HIGH	[SOURce:]RESistance?

[SOURce:]RESistance:LIMit:HIGH	SYSTem:CONFig:UCD?
[SOURce:]RESistance:LIMit:HIGH?	SYSTem:CONFig:UCD:ACTion
[SOURce:]VOLTage	SYSTem:CONFig:UCD:ACTion?
[SOURce:]VOLTage?	SYSTem:CONFig:USER:TEXT
[SOURce:]VOLTage:LIMit:HIGH?	SYSTem:CONFig:USER:TEXT?
[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:MODE	SYSTem:NOMinal:RESistance:MAXimum?
SYSTem:CONFig:MODE?	SYSTem:NOMinal:RESistance:MINimum?
SYSTem:CONFig:OCD	SYSTem:NOMinal:VOLTage?
SYSTem:CONFig:OCD?	SYSTem:SINK:ALARm:COUNt:OCURrent?
SYSTem:CONFig:OCD:ACTion	SYSTem:SINK:ALARm:COUNt:OPOWer?
SYSTem:CONFig:OCD:ACTion?	SYSTem:SINK:CONFig:OCD
SYSTem:CONFig:OPD	SYSTem:SINK:CONFig:OCD?
SYSTem:CONFig:OPD?	SYSTem:SINK:CONFig:OCD:ACTion
SYSTem:CONFig:OPD:ACTion	SYSTem:SINK:CONFig:OCD:ACTion?
SYSTem:CONFig:OPD:ACTion?	SYSTem:SINK:CONFig:OPD
SYSTem:CONFig:OUTPut:RESTore	SYSTem:SINK:CONFig:OPD?
SYSTem:CONFig:OUTPut:RESTore?	SYSTem:SINK:CONFig:OPD:ACTion
SYSTem:CONFig:OVD	SYSTem:SINK:CONFig:OPD:ACTion?
SYSTem:CONFig:OVD?	SYSTem:SINK:CONFig:UCD
SYSTem:CONFig:OVD:ACTion	SYSTem:SINK:CONFig:UCD?
SYSTem:CONFig:OVD:ACTion?	SYSTem:SINK:CONFig:UCD:ACTion
SYSTem:CONFig:UCD	SYSTem:SINK:CONFig:UCD:ACTion?

2.3.2.3 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.

2.3.3 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 message coming. In case it runs out, 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

2.3.4 Remote control via the analog interface

2.3.4.1 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 terminal)
- Remote alarm monitoring (OT, OVP, PF, OCP, OPP)
- Remote monitoring of actual values
- Remote on/off switching of the DC terminal

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 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 (solder bridge or different), so it gives 100%
- Switching between sink and source mode can only be done with the voltage level on pin VSEL. Also see example d) in *2.3.4.7*.

2.3.4.2 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.

2.3.4.3 Analog interface specification

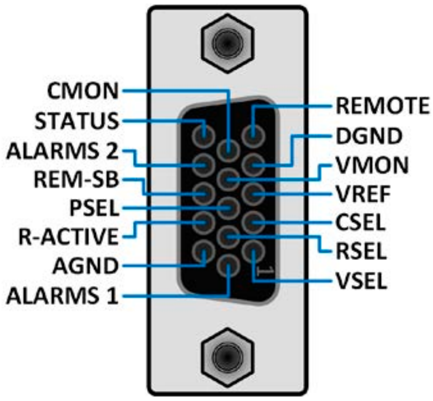
Pin	Name	Type [1]	Description	Default levels	Electrical specifications
1	**VSEL**	AI	Voltage set value	0...10 V or 0...5 V correspond to 0..100% of U_{Nom}	Accuracy 0-5 V range: < 0.4% [5] Accuracy 0-10 V range: < 0.2% [5] Input impedance R_i >40 k...100 k
2	**CSEL**	AI	Current set value (source & sink)	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	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 $U_{LOW\ to\ HIGH\ typ.}$ = 3 V Rec'd sender: Open collector against DGND
13	**REM-SB**	DI	DC terminal OFF (DC terminal 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 regulation active	CV = LOW, U_{Low} <1 V CC/CP/CR = HIGH, U_{High} >4 V	
			DC terminal	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 terminal of the device

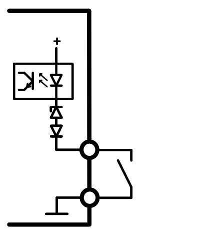
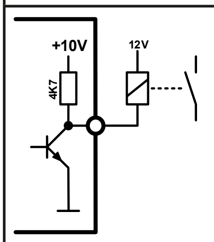
2.3.4.4 Resolution

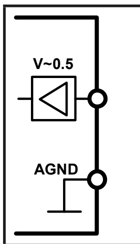
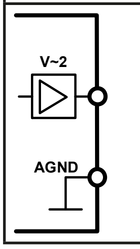
The analog interface is internally sampled and processed by a digital microcontroller. This causes a limited resolution of analog steps. The resolution is the same for set values (VSEL etc.) and actual values (VMON/CMON) and is 26214 for 0...100% when working with the 10 V range. In the 5 V range this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

