Dynamics Monitor for Electrical Power Grids

Type DMR-D

- **In wall mounting housing**
- **In panel mounting housing**
- **As 19" plug-in module**

1. Applications

Economic pressure to maximize line utilization and the growing inclusion of decentralized energy generation are today's biggest challenges to the stability of the electrical grid. With security margins continually decreasing, there is a clear need for enhanced monitoring functions during grid operation.

In a highly utilized system close to the stability boundary, poorly damped power system oscillations can occur even after relatively unexceptional disturbances. Faults but also routine switching events cause generator oscillations which are observable e.g. in voltage and frequency. Analyzing the magnitude of these oscillations reveals the capability of the system to safely reach a new and stable operating point.

In other situations, poorly tuned generator controls will cause such low frequency oscillations. Certain types of large industrial loads also create subharmonic disturbances through internal production processes with fluctuating power input.

Traditionally, such effects have been a concern mainly in the transmission grid and in conjunction with large power stations. Recently however, the growing inclusion of large numbers of small, fluctuating energy sources into the lower voltage levels causes such effects also in the distribution network. Increasingly, unexpected interaction effects between multiple generation sites are reported. It cannot always be guaranteed that groups of individually stable generators are similarly well-behaved when installed in close proximity and coupled via electrical lines.

In general it can be said that wherever many small fluctuating production sites replace fewer but significantly larger power stations, the energy storage capability of the grid is diminished and resilience towards dynamic disturbances is reduced.

In the past, grid oscillations have not only lead to isolated trippings of network elements but even played a significant role in outage cascades and blackouts. Thus, the deployment of suitable monitoring systems is an essential prerequisite if large scale disturbances are to be avoided.

Using the dynamics monitoring relay DMR-D, the user can identify weak spots in the electrical grid. Continuous high resolution analysis of low frequency oscillations in the grid enables the early detection of stability problems.

The list of use cases goes all the way from single generator monitoring (e.g. a rotating machine or a power inverter at its connection point) up to the monitoring of global grid stability using the Lyapunov stability exponent.

The latter application will especially appeal to operators of large industrial complexes or critical infrastructure facilities. The Lyapunov exponent serves as an early indicator, warning of certain types of blackouts, e.g. in the case when there is a fundamental unbalance between production and demand. Valuable reaction time is gained to initiate protective measures for particularly power-sensitive facilities, financial losses are minimized.

Grid operators use DMR-D related measurement results as inputs for their grid planning process on all voltage levels. Typically, after initial commissioning the device, a user will get a first snapshot of the grid in its normal/healthy state. Then, after a significant change in network topology - e.g. connecting an additional wind park - the changes in various measurement quantities reveal whether stability was affected or not.

DMR-D internal measurement quantities are transmitted to SCADA via mA-output and remote control or they are dispatched through modern communication protocols such as e.g. IEC 61850 or IEEE C37.118. For this purpose a number of optional protocol adapters is available.

Typical installation locations of these devices depend on the individual grid topology but are ideally close to high impedance bottlenecks or the connection point of a network element which is to be monitored.

The following examples give a small overview of possible use cases for grid dynamics analysis with DMR-D.

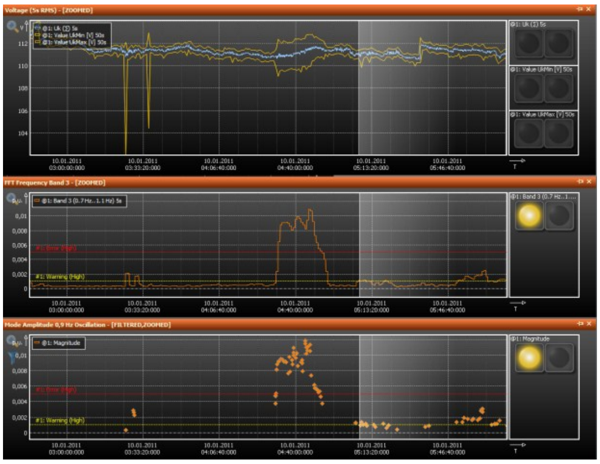


Figure 1: Voltage at the measurement site (upper panel). FFT frequency band 3 and oscillation amplitudes in damping monitor (middle / lower panel).

The data displayed in figure 1 was measured during a major fault in a live transmission system. In the upper panel, two short voltage dips can clearly be seen. These dips indicate the time of the power system fault and a subsequent line tripping. This event happened in the proximity of a large power station.

