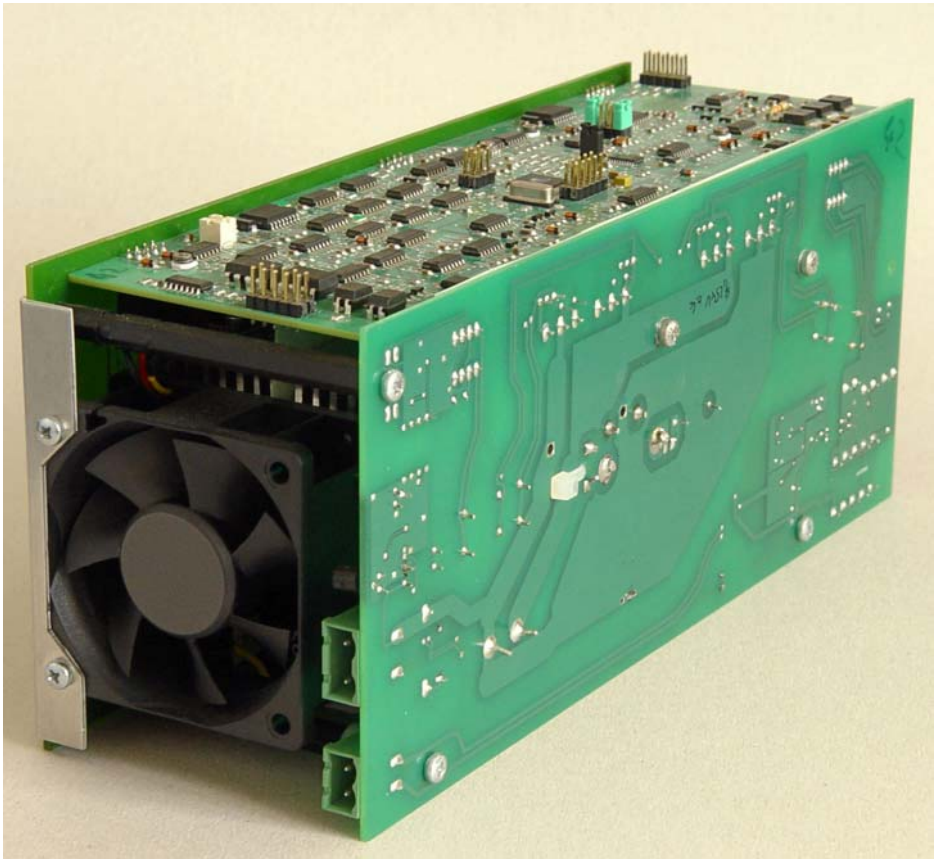
FLEXIVA

User Manual



PM3K030 PM3K045 PM3K060 PM3K120

Bidirectional 2.5 kW DC/DC Converter Module

Article No.: BNH-PM3Kxxx
Edition/Review date: 27.03.2015

Preface

This technical documentation shall provide an appropriate manipulation of the DC/DC Converter modules PM3Kxxx. The modules serve the purpose of bidirectional transformation of direct current voltages.

The instruction handbook should be preserved.

Texts, diagrams and tables shall neither be copied nor reproduced nor shall they be made available to third parties without our express authorisation.

We are also pointing out that this technical documentation is not part of an existing or previous agreement or consent or part of a legal relationship.

All obligations and liability result from the sales contract that also, solely contains the guarantee regulation. The contractual provisions are not affected by the technical documentation.

The documentations of the sub-suppliers are also effective to this documentation of the manufacturer.

As a supplement to this instruction handbook, all the universally valid legal and other binding regulations with respect to prevention of accidents and on environmental protection shall be respected and instructed.

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Table of Contents

Table of Figures

Table of Tables

1 Introduction

In order to ensure the operator's safety as well as to avoid possible damages on the module, it must be unconditionally assured, before utilisation of the module or facility connected thereto, that this user manual is completely read.

The present user manual shall thereby help to better understanding of the DC/DC module as well as to be able to appropriately make use of the application/employment possibilities in accordance with the regulations.

The operating personnel shall be very acquainted with all the components before start of operation. Special attention shall be paid to the section safety.

The present user manual contains important information on the proper and economical utilisation of the DC/DC-Module. Observation of these instructions shall contribute to avoidance of danger, reduction of repair and maintenance costs as well as reduction of the breakdown periods, and an increase in the lifespan of the module.

In the chapters of this manual there are some symbols at the margins. These symbols refer to function of the corresponding text paragraph, and are of importance with respect to the operation or maintenance. They refer to important descriptions or remarks:

Danger

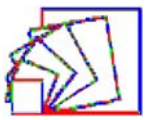
All sections in this technical documentation that contain indications of possible dangers or hazards shall be characterised with the adjoining symbol.
Non-observance can lead to severe injuries! The instructions must be strictly followed.

Caution!

All sections with this symbol give hints on avoidance of damages on the equipment.

Information

Sections with this symbol give important information on an effective utilisation.



The work steps that have been illustrated in logical sequence at the side of this symbol instruct the operator on the most ergonomical procedure of the operation.

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2 Identification

2.1 Product Trademark and Type Designation

ZEMIS® PM3Kxxx

2.2 Product Versions / Version of Software / Editing Status

Product Versions:	PM3K030
	PM3K045
	PM3K060
	PM3K120
Firmware:	01.14
Status:	2015

3 Product description

3.1 General information / Utilisation in accordance with the regulations

The DC/DC converter module serves the purpose of interconnection, through a DC-Link, between different sources, drains and storage elements of electrical energy with different operation voltage ranges between 12V and 120V. It possesses an electrical isolation, high degree of efficiency, flexible control as well as a digital interface. A simple connection of a 230V alternating current network is possible due to the DC-Link voltage of 375V.

Terms and definitions and abbreviations

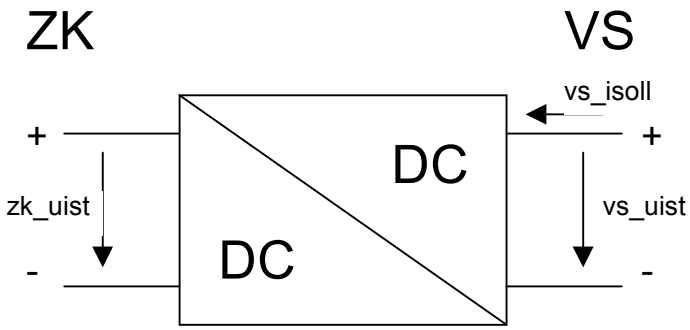

Fig. 1: Principle

ZK: Prefix: _zk	DC link – this is the designation for the side of the module by means of which the coupling with other DC/DC modules or the link of any other 380V DC component (e.g. inverter) can be carried out.
VS: Prefix: _vs	Variable voltage – this is the designation for the side of the module to which the components are connected. The designation output is also used but it is not quite correct because of the bidirectional mode of functioning.
Step-up operation:	Designates the power flow from the variable voltage side to the DC link side. The sign of the current (vs_isoll) is positive.
Step-down operation:	Designates the power flow from the DC link side to the variable voltage side. The sign of the current (vs_isoll) is negative.

3.2 Technical Information and Data

General characteristics

Bi-directional power flow:	yes
Parallel connection:	yes
Galvanic isolation: (ZK vs. VS)	yes

Performance data

Rated power:	2.5 kW	
Voltage and current ranges (type-specific):		
PM3K030:	0*…30V DC	-100...0...100A
PM3K045:	0*…45V DC	-75...0...75A
PM3K060:	0*…60V DC	-50...0…50A
PM3K120:	0*…120V DC	-25...0...25A
DC link voltage:	365…385V DC	
Control interface:	USART (CMOS 5V); galvanic isolated	
Digital outputs:	3 x 0…5 V (current limited with 330Ω)	
Digital inputs:	3 x 0...5 V (CMOS-level)	
Analogue inputs:	2 x 0…10 V (internal resistance 55kΩ)	
Auxiliary power supply:	12…30V DC, 10W; galvanic isolated	
Own consumption:	standby: max. 5W during operation: max. 10W	
Cooling:	forced air cooling (temperature-controlled fan)	
Efficiency:	> 90 %	
Accuracy:	better than ± 3 % of full scale	

*See chapter 5.1.11

Ambient conditions

Ambient temperature range:	-20…50°C (during operation)
Degree of protection:	IP 00
Maximum humidity:	up to 90% (non-condensing)
Pollutants:	The environment must not contain larger quantities of dust, in particular no metal or graphite dust.

Housing

Design:	open frame
Dimensions :	230 mm x 85 mm x 105 mm
Weight:	approx. 1.9 kg

Scope of delivery

- DC/DC-module PM3Kxxx (pre-parameterized)
- Data disk (CD)
- Software for visualisation and parameterization (on CD)
- User manual (on CD)

Optional

- Device system for max. 4 modules (variants on request)
- Pre-parameterization according to the planned application

3.3 Power Connectors

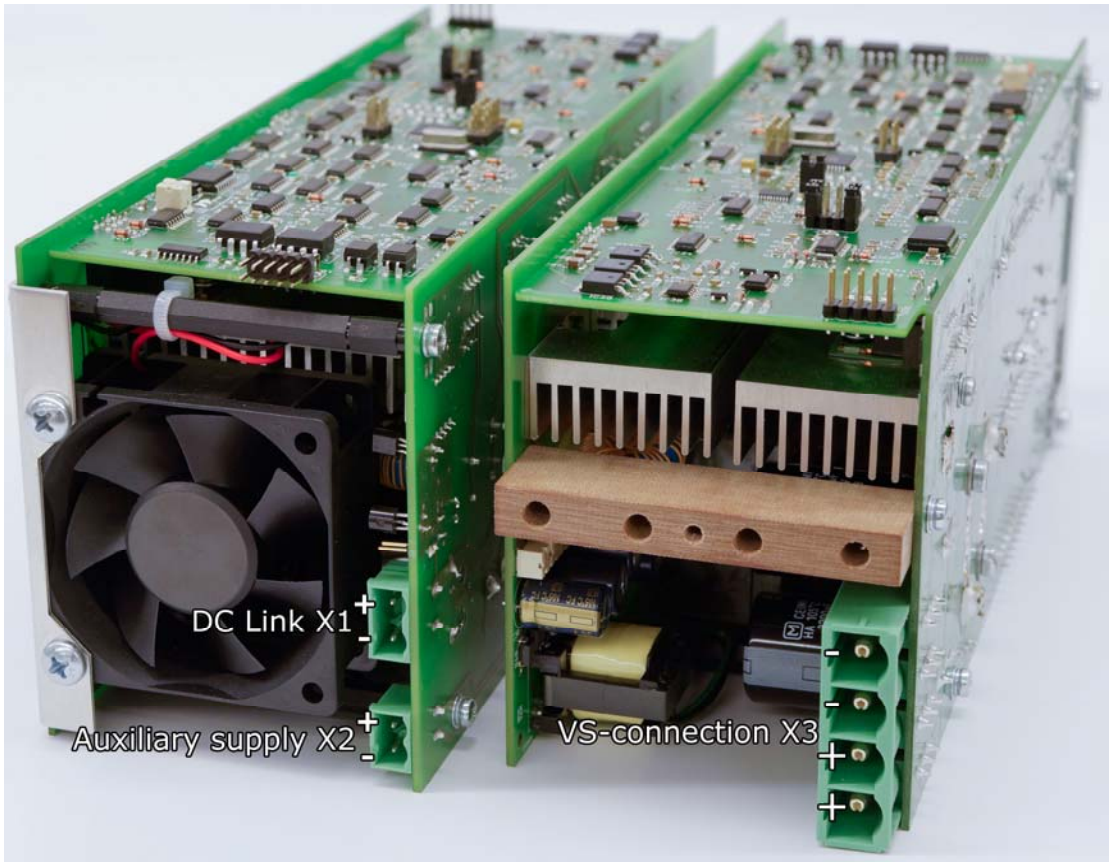

Fig. 2: Power connectors

X1: ZK-connection – DC Link

- Connector with clamp; maximum 2.5mm²

X2: Auxiliary power supply

- Connector with clamp maximum 2.5mm²
- The module requires an auxiliary power supply 12...30V approx. 10W during operation, approx. 5W stand by.
- Isolated onto the VS-side, tested with 600V DC; onto the ZK-side, tested with 6kVp

X3: VS-connection – variable voltage

- Cooling element – facing side is negative terminal
- Connector with clamp; maximum 16mm² (4x)

3.4 Signal connectors

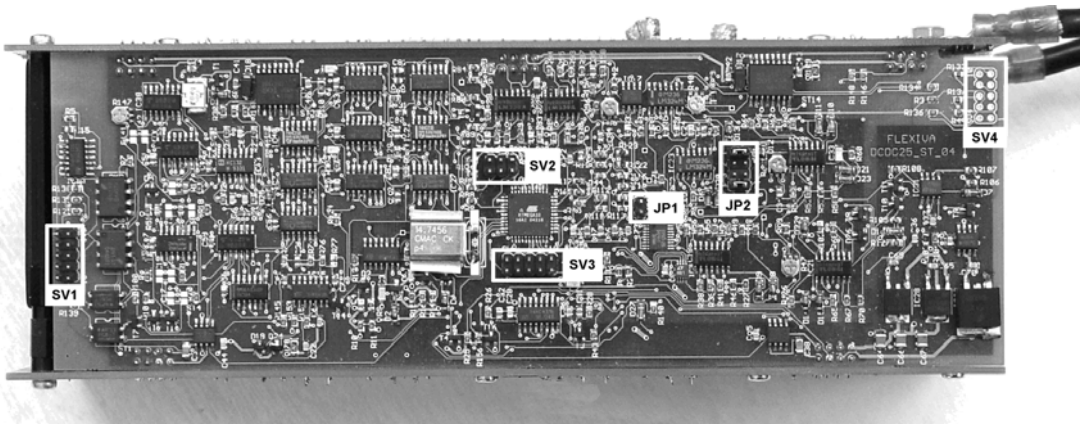

Fig. 3: Signal connectors

JP1: Write protection electronic potentiometer

Jumper JP1 must be position in order to be able to describe/write the electronic potentiometer for over current disconnection and over voltage /under voltage disconnection, on the side of the hardware (Default: Jumper is closed).

