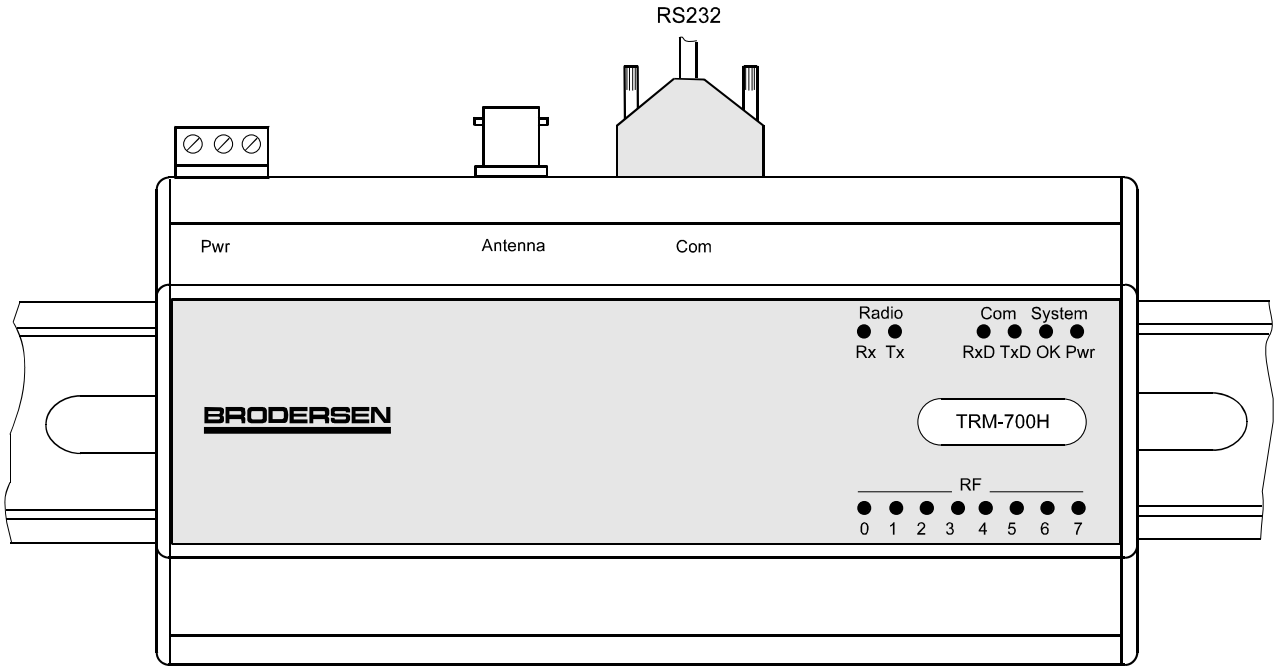
TRM-700 Series
Radio Modems

Version: 01/2002



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1 Introduction

1.1 Overview

This document contains information about installation, settings, and operation of the Model TRM-700 Radio I/O Module. Additional information is also available over the Internet, at the website www.brodersencontrols.com in the FAQ pages. This includes practical guidance relating to antenna selection and installation, operating range, extension modules, software support, etc.

1.2 Safety Precautions

This equipment transmits radio waves in the frequency range 400 to 470 MHz. Under certain circumstances, these radio waves could be harmful to any living being or electronic equipment near it. Installation and commissioning of radio equipment and antennas should be done only by trained persons.

This radio equipment should not be used in life support systems or in safety systems without our prior written permission.

1.3 Disclaimer

We have carefully checked the contents of this document, and the hardware and software described in it, for accuracy, completeness, and compatibility. We cannot however exclude possibilities of discrepancies and cannot guarantee complete conformity of the document with the equipment it describes. If any corrections or improvements are to be made, they will be taken into consideration in the next edition of this document.

Important instructions are marked by the expression “Caution!” These should be carefully observed. Explanations regarding these precautions can be found in the website www.brodersencontrols.com, in the FAQ pages.

2 Software Version

The firmware version and document edition valid for the specific product supplied with this document are:

Firmware Version	Document Version	Comments / Changes
3.00	3.00	First delivered version
3.02	3.02	TRM-700H/M made backward-compatible ("*Z1" output implemented in place of "*Zs1)
3.03		T1X functionality implemented in the TRM-700H/U
3.10		S1U functionality implemented in the TRM-700H/U
3.2	3.2	Features of models TRM-700H/ZZ and -/ZZT combined in the model TRM-700H/M. Either mode selectable via DIP switches. Features of models TRM-700H/S1U and -/S2U combined in the model TRM-700H/U. Either mode selectable via DIP switches. Address setting moved to programming level 4. Backward compatibility for the "ZZ" mode now incorporated. Radio channel now selectable (main programming level).
3.31	3.31	New Layer 1 protocol implemented: timeout with RTS control. New " * " command implemented in model TRM-700H/M, for "ZZ" mode operation: request the field strength of the last received data block (* F).
3.60	3.60	Framing or parity error at the interface leads to rejection of the data block, and protocol-dependent negative acknowledgement (NAK) response.

3 TRM-700: General Description

3.1 Functions and Features

The TRM-700 is an industrial grade radio modem, which includes a serial data interface and radio transmitter/receiver. The unit can be set up to operate at any selected frequency in its specified band, in any of several selectable operating modes, using any one of several serial data communication protocols.

The unit is available in two versions:

The Model TRM-700H/M functions as a **master station** in a point-to-point link or a multi-slave radio network. In either case, communication is between the master and slave station/s: communication between slave stations is not possible. At least one master station must exist in a private radio network operating in the time-slot mode, a network with distinctive slave station addressing, or in a network involving one or more radio repeater stations.

A Model TRM-700H/U operating in "S1U" or S2U" mode can function only as a **slave station** and can communicate only with a master station. TRM-700H/U Slave Modems can also be set up to operate in the "T1X" mode in a peer-to-peer radio network, where there is no dedicated master station. In the "T1X" mode, each slave station transmits message frames, which are received by all the other T1X slave stations in the network. This operating mode does not support either radio repeater stations or the time-slot mode of operation.

The configuration of these radio modems as master or slave units is done at the factory, before delivery, and cannot be changed thereafter. On the other hand, operating modes and communication protocols of TRM-700H/M and TRM-700H/U modems can be selected by the users.

3.2 Operating Modes Explained

3.2.1 TRM-700H/M (ZZ-Mode) Network

A TRM-700H/M modem set up to operate in the "ZZ" mode actively addresses all slave stations in the network. In this case, the network is referred to a ZZ-mode network. In such a network, any of the slave TRM-700H/U modems can operate as repeater stations, for communicating with further slave stations.