2.3.4.5 Overview of the D-sub socket



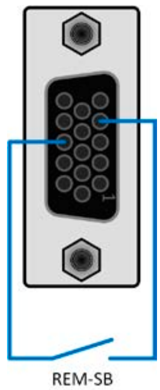
2.3.4.6 Simplified diagram of the pins

	**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 specifications table above.

2.3.4.7 Application examples

a) Switching the DC terminal 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 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 *2.3.4.3.* 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 has not been activated**

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

DC terminal	✚	Level on pin REM-SB	✚	Parameter „REM-SB Level“	➔	Behavior
is off	✚	HIGH	✚	**Normal**	➔	The DC terminal 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 terminal 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.
		LOW	✚	**Normal**		

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

DC terminal	✚	Level on pin REM-SB	✚	Parameter „REM-SB Level“	➔	Behavior
is on	✚	HIGH	✚	**Normal**	➔	The DC terminal 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 in source mode

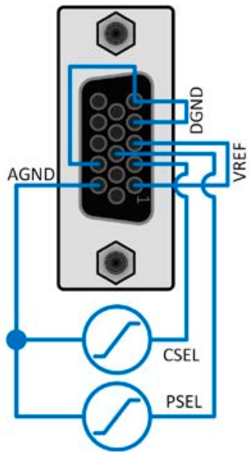
Requires remote control to be activated (pin REMOTE = LOW)

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.

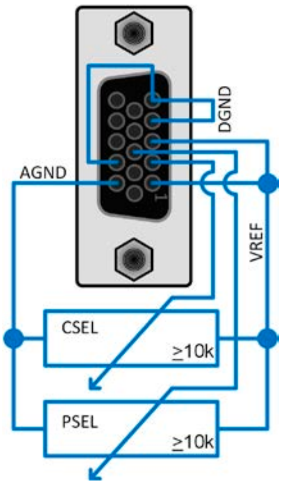
The voltage set value VSEL is directly connected to VREF and will thus be permanently 100%. This also means that the device can only work in source mode. R-ACTIVE is tied to DGND, so resistance mode is off.

If the control voltage is 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.*



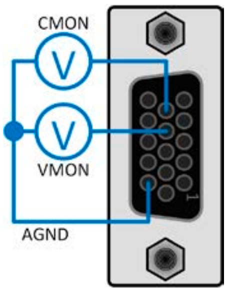
Example with external voltage source



Example with potentiometers

c) Reading actual values

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



d) Switching between source and sink mode

You can also switch between both modes when remotely controlling the device with the AI. This is done using the voltage set value (VSEL), which then must not be tied to a fixed potential, like shown in example b). Rules:

- If the voltage set value on VSEL (in %, not the level) becomes higher than the actual voltage on the DC terminal, the device will switch to sink mode, no matter if the voltage on the DC terminal is generated by the device or from external
- If the voltage set value becomes lower than the actual voltage, the device will switch to source mode.

e) Determining the actual operation mode between source and sink

The limited number of pins on the AI doesn’t allow for a separate signal to indicate sink or source mode. There are basically two ways to determine the actual mode:

- Compare the actual voltage output (VMON) with VSEL and also read the CMON signal -> if the level of VMON is higher than VSEL and CMON isn’t zero, then the device is in sink mode, otherwise if VMON is equal to or lower than VSEL, it’s in source mode, no matter what the level of CMON is
- Configure pins 9 (VMON) and 10 (CMON) either via SCPI/ModBus command or in the Settings app of **EA Power Control** under **Analog interface->VMON/CMON** to **Mode A** or **Mode B** and read both pins; when DC current is flowing in any of both directions, one of the pins will indicate with a level > 0 V.