JP2: Allocation power limits

The current limits can be fixed with the help of the jumper field JP2. There are 3 possibilities hereto:

- Upper and lower limits of the electronic potentiometer (lower value negated) – Jumper JP 2.1 and JP2.4 (Default)
- Upper limit of the electronic potentiometer, lower 0 (only set-up operation possible) – Jumper JP2.1 and JP2.3
- Lower limit of the electronic potentiometer (negated), upper 0 (only set-down operation possible) – Jumper JP2.2 and 2.4

SV1: Communication interface

Communication with the module takes place via an optically isolated serial interface. A supply voltage of 5V (approximately 30mA) shall be provided for the control of the optocoupler. The signals RXD and TXD can be switched on with the help of SELECT, in order to activate several modules by a simple method. If SELECT is low, TXD will be highly resistive and RXD shall receive no signals. Hence, in case of utilisation of

several modules, the RXD and TXD lines can be switched on parallel, and the module currently activated can be selected with the aid of SELECT. All signals at this interface are on 5V CMOS level. That means for connection with a PC a level converter is necessary. An example is shown in the appendix.

Data rate: 115200bps,

Format: 8bit+1 Stop bit

The signals OC_OK and OC_EN are provided for an additional safety feature: OC_OK shall be low if the DC-Link voltage exceeds the upper limit. Hence a module can inform all the others when this event occurs, whereby all the OC_OK signals are AND linked and OC_EN added. Through this means, it is then possible to avoid large scale damages during breakdown of the DC-Link voltage measuring amplifier.

Pin	abbreviation	Explanation
1	GND	Ground
2	VCC	+5 V
3	OC_OK	H: no ZK-over voltage
4	NC	Not used
5	NC	not used
6	SELECT	H: Serial interface activated L: Serial interface deactivated
7	OC_EN	H: Module enabled
8	RXD	Input data
9	NC	not used
10	TXD	Output data

Tab. 1: Pin-configuration SV1

SV2 / SV3: Service interfaces

SV2 and SV3 are programming connections for the micro controllers of the modules. They are not required for the operation and have to be left a lone.

SV4: External signal inputs / signal outputs

The module is equipped with additional inputs and outputs. These are 3 digital inputs, 3 digital outputs and 2 analogue inputs, in order, either to collect data from connected components or to operate the module by means of the applied signals on these inputs.

The ground of these connections is connected to the power ground of the VS – side. A direct connection of these two grounds should not be carried out, else a ground loop shall be produced and this will lead to malfunctioning and destruction of the module or the components connected thereto.

Digital inputs: 0...5 V CMOS-level, rather not protection-wired

Digital outputs: 0…5 V, power limited with 330Ohm-resistance

Analogue inputs: 0..10 V ⇔ 0..1000, internal resistance 55kOhm

Pin	Abbreviation	Explanation
1	GND	Ground
2	DO2	Digital output 2
3	AIN1	Analogue input 1
4	DO1	Digital output 1
5	AIN2	Analogue input 2
6	DI3	Digital input 3
7	VCC	+5 V
8	DI2	Digital input 2
9	DO3	Digital output 1
10	DI1	Digital input 1

Tab. 2: Pin-configuration SV4

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3.5 Safety information

The DC/DC converter module was designed and manufactured according to recognised regulations and provisions of technology, and came under safety test scrutiny before delivery.

There is however danger for persons and for the DC/DC converter module itself, in case of faulty operation.

Every person, who installs, operates or carries out maintenance on the module must:

1. read and particularly respect the instructions in this user manual
2. must be trained for this function and be well instructed

Protection rating II

Test voltage between the ZK-Side and all the other potentials 6kVp

Test voltage between auxiliary power supply and the VS-side 600Vp

3.5.1 Safety measures during installation

In order to ensure a trouble-free operation and to obtain durability of the electronic components, heat accumulation shall be avoided, especially on the front side of the module (ventilator and opposite side). The installation location must be appropriately chosen, so that the module can be adequately ventilated or aerated during operation.

Caution!

The cooling elements are connected to potentials, i.e. it is not permitted to touch them!

3.5.2 Residual dangers

The described product meets the technological standards and the recognised technical safety provisions. However danger might still occur.

The possible residual dangers in connection with the operation of the module that might occur, can originate through:

- Utilisation of electrical / electronic components (sources, drains, storage or accumulators) of the third party supplier.
- Electricity itself

The effective specifications and safety instructions of all the corresponding components mounted hereby, with respect to the operation and installation or mounting location must be respected and followed.

3.5.3 Skills and qualification of the operating staff

Placing into operation and the connection of the module shall be carried out only by persons who have undergone professional training in electro-technics or electrical engineering and who are in position to carrying out the power connections professionally.

Basic knowledge of PCs and handling of the current WINDOWS operating system is necessary for the utilisation of the delivered software in the scope of delivery. Details in this respect are found in the enclosed comprehensive programme description.

4 Preparation/priming of the product for application

4.1 Transportation

During transportation the module shall not be exposed to vibrations, intense agitations as well as thrust, else this might possibly lead to damages of the sensible components.

4.2 Packaging

Basically, appropriate, proper and environmentally friendly packaging materials shall be used for transportation and consignment.

Due to the fact that the module itself possesses a degree of protection IP00, a transport package that averts infiltration of water, dirt and dust must be selected. Positioning of conventional dehumidification materials in the package is recommended. .

4.3 Storage

Permanent or long-lasting storage: closed rooms, dry, room temperature

4.4 Initial operation

The following conditions must be ensured and checked before initial operation:

- The professional installation and layout of all the necessary electrical connecting cables as well as the correct connection of all the components to the module.
- The acknowledgement of the instructions and guidelines of this user manual.

4.4.1 Connection DC-Link (ZK)

- The diameter of the conductor/wire must be chosen in accordance with the anticipated electric current, 1.5mm² is recommended.
- Take note of the polarity

4.4.2 Connection variable voltage (VS)

- The diameter of the conductor/wire must be chosen in accordance with the anticipated electric current.

- Take note of the polarity
- Conductors or wires must be provided with thimble or cable lugs and fixed by means of M5 screws, appropriate screw nuts and two washers or grommets.

4.4.3 Setting module into operation

1. Read this documentation!
2. Install auxiliary power supply
3. Parameterise
4. Install DC-Link and/or variable voltage
5. Switch on

5 Operation

5.1 Mode of operation

The DC/DC converter module can bi-directionally transfer power between DC-Link with a voltage of 350V…400V and a side with variable voltage. An extensive or comprehensive parameterisation is necessary due to the fact that several degrees of freedom arise thereby. In order to attain maximum flexibility hereby, the adjustment of the DC-Link voltage and the output voltage shall be realised digitally.

A PIDT1 control system exists for the DC-Link and the output (each) respectively. They are differently connected according to the operation mode. The output value of this connection shall be restricted by the corresponding maximum value and transmitted to the hardware by means of the DAC (vs_isoll). Furthermore, the I-units of the control systems shall also be restricted during the limitation, so that they can not run up to the maximum value. They will be held at the boundary value so that a change over from one control system to the other can take place without interruption.

5.1.1 Operation modes

Two possibilities are possible for the connection of the output values of the output voltage regulator and the DC-Link voltage regulator (Isoll_V, Isoll_Z).

In the operation mode 0, a maximum value shall be applied in both control systems. This is suited for operation as an output converter, i.e. power only flows out of the module into a load or for utilisation by a buffer, e.g. of a double-layer capacitor/condenser or accumulator/storage battery. The connection of the control system functions as follows: If the DC-Link voltage is higher than its regulated desired value, the output voltage control system will be active, and maintains vs_uist constant. If the voltage of the DC-Link now drops, the DC-Link voltage control system then wins control and tries to keep the DC-Link voltage constant. Hence the following characteristics arise for this operation mode:

- The output voltage shall be limited upwards, this, for example avoids overcharge of the buffer.
- The DC-Link voltage shall be limited downwards, and this hinders breakdown of the DC-Link in the case of a bigger load.

Voltages	Tendencies	mod_opmode=1	mod_opmode=0
zk_uist < zk_usoll vs_uist < vs_usoll	Isoll_Z ↑ Isoll_V ↓	vs_isoll ↓	vs_isoll ↑
zk_uist > zk_usoll vs_uist < vs_usoll	Isoll_Z ↓ Isoll_V ↓	vs_isoll ↓	vs_isoll ↓
zk_uist < zk_usoll vs_uist > vs_usoll	Isoll_Z ↑ Isoll_V ↑	vs_isoll ↑	vs_isoll ↑
zk_uist > zk_usoll vs_uist > vs_usoll	Isoll_Z ↓ Isoll_V ↑	vs_isoll ↓	vs_isoll ↑

Tab. 3: Behavior in the modes of operation

In the operation mode 1 the minimum value of both control systems shall be used as electricity default value. This is favourable for the connection or coupling of sources e.g. a fuel cell. In this operation mode, it is being avoided that the output voltage exceeds the desired value and thereby, for instance, causing damages to the fuel cell. In normal cases the DC-Link voltage control system is in operation and maintains the DC-Link voltage constant. The output voltage control system shall be active and shall reduce the current so that the desired value can not be undershot, only when the output voltage falls below the desired value.

Parameter: mod_opmode													
Bit								Dec	Hex	Operation mode	Imax	Imin	UsollVS
7	6	5	4	3	2	1	0						
0	0	0	x	0	0	0	0	(16) 0	(0x10) 0x00	Output/buffer	SI	SI	SI
0	0	0	x	0	0	0	1	(17) 1	(0x11) 0x01	Input	SI	SI	SI
0	0	0	x	0	0	1	0	(18) 2	(0x12) 0x02	Output/buffer	SI	AIN1	AIN2
0	0	0	x	0	0	1	1	(19) 3	(0x13) 0x03	input	SI	AIN1	AIN2
0	0	0	x	0	1	0	0	(20) 4	(0x14) 0x04	Output/buffer	AIN1	SI	AIN2
0	0	0	x	0	1	0	1	(21) 5	(0x15) 0x05	input	AIN1	SI	AIN2
0	0	0	x	0	1	1	0	(22) 6	(0x16) 0x06	Output/buffer	AIN1	AIN2	SI
0	0	0	x	0	1	1	1	(23) 7	(0x17) 0x07	input	AIN1	AIN2	SI
0	0	0	x	1	0	0	0	(24) 8	(0x18) 0x08	Output/buffer	SI	SI	AIN1
0	0	0	x	1	0	0	1	(25) 9	(0x19) 0x09	input	SI	SI	AIN1
0	0	0	x	1	0	1	0	(26) 10	(0x1A) 0x0A	Output/buffer	AIN1	SI	SI
0	0	0	x	1	0	1	1	(27) 11	(0x1B) 0x0B	input	AIN1	SI	SI
0	0	0	x	1	1	0	0	(28) 12	(0x1C) 0x0C	Output/buffer	SI	AIN1	SI
0	0	0	x	1	1	0	1	(29) 13	(0x1D) 0x0D	input	SI	AIN1	SI
x	x	x	1	x	x	x	x			Digital inputs/outputs for operation			
x	0	1	x	x	x	x	x			Automatic mode, VS priority			
x	1	1	x	x	x	x	x			Automatic mode, ZK priority			
1	x	x	x	x	x	x	x			ZK under/over voltage regulator			
										SI: serial interface AIN?: analogue inputs			

Tab. 4: Operation modes

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5.1.2 ZK-under-/overvoltage regulator

From firmware 1.03 on there is a 2nd ZK- voltage regulator integrated. This regulator is a simple P-regulator. It limits the current at voltages above 385V in step up direction. At voltages below 365V it limits the current in step down direction.

The ZK- voltage regulator can be enabled by means of bit 7 of the parameter mod_opmode.

100% means the maximal module current

U>=365V : Imin=100%

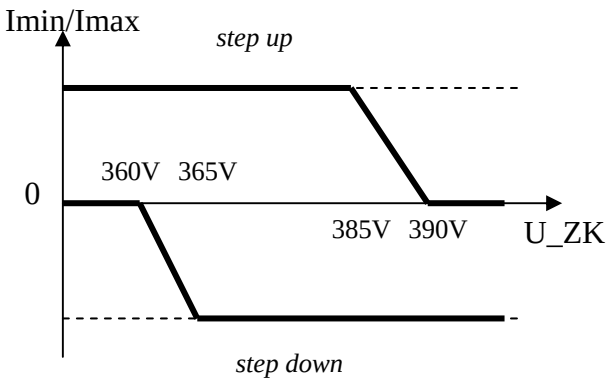
360V<U<365V: Imin=(U-360V)/5V*100%

U<=360V : Imin=0

U<=385V : Imax=100%

385V<U<390V : Imax=(390V-U)/5V*100%

U>=390V : Imax=0



5.1.3 Automatic mode

From firmware 1.03 on there is an automatic mode integrated.

