

ABSOLUTE ROTARY ENCODER WITH PROFIBUS-DP INTERFACE
USER MANUAL

Impressum

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1. Introduction

Absolute rotary encoders provide a definite value for every possible position. All these values are reflected on one or more code discs. The beams of infrared LEDs are sent through 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 8192 steps per revolution (13 Bit). The Multi-Turn version can detect up to 4096 revolutions (12 Bit). Therefore the largest resulting resolution is $25 \text{ Bit} = 2^{25} = 33.554.432$ steps. The standard Single-Turn version has 12 Bit, the standard Multi-Turn version 24 Bit.

The absolute angular encoder meets all specifications according to Profibus-DP, DIN 19245 part 1 and part 3. The integrated Profibus-DP interface of the encoder guarantees the maximum transmission rate of 12 MBaud. The implemented software supports all functions of the encoder profile for Profibus-DP, Class 1 and Class 2. The process data is generally transmitted in binary code.

Following parameters of the absolute rotary encoder can be directly programmed via the Profibus-DP network without any extra device:

- Code sequence (Complement)
- Measuring units per revolution
- Total measuring range in measuring units
- Preset value
- Output of current velocity

To reduce significantly the installation time, one of the provided type files supports the windows version of the COM ET 200. This software package is supplied by SIEMENS for the master module IM 308 C of the SIMATIC S5 and for a variety of modules for the SIMATIC S7.

The successful conformity and interoperability test at the interface center of SIEMENS guarantees an error-free communication of the encoder in all Profibus-DP systems.

1.1. Definitions

Termination-resistor	Resistor for wire adaptation of bus cables; termination resistors are necessary at all cable- and segment-ends.
Baudrate	Velocity of the transmission; given in number of transmitted bits per second (Baudrate = Bitrate).
Busdevice	Device, which sends, receives or repeats data via the bus network.
Diagnostic	Detection, localisation, classification, display, further check of errors, malfunctions and messages.
FREEZE	is a master command to the slave. That way the master can freeze the status of inputs to the actual values. The input data will be refreshed when the command UNFREEZE is sent by the master.
GSD-File	Device-Specific-File. File, in which the slave specific abilities are stored for the master.
DP	Decentral Peripheral
DDL	Direct Data Link Mapper
	Interface between Profibus-DP functions and the Encoder Software.
PROFIBUS	PROcess FieIdbus, european fieldbus norm, which is manifested in the PROFIBUS-Norm (EN 50170). It sets the functional, electrical and mechanical specifications for the bit-serial fieldbus system.

Following abbreviations are used in this user manual:

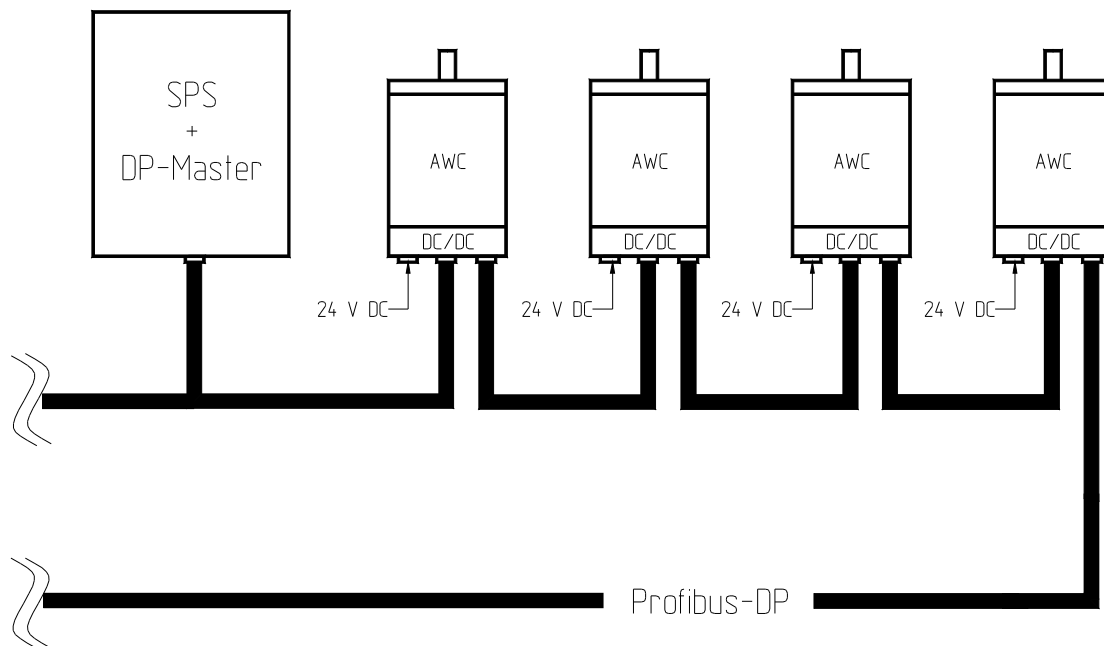
API	Absolute Position-Value
CW	Clockwise. Code sequence in clockwise rotation (as seen on shaft side)
CCW	Counterclockwise. Code sequence in counterclockwise rotation (as seen on shaft side)
PW	Preset Value
PI	Process-Value
VC	Velocity

