POSITAL
FRABA

Absolute Rotary Encoder
with Ethernet Powerlink Interface

Powerlink protocol version 1

User manual

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Document information

File name:	UME-OCD-EP
Date:	August 2005
Version number:	2.00
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1 Introduction

1.1 Absolute Rotary Encoders

Absolute rotary encoders provide a definite value for every possible rotary position. All these values are reflected on one or more code discs. The beams of infrared LEDs are sent through the code discs and detected by Opto-Arrays. The output signals are electronically amplified and the resulting value is transferred to the interface.

The absolute rotary encoder has a maximum resolution of 65,536 steps per revolution (16 Bit). The Multi-Turn version can detect up to 16,384 revolutions (14 Bit). Therefore the largest resulting resolution is 30 Bit = 2^{30} = 1,073,741,824 steps. The standard Single-Turn version has 13 Bit, the standard Multi-Turn version 25 Bit.

The encoder sends the data in decimal code via standard or fast Ethernet (100 Base T). At present it supports the following protocol: Ethernet Powerlink with protocol version 1.

The encoder is able to provide as output data the position value without further calculation

A Powerlink managing node, operating as master, must be in a network to read out the process data from the encoder.

1.2 Ethernet

The present developments in the field of Industrial Ethernet are based on the vision of an integrated access of all data of a company through a uniform communication system. In higher levels of enterprise communication Ethernet is the main medium of data transfers. Combined with other IT technologies it is internationally standardized. In the long run automation engineers will benefit from the rapid technological progress in the mass markets of IT and web technologies.

Ethernet technically provides a system with higher data transfer rates than common field bus systems. TCP/IP and UDP do have a statistical access method to access the medium thereby prohibiting determined response times. Many developments are intensely done on additional real time mechanisms, e.g. Ethernet Powerlink

1.3 TCP/IP

Even though Ethernet and TCP/IP are often used together and sometimes used interchanged, these are three different kinds of terms and you should carefully separate them. The coherences are based on the ISO/OSI reference model after ISO/IEC 7498 that is needed to basically understand these terms.

Ethernet only describes layer 1 and 2 in this model, nevertheless the term is often used in error in engineering as description of all layers between 1 and 7.

The IP protocol of layer 3 was developed in the 70's by the US military (MIL-STD 1777). It allows a universal addressing independent of the hardware involved in heterogeneous networks. It also manages the transfer of large packets by splitting them up into smaller packets. The well-known TCP protocol (MIL-STD 1778) ensures a reliable data transfer.

Http (RFC 2068) and SMTP (MIL-STD 1781) belong to layer 7 of the OSI model and allow to transfer data and documents via web browser or to send e-mails.

1.4 UDP

User **D**atagram **P**rotocol is utilized to send data that does not need to be transferred in a reliable way. The UDP packet is encapsulated in an IP packet which in turn is encapsulated in a PPP packet. Both UDP and IP have checksum octets and the PPP packet has its FCS octets however this can only guarantee that the data and the destination are correct. If a packet is lost, it will not be resent using UDP, this issue is only addressed by the TCP protocol.

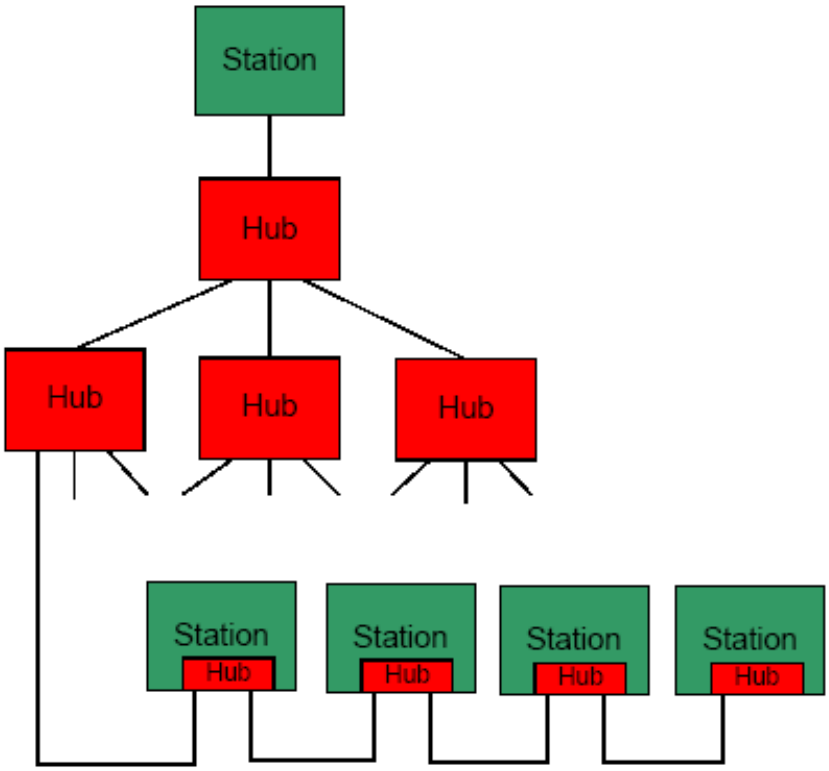
1.5 OSI-Modell

Layer			
7	Application Layer	SMTP, FTP, HTTP	Application
6	Presentation Layer		
5	Session Layer		
4	Transport Layer	TCP and UDP	Data transport
3	Network Layer	IP and IPX	
2	Data Link Layer	Ethernet	
1	Physical Layer	10BASET, 100BASET	Cable