The following radio modules are suitable for use as slave stations in ZZ-mode networks:

TRM-700H/U in the S1U operating mode
RTU-700H
FMC-V24/DA1, -DA2, and –DA4

In the ZZ mode, a TRM-700H/M can be interrogated directly for status and configuration information.

3.2.2 TRM-700H/M (ZZT-Mode) Radio Network

A radio network with a TRM-700H/M master station modem operating in the "ZZT" mode (referred to as a ZZT-mode network) is a protocol-transparent network, in which all slave stations are radio modems with serial data ports. In a ZZT network, a slave station operating in the S2U mode passes the complete message frames unaltered, as received from the master station to the serial data port. Therefore, in this mode, almost any industry-standard serial data communication protocol can be handled by the network: e.g. 3964R, MODBUS, MODBUS-IF, ASCII, etc.

The following radio module is suitable for use as slave stations in ZZT-mode networks:

TRM-700H/U in the S2U operating mode.

Additionally, the model RAR-700H can be used as a radio repeater station in a ZZT-mode network.

3.2.3 TRM-700H/U (T1X Mode) Peer-to-Peer Network

With TRM-700H/U stations operating in this mode, there is no dedicated master station. Message frames transmitted by any T1X station are received by all the other stations on the same network. A TRM-700H/U operating in this mode does not have an adjustable address. Instead, the operating frequency can be set through the DIP switches, within specific frequency bands.

3.2.4 Selection of Radio Modems for Different Frequency Bands

Frequency Band	Master Station	Slave Station	Comments
Radio communication bands (except in Germany)	TRM-700H/M (ZZ mode) (without DCF)	TRM-700H/U (S1U) RTU-700 V24/DA1, -DA2, -DA4	Partially co-coordinated frequencies; no time-slot restrictions
	TRM-700H/M (ZZT mode) (without DCF)	TRM-700H/U (S2U)	
	Peer-to-peer (no master station)	TRM-700H/U (T1X)	
ISM band (433-434 MHz)	TRM-700H/M (ZZ mode) (without DCF)	TRM-700H/U (S1U) RTU-700 V24/DA1, -DA2, -DA4	No restrictions for use: operating licenses and payment of fees not required; interference not preventable. RF power output limit 10 mW (in most countries) or 500 mW (in a few countries)
	TRM-700H/M (ZZT mode) (without DCF)	TRM-700H/U (S2U)	
	Peer-to-peer (no master station)	TRM-700H/U (T1X)	

3.3 Mechanical Details

The housing of a TRM-700 modem is compatible for direct DIN rail mounting. A 9-pin D-type connector is provided for the serial data interface, for connection to a computer or PLC. Power supply to the modem (12 to 24 VDC) is connected through a plug-in type screw-terminal block.

The operational status of the modem is indicated by a set of LED lamps located on its front face.

3.4 LED Functions

LED Designation	Function
System Pwr	Indicates that the power supply input is on
System OK	Indicates that modem is in operating condition; also indicates fault conditions
Radio Tx	Lights up while radio transmission is active
Radio Rx	Lights up while the radio channel is busy (i.e., another station in the network is transmitting)
RF	Indicates the field strength of the received radio signal

The "System OK" LED is continuously lit while the modem is in proper operating condition. If a fault condition occurs, this LED identifies it by coded blinking.

"System OK" LED blinking codes	Fault condition
LED continuously off	Internal fault of the modem (microcontroller subsystem fault); or modem otherwise not in ready condition
LED continuously on	Modem in operating state; no fault existing
Slow blinking: equal on and off periods	The modem is in programming mode
Fast blinking: equal on and off periods	Last settings entered while in programming mode have been accepted
2 blinks followed by a pause	The modem has an invalid address. Addresses must be within the following ranges: slave stations = 1-239; master stations = 0-14
4 blinks followed by a pause	Internal fault of the modem (radio fault)

3.5 Power Supply

The supply voltage is connected via a 3-pole plug-in screw terminal block. The polarity is as follows (front panel of the TRM-700 viewed head-on, with the screw terminal block above):

Outside (left):	Earth
Center:	+12 to +24 VDC
Right:	0 VDC

3.6 V24 / RS-232 Interface

Four serial data interface lines are provided, of which three are normally used:

Data transmit	TxD	TRM-700 → PC
Data receive	RxD	TRM-700 ← PC
Clear to send	CTS	TRM-700 → PC
Request to send	RTS	TRM-700 ← PC

TxD is the "data transmit" line of the TRM-700.
RxD is the "data receive" line.
CTS is an outgoing control signal of the TRM-700, and indicates to the connected equipment (computer, PLC, etc.) that the radio modem is ready to receive data.
RTS is a handshake input signal to the TRM-700. The "RTS timeout" operating mode is implemented by using this signal. Note: in other operating modes, this signal line is ignored.

Serial data interface parameters:

The serial data interface parameters are user-configurable. The data rate is selectable from 2400 to 19200 bps. Data word length can be either 7 or 8 bits, with odd, even, or no parity. Factory settings are 9600 bps, 8 data bits, no parity, and one stop bit.

If a framing or parity error is detected in the data that is received through the serial port, the entire data block is rejected. When this happens under either the ASCII or 3964R protocol, the connected terminal device receives a negative acknowledgement (NAK) response. Note: the RS-485 interface (available as an extra-cost option), does not use CTS and RTS lines.

The length of a transmitted data block can be up to 512 bytes.

3.7 Serial Data Communication Protocols (Layer 1)

The following protocols are supported for communication between a TRM-700 modem and terminal equipment (PLC or PC) connected via its serial interface:

- 3964R (Siemens)
- ASCII
- Timeout (protocol-transparent)

The Layer 1 Protocol is independent of the connected terminal device and operating mode. The Layer 1 protocol does not describe the user data content of the exchanged message frames, but only the physical connection through which this user data is sent and received. Message frame headers and error control bits are added to the user data blocks, when transmitted over the radio channel.

The Layer 1 protocol of each TRM-700 modem can be set up independently of the other stations in the same radio network. It is therefore possible to link up terminal equipment which use different protocols in a single TRM-700 radio network. For example, the master station modem may be connected to a PC which uses the timeout protocol, while a slave station modem on the same radio network can be connected to a PLC which uses the 3964R protocol.

Details of the relevant Layer 1 protocols are given in the sections that follow.

3.7.1 3964R Protocol

Serial data interface parameters:

Bit rate:	2400 to 19200 bps
Word length:	7 or 8 bits
Start bit:	1 bit
Stop bit:	1 bit
Parity:	None, odd, or even
Character timeout:	220 ms (factory setting)
Acknowledgement timeout:	1000 ms (factory setting)

Data block structure:

Data can be transmitted in either direction between a TRM-700 and a connected computer or PLC. Either side can initiate data exchange. In the following description, the side that initiates a data exchange is referred to as the sender, while the other is referred to as the receiver.

