RS 4 / Software

Information on the RS4 Protocol for external use

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Table of contents

1. Notice

This document is an excerpt from the documents SER_COMM.DOC and CMDPROC.DOC for external use, i.e. when an external organisation requires information regarding the structure of the RS4 protocol.

2. Purpose of the present document

This document describes the structure and protocol of the serial communication between the *RS 4* and the PC configuration program.

It examines the requirements placed on the serial communication, analyses these requirements, uses this analysis to define a protocol for the serial communication and then designs the serial communication.

3. Requirements

Please find below a list of the different requirements to be met by the serial communication.

3.1. Universal requirements

Please find below a list of the universal requirements:

- Requirement 1000:

  Category: universal

  Description: The serial communication should facilitate a secure transmission of messages (with any content) between the *RS 4* and a PC configuration program.

3.2. Type of data

Please find below a list of the requirements which specify the type of information to be transmitted:

- Requirement 2000:

  Category: Type of data

  Description: The serial communication must facilitate the transmission of configuration data.

- Requirement 2010:

  Category: Type of data

  Description: The serial communication must facilitate the transmission of device data.

- Requirement 2020:

  Category: Type of data

  Description: The serial communication must facilitate the output of measurement values.

- Requirement 2030:

  Category: Type of data

  Description: It should be possible to transmit measurement values sector-wise, i.e. it should be possible to suppress the output of measurement values from defined sectors.

3.3. Access restriction

Please find below a list of the requirements which apply to the access restriction of the *RS 4*:

- Requirement 3000:

  Category: Access restriction

  Description: When transmitting messages from the PC configuration program to the *RS 4*, the password for the current authorisation level must always be transmitted together with the message.

  Messages without a password must be ignored by the *RS 4*.

3.4. Protocol

Please find below a list of the requirements which are required for specifying the transmission protocol:

- Requirement 4000:

  Category: Protocol

  Description: Messages should be transmitted optionally with/without acknowledgement.

  The condition, whether the transmission takes place with or without acknowledgement, affects the transmitter (RS4 or PC program) of a message depending on the type of data/information to be transmitted.

  Security-critical data are, in this case, always transmitted with an acknowledgement. This setting is permanently programmed into the respective program.

- Requirement 4010:

  Category: Protocol

  Description: Messages are not transmitted within a network.

- Requirement 4020:

  Category: Protocol

  Description: Errors which could occur during the transmission must be detectable by the serial communication.

- Requirement 4030:

  Category: Protocol

  Description: Binary data should be used for the transmission of messages, i.e. the transmission makes use of all user bits of the serial interface.

- Requirement 4040:

  Category: Protocol

  Description: The connection of a terminal over the serial interface of the *RS 4* is not intended.

- Requirement 4050:

  Category: Protocol

  Description: The following status information is transmitted each time the *RS 4* performs an output function:

  - Operating status
  - Protected fields busy
  - Warning
  - Error
  - Restart-disable
  - Identifier of the current protected field pair

- Requirement 4060:

  Category: Protocol

  Description: The protocol should transmit information with as little redundancy as possible.

- Requirement 4070:

  Category: Protocol

  Description: It should be possible to transmit measurement values both word-wise (16 bit) as well as byte-wise (8 bit).

  16 bit: The resolution is 2 mm, i.e. 0 … approx. 65 m
  8 bit: The resolution is 16 mm, i.e. 0 … approx. 4 m

- Requirement 4080:

  Category: Protocol

  Description: The transmission protocol must be capable of synchronising the *RS 4* and PC configuration program on start and stop if an error occurs during a previous transmission.

- Requirement 4090:

  Category: Protocol

  Description: Messages from *RS 4* to PC and from PC to *RS 4* have the same structure.

3.5. Realization

Please find below a list of requirements which are necessary for realizing the serial communication:

- Requirement 5000:

  Category: Realization

  Description: Only a single transmission buffer should be used in the *RS 4* for the output of messages.