The middle and lower panels show low frequency spectral analysis results from a DMR-D which was installed in the same grid region. It can be seen that large poorly damped oscillations around 1 Hz occurred. The root cause for this was the increased grid impedance which itself was a consequence of the missing/ tripped line. The power stations generators which were still operating at full input power could not find a suitable operating point anymore and entered an unstable regime characterized by oscillatory behavior. DMR-D enables the online monitoring of such events, with amplitude and damping readings allowing a simple assessment of the current risk level.

Another use case measured in a low voltage distribution grid is displayed in Figure 2. The data shows the dynamic properties of a single 400V line in a rural grid where multiple privately owned PV generators are connected. One of the owners had previously complained massively about inexplicable trippings of his generator. A power quality measurement had shown raised Flicker levels. The upper panel of figure 2 shows large amplitudes in the FFT-band 4-14 Hz - a highly Flicker-relevant band.

Detailed analysis of oscillation frequencies and the corresponding amplitude spectrum (middle and lower panels) reveals a dominant 9 Hz oscillation. It is directly responsible for the poor Flicker level. An additional investigation showed that the 9 Hz mode occured predominantly under reverse power flow conditions and that feed-in is interrupted.

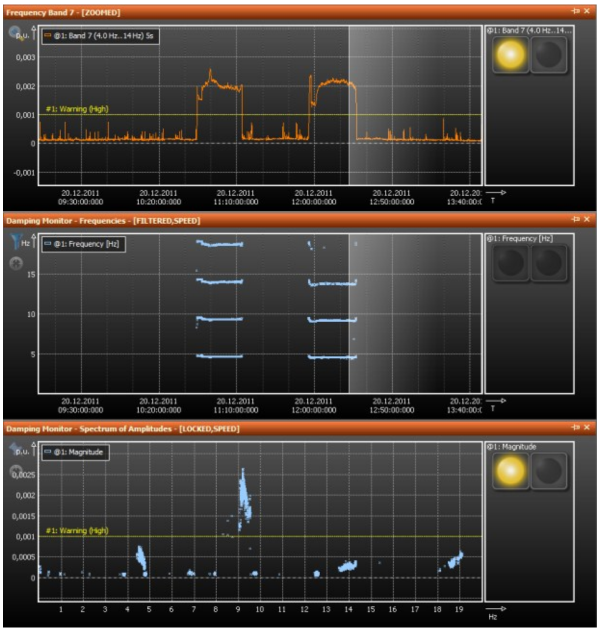


Figure 2: Analysis of PV feed-in problems in a rural distribution grid

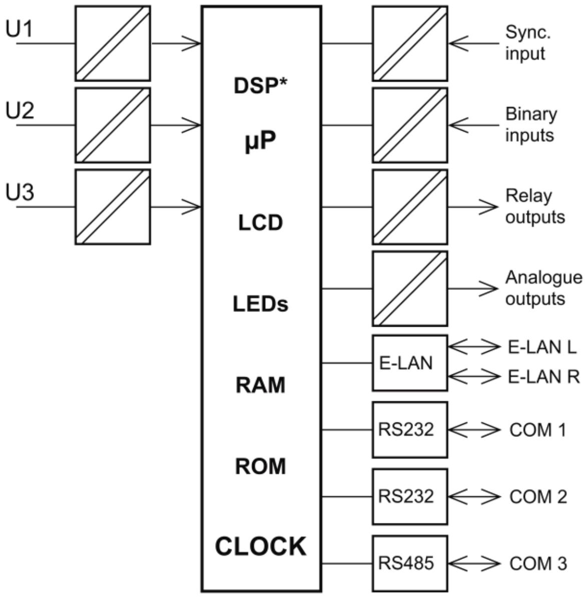
This indicated that the 9 Hz disturbance was involved in the inverter trippings. The network operator then cut the electrical connection between the affected and a neighboring PV generator. As a result, the 9Hz oscillation stopped and the feed-in problems disappeared. In conclusion this was a strong indication that a controller interaction between two PV inverters had been the root cause of the problems.

1.1 Summary of the DMR-D characteristics:

- Spectral analysis of voltages with high frequency resolution
- High resolution frequency monitoring: f, df/dt, oscillations. Maximum rate: 10 ms.
- Monitoring of the grid´s damping profile (damping monitor)
- On-line calculation of the Ljapunov exponent of the network
- Fault recorder function
- Variable signalling via several programmable relay outputs
- Generation of input data to be used for asset management and grid planning

Furthermore, critical grid incidents are stored in an event recorder, including pre- and post-event history. Synchronization of measurement data to real time (DCF 77, GPS, NTP) is also possible.