If the connected computer or PLC has an adjustable communication priority setting, it should be set to a low priority.

Data communication is initiated when the sender transmits the code "STX". The receiver acknowledges this with the response code "DLE". Following this, the user data block is transmitted, and concluded with the sequence "DLE-ETX-BCC". The receiver acknowledges receipt of the data block by returning the code "DLE". If the character 10h (which represents the control character “DLE”) should occur within a user data block, it is doubled and transmitted as 10h-10h.

If several characters are transmitted, they cannot have intervening time intervals of more than 220 ms (the character timeout limit): if a longer character interval occurs, the receiver will transmit an NAK character, which results in the data transmission in progress being aborted.

The delay between a request to send (STX), or the end of the data block (DLE-ETX-BCC), and the DLE response should not be more than the specified acknowledgement timeout limit of 1000 ms. If the delay exceeds this timeout limit, the receiver sends an NAK character, and the transmission in progress is aborted.

If a computer / PLC rejects a data block sent by the TRM-700, then the latter makes 2 further attempts to send the data block, if data was received from a slave station. In the ZZ mode of operation, control data segments beginning with " * " are not transmitted again.

User data:

After communication is established, the user data is transmitted transparently, as 8-bit characters in the range 00h through FFh. An exception is made when the character 10h is encountered. Since this value represents the control character "DLE", this byte is transmitted twice (referred to as "DLE doubling"). Therefore, if the value 10h occurs in the user data stream, it must be transmitted as 10h -10h. When DLE doubling occurs, both bytes are counted in the block check character (BCC) computation.

Start character:

The character STX (02h) is used as the "start" character. To confirm the establishment of communication, the other must respond with a DLE character.

End character:

The sequence DLE-ETX (10h-03h) marks the end of a data block.

Checksum (BCC):

The block check character BCC is always added at the end of the data block. The checksum is calculated as follows:
BCC = data byte 1 (exor) data byte 2 (exor) ...data byte n (exor) DLE (exor) ETX..
The STX character is not included in this computation.

Caution:

a) BCC can have any value, including values corresponding to ETX, STX, DLE, etc.
b) Doubled DLE occurrences are included in the BCC computation

If the BCC computation results in the value 10h (corresponding to the control character DLE), in this case it is not doubled.

Example:

The status of the Station 16 is to be reset. For this, the required message frame to be transmitted by the master station is: 28h-10h-00h-00h-00h-00h.

The slave station (# 16) responds with: A8h-00h-10h-00h-00h-00h.

PLC / PC → TRM-700: Starts communication.

02h
STX

TRM-700 → PLC / PC: Confirms establishment of communication.

10h
DLE

PLC / PC → TRM-700: Transmits data block.

28h	10h	10h	00h	00h	00h	00h	10h	03h	3Bh
	DLE doubling						DLE	ETX	BCC

TRM-700 → PLC / PC: Acknowledges receipt of data block.

10h
DLE

- Data is transmitted over the radio link -

TRM-700 → PLC / PC: Acknowledgement data block transmitted by the slave station.

02h
STX

PLC / PC → TRM-700: Confirms establishment of communication.

10h
DLE

TRM-700 → PLC / PC: Acknowledgement data block transmitted by the slave station

A8h	00h	10h	10h	00h	00h	00h	10h	03h	BBh
		DLE doubling !					DLE	ETX	BCC

PLC / PC → TRM-700: Acknowledges correct receipt of data block.

10h
DLE

Control characters:

Control characters used in the 3964R protocol and their corresponding hexadecimal values are given in the following table:

Control function	Acronym	Value
Start of text	STX	02h
End of text	ETX	03h
Acknowledge	ACK	06h
Data link escape	DLE	10h
Negative acknowledge	NAK	15h

3.7.2 ASCII Protocol

Serial data interface parameters:

Bit rate:	2400 to 19200 bps
Word length:	7 or 8 bits
Start bit:	1 bit
Stop bit:	1 bit
Parity:	None, odd, or even
Character timeout:	220 ms (factory setting)
Acknowledgement timeout:	1000 ms (factory setting)

Data block structure:

Data can be transmitted in either direction between a TRM-700 and a connected computer (PC) or PLC. All data blocks begin with a "Start of Text" character, followed by the ASCII-coded user data, an "End of Text" character, and a "Block Check Character". If the data block is correctly received by the other side, a positive response (ACK) is transmitted by it. If not, a negative response (NAK) is sent. If the communication in progress is to be aborted, then an EOT character is transmitted. If the sender receives an NAK, it transmits the same data block once more.

The communication set-up should ensure that pauses between characters in a data block do not exceed 220 ms, otherwise the data block will be rejected (the TRM-700 transmits an NAK in this event).

Acknowledgements must always be sent within the acknowledgement timeout limit of 1000 ms. If an acknowledgement is not received by a TRM-700 within this time, it will make up to two repeat attempts to send the same data block (except with " * " commands in the "ZZ" mode). If no acknowledgement is received even after the last repetition, then the TRM-700 terminates the communication in progress, by transmitting EOT (except with "*-" commands).

Start character:

STX (02h) is used as the start character.

User data:

The user data consists of a pure ASCII string. Binary values are represented in ASCII as hexadecimal numbers. Only the numeric characters 0 through 9 and the alphabetic characters A through F may be used.
Example: A user data byte with the value 7Eh is transmitted as a 2-byte string "7" - "E".

Control characters starting with "*" are handled as exceptions. These are transmitted as pure ASCII characters following the "*".
Example: "*Z1" is transmitted as: STX - "*" - "Z" - "1" - ETX - LRC.

End character:

ETX (03h) is used as the end character.

Checksum:

The checksum is calculated as follows:
LRC = data byte 1 (exor) data byte 2 (exor) …data byte n (exor) ETX.
The STX character is not included in this computation.

Caution: BCC can have any value, including values corresponding to ETX, STX, EOT, etc.

Example:

The status of the station 1 is to be reset. For this, the required message frame to be transmitted by the master station is: 28h-01h-00h-00h-00h-00h.

The slave station (# 16) responds with: A8h-00h-01h-00h-00h-00h.

PC/SPS → TRM-700: Transmits data block

02h	32h	38h	30h	31h	30h	30h	30h	30h	30h	30h
STX	"2"	"8"	"0"	"1"	"0"	"0"	"0"	"0"	"0"	"0"

30h	30h	03h	08h
"0"	"0"	ETX	LRC

TRM-700 → PLC / PC: Acknowledges receipt of data block.