- Requirement 5010:

  Category: Realization

  Description: Only a single reception buffer should be used in the *RS 4* for the reception of messages.

- Requirement 5020:

  Category: Realization

  Description: The reception buffer is not overwritten until a received message has been processed.

- Requirement 5030:

  Category: Realization

  Description: The transmission buffer is not overwritten until a message to be transmitted has been output.

- Requirement 5040:

  Category: Realization

  Description: The serial communication must function effectively and with an efficient use of resources.

3.6. Characteristics of the interface

Please find below a list of the requirements which are necessary for setting the serial interface.

- Requirement 6000:

  Category: Characteristics of the interface

  Description: The following serial interface settings should be available:

  - Baud rate 4800 baud and more
  - Data format: 8N1

4. Analysis

This chapter analyses the various requirements listed in chapter *0 Requirements* and, using this analysis, establishes a transmission protocol for the communication between the *RS 4* and the PC configuration program. The analysis is also used to create transmission strategies for the transmission of data.

4.1. Protocol

In general, a distinction must be made between the protocol and the interpretation of the transmitted data. The protocol defines a language which assists the *RS 4* and the PC communication program in exchanging data with one another.

In this case it must be irrelevant to the protocol which type of data are being transmitted.

In order to achieve this, the protocol generates a frame for interpreting the data to be transmitted independent of the data. In this way the protocol defines for each message to be transmitted a header, which precedes the actual information, and a footer, which is appended to the actual information. Each message between the two communicating partners is composed of such a package with a header, the information itself and a footer.

The following diagram illustrates this:

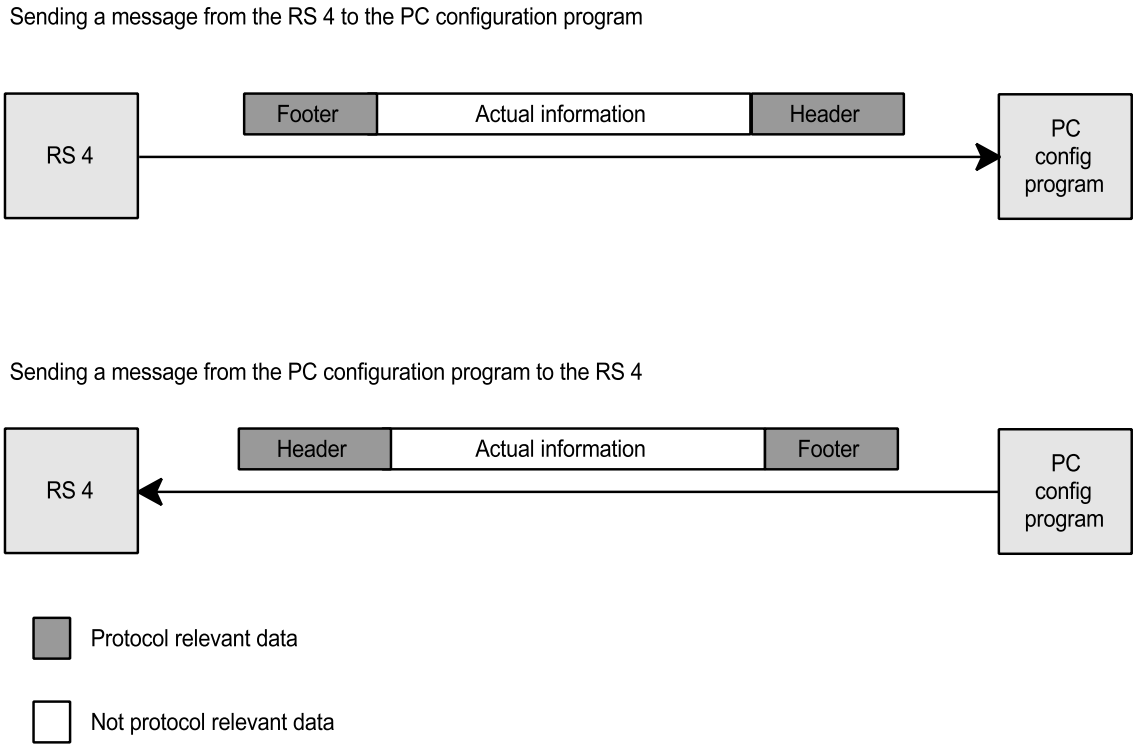


Figure 0-1 Protocol relevance

In this chapter the requirements from chapter *0 Requirements* are analysed and the header and footer formats specified according to these requirements.

4.1.1. Requirement and impact

This chapter lists the relevant requirements and their corresponding impacts. These impacts are then converted into a protocol specification.

Requirement:	Impact
3000	The frame must contain a field in which a password can be transmitted together with the message.
3000 4090	It must be possible to set for each message whether or not a password is to be included in the transmission, as the password is only required for messages transmitted from the PC configuration program to the *RS 4* and the protocol structure must be identical in both directions. Messages from PC to RS4 thus always include the password. Messages from RS4 to PC include no password. -> Option
4000	It must be possible to set for each message whether or not an acknowledgement is desired. This setting is permanently programmed into the respective program. -> Option
4010	An address can be omitted.
4020	A checksum must be transmitted within the frame in order to detect transmission errors. A time-out is specified between the individual characters in order to detect a missing message end.
4030 4040 4080 6000	No extra bits may be used for identifying the frame, as all data bits of the individual characters are required for the data transmission. Therefore, a token must be used for identifying the frame. A token is a special combination of characters which does not occur in the data transmission. As, in principle, all combinations of characters are possible when transmitting binary data, the corresponding combination of characters must be suppressed when transmitting the binary data. It is best when the combination of characters representing a token appears as seldom as possible within the frame. Readability of the messages on a terminal is not necessary, as the data can be transmitted in binary format without worry.

Requirement:	Impact
4050	The following additional information must also be transmitted within the frame: · Operating status of at least 4 different states · act. personal safety field busy · act. object safety field busy · 2. personal safety field busy · 2. object safety field busy · selected pair of protected fields · 2. pair of protected fields · Warning · Error · Restart-disable In order for everything to function quickly, the states of the protected fields + error + warning + restart-disable do not need to be transmitted when they are not set (i.e. "Off"). The operating status should always be included in the transmission. -> Option

Table 0-1 Requirements and their impacts

4.1.2. Specifications of the transmission protocol

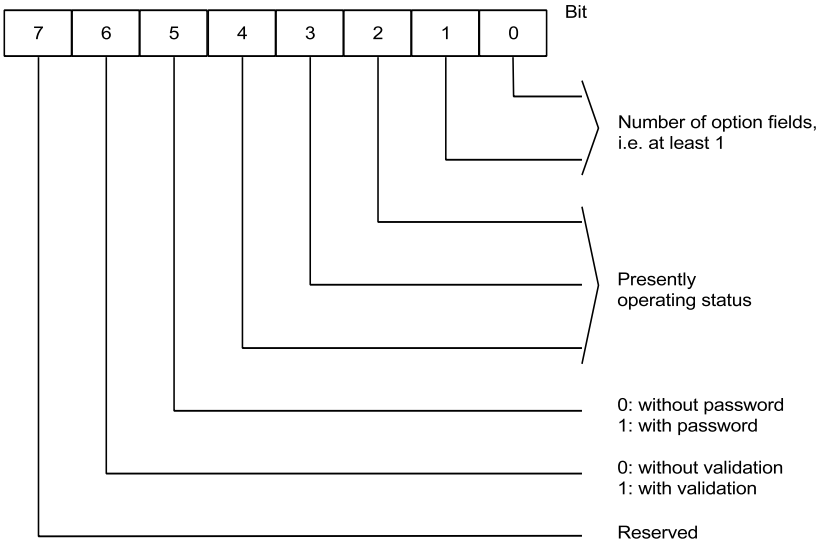
This chapter describes the specifications of the transmission protocol. For this purpose, the requirements from chapter *0 Requirements* and the impacts from chapter *0 Requirement and impact* are used.