1.2 Description



* DSP : Digitaler Signal Prozessor

Dynamic Monitor Function

2. Technical Characteristics

Regulations and Standards

IEC 61010-1 / DIN EN 61010-1

IEC 60255-22-1 / DIN EN 60255-22-1

IEC 61326-1 / DIN EN 61326-1

IEC 60529 / DIN EN 60529

IEC 60068-1 / DIN EN 60068-1

IEC 60688 / DIN EN 60688

IEC 61000-6-2 / DIN EN 61000-6-2

IEC 61000-6-4 / DIN EN 61000-6-4

IEC 61000-6-5 / DIN EN 61000-6-5

Voltage inputs		
Option	**E1**	**E2**
Nominal voltage	100 V	230 V
Voltage end range	200 V	460 V
Input resistance	360 k Ω	810 k Ω
Measurement fault	< ±0.1% von U_{din} Range 10% ... 150% of U_{din}	
Insulation category	CAT III / 300 V	

Analog Outputs (AO)	
Number	See ordering information
Output range Y1...Y2 Y1 and Y2	 -20 mA...0...20 mA programmable
Electrical isolation	Optocoupler
Load range	0 ≤ R ≤ 8 V / Y2
Alternating component	<0.5 % von Y2

The outputs can be continuously short-circuited or remain in open circuit. All output connections are isolated from all other circuits.

Binary Inputs (BI)	
Control signals U_{st}	in the range AC/DC 48 V ... 230 V
Wave form – H – level – L – level l	Rectangle, sinus ≥ 48 V < 10 V
Signal frequency	DC ... 50 Hz
Input resistance	108 kΩ
Electrical isolation	Optocoupler

Binary Outputs (BO)	
Max. switching frequency	≤ 1 Hz
Electrical isolation	Isolated from all internal potentials
Contact load	AC: 250 V, 5 A $(\cos\varphi = 1{,}0)$ AC: 250 V, 3 A $(\cos\varphi = 0{,}4)$ DC: 220 V, 150 W Switching capaci-ty
Number of operations	≥ $1 \cdot 10^4$ electrical

Limit value monitoring	
Limit values	Programmable
Response time	Programmable
Alarm displays	Programmable LED

Measured quantities (selection)	
Voltages TRMS	U_{12}, U_{23}, (U_{31})
Frequency	f

Reference conditions	
Reference temperature	23°C ± 1 K
Input quantities	U_E = 90 ... 110V
Auxiliary voltage	H = Hn ± 10 %
Frequency	50 Hz...60 Hz
Load (only for feature M92)	Rn = 4 V / Y2 ± 1 %

Transmission behaviour	
Error limit – Voltage: – Frequency:	0,1 % 0,01 % all error information referred to Y2
Measurement cycles	10 ms, 5 s, 50 s, 10 min
Sampling rate	2,048 kHz

Storage of measurement values	
Memory	64 MB

Electrical Safety	
Protection class	I
Degree of pollution	2
Overvoltage category	II,III

III	II
Current and voltage inputs Auxiliary voltage	Control circuits Analogue outputs COMs, E-LAN

Operating voltages		
50 V	**120 V**	**230 V**
E-LAN, COM1 ... COM3 Analogue out-puts	Overvoltage category	Auxiliary voltage Binary inputs Binary outputs

Electromagnetic compatibility	
Interference emissions	Group 1 limit class A according to EN 55011:1991
Interference immunity	Electrostatic discharge according to EN 61000-4-2:1995 Air discharge: 8 kV Contact discharge: 4 kV Electromagnetic fields according to EN 50140:1993 and ENV 50204:1995 80 - 1000 MHz: 10 V/m 900 ± 5 MHz: 10 V/m pulse modulated Fast transient interferences (bursts) acc. to EN 61000-4-4: 1995 Supply voltage 230 V AC: 2 kV; Data cables 1 kV Conducted interferences acc. to ENV 50141:1993 0.15 - 80 MHz: 10 Veff 50 Hz magnetic fields ac-cording to EN 61000-4-8:1993 30 A/m

Test voltages	
Mounting rack / housing	2.5 kV
Auxiliary voltage	3.1 kV
COM´s, E-LAN, Time-/Trigger-BUS	0.35 kV
Binary outputs	1.8 kV
Binary inputs (250 V)	1.8 kV
Analogue outputs	0.35 kV
Input voltage (E1, E2)	1.4 kV
Input currents	1.4 kV