06h
ACK

- Data is transmitted over the radio link -

TRM-700 → PLC / PC: Acknowledgement data block transmitted by the slave station

02h	41h	38h	30h	30h	30h	31h	30h	30h	30h	30h
STX	"A"	"8"	"0"	"0"	"0"	"1"	"0"	"0"	"0"	"0"

30h	30h	03h	88h
"0"	"0"	ETX	LRC

PLC / PC → TRM-700: Acknowledges receipt of data block.

06h
ACK

Control characters:

Control characters used in the 3964R protocol and their corresponding hexadecimal values are given in the following table:

Control function	Acronym	Value
Start of text	STX	02h
End of text	ETX	03h
End of transmission	EOT	04h
Acknowledge	ACK	06h
Negative acknowledge	NAK	15h

3.7.3 Timeout Protocol

The "Timeout" protocol is available with or without RTS control. With it, data transmission can be halted using the RTS line. Therefore, when this protocol is used, the RTS line must be connected: without it data communication cannot take place.

Serial data interface parameters:

Bit rate:	2400 to 19200 bps
Word length:	7 or 8 bits
Start bit:	1 bit
Stop bit:	1 bit
Parity:	None, odd, or even

Data block structure:

The timeout protocol is a transparent protocol, in which only user data is communicated. Start, end, and checksum characters are not used.

User data:

The data to be transmitted is transferred unmodified to the TRM-700. The communication set-up should ensure that the time interval between two successive characters is not more than the equivalent time for 10 characters (at 9600 bps, this is about 10 ms).

The end-of-message criterion in this case is timeout. If no character is received via the serial interface for time equivalent to 10 characters, it is treated as the completion of the data block, and the data received up to that point is transmitted over the radio channel or interpreted as commands by the TRM-700 ("*" commands, in the "ZZ" operating mode).

A Layer 1 acknowledgement is not implemented for the timeout protocol.

3.8 Basic Rules of Operation

Data block length:

Data blocks can be up to 512 bytes in length. Shortly before reaching the maximum data block length, the interface signal CTS is deactivated. When the serial data interface is assumed to be ready again for data, the CTS signal is activated once more.

Data block end criterion with Layer 1 timeout protocol:

All the individual bytes of the data block must be transferred unmodified by the control system to the TRM-700. After a minimum of one byte has been received, if the TRM-700 encounters an interruption in data longer than the equivalent time for 10 characters (10ms at 9600 bps), it treats this as the end of the data block, and transmits whatever it has received up to that instant over the radio channel.

Data block end criterion with Layer 1 3964R and ASCII protocols:

If either of these protocols is in use, the end of the data block is defined by the appropriate character string specified for that protocol (DLE-ETX-BCC for the 3964R protocol, or ETX-LRC for the ASCII protocol).

Acknowledgment timeout (applicable particularly to ZZT-mode networks):

The host control system software should take into consideration the acknowledgement delays likely to be encountered in a radio network due to transmit/receive switchover time, etc.

For an approximate estimate of such delays, allow 50 ms for radio carrier keying, 20 ms for the message frame header, and 5 ms for each data byte (at 2400 bps radio data rate). To this must be added the time required by the slave station to transmit the data over the serial data interface, and receive an acknowledgement from the connected PC/PLC (approximately 1 ms per data byte, at 9600 bps).

Addressing and acknowledgement responses (ZZT-mode networks)

Radio data blocks transmitted by a ZZT-mode master station are received time-synchronously by all the slave stations. Each slave station outputs this data (also time-synchronously) using the Layer 1 protocol selected for the PC/PLC connected to its serial data port. The CTS line of the serial data (RS-232) port is activated the instant the slave station receives the first data block, and deactivated at the end of the time slot in time slot operation mode.

The PC / PC connected to the slave station has to check the address within the message frame, and act on it only if that address matches its own.

Protocol selection (ZZT-mode networks)

When a radio link is used in the protocol-transparent "timeout" mode, it is recommended that a protocol be used that requires the minimum number of message exchanges. MODBUS-RTU is suitable, since in each case only one data block is transmitted, and only one acknowledgement message is received. By contrast, the 3964R protocol would require a total of 8 (EIGHT !) radio messages to complete a "fetch data" transaction. Therefore the 3964R protocol is not recommended for use in protocol-transparent "timeout" radio networks operating in time-slot mode.

If a ZZT-mode radio network must be operated with terminal equipment (PCs / PLCs) that uses the 3964R protocol, this could be handled in the following way. The -/ZZT master station and -/S2U slave stations can be set up for interfacing with 3964R protocol terminal equipment connected to their respective serial data ports. At the master station, a data block to be transmitted by (say) the host PC is transferred to the TRM-700/ZZT modem using the 3964R protocol. The TRM-700/ZZT re-transmits this data block in the time-slot radio link to the destination TRM-700/SU slave modem, in the timeout mode. The TRM-700/SU slave modem then transfers this data block through its serial data port to the PLC using the 3964R protocol.

In this way, only one radio message exchange takes place for each data block to be transmitted. A positive acknowledgement (ACK) received through the 3964R protocol by a PC / PLC on one side would mean only that the connected TRM-700 has received the data correctly: it cannot be taken as confirmation that the remote slave station has received the data.

4 TRM-700H/M Master Station Modem

4.1 ZZ Operating Mode

When the TRM-700H/M is set up in the ZZ mode, it can operate with any of the following slave station modules:

- RTU-700H
- TRM-700H/S1U
- FMC-V24/DA1, -DA2, and –DA4.

The user data depends in each case on the slave station that is accessed. Communication with connected terminal equipment takes place using one of the supported Layer-1 protocols.

The TRM-700H/M automatically generates the so-called time-byte (ZB) and inserts it into every message frame that it transmits. **Note: this byte should not be included in the user data block!**

The TRM-700H/M has a 4-bit address, which is selectable by the user within the range of 0-14. This address does not affect the addresses of the slave stations in the network, each of which would have its own distinctive network address. If, however, there are several ZZ-mode stations with identical user-defined addresses, where one ZZ-mode station is within radio range of other slave stations, then each ZZ- and ZZT-mode station should be given a distinctive address. This prevents master stations from accidentally receiving and transferring message frames from slave stations in neighboring networks.

Slave station addresses should be unique, not only within a radio network, but also among all networks operating within radio range of each other. Each such network should have a reserved range of slave station addresses. This way, message frames will not be accidentally received from, or transmitted to, neighboring networks.