2 Hardware set-up and Ethernet Connection

2.1 Network Topology

Using Ethernet there are different kinds of topologies possible. The connection of the encoder can be made directly to a hub. If you use a direct connection to a computer without network components in between, you need to use a standard, “straight” network cable (not a crossover cable). You need at least a cable of category 5 to get a data transfer rate up to 100 Mbit.



The symbolized structure shows a classic star topology and a line cabling structure. With encoder version 00 you must directly connect the encoder device to a hub. An integrated hub in encoder version A1 offers both: star or more useful a line structure.

Only hubs should be used because of low frame jitter and latency time. For fulfilling time requirements up to 10 hubs can be connected together with a maximum cable length of 100m.

These requirements are specified in Powerlink specification. For more details visit the web site: www.ethernet-powerlink.org.

2.2 Connecting an Absolute Encoder

The encoder is connected by a 5 pin M12 connector for the power supply and one 4 pin, D-coded M12 connector for Ethernet.

Encoder version A1 uses a second D-coded connector and provides an integrated hub functionality. On or in the packaging of the connector is the mounting description.

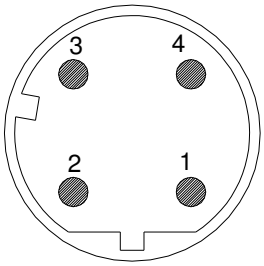
Connector Ethernet
4 pin female, D-coded

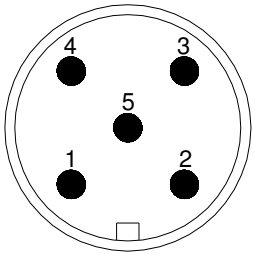
Pin Number	Signal
1	Tx +
2	Rx +
3	Tx -
4	Rx -

Connector power supply
5 pin male, A-coded

Pin Number	Signal
1	+24 V
2	+24 V
3	0 V
4	0 V
5	PE

Sketch on encoder view





2.3 Ethernet Cables

2.3.1 RJ45 – M12 crossed

Signal	RJ45 Pin	M12 Pin	Signal
Tx+	1	2	Rx+
Tx-	2	4	Rx-
Rx+	3	1	Tx+
Rx-	6	3	Tx-

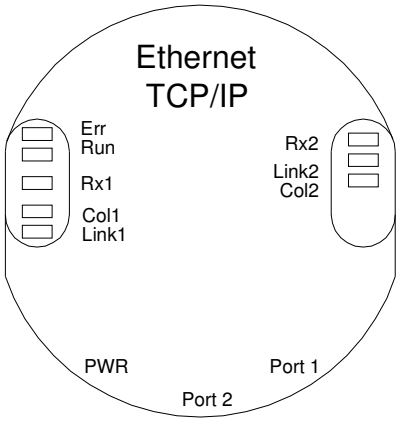
2.3.2 RJ45 – M12 straight

Signal	RJ45 Pin	M12 Pin	Signal
Tx+	3	1	Tx+
Tx-	6	3	Tx-
Rx+	1	2	Rx+
Rx-	2	4	Rx-

2.3.3 M12 – M12 crossed

Signal	M12 Pin	M12 Pin	Signal
Tx+	1	2	Rx+
Tx-	3	4	Rx-
Rx+	2	1	Tx+
Rx-	4	3	Tx-

2.4 Diagnostic LED's



LED	Color	Description for LED = on
Rx1	Yellow	Incoming and outgoing traffic for port 1
Link1	Green	Link to another Ethernet component for port 1
Collosion1 *	Red	Ethernet collisions on the bus for port 1
Rx2 *	Yellow	Incoming and outgoing traffic for port 2
Link2 *	Green	Link to another Ethernet component for port 2
Collosion2 *	Red	Ethernet collisions on the bus for port 2
Error *	Red	Reserved
Run *	Green	Reserved