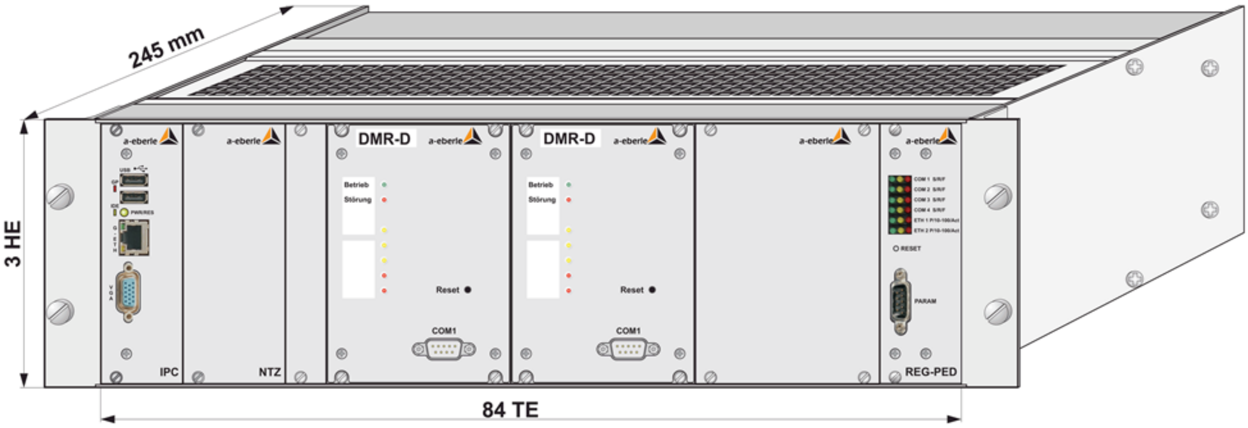
Note: All test voltages are AC voltages in kV, which may be applied for 1 minute

Power supply		
Feature	**H1**	**H2**
AC	85 ... 264 V	-
DC	88 ... 280 V	18 ... 72 V
Power consumption	≤ 15 VA	≤ 15 Watt
Frequency	45 ... 400Hz	-
Microfuse	T1 250 V	T2 250 V

The following applies to all features:
Voltage dips ≤ 80 ms cause neither loss of data nor malfunction

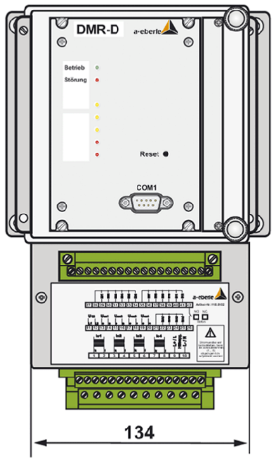
Climatic stability	
Temperature range	
– Function (housing)	-10 °C ... +50 °
– Function (plug-in module)	-10 °C ... +60 °C
– Transport and storage	-25 °C ... +65 °C

Data storage	
Device parameters	Serial EEPROM with ≥ 1000 k write/ read cycles
RAM - data	Li-battery, laser-welded