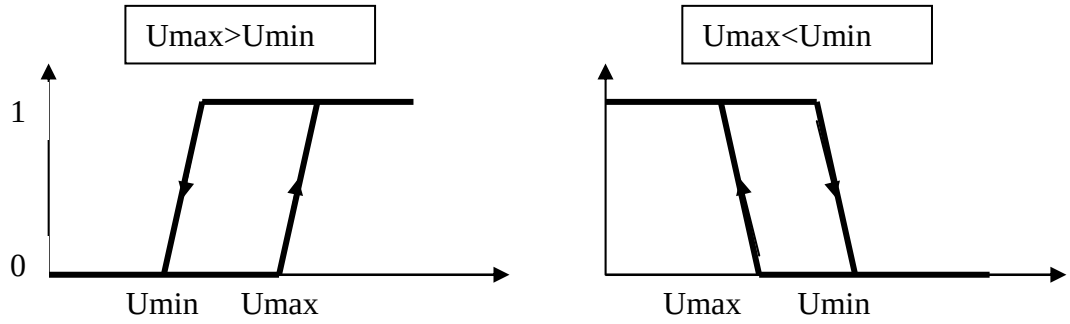
This mode automatically switches the module on or off in the dependency of the VS- and the ZK-voltage.

This automatic mode can be enabled by means of bit 5 of the parameter mod_opmode.

The on-/off- set points are set with the parameters zk_umax_g, zk_umin_g, vs_umax_g and vs_umin_g, where the …umax… are the switching on set points, the …umin…are the switching off set points.

Two operating modes are possible. If …umax…>…umin…, the module is switched on if the voltage exceeds …umax… and is switched off if the voltage is below …umin… . This mode can be used for switching off the module in the case of under voltage shutoffs.

If …umax…<…umin…, the module is switched on if the voltage is below …umax… and is switched off if …umin… is exceeded. This mode can be used for switching off the module in the case of charging end shutoffs.



Because the modes of the ZK- and the VS- voltage can be used at the same time, a priority must be determined.

Bit 6 of the parameter mod_opmode is used to determine, whether the VS side or the ZK site has the prior. If bit 6 is 0, the VS side has the prior. If bit 6 is 1, the ZK side has the prior.

Priority VS: Bit 6 = 0

comparison ZK	**ON**	**x**	**OFF**
comparison VS			
ON	ON	ON	ON
x	ON	x	OFF
OFF	OFF	OFF	OFF

Priority ZK: Bit 6 = 1

comparison ZK	**EIN**	**x**	**AUS**
comparison VS			
ON	ON	ON	OFF
x	ON	x	OFF
OFF	ON	OFF	OFF

In the automatic mode all errors are resetted automatically after 3 seconds.

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5.1.4 Operation without a digital interface

Besides parameter transmission through the serial interface, the input of the desired values can also be carried out via the analogue inputs. The corresponding operation mode (Tab. 4) shall be selected for this purpose. The valued are thereby scaled as follows:

- Voltages: 0V ≙ min, 10V ≙ max
- Electricity/currents: 0V ≙ -max, 5V ≙ 0, 10V ≙ +max

It is also possible to operate the module via the digital inputs and outputs (Tab. 5). Hereto Bit 4 shall be set in the parameter mod_opmode (values in brackets in Table 4).

Interface/connection		Function	
DO1	Doutj	State of operation	L: off H: on
DO2	Doutk	Error	H: Error
DO3	Doutl		
DI1	Dina	On	H: on
DI2	Dinb	Reset error	H: Reset (edge)
DI3	Dinc		

Tab. 5: I/O-Special configurations

5.1.5 Parallel connection of modules on the VS-side

For the enhancement of the performance, it is possible to interconnect several DC/DC converter modules on the VS side. However, this interconnection has the following disadvantages: Due to the fact that PI-regulators are used, the output voltage is regulated at exactly the desired or obliged value. In case of two DC/DC converters connected in parallel, there are constantly minor differences in the voltage frequencies, such that a DC/DC converter always takes over the full load until its current/electricity limit is attained. This is disadvantageous because the degree of efficiency of the DC/DC converter merely lies in the average range of performance, i.e. the highest level it can achieve.

This problem can be solved by a drop in the voltage/current characteristic. Principally, this is already existing through the resistances of the connecting cables, but just too small. The decreasing characteristic curve can be attained, by a simple means, through a P-regulator for the output voltage. This is disadvantageous here due to the digital control system, because high quantization skips/jumps of the obliged current value will occur as a result of the high necessary amplifications. Therefore the following configuration/arrangement is advantageous:

A PI-regulator shall be employed here as a control system. A multiplex of the current/electricity value that has been smoothed beforehand by means of a PT1

element with a relatively long time constant or delay time shall be added to the obliged voltage value. The structure then exhibits a similar characteristic similar to that of a voltage source afflicted with internal resistance that is over pressed with a big capacitor. This functionality is already provided through the parameter vs_fkkp and vs_fkkt.

5.1.6 Virtual capacitor

With the parameter setting for the functionality of the virtual capacitor, the module can thereby be parameterised that the output voltage can be represented or mapped to desired value of the DC-Link voltage. For instance, if one connects a double layer capacitor to the output of a module, the voltage of the capacitor changes with respect to the charging condition of this capacitor. This shall be detected by the module, and can be furnished/endued with an offset (zk_vcko), will then be amplified (zk_vckp) and eventually filtered (zk_vckt) (Fig. 4).

5.1.7 Safety disconnection

The DC/DC converter module possesses, beside the already mentioned cross-linked DC-Link voltage monitoring system, additional safety disconnections on the side of the hardware.

Altogether the following are available:

- Disconnection in case of excess temperature
- Disconnection in case of under-voltage on the VS-side
- Disconnection in case of over-voltage on the VS-side
- Disconnection in case of over-current on the VS-side
- Disconnection in case of over-voltage on the DC-Link

In the case of disconnection due to excess temperature, the temperature of the cooling element and that of the converter are monitored. Disconnection takes place if the temperature of the cooling element or that of the converter is more than 93 °C.

The output voltage is being monitored with respect to overstepping or undershooting of a limit value. Disconnection as a result of over-voltage serves the purpose of protecting the batteries or fuel cells in case of failure or malfunctioning of the control system. Disconnection is activated at an overstepping or an undershooting of the limit value by approximately 3%.

Over-current disconnection is also activated in case of failure or malfunctioning of the control system.

The limit values for over-current or over-voltage disconnection are stores in an electronic potentiometer. However, these values are assumed or taken-over in this device only after the module has been switched off and switched on once more or re-started. The jumper JP1 must be set during this process.

All the errors shall be deviated into the variable mod_state and must be acknowledged and therewith reset or re-initialised. This is implemented by setting err_quit to 1.

Parameter: mod_state												
Bit								Dec	Hex	State	Reaction of the System	Restart, when error is eradicated
7	6	5	4	3	2	1	0					
0	0	0	0	0	0	0	0	0	0x00	No error	Disconnection, err_quit=0	err_quit=1
0	0	0	0	0	0	0	1	1	0x01	I_ZK too high	Disconnection, err_quit=0	err_quit=1
0	0	0	0	0	0	1	0	2	0x02	U_ZK too low	Disconnection, err_quit=0	err_quit=1
0	0	0	0	0	1	0	0	4	0x04	Hardware error	Disconnection, err_quit=0	err_quit=1
0	0	0	0	1	0	0	0	8	0x08			
0	0	0	1	0	0	0	0	16	0x10	Overtemperature	Disconnection, err_quit=0	err_quit=1
0	0	1	0	0	0	0	0	32	0x20	I_VS too high	Disconnection, err_quit=0	err_quit=1
0	1	0	0	0	0	0	0	64	0x40	U_VS too low / high	Disconnection, err_quit=0	err_quit=1
1	0	0	0	1	0	0	0	128	0x80	U_ZK too high	Disconnection, err_quit=0	err_quit=1

Tab. 6: Error codes

5.1.8 Miscellaneous errors

The errors generated by the software in the variable mod_state shall be further on registered. These are the errors 0x02 and 0x04. The error 0x04 occurs when the power supply of the module is not secured or assured or if the connected or linked DC-Link-over-voltage-disconnection has been activated.

The error 0x02 shall be generated, if there is a breakdown of the DC-Link voltage during operation.

5.1.9 Reducing current during high variable voltage

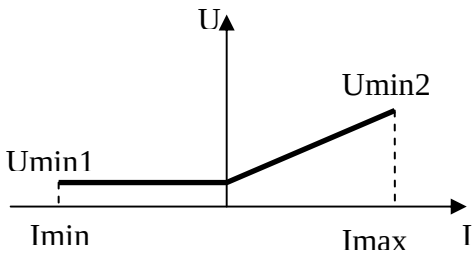
A linear reduction of the maximum output current takes place at voltages over 5/6 of the maximum variable voltage, such that the maximum current /electricity is available at a maximum output voltage of 83.3%.

5.1.10 Empty DC-Link

In case the DC-Link is empty, the module sets to an DC-Link charging mode, after switch on, and charges the DC-Link. It is only after completion of this process and after the module is in normal operation, that other modules can be connected to the DC-Link.

5.1.11 Minimum of the VS-voltage

Due to the principle, the VS voltage must not fall below certain minimum values, depending on the module type and the actual current. If the actual voltage falls below these minimum values and the module is in operating mode (mod_on=1), a shutdown with the error "UVS too low / high" (0x40) occurs.



Module type	Imin/Imax	Umin1	Umin2
30V	-100A/100A	0,2V	1,5V
45V	-75A/75A	0,3V	2,3V
60V	-50A/50A	0,4V	3V
120V	-25A/25A	0,8V	6V

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5.2 Basic parameterisation

The parameterisation of the module can only take place via the serial interface. However, this can be carried out, more comfortably, through the software.

R readable

W writable (parameterizable)

E stored in EEPROM (EEP)

B can be changed in switched-on state (mod_on=1)

5.2.1 Currents: variable voltage side (VS side)

Scalings			
Module type	**Value range**	**Communication value**	**Resolution**
30V	-100…100A	-10000…10000	100mA
45V	-75… 75A	-7500… 7500	75mA
60V	-50… 50A	-5000… 5000	50mA
120V	-25… 25°	-2500… 2500	25mA

parameter	**vs_imin**	
description	Current, minimum	
explanation	Minimum of the desired current	
command	wj	**RW B**

parameter	**vs_imax**	
description	Current, maximum	
explanation	Maximum of the desired current	
command	wi	**RW B**

parameter	**vs_imin_f**	
description	Current, minimum, initial value in EEPROM	
explanation	vs_imin receives this value directly after initial operation of the module through connection of the operation voltage.	
command	wl	**RW E**

parameter	**vs_imax_f**	
description	Current, maximum, initial value in EEPROM	
explanation	vs_imax receives this value directly after initial operation of the module through connection of the operation voltage.	
command	wk	**RW E**

parameter	**vs_imin_g**	
description	Current, lower limit	
explanation	not used	
command	wn	**RW E**

Parameter	**vs_imax_g**	
description	Current, upper limit	
explanation	not used	
command	wm	**RW E**

parameter	**vs_iminmax**	
description	Current, switch-off value	
explanation	if actual value is below/above -> error shutdown; for changing, jumper JP1 must be closed; default: JP1 is closed; Meaning depends on jumper JP2	
command	wg	**RW E**

parameter	**vs_isoll**	
description	Current, desired value (=actual value)	
explanation	output value of the regulator that is transferred to the hardware as the desired value of the current; is normally adjusted	
command	wa	**R**

Parameter	**vs_iist**	
Beschreibung	Current, actual value	
Erläuterung	actual current at the VS side	
Befehl	wb	**R**

5.2.2 Voltages: variable voltage side (VS side)

Scalings			
Module type	**Range of values**	**Communication value**	**Resolution**
30V	0*… 30V	0… 3000	30mV
45V	0*… 45V	0… 4500	45mV
60V	0*… 60V	0… 6000	60mV
120V	0*…120V	0…12000	120mV

* See chapter 5.1.11

parameter	**vs_umax_g**	
description	Voltage, upper limit	
explanation	only used in automatic mode	
command	vm	**RW E**

parameter	**vs_umin_g**	
description	Voltage, lower limit	
explanation	only used in automatic mode	
command	vn	**RW E**

parameter	**vs_umaxmax**	
description	Voltage, switch-off value, upper limit	
explanation	if actual value is above -> error shutdown; for changing, jumper JP1 must be closed; Default: JP1 is closed	
command	vo	**RW E**

parameter	**vs_uminmin**	
description	Voltage, switch-off value, lower limit	
explanation	if actual value is below -> error shutdown; for changing, jumper JP1 must be closed; Default: JP1 is closed	
command	vp	**RW E**

parameter	**vs_usoll_f**	
description	Voltage, desired initial value in EEPROM	
explanation	vs_usoll receives this value directly after initial operation of the module through connection of the operation voltage	
command	vv	**RW E**

parameter	**vs_usoll**	
description	Voltage, desired value	
explanation	Desired value at the VS side	
command	vu	**RW B**

parameter	**vs_uist**	
description	Voltage, actual value	
explanation	actual voltage at the VS side	
command	va	**R**

5.2.3 Voltages: DC link (ZK Side)

Scalings			
Module type	**Range of values**	**Communication value**	**Resolution**
all types	350…400V	3500…4000	100mV (internal 50mV)

Attention!