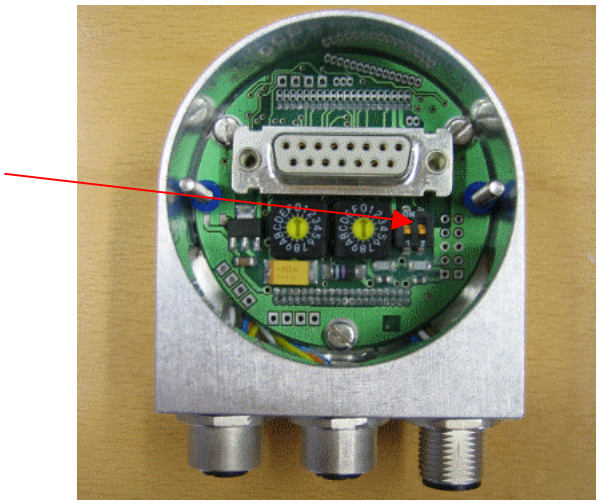
* Only for version A1

3 Network Configuration

The rotary encoder can be used either with the Ethernet Powerlink IP address which can be programmed or the wired IP 10.10.10.10. A switch to choose corresponding option is located in the connection cap. If the switch 2 is in position “off”, the POWERLINK IP has been chosen (default!).

Powerlink Protocol version 1:
The encoder is pre-configured with a fixed Powerlink node number 100, which cannot be changed by the user. Be aware of this restriction! The hex coded rotary switches cannot be found in the cap as shown in the picture.

The function of the DIP switch can be used if another than EPL IP address is needed or the user is not sure about a programmed node IP.



Encoder version A1:
Both Hex rotary switches are used to configure the Powerlink (EPL) node address. Allowed address range for a controlled node is: 1-239.

4 Project integration

This integration description is related to B&R control units and automation studio.

For adding an encoder into your project a generic Powerlink device is needed. So you have to add the library 'POWERLNK' first and use a generic device. To realize a data connection the following information must be configured for the generic device (here: encoder):

- Controlled node number
- Offset for the data pointer within data frame
- Length of data type

The Powerlink encoder with EPL protocol V1 has currently a fixed node number 100 at factory. There is no data offset in the EPL frame, because only one process value is used: position value. The data length is 8 bytes whereby only 4 bytes contain really updated values. All other bytes are set to 0. Ordered data bytes of a read position value within a EPL frame is low byte first and at least MSB.

Position value coding:

DB1	DB2	DB3	DB4	DB5	DB6	DB7	DB8
LSB			MSB	00	00	00	00

Data exchange direction:

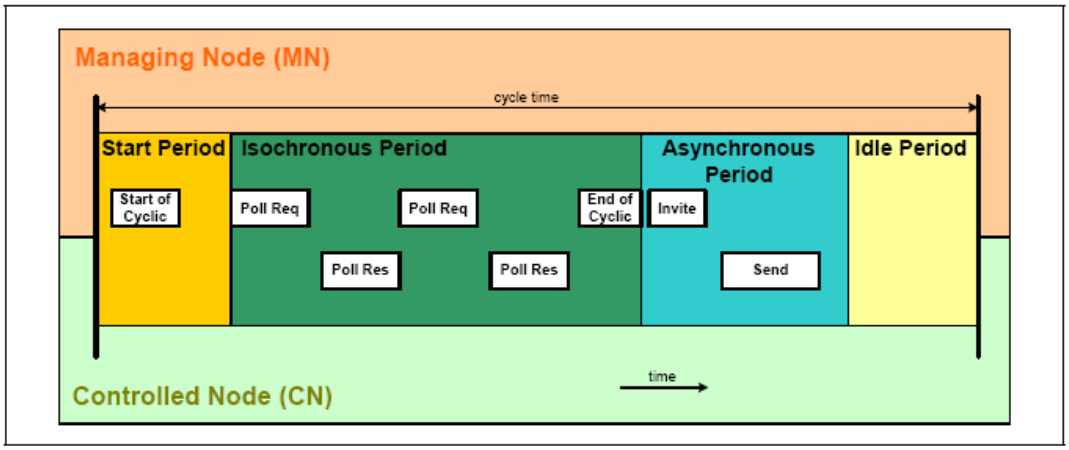
The encoder offers only IN Data as Poll Response message (PRes). No data out messages contained within Poll Request (PReq) message can be transmitted to the encoder.

5 Powerlink protocol

5.1 Powerlink cycle

The Powerlink protocol offers an isochronous communication. A deterministic transmission is a requirement out of high performance applications. The deterministic network cycle is achieved with a time slot principle, which is descripted in following picture. An EPL cycle is divided into 4 periods: Start, Isochronous, Asynchronous, Idle Period.

With Start period the devices latch their process data. This action is synchronous realized via the whole EPL network.
Isochronous period: CN are processed what means that the MN node request the nodes after each other. In this time slot the process values are transmitted.
Asynchronous period: Used for non time critical data.
Idle period: Remaining time till next cycle. Used to compensate different processing cycle times to achieve an outside constant cycle time.