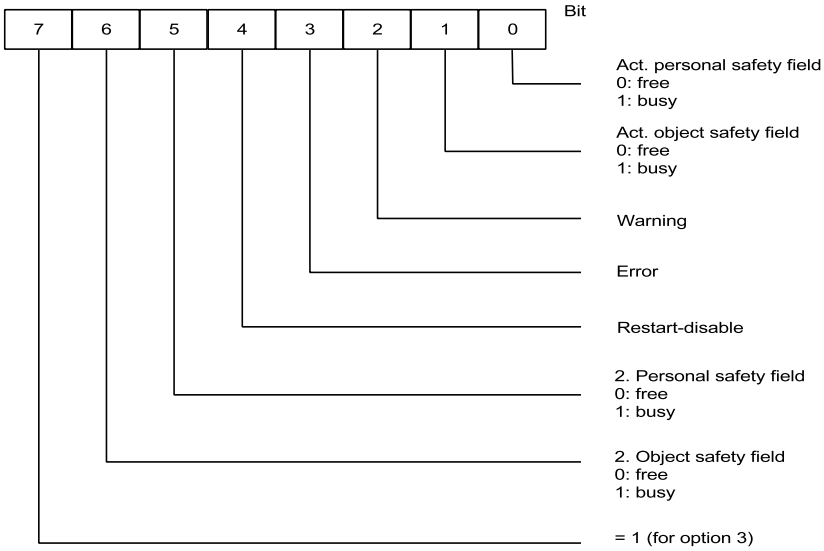
Each message transmitted by the *RS 4* to the PC configuration program or from the PC configuration program to the *RS 4* has the following structure:

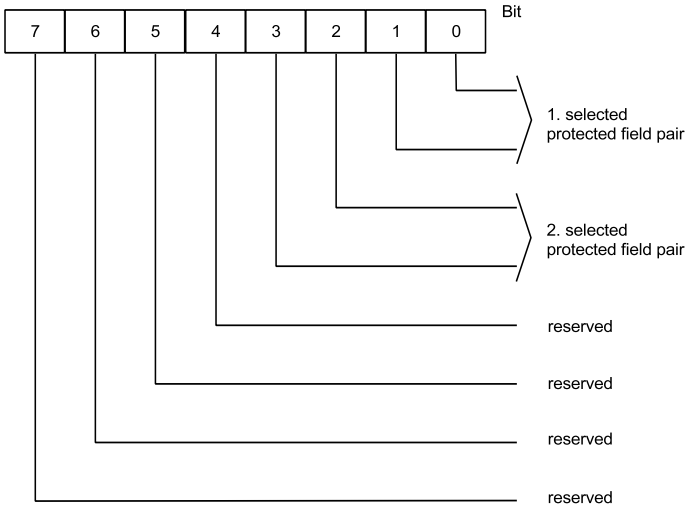
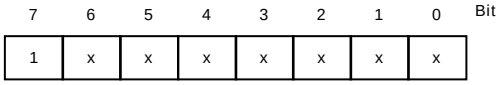
Two consecutive 0x00 are used as token characters, i.e. identifier of a special value (control character). Within the actual information, the occurrence of a { 0x00, 0x00 } is extended with a 0xFF to avoid confusing with the token character, i.e. it must be prevented that a 0xFF follows a token in the protocol (by means of an appropriate specification). In this way, the occurrence of a { 0x00, 0x00, 0xFF } can be unmistakably resolved as { 0x00, 0x00 }. The additional 0xFF is also used in the calculation of the checksum.