4.1.1 TRM-700 (ZZ Mode): Communication Control (Logical Level)

Communication between a computer (or other control system) and a TRM-700 radio modem involves some considerations relating to data block structure and protocol usage. The following commands are represented as pure user data, and are valid for being handled by the TRM-700/ZZ as part of the Layer 1 protocol. For example, in the case of a TRM-700/ZZ using the ASCII protocol, the query command for the time slot is “*Z”, and is transmitted as "STX - *Z - ETX - LRC". The acknowledgement is similarly protocol-dependent: “DLE” in the 3964R protocol, “ACK” in the ASCII protocol, and no acknowledgement in the timeout protocol.

4.1.2 TRM-700 (ZZ Mode): Power-Up Message

On switching on a TRM-700, it transmits its version number and unit number over the serial interface.

If the TRM is set up to use the 3964R protocol, it first transmits an NAK before transmitting the version and unit numbers.

Example of power-up message:
TRM-700: * V03.00 4711
Terminal equipment: Acknowledgement (except with the timeout protocol)

4.1.3 Interrogation of Version and Unit Numbers

The stored firmware version and unit numbers of a TRM-700 can be read by software. Therefore the functional capabilities of each radio modem on a network can be determined at any time, even if a modem is replaced with a later version.

Example of interrogation for the version number (software version 3.10, unit number 4711):

Host: *V
TRM-700: Acknowledgement (except when using the timeout protocol)
TRM-700: *V03.10 4711
Host: Acknowledgement (except when using the timeout protocol)

The version and unit numbers string is structured as follows:
"*" (asterisk) - V (identifier character) - XX (first 2 digits of the version number) - "." (dot) - XX (last 2 digits of the version number) - space - XXXX (4 digit unit number).

4.1.4 TRM-700H/M (ZZ Mode) RF Field Strength Measurement

While a slave station is transmitting a data block, a TRM-700H/M-ZZ master station measures the field strength of the received signal at various points in the message frame. These values of received field strength are averaged and stored as a percentage in the range 0 - 100. This value can be interrogated by the connected terminal equipment (PC / PLC) with the command "*F".

The field strength data is a 3-digit value in the range 000 through 100. If the 3-digit string 999 is returned, it means that a valid value of field strength is not available at that moment.

After the field strength value is interrogated, it is re-set to 999 (invalid value), until the next updated average value is registered.

Example of interrogation for field strength:

Host: *F
TRM-700: Acknowledgement (except when using the timeout protocol)
TRM-700: *F067
Host: Acknowledgement (except when using the timeout protocol)

The following table gives the equivalence between percentage readings and electrical field strength values. These are approximate relationships, due to the tolerance spread of electronic circuit component values.

Field Strength	% Value	LED Lamps Pattern	Comments
0,5µV	17%	3 red	Evaluation limit
1µV	28%	Yellow	Good signal strength
5µV	51%	1 green	Very good signal strength
10µV	61%	2 green	
30µV	75%	3 green	
150µV	98%	4 green	

4.2 Registers Structure: TRM-700M (ZZ)

Some operation / status parameters of modem units (e.g., version number, unit number, etc.) can be accessed through registers. This access has to take place using the MoP protocol, which is also used for communicating with RTU-700 destination stations. Such access is possible only by master stations operating in the ZZ mode. All registers are 16 bits wide.

Register types:
(R): Register can be read
(W): Register can be read and written
(WP): Register can be read and contains factory settings
(E): Register value is stored in EEPROM

The functions of available registers and their address codes are listed in the table that follows.

4.2.1 TRM-700H Registers

Register	Function	Description
906	Model identity	Identifies the model and operating mode of the modem (R)
907	Firmware version	Firmware version (R) e.g., 0115h corresponds to version 01.15
914	Received signal field strength	Radio signal field strength during the last received message frame, in percent (R)
916	Station address	Logical address of station (R/W/E)
932	Character timeout limit	Sets the character timeout limit for the 3964R and ASCII protocols, in 10 ms units (Default value: 22 = 220 ms) (R/W/E)
933	Acknowledge-ment timeout limit	Sets the acknowledgement timeout limit for the 3964R and ASCII protocols, in 10 ms units (Default value: 100 = 1000 ms) (R/W/E)

4.2.2 Description of Register Functions

Information about the various operational parameters of the radio modem is stored in registers where they can be accessed when required. The addresses of these registers start from 900. Registers are of the following types: read only, read-write, or factory pre-written. Some of these registers are stored in non-volatile memory, protected from power interruptions.

Station Address Register

The DIP-switch configured station address is stored in this register. Addresses can be selected in the range 0-14 for master stations, and 1-239 for slave stations.

Model Identity Register

This register identifies the model number and operating mode of the radio modem, which can be interrogated remotely to verify the network configuration details, or to check if a specific station is using the correct type of radio modem.

The model identity register codes for the TRM-700 modems are as follows:
0021h: TRM-700H/M, operating mode ZZ
0022h: TRM-700H/M, operating mode ZZT

0028h: TRM-700H/U, operating mode S1U
0029h: TRM-700H/U, operating mode S2U
002Ah: TRM-700H/U, operating mode T1X

Firmware Version Register

This register identifies the embedded software version of the modem. A value of 0320h means that version 3.20 of the modem's firmware is used in that specific unit.

Received Field Strength Register

The field strength (as a percentage value, in the range 0 – 100 %) of the radio signal during the reception of the last message frame.

Character Timeout Limit Register

The 3964R and ASCII protocols use character timeout monitoring. If, after a character is received, the next character is delayed beyond this timeout value, the data block is rejected. The default register value is 22, which corresponds to 220 ms.

Acknowledgement Timeout Limit Register

The 3964R and ASCII protocols also use acknowledgement timeout monitoring. If, after a data block is transmitted, an acknowledgement is not received within the timeout limit, the same data block is transmitted again, with up to 2 repetitions. Commands with the "*" prefix are not repeated after being transmitted once. The acknowledgement timeout value is stored in 10 ms units. The default value is 100, corresponding to 1000 ms.

4.2.3 The MoP Protocol

The registers of the TRM-700H/M (ZZ) are accessed using the MoP (MODBUS over Brodersen) protocol. This protocol is also used for communicating with the RTU-700H slave stations.

The MoP protocol is based on the industry-standard MODBUS-RTU protocol, but with added features that optimize the protocol for radio data communication. With the MoP protocol, a complete data exchange (reading and writing of a slave station's registers) is executed in a single radio data exchange cycle, consisting of one data block transferred from the master to the slave station, and one data block from the slave to the master. On the other hand, the standard MODBUS protocol needs 4 message frame transfers for the same purpose (2 message frames for writing to the registers, plus two for reading from the registers).

The MoP message frame consists of a header followed by a user data block. The header includes the function code (60h) that declares the MoP protocol, the receiving and transmitting station addresses, and up to 2 repeater station addresses.