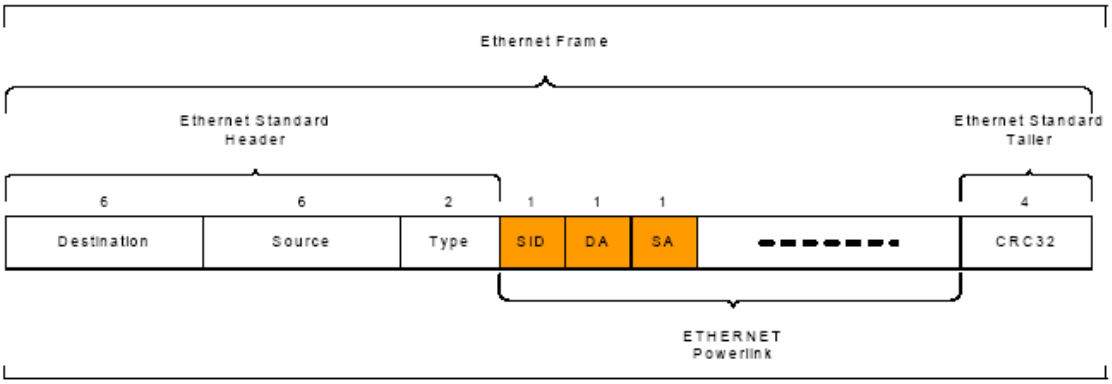
5.2 Powerlink messages

Ethernet Powerlink frames are embedded in a standard Ethernet frame. Because of that it is possible to use standard diagnostic tools in an EPL network. But you must be aware, that a standard PC can be able to interrupt the controlled EPL cycle. As a result the cycle can not be deterministic anymore.

The Ethernet frame is divided into 3 parts: Ethernet standard header, Ethernet powerlink part as standard Ethernet data and annex. For destination and source address within Ethernet standard header the MAC address is given. A MAC address is built up with 6 bytes, here are the first 5 bytes constant: 00-60-65-00-49., the sixth octet is the node number. The Ethernet type field is set to: xxxx.

Powerlink specific data:

See the marked entries, which are fixed for all other EPL frames. The rest is defined depending on the specific service identifier (message type).



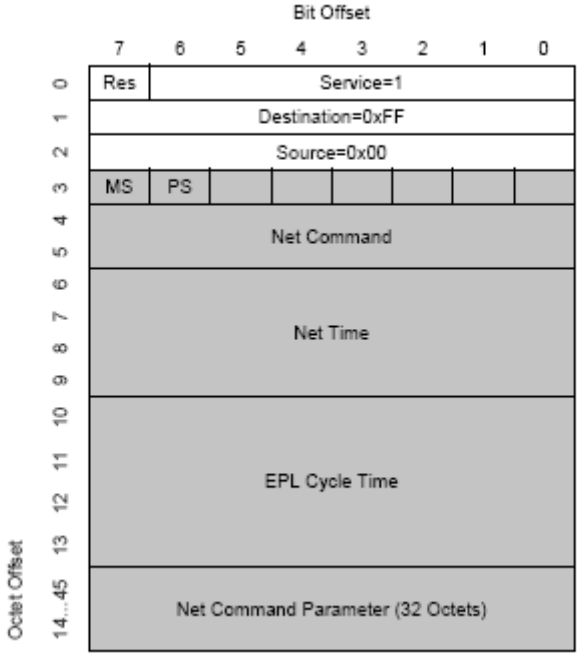
Code	Name	Description
SID	Service identifier	Identifies the additional reference data.
DA	Destination Address	Node which the frame is sent to.
SA	Source Address	Node which sent the frame.

Service number	Description	Transfer type	Comment
1	Start of Cyclic (SoC)	Broadcast	Marks begin of EPL cycle and isochronous part.
2	End of Cyclic (EoC)	Broadcast	Marks end of isochronous part
3	Poll Request (PReq)	Unicast	Transfer request of MN to CN to send isochronous data. CN answers with PollResponse frame. Frame can include data from MN to CN.
4	Poll Response (PRes)	Broadcast	Contains isochronous data of a CN.
5	Acyclic Invite (AInv)	Unicast	Frame in asynchronous part for MN to request asynchronous data from a particular CN.
6	Acyclic Send (ASnd)	Unicast/Broadcast	Frame in asynchronous part of the cycle to send asynchronous data (to a CN or to the MN).
7			Reserved

5.2.1 Powerlink messageSoC

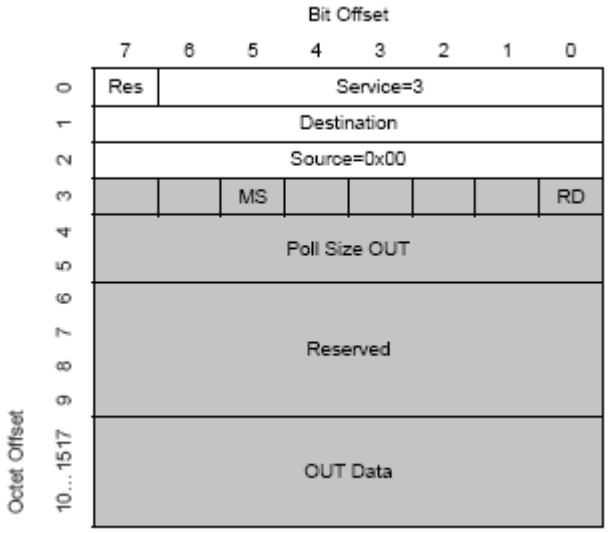
This message is sent as a broadcast telegram to all CN on the network. All devices will sample on receiving this telegram their input state. The encoder is latching in this moment the current position value. Total number of transmitted bytes is 64 octets, according to Ethernet standard framing. If you compare the given table below with the information from chapter 5.2 you can see, that the first three entries are out of the EPL frame. Grey colored area is specific data according to the SoC message.