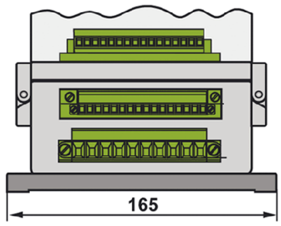


19"rack with plug-in cards, 84 TE, feature B92

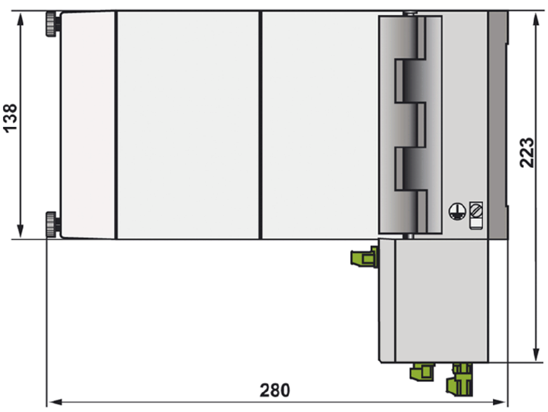
Front view



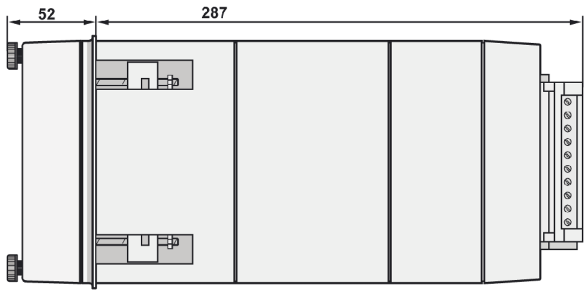
View from below

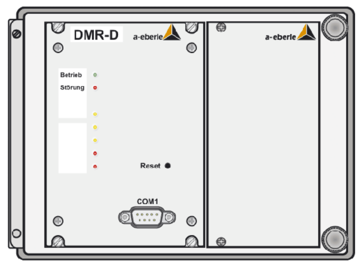


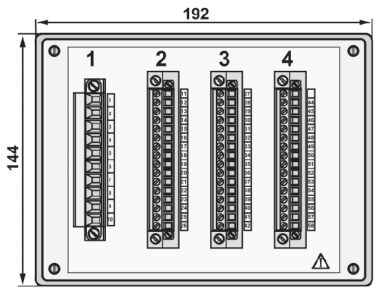
Side view

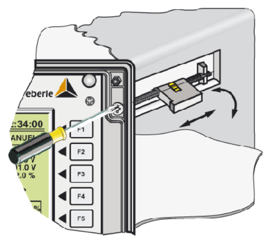


Wall mount housing 20 TE feature B 90









View of fixing control panel cutout:
184,5 + 0,2 mm x 138,3 + 0,2 mm

Panel mount housing 30 TE feature B91, terminal assignment exemplary

3. Mechanical design

Plug-in module	
Front panel	Aluminium, RAL 7035 grey
Height	3 U (132.5 mm)
Width	18 TE (91.44 mm)
Circuit board	160 mm x 100 mm
Mass	≤ 1.0 kg
Degree of protection – Plug-in module – Socket connector	 IP 00 IP 00
Mounting	according to DIN 41494 part 5
Plug-in connector	DIN 41612

Housing

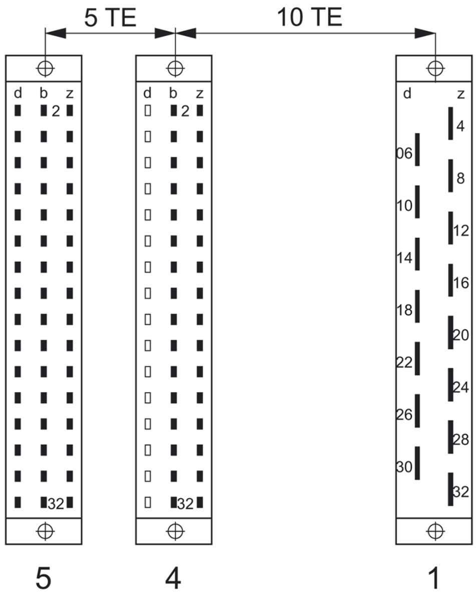
A wide range of housing options is available for DMR-D.

Only a selection of possible housing options is presented here.

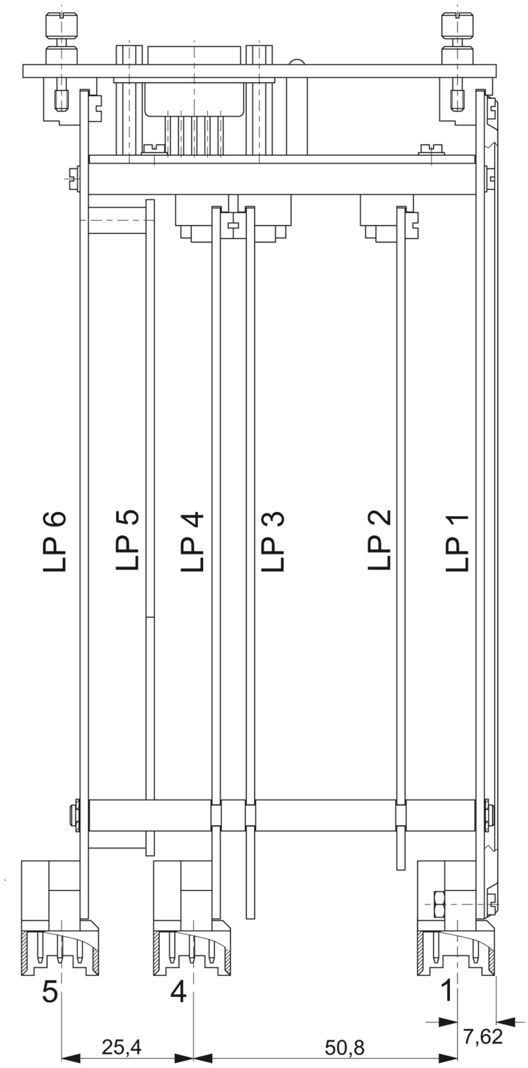
Standard housings are those identified by feature B90 and B92.