The DC-Link voltage shall be measured only in the range between 350V and 400V. In case it is smaller than 350V, the value 3500 shall be displayed. The DC-Link voltage must be measured and the DC-Link discharged before any works can be carried out in the DC-Link cables.

parameter	**zk_umax_g**	
description	Voltage, upper limit	
explanation	only used in automatic mode	
command	zm	**RW E**

parameter	**zk_umin_g**	
description	Voltage, lower limit	
explanation	only used in automatic mode	
command	zn	**RW E**

parameter	**zk_usoll**	
description	Voltage, desired value	
explanation	Desired value of the DC link voltage	
command	zu	**RW B**

parameter	**zk_usoll_f**	
description	Voltage, desired initial value in EEPROM	
explanation	zk_usoll receives this value directly after initial operation of the module through connection of the operation voltage	
command	zv	**RW E**

parameter	**zk_uist**	
description	Voltage, actual value	
explanation	actual value of the DC link voltage	
command	za	**R**

5.2.4 External

module type	**I / O**	**specification**
all Types	Digital outputs	0…5 V
	Digital Inputs	0…5 V
	Analogue Inputs	0…10 V

Parameter	**doutj**	
Description	digital output 1	
Explanation	special function, see Tab. 5	
Command	pj	**RW B**

Parameter	**doutk**	
Description	digital output 2	
Explanation	special function, see Tab. 5	
Command	pk	**RW B**

Parameter	**doutl**	
Description	digital output 3	
Explanation	not used	
Command	pl	**RW B**

Parameter	**dina**	
Description	digital input 1	
Explanation	special function, see Tab. 5	
Command	pa	**R**

Parameter	**dinb**	
Description	digital input 2	
Explanation	special function, see Tab. 5	
Command	pb	**R**

Parameter	**dinc**	
Description	digital input 3	
Explanation	not used	
Command	pc	**R**

Parameter	**ainx**	
Description	analogue input 1	
Explanation	special function, see Tab. 5	
Command	px	**R**

Parameter	**ainy**	
Description	analogue input 2	
Explanation	special function, see Tab. 5	
Command	py	**R**

5.2.5 Information

Parameter	**mod_state**	
Description	module, status	
Explanation	see Tab. 6	
Command	is	**R**

Parameter	**mod_opmode**	
Description	module, operating mode	
Explanation	see Tab. 4	
Command	im	**RW E**

Parameter	**-**	
Description	module, type	
Explanation	module type: 30V / 45V / 60V / 120V	
Command	it	**R**

Parameter	-	
Description	module, firmware	
Explanation	software version of the firmware	
Command	if	**R**

Parameter	-	
Description	module, serial number	
Explanation	serial number of the manufacturer	
Command	in	**R**

Parameter	-	
Description	module, date of manufacture	
Explanation	date of manufacture	
Command	id	**R**

Parameter	**t_kk**	
Description	temperature, heat sink	
Explanation	scaling: -273…127°C -> 0…1000	
Command	tk	**R**

Parameter	**t_kk (from firmware 1.13 on)**	
Beschreibung	temperature, heat sink	
Erläuterung	skaling: -112…160°C -> -1120…1600	
Befehl	tl	**R**

Parameter	**t_trafo**	
Description	temperature, transformer	
Explanation	scaling: -273…127°C -> 0…1000	
Command	tt	**R**

Parameter	**t_trafo (from firmware 1.13 on)**	
Beschreibung	temperature, transformer	
Erläuterung	skaling: -112…160°C -> -1120…1600	
Befehl	tu	**R**

5.2.6 Commands

Parameter	**mod_on**	
Description	module on / off	
Explanation	1: on 0: off	
Command	ce	**RW B**

Parameter	**err_quit**	
Description	acknowledge an error	
Explanation	1: acknowledging the error	
Command	cq	**RW B**

Parameter	**com_mode**	
Description	communication mode	
Explanation	0: ASCII short 1: ASCII long	
Command	cc	**R B**

5.2.7 Oscilloscope

For the adjustment of the regulator parameter and for monitoring during operation, an oscilloscope functionality is integrated in the software. This permits the recording of the output voltage, DC-Link voltage as well as the output current. 256 values shall be recorded with a resolution of 8bit. The possible sampling rate lies in the domain between 6 kHz and 23.4 Hz.

The triggering channel can be selected independent of the recording channel.

There are different possibilities available for the mapping of the 10-bit or 11-bit values of voltages and currents onto the 8-bit recording range. The entire range of values can either be scaled on 0...256, whereby with I_VS, 0 lies at 128. Likewise, only the magnitude of the positive or negative range of values can be mapped onto 0 to 256. Or the complete resolution can be selected (currents: -1000...1000, voltages 0...1000) and displaced to the recording range 0…256 by means of an offset.

	Scaled range	**Real or actual range**			
		30V-Module	**45V-Module**	**60V-Module**	**120V-Module**
I_VS	-1000 0 +1000	-100A 0A +100A	-75A 0A 75A	-50A 0A +50A	-25A 0A +25A
U_VS	1000 0	30V 0	45V 0	60V 0	120V 0
U_ZK	1000 0	400V 350V	400V 350V	400V 350V	400V 350V

Parameter	**osz_ch**	
Description	channel	
Explanation	0: U_VS 1: U_ZK 2: I_VS	
Command	ok	**RW B**

Parameter	**osz_ft**	
Description	frequency divider	
Explanation	clock: 6kHz/osz_ft 0 corresponds to 6kHz/256	
Command	of	**RW B**

Parameter	**osz_tr**	
Description	trigger value	
Explanation	trigger value for all channels parameter range: -1000…1000	
Command	ot	**RW B**

Parameter	**osz_tch**	
Description	trigger channel	
Explanation	0: U_VS 1: U_ZK 2: I_VS	
Command	oc	**RW B**

Parameter	**osz_m**	
Description	storage mode	
Explanation	see Tab. 7	
Command	om	**RW B**

Parameter: osz_m										
Bit								**Dec**	**Hex**	**Meaning**
7	**6**	**5**	**4**	**3**	**2**	**1**	**0**			
x	x	x	x	x	x	x	0	0	0x00	Trigger at value > trigger value
x	x	x	x	x	x	x	1	1	0x01	Trigger at value < trigger value
x	x	x	x	x	0	0	x	0	0x00	Entire value range on 0…255
x	x	x	x	x	0	1	x	2	0x02	Value(10-bit)-Offset truncated on 0..255
x	x	x	x	x	1	0	x	4	0x04	Positive range of values on 0..255
x	x	x	x	x	1	1	x	6	0x06	Negative range of values inverted on 0..255
x	x	x	0	0	x	x	x	0	0x00	Trigger position 0 %
x	x	x	0	1	x	x	x	8	0x08	Trigger position 25%
x	x	x	1	0	x	x	x	16	0x10	Trigger position 50%
x	x	x	1	1	x	x	x	24	0x18	Trigger position 75%

Tab. 7: Operation modes oscilloscope

Parameter	**osz_offs**	
Description	offset	
Explanation	for the storage mode with offset	
Command	oo	**RW B**

Parameter	**osz_on**	
Description	oscilloscope on / off	
Explanation	oscilloscope start / state	
Command	oe	**RW B**

Parameter	**-**	
Description	read data	
Explanation	readout of the 256 values (ASCII)	
Command	or	**R**

Parameter: osz_on										
Bit								**Dec**	**Hex**	**Meaning**
7	**6**	**5**	**4**	**3**	**2**	**1**	**0**			
x	x	x	x	x	x	x	0	0	0x00	not running
x	x	x	x	x	x	x	1	1	0x01	runs, waits for trigger
x	x	x	x	x	x	1	x	2	0x02	runs, triggered
x	x	x	x	x	1	x	x	4	0x04	runs, forerun before trigger

Tab. 8: State values oscilloscope

5.3 Regulator Settings

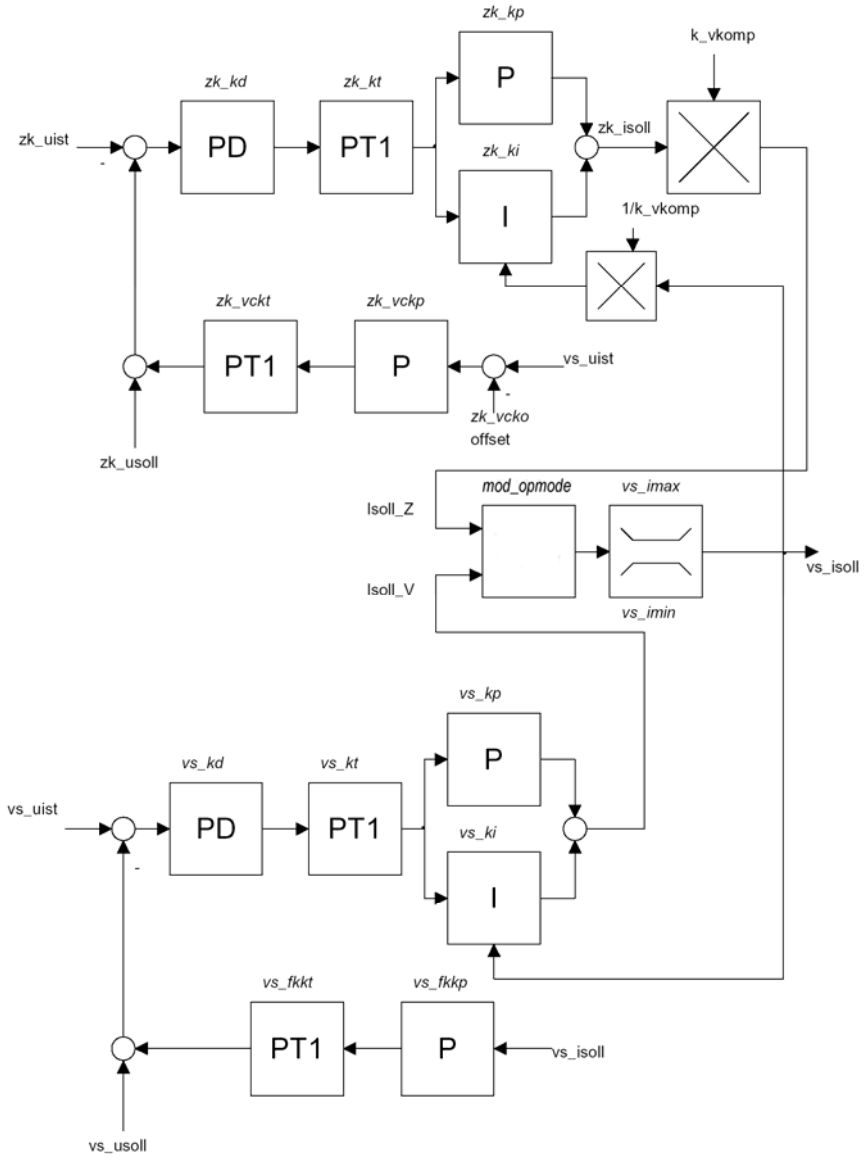


Fig. 4: Block circuit diagram of the voltage regulators

5.3.1 Parameters of the VS-Regulator

Basic amplifications (not illustrated in block circuit diagram):

30V-Module: 0.833A/V

45V-Module: 0.416A/V

60V-Module: 0.208A/V

120V-Module: 0.052A/V

Parameter	**vs_ki**	
Description	regulator, I-component	
Explanation	parameter range: 0…255 transfer function: $G=V_I/p$ V_I: 0…12000s^{-1} $V_I=12000s^{-1}/256*vs\_ki$	
Command	ui	**RW E**

Parameter	**vs_kp**	
Description	regulator, P-component	
Explanation	parameter range: 0…255 amplification: 0…255	
Command	up	**RW E**

Parameter	**vs_kd**	
Description	regulator, D-component	
Explanation	parameter range: 0…255 transfer function: $G=V_D*p+1$ V_D: 0…1.67ms V_D=vs_kd*1/6000Hz	
Command	ud	**RW E**

Parameter	**vs_kt**	
Description	regulator, time constant	
Explanation	parameter range: 0…255 transfer function: G=1(1+pT) T: 43ms…0.17ms T=256/(vs_kt*6000Hz)	
Command	ut	**RW E**

Parameter	**vs_fkkp**	
Description	falling characteristics, amplification	
Explanation	parameter range: 0…255 30V-module: v=(0.6V/A)/256*vs_fkkp 60V-module: v=(2.4V/A)/256*vs_fkkp 120V-module: v=(9.6V/A)/256*vs_fkkp	
Command	uk	**RW E**

Parameter	**vs_fkkt**	
Description	falling characteristics, time constant	
Explanation	parameter range: 0..255 transfer function: G=1(1+pT) T: 43ms..0.17ms T=256/(vs_fkkt*6000Hz)	
Command	uz	**RW E**

5.3.2 Parameters of the ZK-Regulator

Basic amplification (not illustrated in block circuit diagram): 0.020A/V
(with 45V-Module: 0.023A/V)

Parameter	**zk_ki**	
Description	regulator, I-component	
Explanation	parameter range: 0…255 transfer function: $G=V_I/p$ V_I: 0…12000s^{-1} V_I=12000s^{-1}/256*zk_ki	
Command	yi	**RW E**

Parameter	**zk_kp**	
Description	regulator, P-component	
Explanation	parameter range: 0…255 amplification: 0…255	
Command	yp	**RW E**

Parameter	**zk_kd**	
Description	regulator, D-component	
Explanation	parameter range: 0…255 transfer function: $G=V_D*p+1$ V_D: 0…3.33ms V_D=zk_kd*1/3000Hz	
Command	yd	**RW E**

Parameter	**zk_kt**	
Description	regulator, time constant	
Explanation	parameter range: 0…255 transfer function: G=1(1+pT) T: 85ms…0.33ms T=256/(zk_kt*3000Hz)	
Command	yt	**RW E**

Parameter	**zk_vckp**	
Description	virtual capacitor, amplfication	
Explanation	parameter range: 0…255 30V-Module: v=1.670/256*zk_vckp 60V-Module: v=0.833/256*zk_vckp 120V-Module: v=0.416/256*zk_vckp	
Command	yk	**RW E**

Parameter	**zk_vckt**	
Description	virtual capacitor, time constant	
Explanation	parameter range: 0…255 transfer function: G=1(1+pT) T: 85ms…0.33ms T=256/(zk_vckt*3000Hz)	
Command	yz	**RW E**

Parameter	**zk_vcko**	
Description	virtual capacitor, offset	
Explanation	equivalent to voltage on the VS-Side 30V-Module: 0…3000 45V-Module: 0…4500 60V-Module: 0…6000 120V-module: 0…12000	
Command	yo	**RW E**

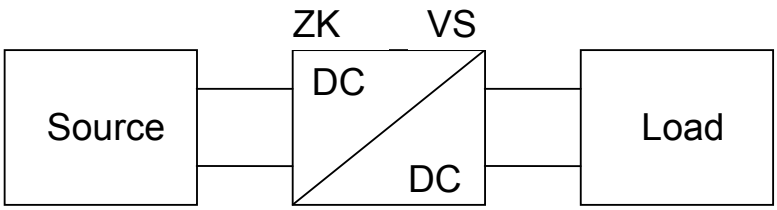
5.4 Typical application cases / Parameterisation examples

In order to operate the DC/DC converter module in a particular configuration or arrangement, a couple of parameters have to be correctly set. Useful information on correct parameterisation has been presented in the following configuration example.