The structure of the frame is given in the following picture.



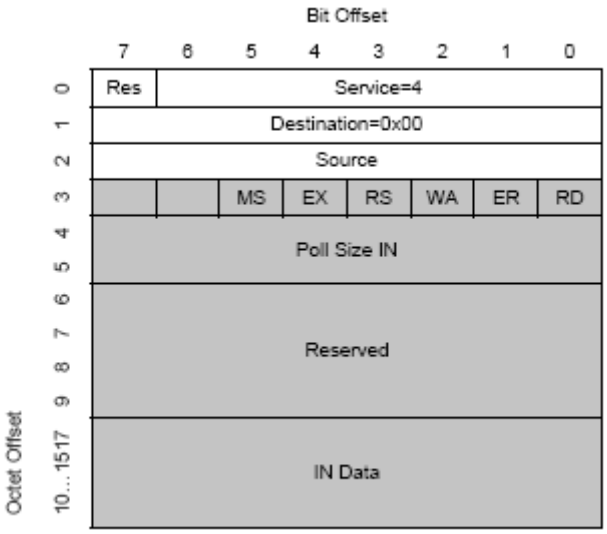
5.2.1 Powerlink message Poll Request

Data (out data) which is sent from the Managing node (MN) to the Controlled node (CN). Independent if data has to be send out, the PReq message is needed to get input data from the controlled node. This message is used to allow the CN a time slot for transmission within an



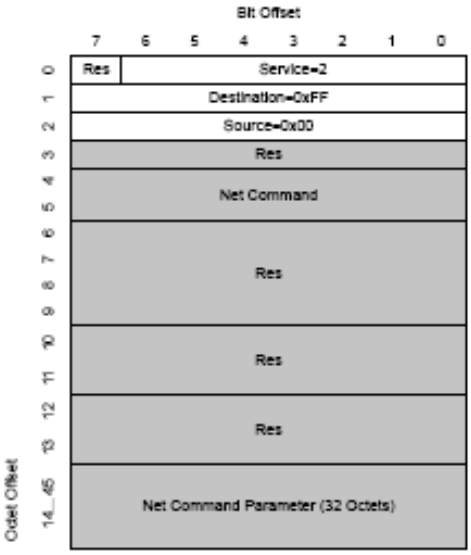
5.2.2 Powerlink message Poll Response

transferred data from a CN to a MN. If the sent data is valid, which is indicated by a set RD flag, the encoder position value is given in the IN DATA field. Minimum size for IN Data is 36 octets according to standard Ethernet framing. Poll size is the size of input data in octets. ER flag: Fatal error in CN with break down of service. MS is used, when multiplexed time slot mode is in operation. WA is a warning flag and the CN is still in operation. EX indicates an exception, that unread entries exist.



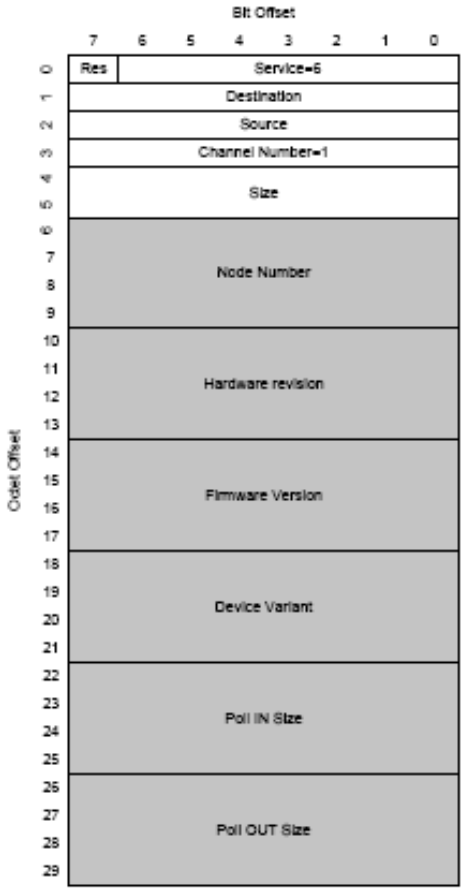
5.2.2 Powerlink message End of Cycle

The End of Cycle message is sent as broadcast information to all CN in the EPL network. With this message the CN are allowed to take over their out data. Additional the end of isochronous cycle is indicated. The MN is not sending this frma if an error occurred. Frame size is 64 octets in total with overhead.