2. Network of Profibus-DP

The interface of the absolute rotary encoder is based on the regulations of PROFIBUS-DP (DIN 19245, Part 1 and 3). To use the encoder with Profibus-DP interface as a slave in the network, a master module for Profibus-DP is required in a PLC. E.g., following master modules can be used:

PLC	Master Module	Software Package
SIMATIC S5	IM 308 B	COM-ET-200 V4.X
SIMATIC S5	IM 308 C	COM-ET-200 WINDOWS
SIMATIC S7	CPU 315-2 integrated	Step 7
SIMATIC S7	CPU 342-5 DP	NCM Step 7
SIMATIC S7	CPU S7-DP	Step 7 (V2.X, V3.X)

Below the connection to the PROFIBUS-DP is shown schematically:



In following pages it is taken for granted the use of the software packages COM-ET 200 and COM-ET 200 WINDOWS.

3. Encoder Classification

The absolute encoders with Profibus-DP interface transmit the process value and optionally the velocity in binary code. There are two different classes of encoders: the non-programmable version (Class 1) and the programmable versions (Class 2, „3“). Six configurations are possible by the implemented software. This way the requirements of a variety of applications can be met by this encoder.

3.1. Class 1 Encoder

The absolute encoders of Class 1 are non-programmable. Depending on the resolution two configurations can be chosen:

Conf. No.	Type	Configuration		Input-Word	Output-Word	Description
	Class	Length	Byte	No.	No.	
1	1	1	D0	1	0	16 Bit PI
2	1	1	D1	2	0	32 Bit PI

If the resolution of the encoder is less than 16 Bit, configuration 1 can be chosen. The PI is transmitted to the PROFIBUS-Master according to the resolution of the hardware side of the encoder.

3.2. Class 2 Encoder

The absolute encoders of Class 2 are programmable. Depending on the resolution two configurations can be chosen:

Conf. No.	Type	Configuration		Input-Word	Output-Word	Description
	Class	Length	Byte	No.	No.	
3	2	1	F0	1	1	16 Bit PI 16 Bit PW
4	2	1	F1	2	2	32 Bit PI 32 Bit PW

If the resolution of the encoder is less than 16 Bit, configuration No. 3 can be chosen. Class 2 encoders offer extensive programming possibilities, e.g. preset function and programmable resolution.

3.3. Class „3“ Encoder

The absolute encoders of Class „3“ are according Class 2 encoders with the additional output of the velocity. Following configurations are possible:

Conf. No.	Type	Configuration		Input-Word	Output-Word	Description
	Class	Length	Byte	No.	No.	
5	„3“	1	D3	4	0	16 Bit PI 16 Bit PW
6	„3“	2	D3 E1	4	2	32 Bit PI 32 Bit PW

The encoder with configuration no. 5 can be programmed as Class 2 encoders except the preset function.

The PI is transmitted in the DDLM_Data_Exchange Modus according to following telegramm:

Configurations No.: 1 and 3

Octet	1	2
Bit	15 - 8	7 - 0
Data	2^{15} bis 2^8	2^7 bis 2^0
Data_Exchange - 16 Bits		

Configurations-No.: 2 and 4

Octet	1	2	3	4
Bit	31 - 24	23 - 16	15 - 8	7 - 0
Data	2^{31} bis 2^{24}	2^{23} bis 2^{16}	2^{15} bis 2^8	2^7 bis 2^0
Data_Exchange - 32 Bits				

Configurations-No.: 5 and 6

Octet	1,2	3,4	5,6	7,8
Bit	63 - 48	47 - 32	31 - 16	15 - 0
Data	2^{63} bis 2^{48}	2^{47} bis 2^{32}	2^{31} bis 2^{16}	2^{15} bis 2^0
Data_Exchange - 64 Bits				

4. Programmable Encoder-Parameters

In the following the encoder parameters are described, which can be programmed according to the chosen configuration. The Class 2 and „3“ parameters use the DDLM_Set_Prm function. Programmable parameters are shown in the table below:

Parameter	Data Type	Parameter Octet Number	Encoder Class
Code Sequence	Bit	9	1
Class 2 functionality	Bit	9	2
Comissioning diag. control	Bit	9	optional
Scaling function control	Bit	9	2
Measuring units per rev.	unsigned 32	10 - 13	2
Total measuring range	unsigned 32	14 - 17	2
Reserved for further use		18 -25	2
Reserved for manufacturer		26 ...	optional

Overview Operating Parameter (Octet 9):

Bit	Parameter
0	Code Sequence
1	Class 2 functionality
2	Commissioning diagnostics
3	Scaling function control

Bit	Parameter
4	Reserved
5	Reserved
6	Reserved
7	Time base velocity

4.1. Code Sequence

The code sequence defines whether increasing position values are output when the encoder shaft rotates clockwise CW or counterclockwise CCW (as seen on shaft). The code sequence bit is set with the code sequence bit 0 in the operating parameters Octet 9.