Beside the basic parameters mod_opmode, vs_imax, vs_imin, vs_usoll, zk_usoll, it is also advisable to change the regulator parameter, under specific conditions, and to use only a P - regulator instead of a PI – regulator.

Attention

During the initial charging of the DC link it must be unloaded, i.e. there have to be no additional electrical capacities and / or electrical loads connected to the DC link.

a)	
Application	possible sources: DC-power line, PFC possible load/charge: arbitrary
Parameter	mod_opmode: 0 vs_imax: 0 bzw. >0 vs_imin: - desired current limit zk_usoll: Desired value DC-Link voltage, smaller than the minimum occurring ZK voltage vs_usoll: desired output voltage

In this particular application case, the module functions as a typical electric power supply: it maintains the output voltage constant in the desired value, vs_usoll, and limits the current, during overcharge, to vs_imin. (Attention: vs_imin is negative, because the direction of current is defined into the module). The parameter vs_imax must stay at 0, so that no current can flow into the module. In some cases hereby it can occur that the voltage runs high, as a result of offset errors, if no load is connected. It is recommended in this case to allocate a small positive value of approximately 1…3A to vs_imax, so as to be able to maintain the voltage on the desired value.

The parameter zk_usoll is the desired value for the DC-Link voltage. If this falls below this value, the ZK - voltage regulator tries to maintain the value. It does this by preventing power to flow from the DC-Link into the VS- side. This means the output voltage disintegrates or breaks down during overcharge. If this method is undesired, but instead that a hard disconnection should take place during overcharge, zk_usoll should be set to the possible minimum value 3500 (equivalent to 350V). If break down or disintegration of the DC-Link voltage now occurs, the regulator can not intervene and the module switches off due to low DC-Link voltage.

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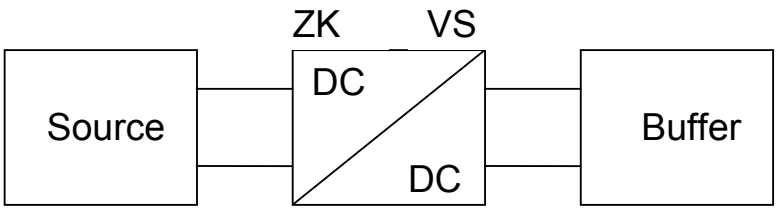
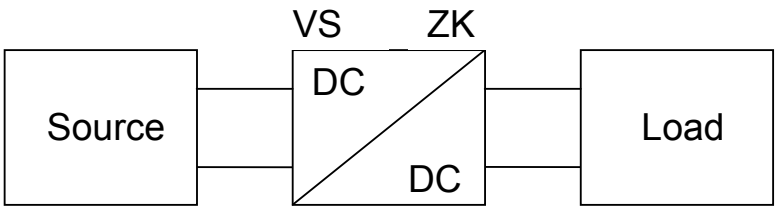
b)	
Application	Buffering of an DC-Link, e.g. with a storage battery or double layered capacitor
Parameter	mod_opmode: 0 vs_imax: + desired current limit vs_imin: - desired current limit zk_usoll: desired ZK- voltage vs_usoll: maximum buffer voltage

This configuration or arrangement serves the purpose of buffering an DC-Link. vs_imax is fixed her as the maximum current flowing into the module, thus the buffer charge current, vs_imin is set here as the maximum current flowing out of the module, buffer charge current. The parameter vs_usoll serves the purpose of setting an upper limit of the buffer voltage. If one equally wants to set the lower limit of the buffer charge voltage, this can be realised with the parameter vs_uminmin - however, one has to take into consideration here a discrepancy of 1/120 of the VS – voltage range.

The DC-Link voltage regulator now keeps the voltage at the desired value zk_soll constant. If the DC-Link voltage is above the desired value, the buffer will be charged; if the DC-Link voltage is below the desired value the buffer will be discharged. A supple characteristic that is being offered, for example in the case of intermittent DC-Link voltages, can be attained if the ZK – voltage regulator is parameterised as a P - regulator.

c)	
Application	Possible sources: Fuel cells, accumulator/storage battery Possible loads: Switching power supply, motor power converter, inverter
Parameter	mod_opmode: 1 vs_imax: + desired current limit vs_imin: 0 zk_usoll: desired DC-Link voltage vs_usoll: smaller than the minimum input voltage

Similarly, a possible case of application is the production of a high DC-Link voltage from a source with low voltage. By selecting mod_opmode=1, the ZK - voltage regulator will be active for vs_uist > vs_usoll and the DC-Link voltage shall be controlled or adjusted to the desired value. Only if the value vs_usoll, in the VS- side, is undershot, that the VS – regulator shall intervene and prevent under voltage at the source. If, in this case, the charge remains constant, the DC-Link voltage will fall and this will lead to disconnection or interruption.

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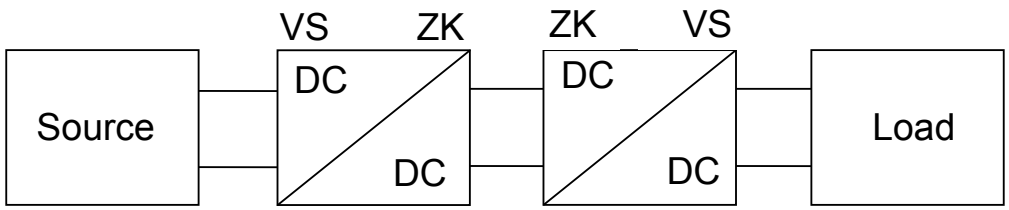
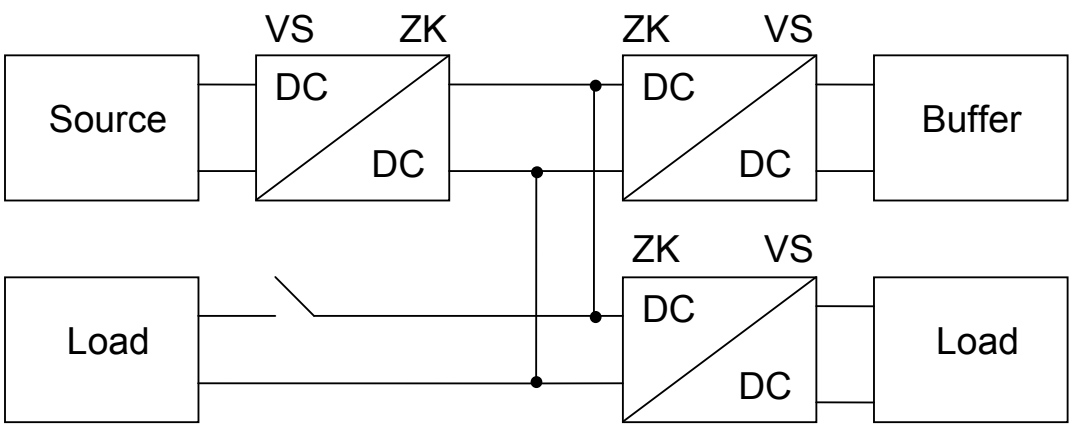
d)	
Application	Arbitrary application, disadvantage: lower degree of efficiency
Parameter Module to the source	mod_opmode: 1 vs_imax: + desired current limit vs_imin: 0 zk_usoll: Desired value DC-Link voltage vs_usoll: smaller than the minimum input voltage
Parameter Module to the charge	mod_opmode: 0 vs_imax: 0 or >0 vs_imin: - desired current limit zk_usoll: Desired value DC-Link voltage, smaller than the minimum emerging ZK - voltage vs_usoll: Desired output voltage

This case is the interconnection of the configuration a) with configuration c). The following procedure or course must be observed during switching on: switch on module to the source, wait till DC-Link charged, and switch on module to the load.

e)		
Application	Complete system, comprising source, load and buffer	
Parameter Module to the source	mod_opmode: vs_imax: vs_imin: zk_usoll: vs_usoll:	1 + desired current limit 0 desired value DC-Link voltage smaller than the minimum input voltage
Parameter Module to the buffer	mod_opmode: vs_imax: vs_imin: zk_usoll: vs_usoll:	0 + desired current limit - desired current limit desired value ZK - voltage maximum buffer voltage
Parameter Module to the charge	mod_opmode: vs_imax: vs_imin: zk_usoll: vs_usoll:	0 0 or >0 - desired current limit Desired value DC-Link voltage, smaller than the minimum emerging ZK - voltage desired output voltage

In principle this case is an interconnection of the configurations a) to c). However, there are several possibilities of the (power) distribution.

In the simplest case, one parametrises zk_usoll_{load}<zk_usoll_{buffer}<zk_usoll_{source}. In case the charge is bigger or higher than the source can deliver (variable voltage shall be

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allocated a lower limit) the ZK – voltage breaks down and the converter to the buffer maintains or keep it at its desired value. In case the charge once more becomes smaller, the converter to the source remains in the mode VS – voltage regulation, while the buffer recharges once more. If the buffer is full, the VS – regulator acts on the buffer and limits the voltage of the buffer upwardly. In order to limit current rise (step-up of current) at the source, in this operation mode, e.g. in order to protect a fuel cell, the delay of the ZK – voltage regulators must be increased, that is a smaller value must be allocated to zk_kt.

A further possibility is the application of the operation mode "Virtual capasitor". Hereby, a continuous process or progression of the ZK – voltage proportional to the charging level of the buffer shall be attained. The DC/DC converter, connected to the charge, once more extracts its power from the DC-Link. The buffer converter keeps the DC-Link voltage constant by means of a PI – regulator. However, the desired value for the DC-Link voltage will now be changed in dependency on the state of charge of the buffer. The lesser the buffer is charged the lower the DC-Link voltage will be. The DC/DC converter module connected to the source now possesses a P-regulator with delay for smoothing of the desired value. The DC/DC converter shall deliver more power in case the DC-Link voltage becomes lower. If the charge once more becomes less, power will then flow into the buffer. The DC-Link voltage shall therefore increase and the power taken from the fuel cell will sink.

The third possibility is the control of power flow with the help of a superior or high-ranking control system (internal or external). In such a system, the buffer maintains or keeps the ZK – voltage constant, the superior control system monitors the state of charge of the buffer and controls, on this basis, the source. Along this line, the combination of several sources and buffers is therefore possible (e.g.: Long-term and short-term storage).

5.5 Troubleshooting

Acknowledge errors, eliminate cause, and switch-on once more.

6 Programming / Parameterisation

6.1 Preliminary remarks

The DC/DC-Module offers a comfortable software interface. All the parameters / commands / measured values can be written and/or read by means of a simple ASCII-protocol. All the variables of the module, either representing a parameter, a measured value or a command, are activated by means of a command code that is made up of two characters. Whereby, the first character, hereby, indicates the group membership, e.g. „z“ for voltage parameter of the DC-Link and the second character then specifies the precise variable. A complete list of all these command codes is an integral part of this documentation.

The serial interface of the module serves as (Hardware-) communication interface. For example, it can be connected with the RS232-interface of a PC. The following adjustments are necessary:

Bits per Second	115200
Data bits	8
Parity	None
Stop bits	1
Flow control	None

Tab. 9: Settings RS232

6.2 The ASCII protocol used

The transfer of the corresponding commands in the ASCII format is done in a simple scheme. All characters transferred to the module are immediately evaluated by the same and checked with regard to their validity within the respective sequence of commands. This means concretely: If, for example, a plus/minus sign is expected at a certain point of a sequence of commands, the module only accepts the signs plus(+) or minus(-). Valid characters are directly mirrored (exceptions: control characters for the protocol changeover and CR), invalid characters are immediately rejected. With the aid of this procedural method, a complex and extensive protocol (checksums, length specifications etc.) can be avoided and, nevertheless, faulty insertions can be minimized.

From firmware 1.14 on, a protocol with checksum is available (see further chapter).

6.2.1 Read / write without checksum

Basically, you have to distinguish between "Reading" and "Writing" as far as the sequences of instructions to be sent to the module are concerned. If, for example, the value stored in a module variable is only to be read, you have to send the corresponding command code as a sequence followed by Return. If a new value is to be stored in a variable, the corresponding command code, the plus/minus sign of the new value, the new value itself and Return are to be sent.

Read	Write
Command code + CR	Command code + sign + new value + CR

Tab. 10: Command sequences without checksum in general

6.2.2 Read / write with checksum

Basically, you have to distinguish between "Reading" and "Writing" as far as the sequences of instructions to be sent to the module are concerned. If, for example, the value stored in a module variable is only to be read, you have to send the corresponding command code as a sequence followed by Return. If a new value is to be stored in a variable, the corresponding command code, the plus/minus sign of the new value, the new value itself, the checksum and Return are to be sent.

Read	Write
Command code + Σ + CR	Command code + sign + new value + Σ + CR

Tab. 11: Command sequences with checksum in general

The following table lists all possible command codes for the communication with the module and they are arranged in groups. At the same time, the names of the respective module variables as well as the place of storing and the parameterability are shown.