5.2.2 Powerlink message Ident Channel

This message is only MN internal and can not be accessed by an application. With this message the MN can identify, how the CN is configured and additional information.



Field	Description
Node number	Number of the node
Hardware revision	CN hardware revision if available, otherwise 0xFFFFFFFF
Firmware version	Firmware version of node. Higher number = newer version.
Firmware variant	To identify firmware targets. Every device has a unique variant number.
Poll IN Size	Number of isochronous net data octets CN'MN (Poll Response frame).
Poll OUT Size	Number of isochronous net data octets MN'CN (Poll Request frame).

Encoder settings

Hardware revision: 1

Firmware revision: 1

Device variant: 150 (dez)

Poll In size : 8

Poll out size: 0

6 Technical Data

6.1 Electrical Data

Supply voltage	10 - 30 V DC* (absolute limits)
Power consumption	max. 4 Watt
EMC	Emitted interference: EN 61000-6-4
	Noise immunity: EN 61000-6-2
Bus connection	Ethernet Powerlink V2, V1
Transmission rate	100 MBit
Accuracy of division	± ½ LSB (12 bit), ± 2 LSB (16 bit)
Step frequency LSB	Max. 800kHz (internal valid code)
Electrical lifetime	> 10^5 h
Device addressing	Programmable IP-Address with 2hex coded rotary switches

6.2 Mechanical Data

Housing	Aluminum, optional stainless steel
Lifetime	Dependent on shaft version and shaft loading – refer to table
Max. shaft loading	Axial 40 N, radial 110 N
Inertia of rotor	≤ 30 gcm^2
Friction torque	≤ 3 Ncm (without shaft sealing)
RPM (continuous operation)	Singleturn: max. 12.000 RPM
	Multiturn: max. 12.000 RPM
Shock (EN 60068-2-27)	≤ 100 g (halfsine, 6 ms)
Permanent shock (EN 60028-2-29)	≤ 10 g (halfsine, 16 ms)
Vibration (EN 60068-2-6)	≤ 10 g (10 Hz ... 1,000 Hz)
Weight (standard version)	Singleturn: ≈ 500 g
	Multiturn: ≈ 700 g
Weight (stainless steel version)	Singleturn: ≈ 1,000 g
	Multiturn: ≈ 1,400 g

Flange	**Synchro (S)**		**Clamp (C)**	**Hollow shaft (B)**
Shaft diameter	6 mm	10 mm	10 mm	15 mm
Shaft length	10 mm	20mm	20 mm	-
hollow shaft depth min. / max.	-	-	-	15 mm / 30 mm

6.3 Minimum (mechanical) lifetime

Flange	Lifetime in 10^8 revolutions with F_a / F_r		
	40 N / 60 N	40 N / 80 N	40 N / 110 N
C10 (Clamp flange 10 x 20)	247	104	40
S10 (Synchro flange 10 x 20)	262	110	42
S6 (Synchro flange 6 x 10) without shaft sealing	822	347	133

S6 (Synchro flange 6 x 10) with shaft sealing: max. 20 N axial, 80 N radial

6.4 Environmental Conditions

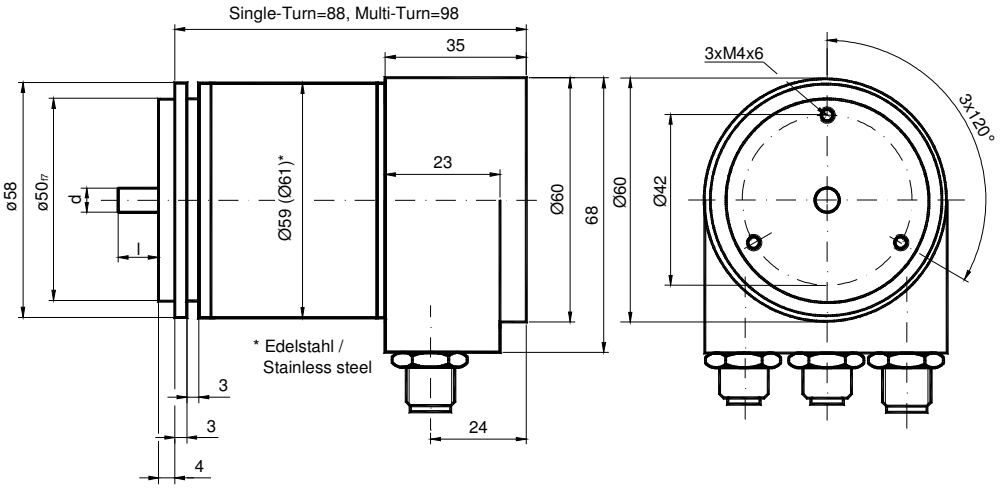
Operating temperature	0 .. +60°C
Storage temperature	- 40 .. + 85 °C
Humidity	98 % (without liquid state)
Protection class (EN 60529)	Casing side: IP 65
	Shaft side: IP 64 (optional with shaft sealing: IP66)