Bit 0	Code sequence	Output code
0	CW	increasing
1	CCW	increasing

4.2. Class 2 Functionality

This bit enables/disables the device class 2 functionality. The default setting is disabled (0), which means that a DP-Master must set this bit to be able to use the class 2 functions. When the class 2 functionality is disabled, the encoder performs exactly like a class 1 encoder. To use class 2 functionality, set bit 1 in Octet 9:

Bit 1	Class 2 Functionality
0	disabled
1	enabled

Attention:

If the encoder is set to Class 1 functionality, all programmed parameters will be stored in the RAM until first turn off!

4.3. Commissioning Diagnostics (optional)

With the commissioning diagnostic function it is possible to check the encoder components responsible for position detection at encoder standstill. In conjunction with the position alarms, this enables an extensive check of the correctness of the position values. The commissioning diagnostics are initiated by the bit 2 in octet 9. If errors are detected it will be announced by the commissioning diagnostic alarm bit in the diagnostic function (see Alarms).

Bit 2	Commissioning Diagnostics
0	disabled
1	enabled

The commission diagnostic function is optional. To find out if the encoder supports commissioning diagnostics, the „Operating Status“ should be read with the diagnostic function and the commissioning diagnostic bit checked.

4.4. Scaling Function

With the scaling function the encoder internal numerical value is converted in software to change the physical resolution of the encoder. The parameters „Measuring Units per Revolution“ and „Total Measuring Range in Measuring Units“ are the scaling parameters set by the scaling function control bit 3 in octet 9.

Bit 3	Scaling Function
0	disabled
1	enabled

4.5. Time Base Velocity

Encoder in Class „3“ configuration transmit the current velocity additionally to the process value. The velocity is calculated three times over the time base, which is set with bit 7 in octet 9, by measuring the difference of the encoder steps and after that averaged over the last 16 values. With each new measurement the oldest velocity value is taken off and the new is averaged in. With the parameter „Time Base Velocity“ the time base can be chosen between ms and 10 ms.

Bit 7	Time Base Velocity
0	3 Measurements / 1 ms
1	3 Measurements / 10 ms

4.6. Measuring Units per Revolution

The parameter „Measuring Units per revolution“ is used to program the desired number of steps per revolution. Each value between 1 and 4096 can be realized.

Octet	10	11	12	13
Bit	31 - 24	23 - 16	15 - 8	7 - 0
Data	2^{31} bis 2^{24}	2^{23} bis 2^{16}	2^{15} bis 2^8	2^7 bis 2^0
Measuring Units per Revolution				

If a value larger than 4096 (8192 for a 13 Bit encoder) is set, the process value of the encoder will not be single stepped and values will be skipped while rotating the shaft. So, it is recommended, to keep the measuring units per revolution below 4096 measuring units.

4.7. Total Measuring Range in Measuring Units

This parameter is used to program the desired number of measuring units over the total measuring range. This value must not exceed the total resolution of the encoder with 16777216 steps (25 Bit = 33554432).

If the encoder is used in a continuous measuring application, the parameter must be programmed in values with powers of 2 (2^x with $x < 12$).

Octet	14	15	16	17
Bit	31 - 24	23 - 16	15 - 8	7 - 0
Data	2^{31} bis 2^{24}	2^{23} bis 2^{16}	2^{15} bis 2^8	2^7 bis 2^0
Total Measuring Range in Measuring Units				

4.8. Preset Value

The parameter „Preset Value“ is the desired position value, which should be reached at a certain physical position of the axis. The position value of the encoder is set to the desired process value by the parameter Preset. The preset value must not exceed the parameter „Total Measuring Range in Measuring Units“. The preset function is used after the scaling function which means that the preset value is given in the current measuring units. The preset value is written to the encoder as output data in the Data_Exchange function.

The MSB of the preset value controls the preset function in the following way:

Normal operating mode: MSB = 0 (Bit 31, optional Bit 15 for configuration no. 3)

The encoder will make no change in preset value.

Function	Statusbits								Process Value																							
Bit	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
	0	0	0	0	0	0	0	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X

Preset mode: **MSB = 1** (Bit 31, optional Bit 15 for configuration no. 3)

With MSB=1 the encoder accepts the transferred value (Bit: 0-24) as a preset value in binary code.

Function	Statusbits								Preset Value																							
Bit	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
	1	0	0	0	0	0	0	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X

The encoder reads the current position value and calculates an offset value from the preset value and the read position value. The position value is shifted with the calculated offset value.

When the output position value equals the preset value after appr. 100 ms the preset mode is ended and the MSB can be set to zero by the master. The offset value can be read with the diagnostic function and is securely stored in case of voltage breakdown in the encoder Flash-EPROM.

The internal programming time of the Flash-EPROM takes about 2 seconds. During that time period no process values can be transmitted. The burn cycles of the Flash-EPROM are limited to approximately 100 000 cycles.

Attention:

The preset function should only be used at encoder standstill!

5. Diagnostic Information

The encoder supports extensive diagnostic routines. A large number of different parameters can be tested via the network.