Please find below a description of the structure

Name	Numb. Bytes	Description
Start	2	The start character consists of the token (i.e. 0x00,0x00) Together with the following command character, which possesses a value range from 0x01 - 0xFE, the start sequence (consisting of start character and command character) can be unmistakably different from the *end character* and from a {0x00, 0x00, 0xFF} in the user information.
Command	1	The command character possesses a value range from 0x01 - 0xFE. The command character specifies the method with which the user information which is to be transmitted must be interpreted. The command character is not analysed by the protocol, but rather according to the given operating status.

Name	Numb. Bytes	Description
		The command is specified in chapter 0 Command description.
Option 1	1	The option characters transmit certain control flags, e.g. status information, which is transmitted together with each message. The first option character is always transmitted and defines protocol information, e.g. the total number of option characters being transmitted. All other option characters are transmitted only when required by the transmission, i.e. when at least one status bit is set. This option character is always transmitted together with the message being transmitted and has the following structure:  The number of option fields is, thus, limited to 1-3 (bit 0 & bit 1) The field *current operating status* (bits 2-4) indicates the currently active operating status and has the following structure: 000 - no data (for messages from PC -> *RS 4*) 001 - initialization 010 - measurement operation 011 - configuration 100 - error/fault As the number of option fields must be at least 1, the field *Option 1* never has the value 0x00.
Option 2	1	This option character transmits status information regarding the individual protected fields + error + warning + restart-disable. This option character is only transmitted when at least one flag is set, i.e. this field cannot possess the value 0x00. If this field is transmitted, the number of option fields in field *Option 1* must be at least 2.

Name	Numb. Bytes	Description
		This option character has the following structure:  This field has no meaning for messages from the PC to the *RS 4*. Bit 7 is set to 1 when Option 3 needs to be transmitted to prevent Option 2 from taking the value 0.

Name	Numb. Bytes	Description
Option 3	1	This option character transmits status information regarding the selected protected field pair. This option character is only transmitted when at least one flag is set, i.e. this field cannot possess the value 0x00. If this field is transmitted, the number of option fields in field *Option 1* must be at least 3. This option character has the following structure:  As it is possible that two protected field pairs be simultaneously selected during protected field switching, two pieces of information are required for the selected protected field pair. for the selected protected field pairs: · 0: means nothing selected · 1-4: means protected pair 1-4 selected This field has no meaning for messages from the PC to the *RS 4*.
Password	8	The password is transmitted in this field when bit 5 of *Option 1* is set. The number of characters is always 8. The structure of the individual characters is as follows:  i.e. bit 7 of the individual characters is always set. This is necessary to prevent consecutive 0x00. The individual characters of the password thus have a value range from 0x00 - 0x7F. If the password has no content (e.g. authorisation level 1), 0xFF is transmitted 8 times.
Actual information	varia-ble	All actual information is transmitted with 8 bits. The actual information is not interpreted by the protocol, but rather depending on the command and the current operating status of a command process.

Name	Numb. Bytes	Description
Check characters	1	The check character corresponds to an XOR link of all transmitted characters, including command characters, password, option characters, i.e. following the start character to the last character preceding the check character. In order to prevent confusing with the end character, the check character must never possess the value 0x00. If the result of the XOR link is determined to be a 0x00, a 0xFF is transmitted and considered in the analysis. *Comment: when transmitting configuration data, a CRC signature must be calculated and transmitted for the user information of all messages. This increases the level of security during the transmission of configuration data.*
End	3	The end character consists of the token (i.e. 0x00 0x00) followed by a 0x00. The end character can, thus, be unmistakably different from the start sequence (start character and command character) and a {0x00, 0x00, 0xFF}.

Table 0-2 Protocol structure

The protocol makes it possible for the transmitter and receiver to mutually synchronize one another. This is because the reception of {0x00, 0x00} followed by a character not equal to 0x00 or 0xFF always identifies the start of a message and the reception of {0x00, 0x00, 0x00} always identifies the end of a message.