7 Mechanical Drawings

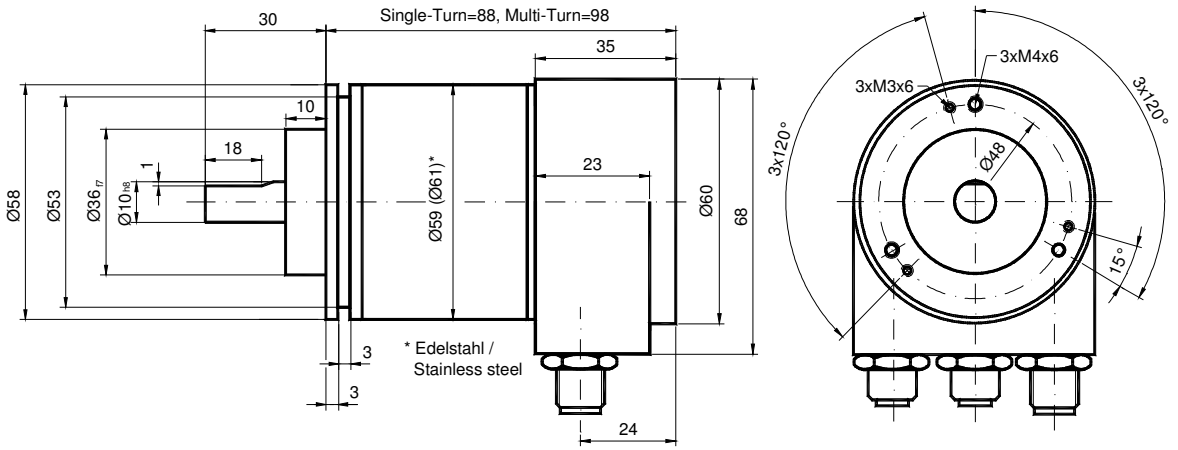
7.1 Synchro Flange (S)

available in 2 versions

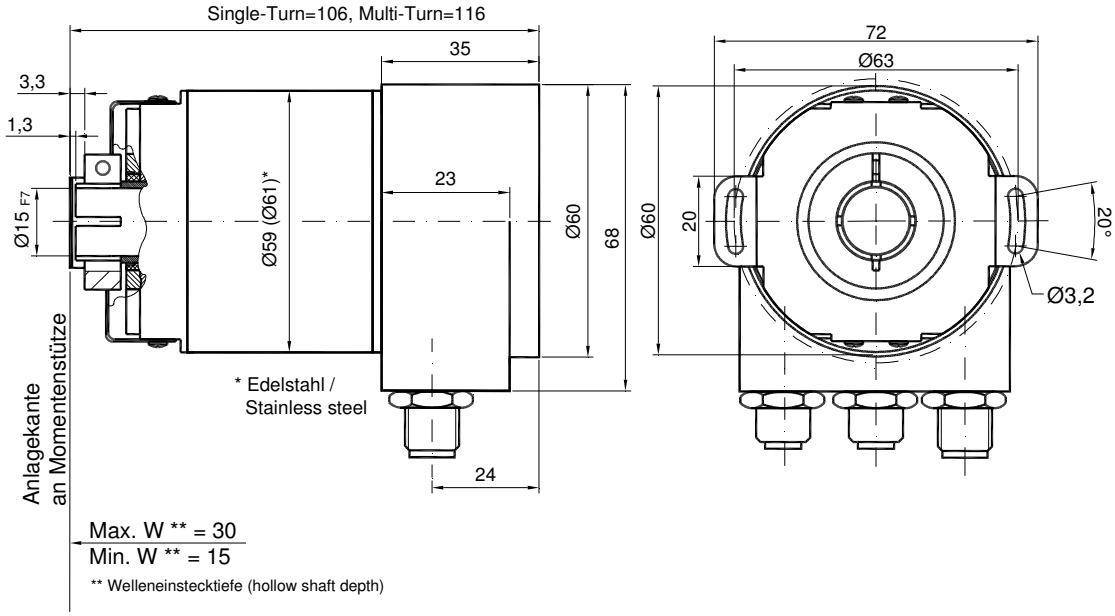
Synchro flange	d / mm	l / mm
Version S06	6_{f6}	10
Version S10	10_{h8}	20



7.2 Clamp Flange (C)



7.3 Hollow shaft (B)



Mounting instructions

The clamp ring should only be tightened after the shaft of the driving element was inserted into the hollow shaft.

The diameter of the hollow shaft can be reduced to 12 mm, 10 mm or 8 mm by using an adapter (this reducing adapter can be pushed into the hollow shaft).