Diagnostic Function	Data Type	Diagnostic Octet Number	Encoder Class
Extended Diagnostic Head.	Octet String	7	1
Alarms	Octet String	8	1
Operating Status	Octet String	9	1
Encoder Type	Octet String	10	1
Measuring Units per Revolution	unsigned 32	11 - 14	1
Number of Revolutions	unsigned 32	15, 16	1
Additional Alarms	Octet String	17	2
Supported Alarms	Octet String	18, 19	2
Warnings	Octet String	20, 21	2
Supported Warnings	Octet String	22, 23	2
Profile version	Octet String	24, 25	2
Software version	Octet String	26, 27	2
Operating Time	Unsigned 32	28 - 31	2

5.1. Extended Diagnostic Header

The diagnostic header byte 7 specifies the length of the encoder diagnostics including the header byte. The format of the length value is hexadecimal. For the encoders with Class 1 configuration the length of the encoder specific diagnostics is 10 bytes (0A hex).

Bit	7	6	5 - 0
Data	0	0	xxh
			Length including header

5.2. Alarms*

An alarm is set if malfunction in the encoder could lead to incorrect process values. Octet 8 in the diagnostic function (DDLMSlave_Diag) shows the status of the alarms. Additional alarms for class 2 encoders are added in diagnostic octet 17.

If an alarm occurs, then the Ext_Diag bit and the Stat_Diag bit in the diagnostic function is set to logical high until the alarm is cleared and the encoder is able to provide an accurate process value. Alarms are cleared when the functionality is within the specification and the process value is correct.

Bit	Definition	= 0	= 1
0	Position error	No	Yes
1	Supply Voltage error	No	Yes
2	Current too high	No	Yes
3	Commissioning diagnostics	OK	Error
4	Memory error	No	Yes

(*) The output of these alarms is in preparation.

5.3 Operating Status

Octet 9 in the diagnostic function gives information on encoder internal parameters.

Bit	Definition	= 0	= 1
0	Code sequence	CW	CCW
1	Class 2 functionality	No	Yes
2	Commissioning diagnostics	No, not supported	Yes
3	Scaling function	Disabled	Enabled
7	Time base velocity	1ms	10 ms

5.4 Encoder Type

The encoder type can be read in Octet 10 of the diagnostic function. The encoder type is given in hex code.

Code	Definition
00 h	Single-Turn absolute rotary encoder
01h	Multi-Turn absolute rotary encoder

5.5 Single-Turn Resolution

The diagnostic octet 11 to 14 gives the number of measuring steps per revolution that are output for the absolute singleturn position value. The value is stored in binary code.

5.6 Number of Distinguishable Revolutions

The number of distinguishable revolutions that the encoder can output is given in octet 15 and 16 of the diagnostic function. The value is stored in binary code.

5.7. Additional Alarms

Diagnostic octet 17 is reserved for additional alarms, which are currently not assigned.

5.8. Supported Alarms

Information on supported alarms can be read in diagnostic octets 18 and 19.

Bit	Definition	= 0	= 1
0	Position error	Not supported	Supported
1	Supply Voltage error	Not supported	Supported
2	Current too high	Not supported	Supported
3	Commissioning diagnostics	Not supported	Supported
4	Memory error	Not supported	Supported
5-15	Reserved		

5.9. Warnings

Warnings indicate that tolerances for certain internal parameters of the encoder have been exceeded. In contrast to alarms warnings do not imply incorrect position values.

Octet 20 and 21 of the diagnostic function shows the status of the warnings. If a warning occurs, then the Ext_Diag bit in the Diagnostic function is set to logical high until the warning is cleared.

All warnings are cleared after the diagnostic message is read from the encoder, but if tolerances are still exceeded the warning will be set again. For the operating time limit (Bit 4) the warning is only set again after power-on sequence.

The warnings are not implemented yet, but will be at the end of 1997.

Bit	Definition	= 0	= 1
0	Frequency exceeded	No	Yes
1	Temperature exceeded	No	Yes
2	Light control reserve	Not reached	Reached
3	CPU Watchdog Status	OK	Reset generated
4	Operating time limit warning	No	Yes
5	Reserved		
6	Reserved		
7 - 15	Reserved		

Informations on supported warnings can be read in the diagnostic octets 22 and 23.

Bit	Definition	= 0	= 1
0	Frequency warning	Not supported	Supported
1	Temperature warning	Not supported	Supported
2	Light control reserve warning	Not supported	Supported
3	CPU Watchdog Status	Not supported	Supported
4	Operating time limit warning	Not supported	Supported
5	Reserved		
6	Reserved		
7 - 15	Reserved		

5.10. Profil Version

Octet 24 and 25 of the diagnostic function gives the DP encoder profile version implemented in the encoder. The octets are combined to a revision number and a index.

Example:

Profile version:	1.40	
Octet no.:	24	25
Binary code:	00000001	01000000
Hex:	1	40

Octet	24	25
Bit	15 - 8	7 - 0
Data	2^7 bis 2^0	2^7 bis 2^0
	Revision no.	Index

5.11. Software Version

Octet 26 and 27 of the DDLM_Slave_Diag function give the encoder software version. The octets are combined to a revision number and an index, like the Profile version.