Group	Description	1. Command Character	2. Command Character	parame-trizable	stored in EEPROM	Parameter
DC Link	voltage: upper limit (only used in automatic mode)	z	m	x	x	zk_umax_g
(DC link side)	voltage: lower limit (only used in automatic mode)	z	n	x	x	zk_umin_g
	voltage: desired initial value in EEPROM	z	v	x	x	zk_usoll_f
	voltage: desired value	z	u	x+		zk_usoll
	voltage: actual value	z	a			zk_uist
	regulator: I-component	y	i	x	x	zk_ki
	regulator: P-component	y	p	x	x	zk_kp
	regulator: D-component	y	d	x	x	zk_kd
	regulator: time constant	y	t	x	x	zk_kt
	virtual capacitor: amplification	y	k	x	x	zk_vckp
	virtual capacitor: time constant	y	z	x	x	zk_vckt
	virtual capacitor: offset	y	o	x	x	zk_vcko
Variable Voltage	current: minimum	w	j	x+		vs_imin
(component side)	current: maximum	w	i	x+		vs_imax
	current: minimum, initial value in EEPROM	w	l	x	x	vs_imin_f
	current: maximum, initial value in EEPROM	w	k	x	x	vs_imax_f
	current: lower limit (not used)	w	n	x	x	vs_imin_g
	current: upper limit (not used)	w	m	x	x	vs_imax_g
	current: desired value (regulator output)	w	a			vs_isoll
	current: actual value	w	b			vs_iist
	current: switch-off value	w	g	x	x (Elpoti)	vs_iminmax
	voltage: upper limit (only used in automatic mode)	v	m	x	x	vs_umax_g
	voltage: lower limit (only used in automatic mode)	v	n	x	x	vs_umin_g
	voltage: switch-off value, upper limit	v	o	x	x (Elpoti)	vs_umaxmax
	voltage: switch-off value, lower limit	v	p	x	x (Elpoti)	vs_uminmin
	voltage: desired initial value in EEPROM	v	v	x	x	vs_usoll_f
	voltage: desired value	v	u	x+		vs_usoll
	voltage: actual value	v	a			vs_uist
	regulator: I-component	u	i	x	x	vs_ki
	regulator: P-component	u	p	x	x	vs_kp
	regulator: D-component	u	d	x	x	vs_kd
	regulator: time constant	u	t	x	x	vs_kt
	falling characteristics: amplification	u	k	x	x	vs_fkkp
	falling characteristics: time constant	u	z	x	x	vs_fkkt
Ports	digital output 1	p	j	x+		doutj
	digital output 2	p	k	x+		doutk
	digital output 3	p	l	x+		doutl
	digital input 1	p	a			dina
	digital input 2	p	b			dinb
	digital input 3	p	c			dinc
	analogue input 1	p	x			ainx
	analogue input 2	p	y			ainy
Temperatures	heat sink	t	k			t_kk
	heat sink (from firmware 1.13 on)	t	l			t_kk
	Transformer	t	t			t_trafo
	transformer (from firmware 1.13 on)	t	u			t_trafo
Info	module state	i	s			mod_state
	module operating mode	i	m	x	x	mod_opmode
	module type	i	t			
	module firmware	i	f			
	module serial number	i	n		x	
	module date of manufacture	i	d		x	
Commands	module on / off	c	e	x+		mod_on
	error quit	c	q	x		err_quit
	communication mode	c	c			com_mode
Oscilloscope	Channel	o	k	x+		osz_ch
	frequency divider	o	f	x+		osz_ft
	trigger value	o	t	x+		osz_tr
	trigger channel	o	c	x+		osz_tch
	storage mode	o	m	x+		osz_m
	Offset	o	o	x+		osz_offs
	oscilloscope on / off	o	e	x+		osz_on
	read data	o	r			

x+ also parametrizable, if the module is switched on (mod_on=1)

Tab. 12: Complete table of the command codes

6.2.3 ASCII-long / ASCII-short

On the part of the module answer, two protocol variants are possible: "long" and "short" ASCII protocol. ASCII-long is particularly suited for the manual entry of instructions, e.g. by using a terminal program such as "HyperTerminal" from Windows. When this protocol is set, the module sends any information and (error) messages in clear text and sees to a distinct representation in the terminal program by means of the transfer of CR and NL control characters at corresponding points.

On the other hand, the protocol ASCII-short should be used when the instruction is to be handed over from another software such as, for example, from the software "ModuleConfigSuite" of Flexiva. If this protocol is set, any information and (error) messages in clear text are suppressed. In case of an error, only error codes are transferred.

	ASCII-long	**ASCII-short**
without error	- command code + CR + NL - sign + readout value + CR + NL - „OK" + CR + NL + NL	- command code + CR - sign + readout value + CR
with error	- command code + CR + NL - error code + CR + NL - error text + CR + NL + NL	- command code + CR - error code + CR

Tab. 13: Module answer for the reading of a parameter / value

	ASCII-long	**ASCII-short**
without error	- command code + sign + new value + CR + NL - sign + read back value + CR + NL - „OK" + CR + NL + NL	- command code + sign + new value + CR - sign + read back value + CR
with error	- command code + sign + new value + CR + NL - error code + CR + NL - error text + CR + NL + NL	- command code + sign + new value + CR - error code + CR

Tab. 14: Module answer for the writing of a parameter / value

6.2.4 ASCII-short with checksum

Starting with firmware 1.14 a communication protocol with checksum is available. This is based on the existing protocol "ASCII-short". However, a 1-byte checksum is used now instead of resending each character received for error checking. This checksum is transmitted in each case as the last character before the CR (dec. 13) in both directions of communication.

The checksum is calculated as the sum of all transmitted bytes modulo 256. If the result is randomly 13, it is replaced by 14 in order to avoid collisions with the CR (dec. 13) as an input terminator.

	ASCII-short with checksum
without error	- command code + Σ + CR - sign + read back value + Σ + CR
with error	- command code + Σ + CR - error code + Σ + CR

Tab. 15: Module answer during reading of a parameter / value

	ASCII-short with checksum
without error	- command code + sign + new value + Σ + CR - sign + read back value + Σ + CR
with error	- command + sign + new value + Σ + CR - error code + Σ + CR

Tab. 16: Module answer during writing of a parameter / value

When reading the data from the oscilloscope no checksum is transmitted. Here, the data transmission is as in the ASCII-short protocol.

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6.2.5 Switching between the protocols

The changeover between the protocol variants is executed by putting a command character in front of the respective first sequence of commands. This command character can also be sent separately. The respective protocol setting is preserved until the next protocol changeover and/or to the next restart (supply voltage gone) or reset of the module. As a standard setting, ASCII-short is set.

Protocol-option	Control character to the module
ASCII-short	$
ASCII-long	%
ASCII-short with checksum	&

Tab. 17: Protocol changeover

6.2.6 Concrete example

To explain the above-mentioned paragraphs, the sequences of instructions to be transferred to the module and the corresponding answers of the module are listed in the following at a concrete example. The case without errors is treated.
The module variable zk_umin_g is to be read-out and a new value is to be stored in it. The corresponding code is "zn", the old value in the variable is "+3500" and the new value is "+3600". This results for the two ASCII modes in the following communication with the module:

6.2.6.1 ASCII-long

To the Module																							
ASCII	%	z	n	CR																			
HEX	25	7A	6E	OD																			
From the Module																							
ASCII		z	n	CR	NL	+	3	5	0	0	CR	NL	O	K	CR	NL	NL						
HEX		7A	6E	0D	0A	2B	33	35	30	30	0D	0A	4F	4B	0D	0A	0A						

Tab. 18: Reading ASCII-long

To the Module																					
ASCII	%	z	n	+	3	6	0	0	CR												
HEX	25	7A	6E	2B	33	36	30	30	0D												
From the Module																					
ASCII		z	n	+	3	6	0	0	CR	NL	+	3	6	0	0	CR	NL	O	K	CR	NL	NL
HEX		7A	6E	2B	33	36	30	30	0D	0A	2B	33	36	30	30	0D	0A	4F	4B	0D	0A	0A

Tab. 19: Writing ASCII-long

6.2.6.2 ASCII-short

To the Module																							
ASCII	$	z	n	CR																			
HEX	24	7A	6E	OD																			
From the Module																							
ASCII		z	n	CR	+	3	5	0	0	CR													
HEX		7A	6E	0D	2B	33	35	30	30	0D													

Tab. 20: Reading ASCII-short

To the Module																							
ASCII	$	z	n	+	3	6	0	0	CR														
HEX	24	7A	6E	2B	33	36	30	30	0D														
From the Module																							
ASCII		z	n	+	3	6	0	0	CR	+	3	6	0	0	CR								
HEX		7A	6E	2B	33	36	30	30	0D	2B	33	36	30	30	0D								

Tab. 21: Writing ASCII-short

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6.2.6.3 ASCII-short with checksum

To the Module																							
ASCII	&	z	n	Σ	CR																		
HEX	26	7A	6E	E8	0D																		
From the module																							
ASCII						+	3	5	0	0	Σ	CR											
HEX						2B	33	35	30	30	F3	0D											

Tab. 22: Reading ASCII-short with checksum

To the Module																							
ASCII	&	z	n	+	3	6	0	0	Σ	CR													
HEX	26	7A	6E	2B	33	36	30	30	DC	0D													
From the Module																							
ASCII											+	3	6	0	0	Σ	CR						
HEX											2B	33	36	30	30	F4	0D						

Tab. 23: Writing ASCII-short with checksum

For computing the checksum the gray values are added. The residue left in the Division by 256 is the checksum. If this value is 13, it is replaced with 14.

```
char checksum;
...
checksum = 0;
   for (i = 0; i < idx; i++) checksum = checksum + buf[i];
   if (checksum == 13) checksum = 14;
...
```

Tab. 24: Example for computing the checksum in C

6.2.7 Error messages during the communication

All sequences arriving in the module are immediately checked and processed. The following errors can occur during the reading / writing and these errors concern exclusively the parameterizing process and are not to be confused with the errors that may arise during the operation of the module and are coded in the status variable mod_state (Tab. 6):

Error code	Meaning in plain text
E0	Reserve
E1	Reserve
E2	Unknown module command
E3	Value beyond the range of values
E4	Value is only readable
E5	Device must be switched-off
E6	Elpotis could not be written. Jumper 1 must be closed.
E7	Mode of operation must be <16
E8	Min value must be smaller than max value
E9	Checksum error

Tab. 25: Error messages

6.3 Communication by means of Terminal-Software

Because of the utilization of an ASCII protocol for the communication interface, a communication with the module is possible by means if any terminal software you like. As an example, HyperTerminal is mentioned here that is part of the older (below windows7) windows versions (see Fig. 5).). Of course, every other software can be also applied (Freeware, self-developed software) by means of which a bidirectional serial communication is possible. For the utilization of terminal software, the protocol setting ASCII-long is recommended.

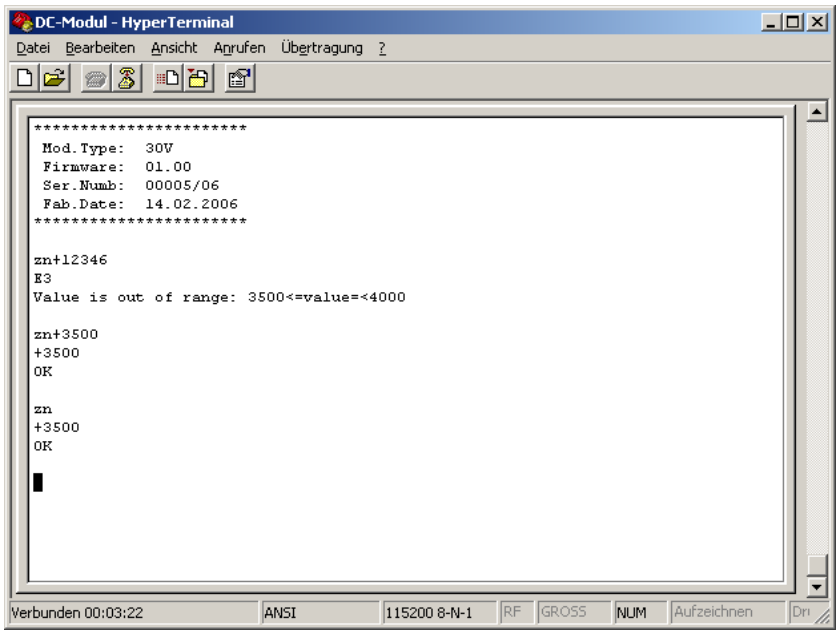


Fig. 5: Module parameterization by means of a terminal-software

6.4 Communication by means of ModuleConfigSuite

Another and much more convenient possibility is the utilization of the Windows software "ModuleConfigSuite" from the company Flexiva that is contained in the scope of delivery of the inverter module as a standard component. This software permits a convenient communication and a closed access (parameterizing / monitoring / storing) to all variables (parameters / commands / measured values) of every single module. Furthermore, it is possible to communicate simultaneously with up to 4 modules. The ModuleConfigSuite uses the protocol setting ASCII-short

7 The parameterisation software „ModuleConfigSuite“

7.1 Preliminary remarks

A Windows-software for the PC is supplied along with the module. It is intended for the convenient parameterization and visualization of all parameters / commands / measured values as well as for the recording of selected data on the PC. In the following, details concerning the function and operation of this software are explained.

System requirements

Hardware:
- customary PC of medium performance and RS232 interface

Operating system/software:
- MS Windows (from Windows XP SP2 onwards)

7.2 Installation

The software is installed like any other conventional Windows software:

1. Insert the data carrier.
2. Start the installation by means of starting the file **setup.exe**.
3. Follow the instructions given by the installation program (path entry etc.).
   a. Installation step backwards by means of a click onto **Back**
   b. Installation step forwards by means of a click onto **Next**
   c. Stop the installation by means of a click onto **Cancel**
4. Terminate the installation by means of a click onto **Finish**

7.3 Deinstallation

If the software is to be removed from the PC, you proceed as follows:

1. Open the **Start menu** of Windows.
2. Select **System control**.
3. In the system control panel click onto the symbol **Software**.
   A list of the available programs is displayed.
4. Select from the list the symbol for **ModuleConfigSuite**.
5. Click onto **Remove**. The software is de-installed now.