The number of inputs, outputs, COMs etc. of a 19” plug-in module is much higher than the number of terminals available on a typical housing. Therefore the terminal assignment for the versions B90...B92 has to be defined individually.

Material	Plastics
Degree of protection	Housing IP 65
Mass	≤ 1.5 kg
Dimensions	See page 5
Connection elements	Screw terminals



Position of socket connectors



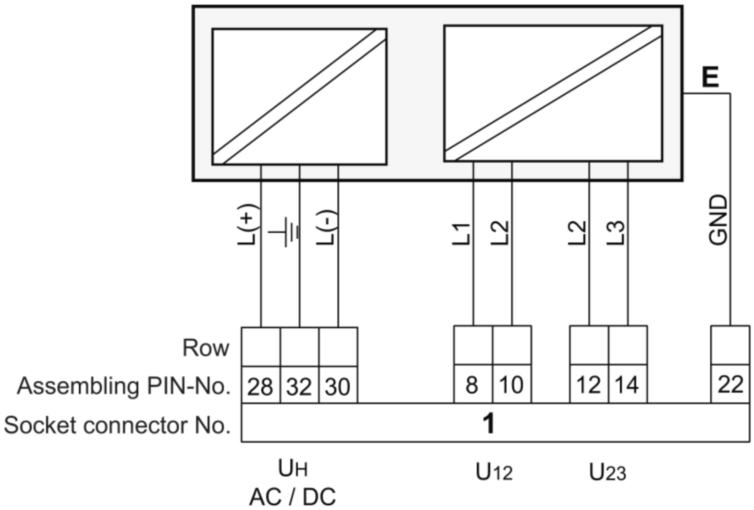
Position of plug connectors and PCBs

4. Assignment of socket connectors 1, 4 and 5

Note:
Regarding the position of the socket connectors
please refer to page 7

Socket connector 1

Auxiliary voltage, voltage inputs
Input voltages U12 … U23 and auxiliary voltage



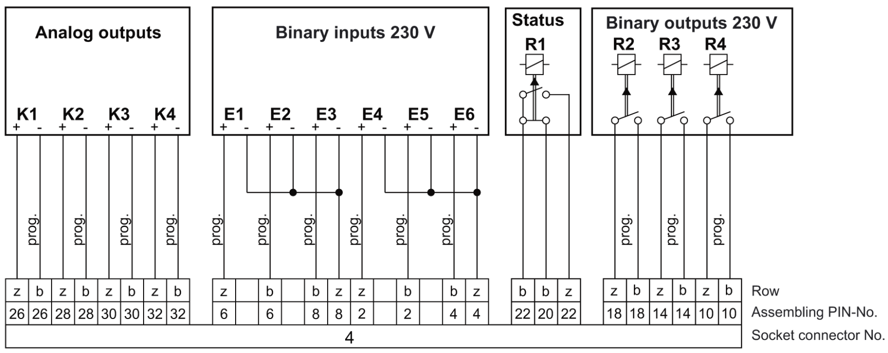
Description		Function	Pin	Assignment
Voltage L1 – L2 (AC)	U_{12}	L1	8	
		L2	10	
Voltage L2 – L3 (AC)	U_{23}	L2	12	
		L3	14	
Functional earthing	E		22	
Auxiliary voltage	U_H	L (+)	28	
		L (-)	30	
		PE	32	

The voltage inputs U12 … U23 can be used to a rated value up to 110 V

Socket connector 4 – feature M92 (Standard)

Binary inputs, outputs, analogue outputs

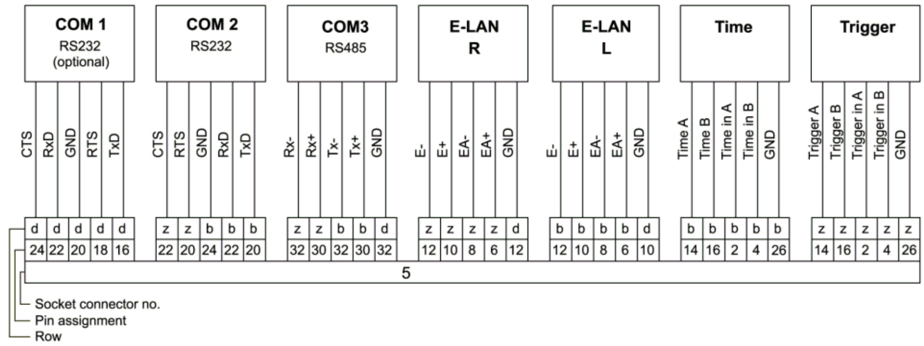
Version with:	6	binary inputs
	3	binary outputs (make contact)
	1	status-relay
	4	analog outputs