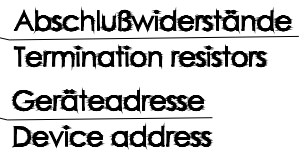
Octet	24	25
Bit	15 - 8	7 - 0
Data	2^7 bis 2^0	2^7 bis 2^0
	Revision no.	Index

5.12. Operating Time

The operating time monitor stores the operating time for the encoder in operating hours. The operating time is stored every 6 minutes in the encoder non volatile memory as long as the encoder is power supplied. The operating time value is presented in 0.1 hours as an unsigned 32 binary value of the function DDLM_Slave_Diag.

This function is in preparation and will be implemented to the end of 1997. Until then the value FF FF FF h is permanently stored.

6.1. Connecting the Connection Cap



The settings of the Profibus-DP device address are achieved by 8 dip switches in the connection cap. Possible (allowed) addresses are between 3 and 124 (decimal) and each can only be used once. The connection cap can easily be opened for installation by removing the two cap screws. The following example shows how the device address 123 (decimal) is set:



There are three resistors provided in the connection cap, which must be used as a line termination on the last device:

Termination resistors:



After the settings are done in the connection cap and the bus lines are hooked up from the master to the devices, the encoder can be powered on.

6.3. Type-Files

For running the encoder at all kinds of Profibus-DP masters a variety of type files were written, which are stored on the floppy disc named DK-DP.

File directory	Type file/Bit map	Master Module	Software package
GSD	FRAB4711.GSD	CP 5412 A2	(PC-card)
		CP 342-5	(master module for S7)
		IM 308 C	WINDOWS COM V3.X
		CPU S7-DP	STEP7 Package V3.X
		Bosch Master, others	
Typ4.X	FR4711TE.200 (english)	IM 308 B	COMET200 V4.X
Typ5.X	FR4711BX.200 AWC58XXn.BMP	IM 308 C	WINDOWS COM V2.0
		CPU 315-2	STEP7 Package V2.X
		CPU S7-DP	STEP7 Package V2.X

The according files (type file and bit map) to the used master module have to be copied to the working directories of the master module (... \typefile*. * and ... \bitmap*. *).

7. Setting Up of DP-Master

The setting up of the Profibus-DP master is shown as an example at the master module IM 308 C with the software package COM-ET-200 WINDOWS, Version 2.0.

7.1. Loading of Type Files

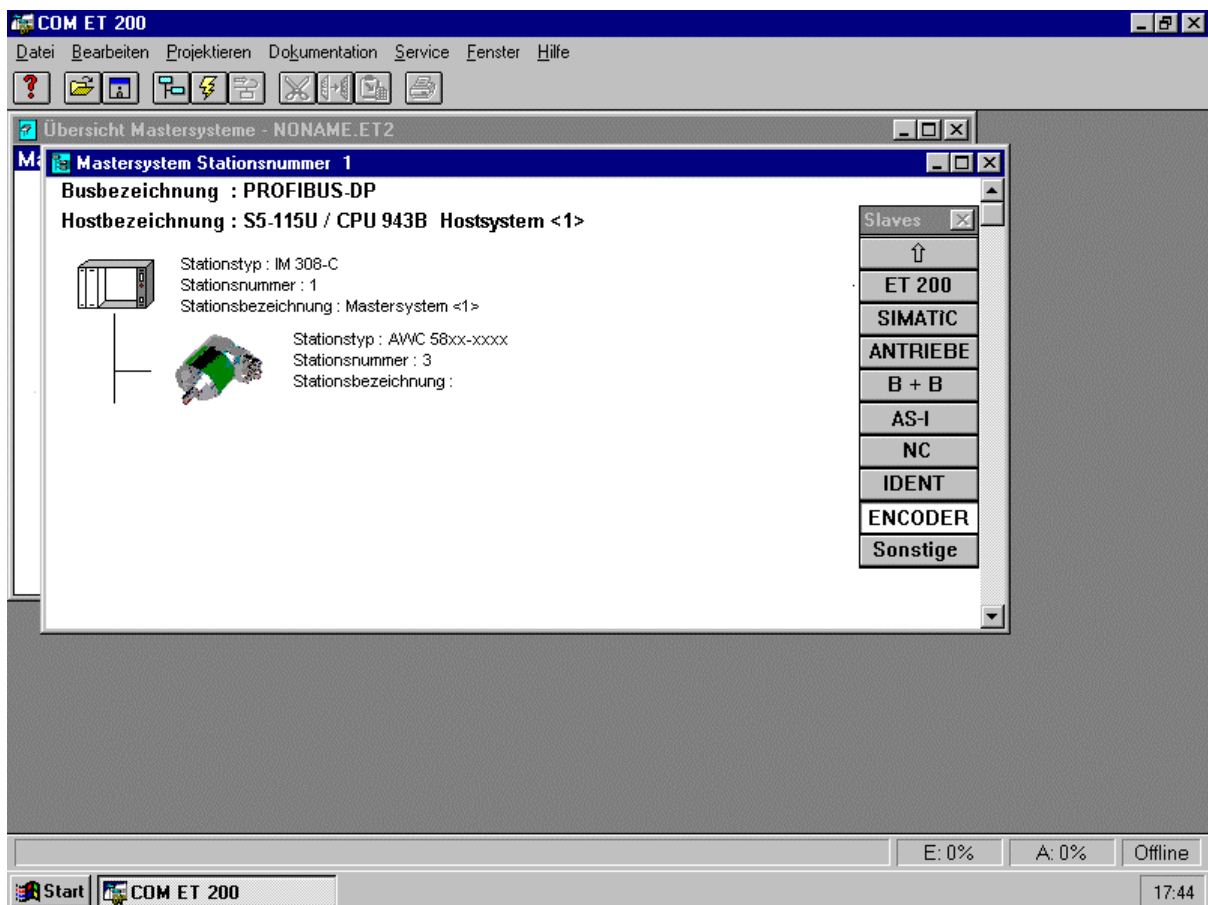
After copying the according type files to the directory ... \ *type_files* and the according bitmap to the directory .. \ *Bitmap*, the COM-ET-200 can be started. Firstly, the type files have to be loaded by clicking in the menu *File* the topic *Loading Type Files*. A message of successful loading is not displayed on screen.