7.4 Software description

7.4.1 Overview

After the start of the software and the successful establishing of a connection to one or several modules (click on "Connect!" in the menu line), the following window is displayed in which a division into three parts that is into a menu line, a button bar directly under the menu line and the remaining display area can be recognized. Only those modules are displayed with which a connection is to be established (see paragraph "Selection and Assignment of the Interfaces“) and a connection was successfully established.

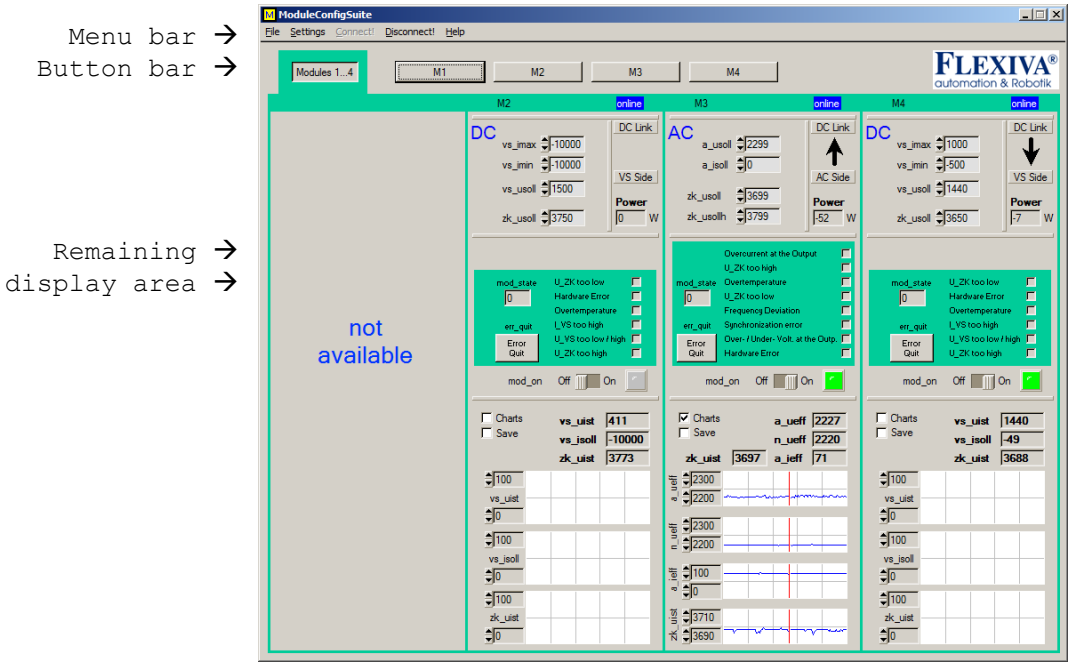


Fig. 6: Basic structure of the software

7.4.2 Single-Mode / Multi-Mode

On principle, the software distinguishes between two modes, the so-called "Single"-mode for the communication with only one single module and the so-called "Multi"-mode for the simultaneous communication with up to 4 modules. In the Single-mode, the access to all parameters of the respective module is possible while in the Multi-mode, the access only to selected parameters of the respective module is possible. In the Single-mode, the digital nameplate and temperature values of the respective module are read-out and visualized additionally. Furthermore, an oscilloscope function and a selection aid for the fixing of the mode of operation (mod_opmode) are available. The changeover between the modes is executed by means of the buttons in the upper window area. After the start of the software, the Multi-mode is automatically set.

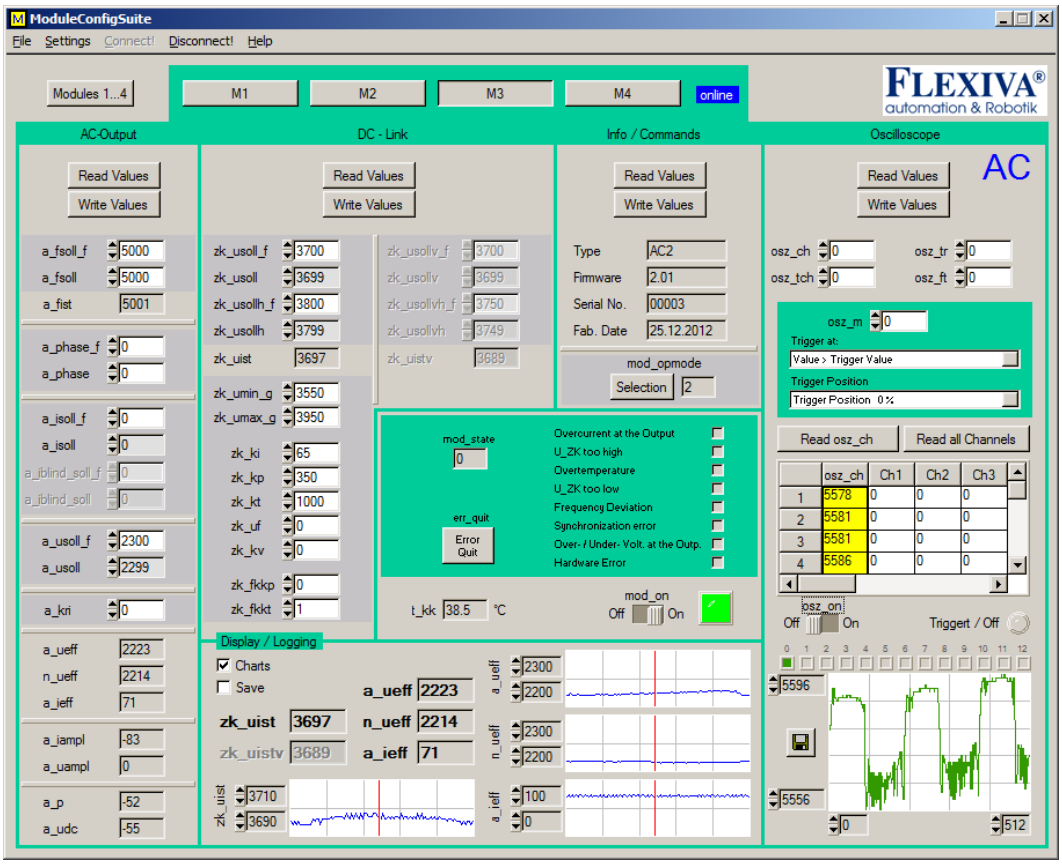


Fig. 7: Single-Mode / Module 3

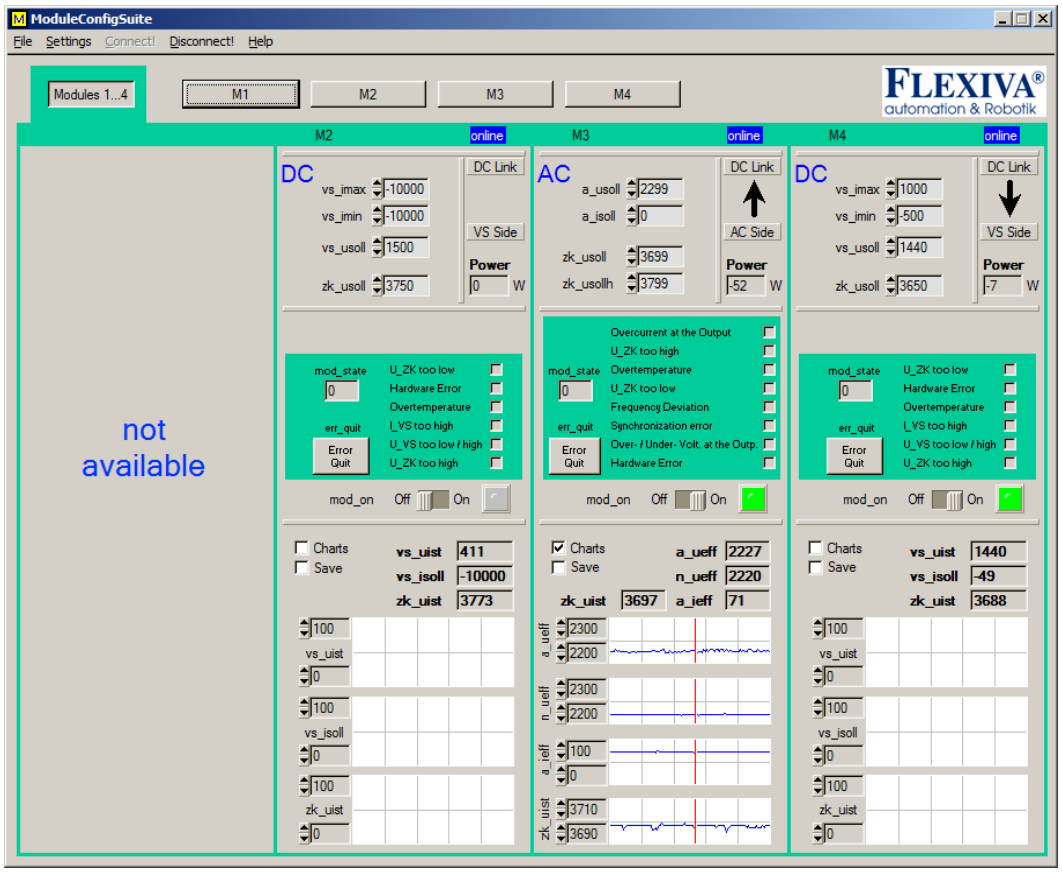


Fig. 8: Multi-Mode

7.4.3 Groupings with the aid of colors / Background colors

As a result of the large number of information to be simultaneously presented and the discrepancy in the information to be processed, the application of different colours for logical grouping proves to be advantageous. The key with an explanation of the colors can be retrieved after selecting the menu item „Help → Color Codes“.

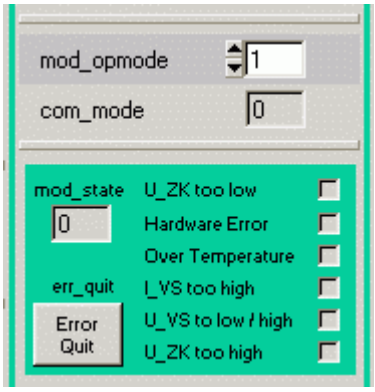


Fig. 9: Example for groupings

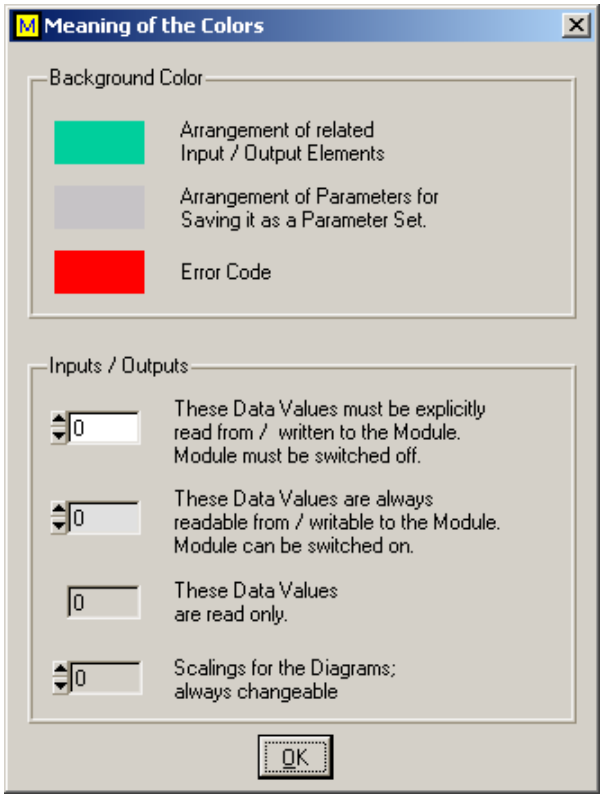


Fig. 10: Color legend

7.4.4 Meaning of the error codes

All data that are transferred (for example, by a click onto one of the buttons "Write Values" in the single-mode) to the module, are immediately checked there with regard to their validity. In case of an error, the corresponding error code is entered in a red field directly next to the respective display / entry element. A table with the meaning of the error codes can be retrieved by selection of the menu item „Help → Error Codes“.

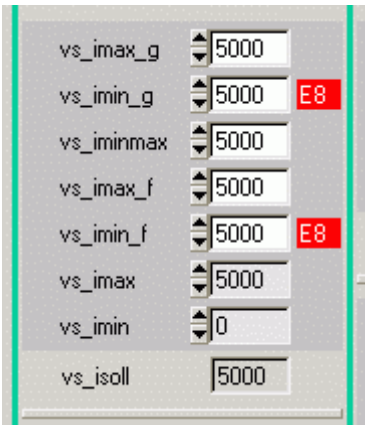


Fig. 11: Example of error codes

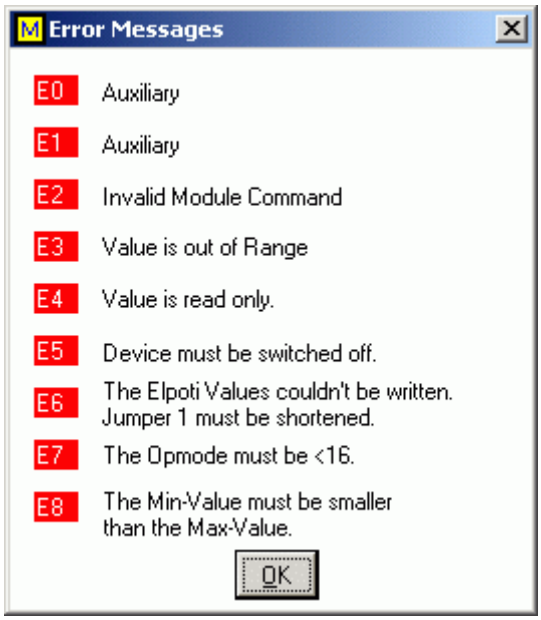


Fig. 12: Meaning of the error codes

7.4.5 Selection and allocation of the interfaces

The selection of the interfaces and their assignment to the modules is carried out by the selection of the menu item "Settings → Connection". Depending on the type of the module carrier, there are various possibilities available. In case of the module carrier of the type 1, the communication is executed by means of 4 separate RS232 interfaces (one for every module). The module carrier of the type 2 needs only one RS232 for the communication with all modules (is multiplexed in the module carrier).