To access the internal registers of a TRM-700H/M modem, the character sequence "00 00 00 00" is to be included in the MoP address header.

Polling data block from a host system to a TRM-700H/M (ZZ mode) using the MoP protocol:

60	00	00	00	00	IR_H	IR_L	IR_X

OR_H	OR_L	OR_X	$D1_H$	$D1_L$	....	Dn_H	Dn_L

60: Function code in the polling message frame that declares the MoP protocol

IR_H / IR_L: Address of the first input register that is to be read

IR_X: Number of input registers that are to be read

OR_H / OR_L: Address of the first output register that is to be written

OR_X: Number of output registers that are to be written

$D..{}_H$ / $D..{}_L$: Data for the output registers. For each output register that is to be written, 2 bytes of data must be transmitted.

Acknowledgement data block from a TRM-700:

E0	00	00	00	00	IR_H	IR_L	IR_X	$D1_H$	$D1_L$	....	Dn_H	Dn_L

E0: Function code in the acknowledgement message frame that declares the MoP protocol

IR_H / IR_L: Address of the first input register that has been read, and whose data is to be transmitted back

IR_X: Number of input registers that have been read

$D..{}_H$ / $D..{}_L$: Data for the input registers. For each output register that is to be written, 2 bytes of data must be transmitted.

Addressing the internal TRM-700H register contents using the MoP protocol (possible only for a TRM-700H/M-ZZ):

All control registers can be interrogated separately or simultaneously, while at the same time other registers can be written. Some control registers are read-write type, while others are read-only. The addresses of these registers start at 900.

All registers are 16 bits wide. If fewer than 16 bits are used for a particular function, the lower bits are the ones that are used.

Example: reading the registers of a TRM-700H:

- The product serial and software version numbers of a TRM-700H/M (ZZ) are to be fetched from its control registers (2 registers, starting with register address 932 = 0A4h):

60	00	00	00	00	03	A4	02	00	00	00

- Acknowledgement message frame, indicating product serial number as 0021h and firmware version 3.20 (register value 0320h):

E0	00	00	00	00	03	A4	02	00	21	03	20

4.3 ZZT Operating Mode

A TRM-700 master station can operate in the ZZT-mode only with TRM-700/S2U slave stations. In this radio network configuration, data communication is fully transparent. Control commands, such as " * " commands in ZZ-mode operation, are not possible in ZZT-mode operation. Data exchanges between a TRM-700H modem and connected terminal equipment (e.g., PC) is handled under the Layer-1 protocol for which each respective modem has been set up, both for the ZZT-mode master station and the S2U-mode slave stations.

The TRM-700H/M has a 4-bit address, which can be programmed in the range 0-14. This address is the basis for a group address for the S2U slave stations on the same network. In such a network, the S2U slave stations have a common group address that must be 1 higher than the master station address. For example, if the master station is assigned the address "0", the S2U slave stations must have the address "1".

If several ZZ- or ZZT-mode stations are operating in the same area, where one or more of them can receive signals from slave stations in other neighboring networks, then the group address for each network must be different. This is necessary to ensure that a ZZ-mode master station does not accept and process a message frame from a slave station that is not on its own network. Also, a slave station group address and frequency channel should be assigned uniquely to each network, if several networks are operating within radio range of each other. S2U modems are the only type which use the same address (in this case, the group address) for multiple slave stations in the same network.

The radio modems and radio I/O modules are all pre-programmed with a customer address code that is unique for each customer. This address takes precedence over the network station addresses. A receiving station will reject any message frame that it receives that has a customer address other than its own. Therefore, it is not possible for stations of one customer to transmit data to, or receive data from, stations of another customer, even if they happen to be within radio range of one another.

4.3.1 ZZT Mode Communication Without Time-Slot Limitations

Time slot limitations are not applicable for radio networks installed outside Germany, nor for ISM band networks everywhere. In these cases, data communication is handled in the same way as the time slot method, except that the ZZT master station can transmit data over the radio channel to the slave stations at any time. Instead of checking received message frames against designated time-slots, the slave stations check the destination addresses in the message frames, to determine whether a message frame transmitted by the master station is to be accepted by it or not. If a slave station accepts the message frame, it activates the CTS line of its serial data interface, and is ready thereafter to receive data from the connected terminal equipment.

Note: When a slave station is started up or re-set, its CTS line is deactivated. Until it receives the first message frame from the master station, a slave station cannot know whether it is to operate in the time slot mode or not. It must first receive a message frame from the master station, before the slave station activates its CTS line.

4.3.2 Radio Repeater Stations

Since all the slave stations in a ZZT-S2U network have the same address (the group address), a slave station cannot function as radio repeater station in such a network. If the topography of the local terrain makes it necessary to use one or more repeater stations in a radio network, the dedicated repeater module RAR-700 can be used with one of the appropriate communication protocols (MODBUS-RTU or MODNET-1). For details, see the RAR-700 technical documentation.

5 TRM-700H/U Slave Station

5.1 S1U Mode Operation

A TRM-700/U in the S1U operating mode can interconnect data acquisition and control (SCADA) system nodes (PLCs, PC, etc.), by linking their respective serial interfaces over a radio network. For this, the master station modem is set up to operate in the ZZ time-slot mode

The exchange of user data over the serial interface of each radio modem takes place under the Layer 1 protocol for which each S1U slave station is set up.

TRM-700/S1U modems can be used with other types of radio stations (e.g., RTU-700 radio remote I/O modules) in the same network. All these types of radio modules can function as radio repeater stations. For example, a data block addressed to a TRM-700/S1U can be routed through two RTU-700 modules that act as radio repeaters, in addition to their basic function of acting as radio remote I/O nodes.

5.1.1 (Missing)

5.1.2 Radio Message Frame Structure

Message frame structures are described in the following sections, independently of the Layer 1 protocol used.

5.1.2.1 Message Frame Transmitted By Master To Slave Stations

All message frames are identically structured. A frame starts with the function code that defines its structure and contents. This is followed by 4 address bytes, a timeout byte, and then the user data block (the last of which can have an arbitrary number of bytes).

Polling message frame from the master to slave station:

F	(ZB)	A1	A2	A3	A4	T	D1	D2	D3	D4	D5			Dn

F: Function code that defines the structure and contents of the frame
(ZB): The time byte, generated automatically by a ZZ-mode master station. **Note:** this byte must not be transmitted by the host (control) system !
A1….A4: Destination station address (A1), repeater station addresses (A2, A3), and sending station address
T: Timeout byte (used when data is read from a TRM-700/S1U)

D1….Dn: User or control data (optional)

5.1.2.2 Acknowledgement From Slave To Master Station

A slave station responds with an acknowledgement message frame to every data block that has been addressed to it. The function code in the acknowledgement message frame is generated by setting the most significant bit to logic "1".