7.2. Configuration Master System

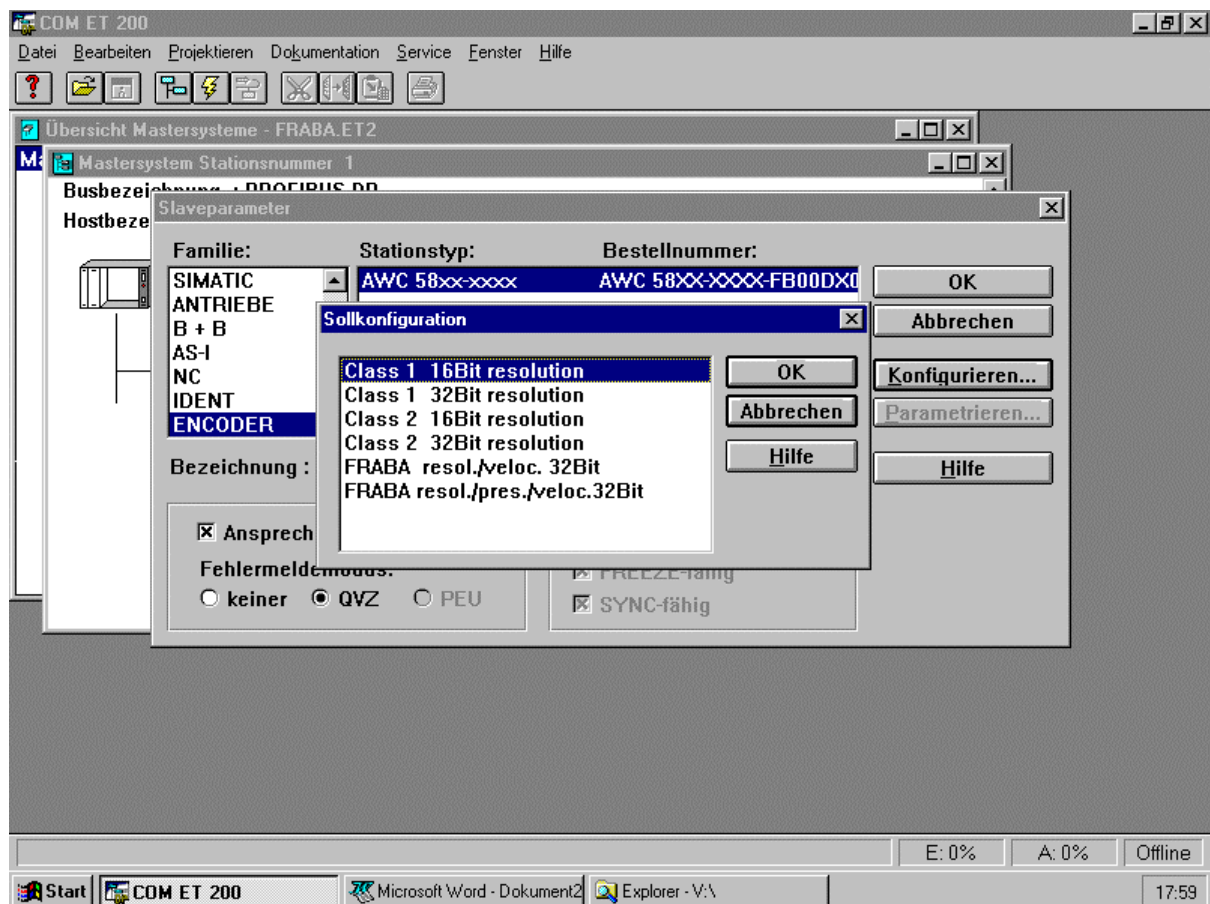
After that in the menu *File* topic *Open* or a already existing configuration file can be opened. Then a master system can be selected from the overview with a pre-defined station number.

7.3. Configuration of the DP-Slave

After loading the type files an additional button *Encoder* is displayed. After clicking on this button the device type *AWC58XX-XXXX* is displayed. Select this type and move it with the mouse for attaching it at the master as shown below. This way, the DP-slave FRABA encoder is added to the configuration table.