Description		Function	Pin	Comment
Analogue outputs	K1	+ -	z26 b26	Freely programmable
	K2	+ -	z28 b28	Freely programmable
	K3	+ -	z30 b30	Freely programmable
	K4	+ -	z32 b32	Freely programmable
Binary inputs 230 V	E1	+	z6	Freely programmable
	E2	+	b6	Freely programmable
	E3	+	b8	Freely programmable
	E1...E3	GND	z8	
	E4	+	z2	Freely programmable
	E5	+	b2	Freely programmable
	E6	+	b4	Freely programmable
	E4...E6	GND	z4	
Binary outputs 230 V	Status R1	Öffner Make contact Pole	z20 z22 b22	
Binary outputs 230 V	R2	Make contact Pole	b18 z18	Freely programmable
	R3	Make contact Pole	b14 z14	Freely programmable
	R4	Make contact Pole	b10 z10	Freely programmable

Socket Connector 5:

Communication COM2, COM3, E-LAN, Time- / Trigger-BUS



Bezeichnung	Funktion	Pin
COM 1 RS 232	CTS	d24
	RxD	d22
	GND	d20
	RTS	d18
	TxD	d16
COM 2 RS 232	CTS	z22
	RTS	z20
	GND	b24
	RxD	b22
	TxD	b20
COM 3 RS 485	Rx -	z32
	Rx +	z30
	Tx -	b32
	Tx +	b30
	GND	d32
E-LAN R (right)	E-	z12
	E+	z10
	EA-	z8
	EA+	z6
	GND	d12
E-LAN L (left)	E-	b12
	E+	b10
	EA-	b8
	EA+	b6
	GND	d10
Time	Time A	b14
	Time B	b16
	Time in A	b2
	Time in B	b4
	GND	b26

Bezeichnung	Funktion	Pin
Trigger	Trigger A	z14
	Trigger B	z16
	Trigger in A	z2
	Trigger in B	z4
	GND	z26

5. Serial Interfaces

RS232 Interfaces

The DMR-D has two serial interfaces RS232 (COM 1, COM 2). COM 1 is located on the front side of the device, COM 2 is accessible over the plug connector.

COM 2 is used to connect the system to higher-level SCADA systems or to modems

Connection elements

COM1	Plug connector, SubMinD on the device front, PIN assignment like PC
COM2	Steckerleiste 5
Connection options	PC, Terminal, Modem
Protocol of databits/ protocol	Parity 8, even, no
Transfer rate bit/s	1200, 2400, 4800, 9600, 19200, 38400, 57600, 76800, 115200
Handshake	RTS / CTS X_{ON} / X_{OFF}

RS 485 interfaces

As standard the DMR-D offers the double-interface E-LAN. It is used for the bus connection to PQI-Ds, voltage regulators REG-Ds, Petersen-coil regulators REG-DPs or to the earth-fault detection system EORSys