Example: On reading the function code 31h in a received message frame, a TRM-700/S1U generates and inserts the function code B1h in the acknowledgement message frame.

Acknowledgement message frame from the slave to the master station:

Q	(ZB)	A1	A2	A3	A4	RZ	D1	D2	D3	D4	D5			Dn

Q: Function code in the acknowledgement message frame
(ZB): The time byte, which is filtered out by the ZZ master station.
Note: this byte is not transmitted to the host (control) system!
A1….A4: Destination station address (A1), repeater station addresses (A2, A3), and sending station address (A4)
RZ: Record counter
D1….Dn: User or control data (optional), confirmed by the slave station

5.1.2.3 Function Codes For The TRM-700/S1U

F (hex)	Interpretation
31	Data transmitted to, and to be read by, the TRM-700/S1U: The user data block in the polling message frame is forwarded by the TRM-700/S1U via its serial data interface, using the Layer-1 protocol set up for that interface. If the timeout byte is >0, the TRM-700/S1U will wait for the period determined by this byte (= T*25 ms) to receive return data from the terminal equipment connected to its serial interface. If this is received within the time limit, the return data block is inserted into acknowledgement message frame, and transmitted onward to the master station. When this happens, the Record Counter value is set to 1. If the acknowledgement message frame does not contain return data, the Record Counter is set to 0.
32	Data from TRM-700/S1U is read: After the TRM-700/S1U receives a polling data block with this function code, it is ready to ready to receive data via its serial interface (within the updated timeout limit), using the Layer 1 protocol set up for that interface. The data block received by it via its serial interface is then forwarded to the master station, with the Record Counter value increased by 1. If no data is received via the serial interface, the radio acknowledgement message frame is sent with the Record Counter set to 0.
33	Last data block re-transmitted: When it receives this function code, the TRM-700/S1U re-transmits the last data block again. This can be necessary if, for example, a data block could not be completely transmitted the first time because the time slot had expired. In this case, the TRM-700/S1U does not read data via its serial port, and the Record Counter remains unchanged.
B1	Acknowledgement code to the function code 31.
B2	Acknowledgement code to the function code 32.
B3	Acknowledgement code to the function code 33.

5.1.2.4 Address Block (With Repeater Stations)

The address block consists of 4 bytes (8 bits each), which includes the addresses of the destination station, the originating station, and (where applicable) up to 2 repeater stations. It has the following structure:

A1	A2	A3	A4

A1 always contains the address of the station that is to process the message frame next. If A2 = 00h, it means there is no repeater station in the path to that destination station: i.e., the station addressed by A1 will directly receive the message frame. If A2 or A3 has a value other than 00h, it means that the transmitted message frame has to be routed through a repeater station. In this case, A1 will have the address of the first repeater station. When a repeater station receives a message frame, it rolls the addresses to the left:

A2	A3	A4	A1

The fourth address byte always has the return address of the master station (0x00) and identifies the end of the address block.

Example 1: No repeater stations

A data block is to be transmitted from a master to a slave that which has the address 35h:

Master:	F	35	00	00	00			

The slave station acknowledges this as follows:

Station 35:	Q	00	35	00	00			

Example 2: With repeater stations

A data block is to be transmitted from a master to a slave station with address 55, via repeater stations with addresses 12 and 13, respectively:

Master:	F	12	13	55	00			

The message frame is received by repeater station12, the address block is rolled to the left and the message frame is retransmitted:

Station 12:	F	13	55	00	12			

The message frame is received by repeater station13, the address block is rolled to the left and the message frame is retransmitted:

Station 13:	F	55	00	12	13			

This message frame is now received by the next station (address 55h). Since the second address byte is 00h, the address 55h is interpreted as that of the destination station.

The destination slave station replaces the polling function code (F) with the acknowledgement function code (Q), rolls the address block to the right, and sends the message frame back over the same route to the master station:

Slave station 55h transmits the acknowledgement message frame to repeater station 13h:

Station 55:	Q	13	55	00	12			

Repeater station 13h re-transmits the message frame to repeater station 12h:

Station 13:	Q	12	13	55	00			

Repeater station 12h re-transmits the message frame to the master station 00h:

Station 12:	Q	00	12	13	55			

The master station then forwards the data block received by it from repeater station 12h to the terminal equipment connected to its serial interface.

5.1.2.5 Timeout Byte T: Master To Slave Station

The timeout byte determines the time limit within which a TRM-700/S1U must receive data via at its serial interface. This value is in 25 ms units: i.e., a timeout byte value of 20 (decimal) represents a timeout limit of 500 ms.

5.1.2.6 Record Counter RZ: Slave To Master Station

The record counter indicates the number of the data blocks transmitted by the TRM-700/S1U to the master station. It is of particular importance when the user data requires several blocks for it to be transmitted completely. The record counter is the basis for confirming that the complete data has been transferred.

The record counter is deleted when the data is sent out (function code 31) by the TRM-700/S1U. Each data block that is read in at the serial interface of the TRM-700/S1U increases the record counter value by 1.

5.1.3 Description Of The Function Codes

The function codes used for communication with the TRM-700/S1U are described below.

For information about the protocol used by the master station, refer to the technical documentation relating to that module.

5.1.3.1 Data Transmitted To A TRM-700/S1U (F = 31h)

Polling message frame:

31	(ZB)	A1	A2	A3	A4	T	D1	D2	D3	D4	D5				Dn

31: The function code that defines the function and structure of the message frame

(ZB): The time byte, generated automatically by the ZZ master station.
Note: this byte must not be transmitted by the host (control) system !

A1…A4: Addresses of the destination station, repeater station/s, and master station

T: Timeout byte. If T = 0, data is given out and not read in at the serial interface, and an acknowledgement is transmitted back immediately over the radio channel (i.e., "output only").
If T > 0, the TRM-700/S1U waits for the appropriate time (see description of timeout byte) for data to be received via its serial interface. It includes this data in a message frame and transmits it to the master station.

D1….Dn: (Optional) user or control data (max. 512 bytes)

After the message frame is received by the TRM-700/S1U, it forwards the extracted user data block through its serial interface.

If the value of the timeout byte is 0, then an acknowledgement message frame without a user data block, and with record counter set to "00", is transmitted back immediately.

If the value of the timeout byte is greater than 0, then the TRM-700/S1U responds as if it had been polled using the function code 32. In this case, the CTS signal is activated for the time duration corresponding to the value of the timeout byte. If the TRM-700/S1U receives data (under the Layer 1 protocol for which it is set up) via its serial interface within this time period, that data is inserted as the user block into the acknowledgement message frame and transmitted to the master station, with the record counter (RZ) set to 1.