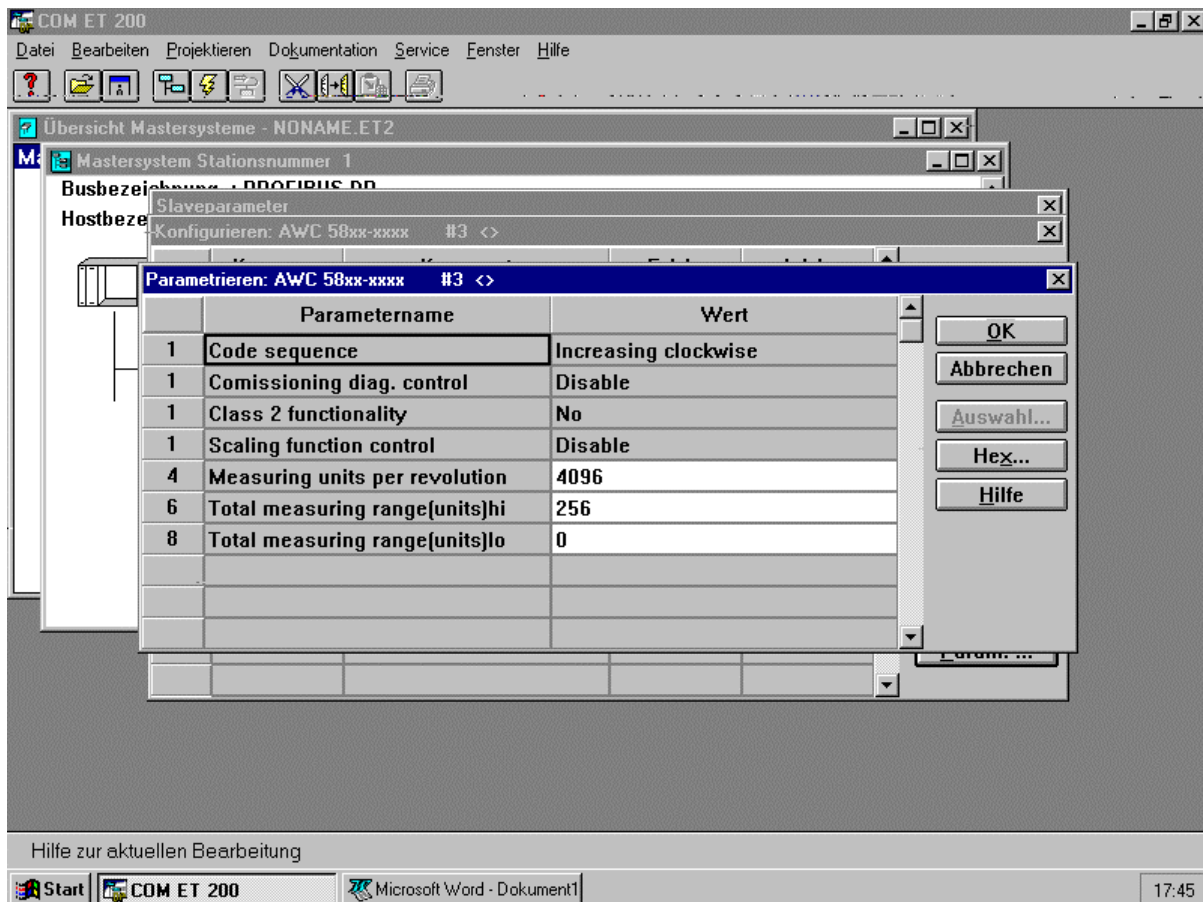


In the slave parameters the desired configuration of the encoder can be selected by pushing the button *Configuration*:



Chose one of the six configurations (as mentioned before) which fits best to your application. In the following screen the numbers of the used Input and Output words according to the selected configuration has to be typed in.

After configuring the encoder, all operational parameters can be programmed. Following screen will be displayed when the mostly used configuration 4 was chosen:



The different parameters, which can be programmed, are explained in chapter 4. With button *Selection* an overview of possible values is displayed and can be picked out.

The number of *measuring units per revolution* is free selectable between 1 and 4096.

The *total resolution* is up to 24 Bit free selectable, but must not be equal or lower than the *measuring units per revolution*. Depending on the WINCOM software, the *total resolution* is divided into LOW and HIGH word, which means that the 24 Bit total resolution are divided into Bit 0 - 15 (LOW word) and Bit 16 - 31 (HIGH word).

8. Technical Data

8.1. Electrical Data

General Layout	according to DIN VDE 0160
Supply Voltage	10 - 30 V DC (absolute limits)
Power Consumption	max. 3,5 Watt
EMC	electro-magnetical emission according to EN 50081-2 electro-magnetical compatibility according to EN 50082-2
Bus connection	galvanically separated by opto-couplings
Interface	Line-Driver according to RS 485
Clock Frequency	max. 12 MBaud
Resolution	up to 4096 steps/revolution up to 4096 revolutions
Accuracy of Division	$\pm \frac{1}{2}$ LSB
Step Rate	max. 100 kHz (valid code)
Code	Binary
Electrical Lifetime	$> 10^5$ h
Device Addressing	programmable by 8 Dip-switches in connection cap
PNO* Certificate	No. Z00175 dated August 06, 1996

Attention:

Absolute rotary encoders must only be used with protected voltage, extra low!