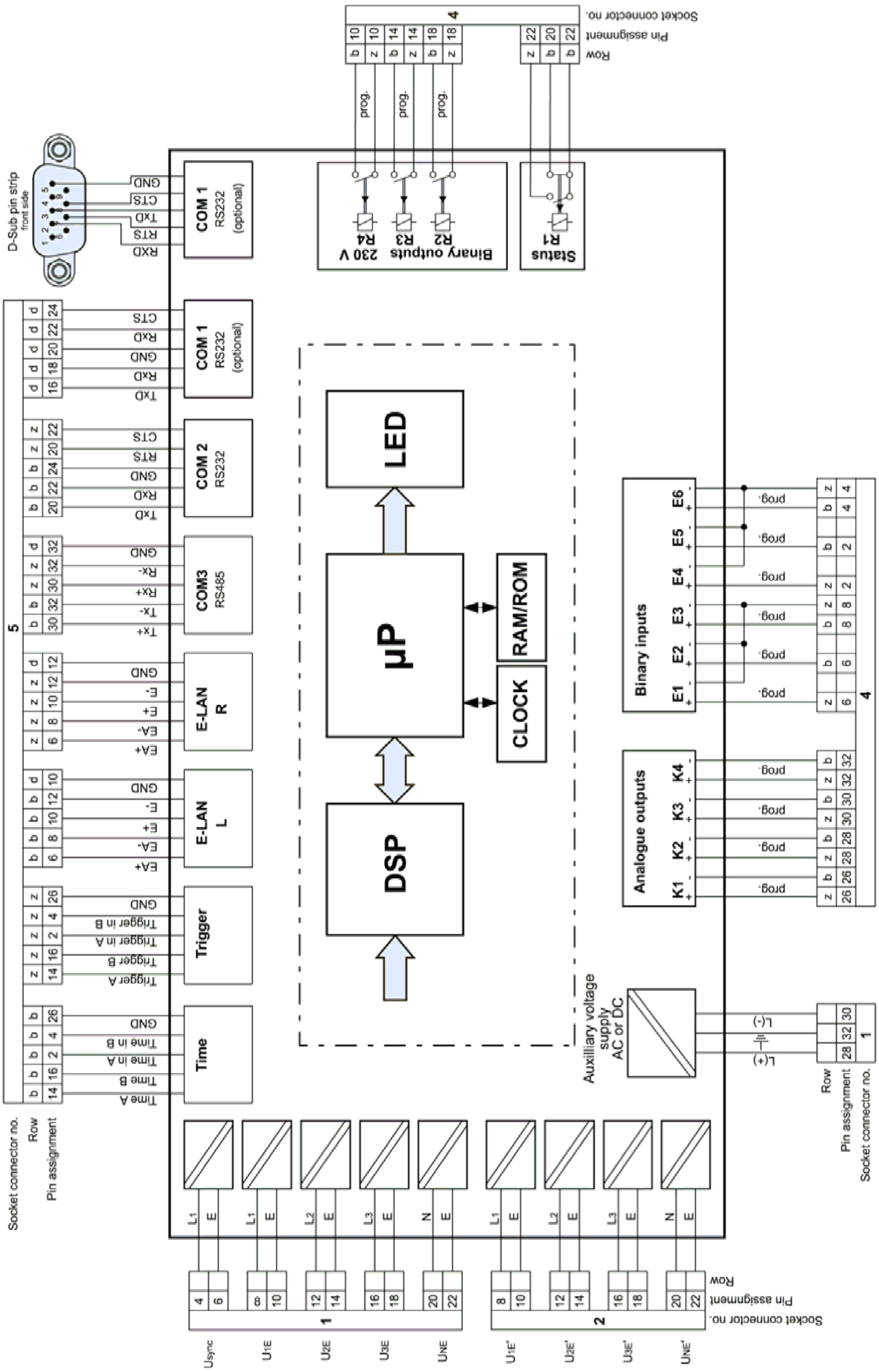
E-LAN (Energy- Local Area Network)

Features

- 255 bus devices can be addressed
- Multimaster-structure
- Integrated repeater function
- Open loop, bus or combination of bus and loop
- Protocol based on SDLC/HDLC frames
- Transfer rates of 62,5 kbit/s or 125 kbit/s
- Telegram length 10 … 30 Bytes
- Average throughput approx. 100 telegrams/s

COM3

For the connection of interface modules (BIN-D, ANA-D) to any DMR-D in any combination.



Block diagram - feature M92

6. Ordering information

When ordering please note

- Only one code with the same capital letter may be selected
- If the capital letter of the code is followed by the number 9, additional details in plain text are required
- If the capital letter of the code is followed by zeros only, this code can be omitted when ordering

FEATURE	CODE
Dynamic-Monitor (18 HP, 3 RU) • for transmission, distribution and industrial networks • with two E-LAN interfaces for communication with the REGSys-components • equipped with COM1, COM2 and COM3 • with 3 programmable binary-outputs plus life contact • with 6 programmable binary inputs, 4 programmable analog outputs	DMR-D M92
Rated input voltage • 100/110V • 230/400V	 E1 E2
Network level (restricted algorithms) • low voltage <1kV (same as W3 but without fingerprint- and drift evaluation) • medium voltage, e.g. distribution up to 100kV (same as W3 but without fingerprint) • high and highest voltage, e.g. transmission >100kV (all algorithms active)	 W1 W2 W3
Design • 19 " plug-in module • wall mounting housing 20 HP (wiring t.b.d.) • panel mounting housing 30 HP (wiring t.b.d.) • installed in 19" frame or housing (type and wiring t.b.d.) • 19"-rack with backplane	 B00 B90 B91 B92 B95
Supply voltage • AC 85V..110V..264V / DC 88V..220V..280V • DC 18V...60V...72V	 H1 H2
System-specific planning and documentation • without • with	 L0 L1
Operating manual • German • English	 G1 G2

Notes

Notes

A. Eberle GmbH & Co. KG

Frankenstr. 160
D-90461 Nuremberg

Tel.: +49 (0) 911 / 62 81 08-0
Fax: +49 (0) 911 / 62 81 08 96
E-Mail: info@a-eberle.de

http://www.a-eberle.de

Software - Version:

____