A message which could not be correctly transmitted is not repeated by the protocol. The transmitter service is responsible for the repetition of faulty messages (for example, when transmitting the configuration data, the function which generated the message).

4.2. Structure of the user information

This chapter describes the function of the data which are exchanged with the aid of the transmission protocol between the *RS 4* and the PC configuration program.

In general, the following types of data are exchanged:

- Measurement values
  During measurement operation, the measured values are transmitted from the *RS 4* to the PC configuration program.

- Configuration data
  The PC configuration program loads the configuration data from the *RS 4* and also stores them on the *RS 4*, i.e. the configuration data are transmitted both from the *RS 4* to the PC configuration program as well as from the PC configuration program to the *RS 4*.

- Diagnostic data
  With the aid of the PC configuration program, it is possible to query various diagnostic values from the *RS 4*, i.e. the diagnostic data are transmitted upon request by the PC configuration program from the *RS 4* to the PC configuration program.

Various commands are defined for the transmission of the various data and for the control of the *RS 4*. The received data can be unmistakably identified by the receiver with the aid of the commands (for a list of the commands, see document *Command Processing (Level 2) CMDPROC.DOC*)

4.2.1. Strategies for the transmission of measurement values

The *RS 4* measures the distance to the next object over an area of 190°. The calculated distance results are internally analysed for protected field monitoring, but may, however, be transmitted for external analysis/display via the serial interface of the *RS 4*.

Please find below a list of the associated data volumes and transmission times:

- The incremental encoder possesses 1000 edge changes over the entire rotation

- The measurement range covers 190°, i.e. 529 measurement values are measured in the measurement range, i.e. 529 measurement values are measured per scan.

- The measurement values have a value range of 16 bits, where the resolution is approximately 2 mm, i.e. 2 bytes are required for the transmission of a measurement value.

- The measurement takes place at 25 rotations/sec. i.e. each rotation is 40 ms in duration. As a scan takes place over 190°, each scan is 21.1 ms in duration.

- Within a period of 21.1 ms, 529 measurement values are determined, i.e. 1 measurement value is determined every 40 µs.

Each scan produces a data volume of 2*529 bytes = 1058 bytes.
Plus the protocol overhead of 10 bytes (start+command+option+check character+end) yields a packet of 1068 bytes / scan for the transmission of all measurement values.

At a baud rate of 57600 baud, 185 ms are required for a packet, i.e. at a baud rate of 57600 baud not all measurement values for a scan can be transmitted.

Realization:

With the RS4, all measurement values are transmitted with 16 bits, where bit 0 specifies whether one of the active protected fields has been violated between the previously output measurement value and the given measurement value. These bits can be used on the PC when displaying the locations in the measurement value contour which violate an active protection field.

The resolution and size of the measurement value output can be defined in such a way that the output begins at a particular sector and ends at a particular sector and only every n-th value (beginning with the output start sector) is output. In this way the size of the measurement value output can be reduced.

The measurement value message is output by means of the RS4 protocol without acknowledgement. As the output of an entire measurement value message may take several rotations, depending on the quantity of data and the baud rate, the output of the measurement value message within the area being monitored is interrupted. While a measurement value is being output, scanning can, therefore, continue and the defined area monitored without overwriting the current measurement value output.

4.2.2. Structure of the transmitted measurement contour

This chapter describes the structure of the user data of the communication protocol during the transmission of a measurement contour from the RS4 to the PC configuration program.

Notice: Each measured contour possesses 529 measurement values (angle -5.04° - 185.04° with 0.36° resolution). Each individual measurement value possesses a number, beginning with 0, i.e. the measurement value at position -5.04° has the number 0 and the measurement value at position 0° has the number 14. Within a measurement message, it is not absolutely necessary that all values of the contour being measured be transmitted (see resolution, output start and output stop).