(*) PNO: **Profibus NutzerOrganisation**

The Profibus Trade Organization (PNO) is the only institution, which is allowed to certificate Profibus components on conformity and interoperability.

8.2. Mechanical Data

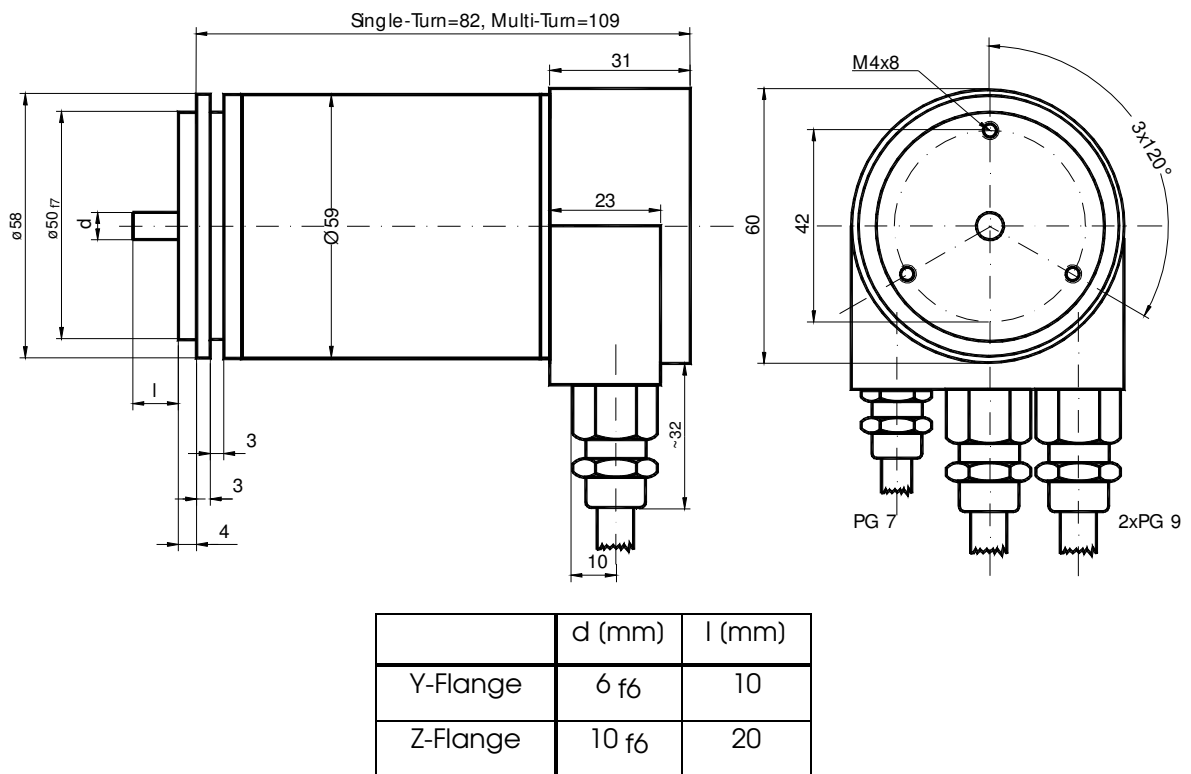
Housing	Aluminium	
Flange	Synchro-Flange (Y,Z)	Clamp-Flange (F)
Shaft Diameter	6 mm, 10 mm	10 mm
Shaft Length	10 mm	20 mm
Shaft Loading	axial 10 N, radial 20 N	axial 20 N, radial 110 N
Friction Torque	$\leq 1 \text{ Ncm}$	$\leq 5 \text{ Ncm}$
Inertia of Rotor	$\approx 20 \text{ gcm}^2$	$\approx 50 \text{ gcm}^2$
Lifetime	$> 10^5 \text{ h at } 1000 \text{ min}^{-1}$	
RPM	6000 min^{-1} (continuously), 10000 min^{-1} (shorttime)	
Shock Stability (IEC 68-2-27)	$\leq 200 \text{ m/s}^2$ (12 ms)	
Vibration Stability (IEC 68-2-6)	$\leq 100 \text{ m/s}^2$ (10 Hz ... 1000 Hz)	
Connection	Connection Cap as T-Coupling with clamps	
Operating Temperature	$0 \dots +70^\circ \text{C}$	
Storage Temperature	$-40 \dots +85^\circ \text{C}$	
Humidity	98% (without liquid state)	
Degree of protection (EN 60529)	Shaft $\varnothing 6 \text{ mm}$	Shaft $\varnothing 10 \text{ mm}$
Casing Side	IP 65	IP65
Shaft Side	IP 54*	IP 65**
Weight (incl. connection cap)	Single-Turn	$\approx 500 \text{ g}$
	Multi-Turn	$\approx 700 \text{ g}$

(*) Optional with shaft sealing (IP 65)

(**) up to 0,5 bar

8.3. Drawings

Synchro-Flange (Y- or Z-Flange)



Clamp-Flange (F-Flange)