3. Other applications (2)

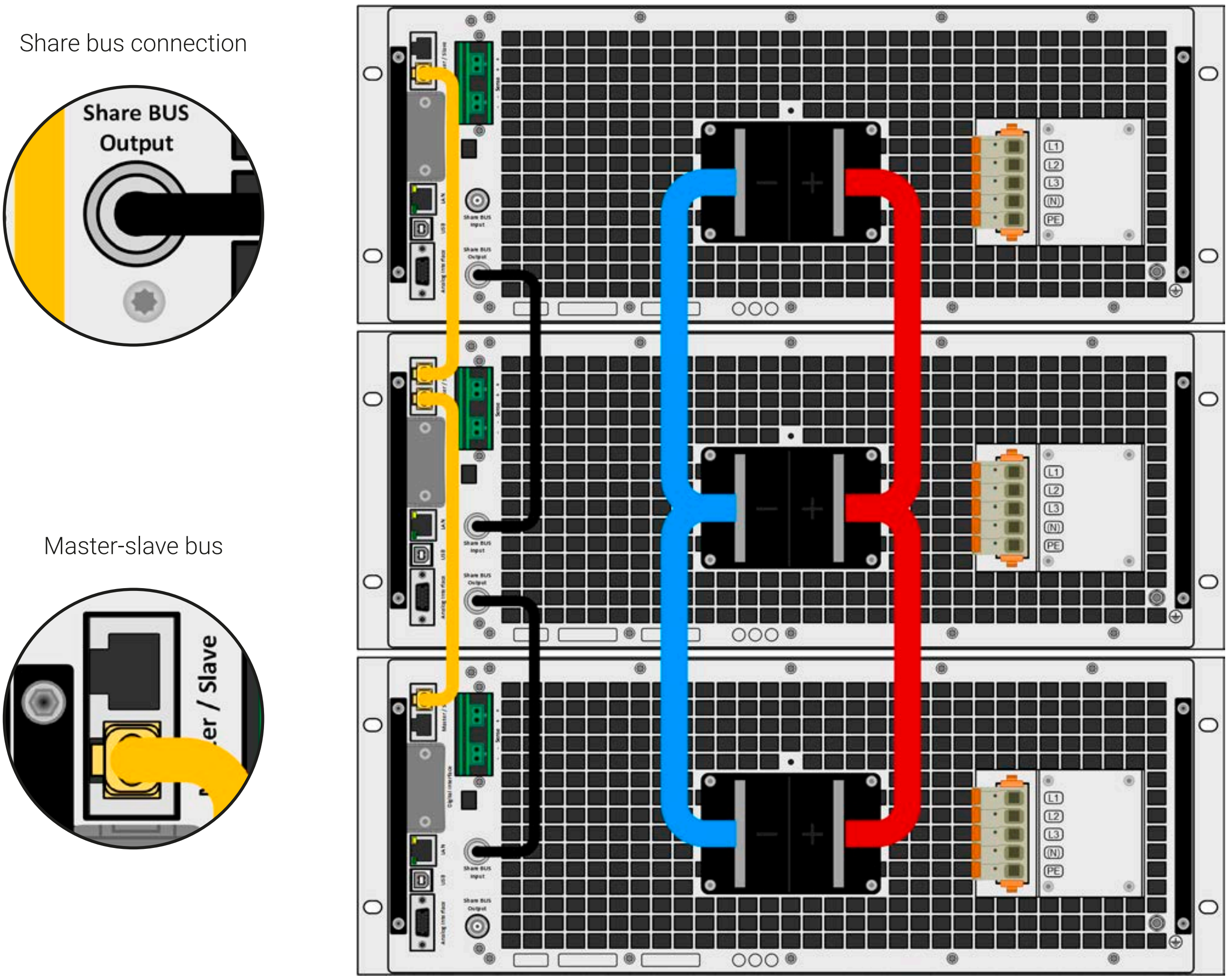
3.1 Parallel operation in master-slave (MS)

The primary and intended form of operation for 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 hence 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 terminal, i.e. in CV mode, especially if the master unit runs a dynamic 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 load or source):



3.1.1 Restrictions

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

- The MS system reacts partly different in alarm situations (see below in *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 PSB 10000 or PSBE 10000 series

3.1.2 Wiring the DC terminals

The DC terminal 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.

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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 and set-up of the digital 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. bidirectional power supply to bidirectional power supply; 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.) and user events (UVD etc.) of the master are adapted to the total number of units. Thus, if e.g. 5 units each with a power of 30 kW are connected to a 150 kW system, then the master can be set in the range 0...150 kW.
- Slaves are no 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 PUB 10000 series in connection with PSB 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

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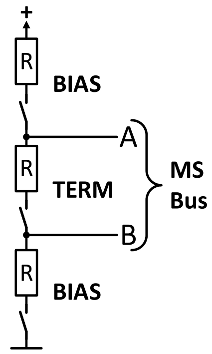
3.1.6 Configuring the master-slave operation

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 digital interfaces. 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. Following applies generally:

- 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 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 terminals 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 do not 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 pop-up screen (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 accidentally multiple or no 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 between the units, it can occur that one unit generates an OCP alarm though the global OCP limit of the MS system was not reached. The same can occur with the OPP alarm.

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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. PUB 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, usually a PSB 10000, it may not yet have this feature. It also cannot be retrofitted.

SEMI F47 specifies a AC supply voltage sag in steps of 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), so it could not 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. power (21000 W or 70%), compared to the rated power of the particular model, thus SEMI F47 is also a sort of derating, but it's not depending on the line voltage but what the AC input circuit (PFC) can cover without running into a power fail. This reduced power rating is activated and deactivated together with SEMI F47

3.2.2 Adjustments

SEMI F47 can be activated/deactivated only via digital interface and only in software **EA Power Control**, unless blocked due to the current device state.

3.2.3 Application

The feature can be activated at any time, unless blocked for the current device, for example when power derating is already active (see *2.2.3.1*). When activating it during normal operation, the device will instantly reduce the max. available power, as well as adapt the power set values, should the adjusted ones be higher than the new maximum. When deactivating the feature it works vice versa, only the power set values remain unaltered then. Due to the fact that the setting is stored beyond shutting down the device, it could directly boot into SEMI F47 mode during next start. In case of PUB 10000 this isn't indicated at all on the control panel, so it looks like if the device has booted normally. The status can, however, be read via any digital interface.

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 it would show 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 side 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, be advised 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.

Following also applies in connection with firmware updates:

- Simple changes in firmwares can have crucial effects on the application the devices are use in. We thus 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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