The following data are transmitted within a measurement contour:

Address within the user data	Name	Description	Size in bytes
0	Scan number	The scan number is incremented by one with each rotation of the RS4. This scan number can be used to determine the temporal separation between two output measurement contours. The actual scan number is 32 bytes in size. In order to prevent a smaller value from creating a double zero during the transmission of 4 bytes, filler bytes with the value 0xFE are inserted between the individual bytes of the scan number. The scan number is thus structured as follows: · Bit 24-31 · 0xFE · Bit 16-23 · 0xFE · Bit 8-15 · 0xFE · Bit 0-7 · 0xFE	8
8	Resolution	This value specifies the distance between two individually transmitted measurement values. Assuming that the measurement contour is output beginning with measurement value 0 and ending with 528 and the resolution is set to value 4, the following values of the measured contour are then output: · 0 · 4 · 8 · ... · 520 · 524 · 528	1
9	Output start	This value specifies with which measurement value the output of the measured contour is to begin.	2

Address within the user data	Name	Description	Size in bytes
11	Output stop	This value specifies which measurement value is to be transmitted last. If the ratio of the number of measurement values to be output (as specified by output start and output stop) to the resolution is not divisible, the measurement value corresponding to the output stop is output in any case.	2
13	Measurement values	The individual measurement values are output in sequence, beginning with the measurement value corresponding to output start and ending with the measurement value corresponding to output stop. Each measurement value corresponds here to the distance measured at the respective angular position in millimetres. Bit 0 of a given measurement value specifies whether the measured contour of a protected field has been violated between the given measurement value and the preceding measurement value, i.e. bit 0 must be masked out when defining the measurement value as a distance value.	-

When transmitting 16-bit values within the message, the high byte is always transmitted first followed by the low byte.

4.2.3. Transmitting errors

Errors and warnings may occur due to various events. In the *RS 4* errors are stored in an error buffer.

An error/warning consists of the following parts:

- Number (2 bytes)
  Specifies the given error/warning
- Parameter (2 bytes)
  Additional parameter for the given error/warning number, e.g. in the event of window soiling an indicator of which area of the window is soiled.
- Error location (2 bytes)
  The location at which the error/warning occurred.

For 16-bit values, first the high byte and then the low byte is transmitted.

The error numbers + corresponding parameters are described in a separate realization document.

The PC configuration program can read out the error buffer of the *RS 4*. For this purpose, the PC configuration program sends a request to the *RS 4*. The *RS 4* then sends the entire content of the error buffer to the PC configuration program.

4.3. Command description

This chapter lists all commands which are transmitted between the *RS 4* and the PC configuration program.

The individual commands may possess a value of 0x01 - 0xFE - for further information, see document *Serial Communication (Level 3)* (*SER_COMM.DOC*)

Operating mode: K - configuration
M - measurement operation
E - error/fault

Command	Group	Signifi-cance (HEX)	Description	RS 4 → PC	PC → RS 4	with pass-word	with ack-nowled-gement	min. Access Level	Operating mode	with user information
Mess 16 RT	Measurement	0x21	Transmission of the measurement values in 16-bit format with current scan number. This number is incremented by 1 with each rotation of the mirror and can be used to determine the distance between two successive measurement value outputs	x				1	M	x
Error Occur	Error	0x53	This command is sent by the *RS 4* to the PC configuration program in the event of an error. The error message is included in the transmission as a parameter (consisting of error number, parameter and error location).	x				1	M/KE	x
Warning Occur	Error	0x54	This command is sent by the *RS 4* to the PC configuration program in the event of a warning. The warning message is included in the transmission as a parameter (consisting of warning number, parameter and warning location).	x				1	M/KE	x

Table 0-3 Commands

If the recipient of a message does not know a command, it is ignored. If, as per the acknowledgement flag of the protocol, the transmitter expects an acknowledgement, the receiver sends in this case a negative acknowledgement.