In addition to the assignment of the interfaces, you also have to select explicitly by marking a checkbox in the configuration dialogue whether communication with the respective module is intended. This offers the possibility to include the individual modules in the communication or not.

During the selection and assignment of the rs232 interfaces, tests are carried through concerning the existence in the PC and/or availability.

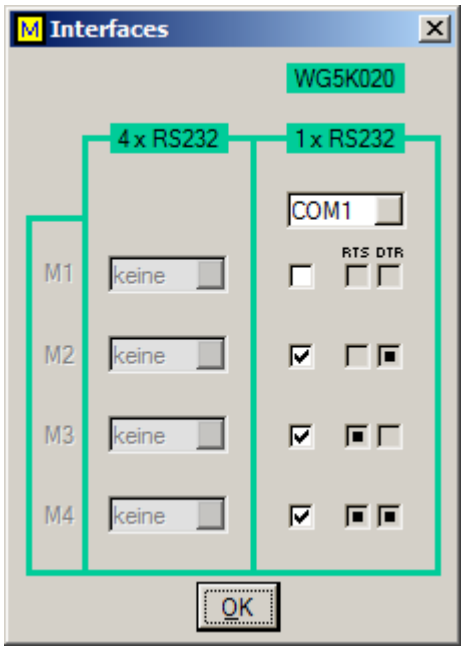


Fig. 13: Assignment of the interface

Attention: Only a test of the selected interfaces and their allocation to the modules shall be performed. The data circuit to the modules shall be built up only after selection of the menu item „Connect!“.

7.4.6 Connecting / disconnecting

By the selection of the menu item "Connect!" it is possible to establish a data connection to the corresponding module (single-mode) and/or to the modules multi-mode). In the single-mode, all data are read-out once completely from the chosen module after the successful establishing of the connection and entered into the respective fields of the screen mask. In the multi-mode, only the relevant data are read-out after the successful establishing of the connection and entered into the respective fields of the screen mask. A selection of the menu item "Disconnect!" cut(s)-off the connection(s).

Fig. 14: Information in case of the cutting-off of the connection

The connection is permanently monitored both during the establishing of the connection and during the existing connection. If the establishing of the connection fails and/or the connection is cut-off a corresponding hint appears.

7.4.7 Storing / Loading of Parameter Sets

In the single-mode, it is possible to store parameter sets on the PC and/or to load parameter sets that are stored on the PC. After the calling of the menu items "File → Load Parameter Set" and/or "File → Save Parameter Set", the corresponding dialogues are called for the loading and storing of files. The parameter files have got a special format that can only be read and write by the ModuleConfigSuite.

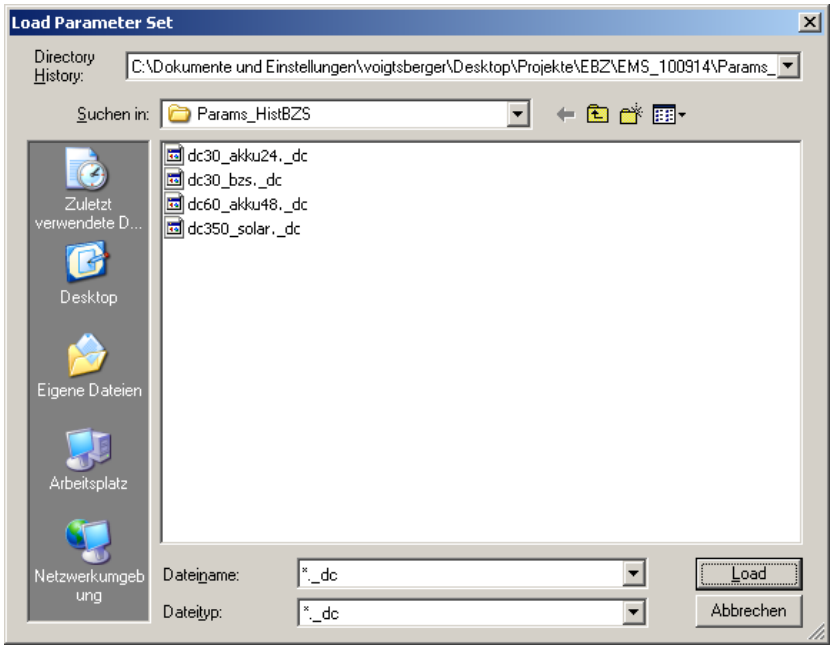


Fig. 15: Dialogue for the loading of parameter files

When such a file is loaded from the PC, all parameters are immediately entered into the corresponding fields. In the reverse case, only the corresponding fields are read-out for the storing of the parameters in such a file. Only such fields with the respective colored background are taken into account.

7.4.8 Readout / Parameterization

All relevant data are automatically read-out from the module and/or the modules during the changeover between the two main modes single-mode and multi-mode (buttons: "Modules 1…4" and "M1" … "M4") or during the establishing of the connection ("Connect!"). In the single-mode, all data are read-out from the selected module and entered into the corresponding fields of the screen mask, in the multi-mode only the relevant ones. The requirement is in both modes an existing data

connection to the respective module and/or to the respective modules.
In addition to that, it is possible in the single-mode to explicitly initiate the reading-out of the data from the module and/or the storing of data in the module by means of a click onto one of the buttons "Read Values" or "Write Values". Only the data of the respective column (e.g. "DC link") are taken into account during this.

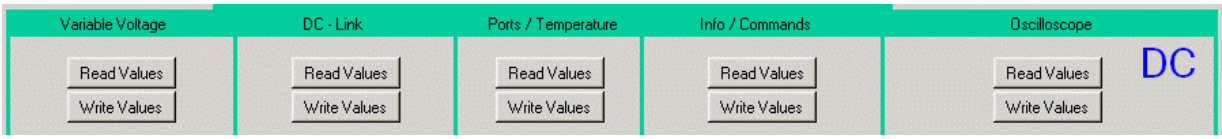


Fig. 16: Buttons for the reading-out / parameterization in the single-mode

In the single mode as well as in the multi-mode, some data are immediately transmitted after their entry / modification (see colour codes). These are in particular the parameters: vs_imax, vs_imin, vs_usoll and zk_usoll.

7.4.9 Data visualisation / Recording

Both in the single-mode and in the multi-mode, in case of an existing connection, the parameters vs_uist, vs_isoll, zk_uist and mod_state are permanently read-out and visualized with a transfer rate of approx. 10 Hz when the connection exists. If the check boxes "Charts" and "Save" are marked, in addition to that, the parameters vs_uist, vs_isoll, zk_uist are simultaneously visualized in diagrams and data are stored (data-logging) in the ASCII format.

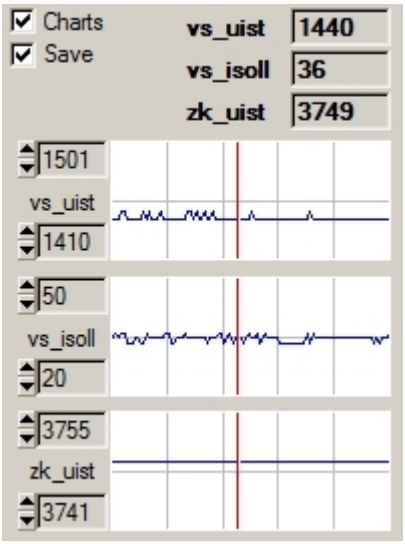


Fig. 17: Dialogue field storing / visualizing

zk_uist	vs_isoll	vs_uist
4011	5710	3069
4011	6810	3069
4011	5710	3069
4011	6730	3069
4011	5550	3069
4011	5095	3069
4011	6340	3069
4011	5315	3069
4011	6260	3069
4011	5785	3069
4011	6575	3069
4011	5710	3069
4011	5865	3069
4011	6655	3069
4011	6340	3069
4011	6810	3069
4011	5785	3069
4011	6025	3069
4011	5080	3069
4011	6025	3069
4011	4860	3069
4011	6730	3069

Fig. 18: Recorded ASCII-Data

During every new establishing of a connection by means of a click onto "Connect!" and a marked "Save", a new data file (a separate one for every module) in the ASCII format with the file extension *.asc is automatically generated in the working directory of the ModuleConfigSuite. For this purpose, it does not matter whether you are in the single-mode or in the multi-mode. The file names of the generated files are composed of the module code as well as date and time of the beginning of the recording. Consequently, the file name “M3_110406_114231.asc“ designates a data recording of the module 3 that started on 11th April 2006 at 11:42:31 a.m.
For safety reasons, the data are stored only in the corresponding mode (single-/ multi-) respectively in the single-mode only for the module just selected. If, for example, the storing is marked for all 4 modules in the multi-mode, only a storing of the data in the file of the corresponding chosen module is carried out in the single-mode and no (background) storing of the data of all 4 modules is executed. Single-mode and multi-mode store to the same data file of the respective module.

8 Maintenance service and repairs by the customer service

According to the general terms and conditions of sale and delivery, WARRANTY is furnished for the device provided by the manufacturer. If malfunctions or damages occur at the device during the warranty period warranty is given for according to the terms and conditions of warranty, the manufacturer shall execute the repair or the replacement of defective components after a prior examination.

The manufacturer shall be responsible for the device in its original configuration.

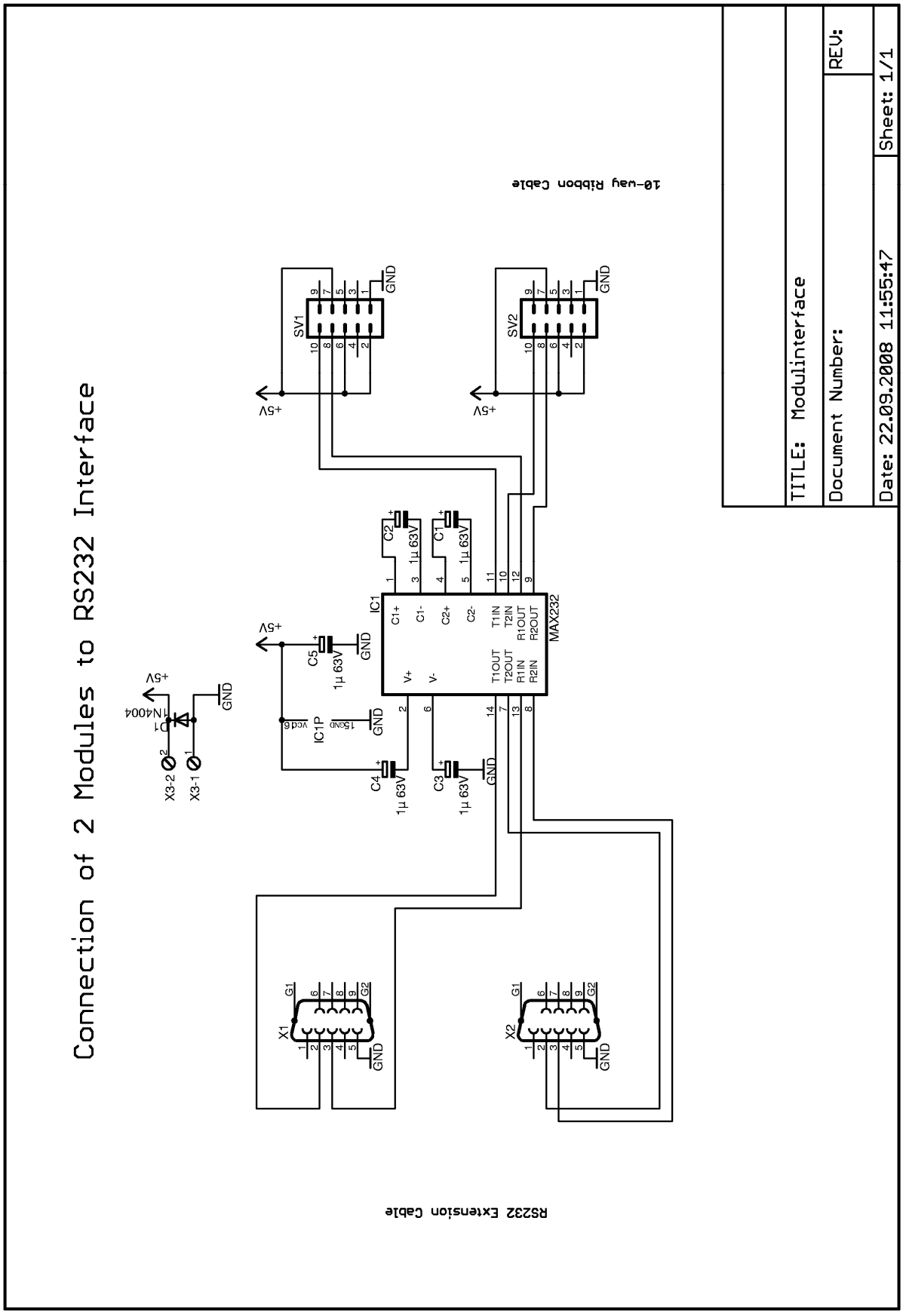
Only the manufacturer shall be authorized to carry out all and any interventions that concern the device, the structure, the software, or the operating cycle of the device or these interventions exclusively require the express prior consent of the manufacturer.

Attention

The environmental conditions agreed in the contract must be met.

The manufacturer shall not be liable for any damages owing to the improper or false utilization of the device as well owing to damages arising from interventions to the device that are not expressly required in the present manual.

9 Appendix



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