Maximum radial and axial misalignment of the drive shaft::

	axial	radial
static	± 0.3 mm	± 0.5 mm
dynamic	± 0.1 mm	± 0.2 mm

8 Models / Ordering Description

Description	Type Key									
Optocode	**OCD-**	E _	_ _	B -	_ _	_ _ -	_	_ _	_ -	_ _ _
Interface Powerlink	EPL V1	**1**								
(Protocol)	EPL V2	**2**								
Version	2 x M12		**00**							
	Integr. hub, 3x M12		A1							
Code	Binary			**B**						
Revolutions (Bits)	Singleturn				**00**					
	Multiturn (4096 revolutions)				**12**					
	Multiturn (16384 revolutions)				14					
Steps per revolution	8,1924					**13**				
(Bits)	65,536					16				
Flange	Clamp flange						**C**			
	Synchro flange						**S**			
	Hollow shaft						**B**			
Shaft diameter	10 mm							**10**		
	06 mm							**06**		
	15 mm (hollow shaft)							**15**		
Mechanical options	Without								**0**	
	Shaft sealing (IP66)								S	
	Stainless steel version								V	
	Customized								C	
Connection	Radial, M12 connectors									**PRM**

Standard = bold, further models on request

9 Accessories and Documentation

Description		Type
Connector		M12 4 pin male D-Coded
Connector		M12 5 pin female
Shaft coupling **	Drilling: 10 mm	GS 10
	Drilling: 6 mm	GS 06
Clamp disc **	4 pcs. / AWC	SP 15
Clamp ring **	2 pcs. / AWC	SP H
Reducing adapter ***	15 mm to 12 mm	RR12
Reducing adapter ***	15 mm to 10 mm	RR10
Reducing adapter ***	15 mm to 8 mm	RR8
User manual *	Installation / configuration manual, English	UMD-EP
User manual *	Installation / configuration manual, German	UME-EP

* These can be downloaded free of charge from our homepage www.posital.de.

** usable only for full shaft

*** usable only for hollow shaft

We do not assume responsibility for technical inaccuracies or omissions. Specifications are subject to change without notice.

10 Glossary

Term	Explanation
10 Base T	Transmission line with 10 Mbit data transmission rate
100 Base T	Transmission line with 100 Mbit data transmission rate
ASCII	**A**merican **S**tandard **C**ode for **I**nformation **I**nterchange ASCII describes as code the correlation from digital integers to a normal font described character.
Batch file	Script program for MS-DOS
Baudrate	Transmission rate; it display the transmission bits per second
Binary	Numeric system with value 0 or 1.
Browser	Software program to display HTML-Sides on different operating systems (Linux, Unix, Windows, ...)
CAT5	Terminations for transmission rates up to 100 Mbit.
CRC	The cyclic redundancy check is a method from the information technology to control a checksum for data, to reduce errors by the transmission.
EMC	**E**lectro**m**agnetic **c**ompatibility, there are rules to verifying devices.
Ethernet	Ethernet is a computer network technology based on frames.
Fast Ethernet	Transmission technology with 100 Mbit transmission rate.
FCS-Bytes	The **F**rame **C**heck **S**equenz-Bytes are a 32 Bit CRC-Checksum.
Flash	Internal memory, saved data will be available after power down.

HTML	The **H**yper**t**ext **M**arkup **L**anguage is a document format used in the World Wide Web to be displayed by a browser
HTTP	The **H**yper**t**ext **T**ransfer **P**rotocol is a stateless transmission protocol for data transmission.
Hub	The hub connects different network segments e.g. in an Ethernet network.
IP-Adresse	IP-address allow a logic addressing from computer in a network.
IP-Protokoll	The **I**nternet **P**rotocol is widespread in computer networks. It is the implementation of the internet layer of the TCP/IP-model
Mbit	Transmission rate or baud rate, million bits per second
OCD	Acronym: **O**PTO**C**O**D**E, name of an encoder series manufactured by FRABA POSITAL.
OSI-Modell	The **O**pen **S**ystem **I**nterconnection reference model is a open layer model for the organisation of a communication.
PPP-Packet	The **P**oint-to-**P**oint **P**rotocol will be need for a connection establishment. It enables the transmission between different network protocols.
SMTP	**S**imple **M**ail **T**ransfer **P**rotocol managed the transmission of e-mails.
Switch	A switch is an electronic device to connect computers e.g. network segments in a local network. Unlike a hub, a switch uses stacks to avoid network collisions.
TCP	The **T**ransmission **C**ontrol **P**rotocol is a connection orientated transmission protocol, in a network.
TCP-Client	MS-DOS program available from FRABA to communicate with the encoder.
UDP	**U**ser **D**atagram **P**rotocol is utilized to send data that does not need to be transferred in a reliable way.

11 History

Version document 1.00
Initial version of this document.

Version document 2.00
With encoder version 01 the pin out of the Ethernet connector is changed. This is documented in the manual revision V2.00.