Acknowledgement by the TRM-700/S1U:

B1	(ZB)	A1	A2	A3	A4	RZ	D1	D2	D3	D4	D5				Dn

B1: Acknowledgement code.
(ZB): The time byte, which is filtered out by the ZZ master station.
Note: this byte is not transmitted to the host (control) system!
A1….A4: Address block of the acknowledgement message frame
RZ: Record counter. If no data is received at the serial interface within the specified timeout limit, the value of the record counter is set to 00. If user data is received and included in the acknowledgement message frame, the value of the record counter is set to 1.
D1....DN: User data (if available, max. 512 bytes).

5.1.3.2 Data Read From The TRM-700/S1U (F = 32h)

Polling message frame header:

32	(ZB)	A1	A2	A3	A4	T

32: The function code that defines the function and structure of the message frame
(ZB): The time byte, generated automatically by the ZZ master station.
Note: this byte must not be transmitted by the host (control) system !
A1…A4: Addresses of the destination station, repeater station/s, and master station
T: Timeout byte.

On receiving a polling message frame such as this, The TRM-700/S1U activates the CTS line of its serial interface, signaling that it is ready to receive data. If data is not received by it within the specified timeout limit, the CTS line is deactivated, and the acknowledgement message frame without a user data block is transmitted back to the master station.

If the TRM-700/S1U receives data (under the Layer 1 protocol for which it is set up) via its serial interface within this time period, that data is inserted as the user data block into the acknowledgement message frame and transmitted to the master station.

Acknowledgement from the TRM-700/S1U:

B2	(ZB)	A1	A2	A3	A4	RZ	D1	D2	D3	D4	D5				Dn

B2: Acknowledgement code.
(ZB): The time byte, which is filtered out by the ZZ master station.
Note: this byte is not transmitted to the host (control) system!
A1….A4: Address block of the acknowledgement message frame
RZ: Record counter. If no data is received at the serial interface within the specified timeout limit, the value of the record counter is set to 00.
D1....DN: User data (if available, max. 64 bytes).

For each new user data block, the record counter is incremented by 1.

5.1.3.3 Request For Repeat Of Last Data Block (F = 33h)

Polling message frame header:

33	(ZB)	A1	A2	A3	A4	00

33: The function code that defines the function and structure of the message frame
(ZB): The time byte, generated automatically by the ZZ master station.
Note: this byte must not be transmitted by the host system !
A1…A4: Addresses of the destination station, repeater station/s, and master station

Acknowledgement from the TRM-700/S1U:

B3	(ZB)	A1	A2	A3	A4	RZ	D1	D2	D3	D4	D5				Dn

B3: Acknowledgement code.
(ZB): The time byte, which is filtered out by the ZZ master station.
Note: this byte is not transmitted to the host (control) system!
A1….A4: Address block of the acknowledgement message frame
RZ: Record counter. This corresponds to the last value of RZ that was transmitted with a valid data block by the TRM-700/S1U. If there is no more user data in memory then this value is set to 00, and no user data is included in the acknowledgement message frame.
D1....DN: User data (if available)

With this function code the data read in previously is requested again. This can be necessary, for example, when a data block could not be completely received due to expiry of the time slot. In this case, the record counter is not incremented, and data is not read in via the serial interface of the TRM-700/S1U.

5.1.4 Example

In this example the data block " TEST " is to be sent to a remote terminal equipment (e.g., PLC), followed by carriage return, at the serial interface of a TRM-700/S1U. The terminal equipment connected to the TRM-700/S1U has to reply to this command with the acknowledgment word “HALLO”. In this example, the TRM-700/S1U has the station address 1 and uses the Timeout protocol, while the ZZ-mode master station uses the ASCII (Layer 1) protocol.

5.1.4.1 Data Transfer: Host System To Master Station Modem

Data is transferred by the host system to the master station radio modem using the appropriate Layer 1 protocol. In this example, the ASCII protocol is used. At the physical level, the master station modem requires a message frame structured as STX - data -…..- data - ETX – LRC. This message frame contains the header (which includes the function code, address block, etc.) and the user data that can be transferred at the logical level. The entire communication at the logical level takes place exclusively in the ASCII format: i.e., the byte FFh is transmitted as a 2-byte string “F” - “F”. Data communication is described in detail section 3.7, which covers Layer protocols.

The data block “TEST” followed by a carriage return would therefore be the hexadecimal string: 54h 45h 53h 54h 0Dh.

Communication: host system to master station radio modem:

33_h	31_h	30_h	31_h	30_h	30_h	30_h	30_h	30_h	30_h	30_h	30_h
31		01		00		00		00		00	

35_h	34_h	34_h	35_h	35_h	33_h	35_h	34_h	30_h	44_h
54		45		53		54		0D	

The message frame is transmitted over the radio channel to the TRM-700/S1U slave station, provided that the appropriate time slot is active.

5.1.4.2 TRM-700/S1U: Send Data To Terminal Equipment

After the data block has been received by the TRM-700/S1U, it sends the following data sequence via its serial interface:

Communication: TRM-700/S1U to connected terminal equipment (Layer 1: Timeout)

54_h	45_h	53_h	54_h	$0D_h$
"T"	"E"	"S"	"T"	CR

5.1.4.3 TRM-700/S1U: Request Data From Terminal Equipment

In this example, we want the terminal equipment connected to the serial interface of the TRM-700/S1U slave station to respond with the acknowledging data block “HALLO”, when it receives the command data block “TEST”. In addition, the master station must request the TRM-700/S1U to read data from the terminal equipment and send it back to the central station. In this example the timeout limit is set to 250 ms (timeout byte = 0Ah).

Communication: host system to master station radio modem

33_h	32_h	30_h	31_h	30_h	30_h	30_h	30_h	30_h	30_h	30_h	41_h
32		01		00		00		00		0A	

5.1.4.4 TRM-700/S1U: Receive Data From Terminal Equipment

After the data block referred to in section 5.1.4.3 is received by the TRM-700/S1U, it activates the CTS line of its serial interface, and keeps it in that state during the timeout period (250 ms), signaling to the connected terminal equipment that it is ready to receive data. The terminal equipment must send the requested data (in this case the acknowledging word “HALLO”) to the TRM-700/S1U.

Communication: terminal equipment to TRM-700/S1U:

48_h	41_h	$4C_h$	$4C_h$	$4F_h$	Pause
"H"	"A"	"L"	"L"	"O"	>10 characters

With the timeout (Layer 1) protocol, a pause time greater than the equivalent time for 10 characters is interpreted as the end of message, and results in the TRM-700/S1U transmitting the data block onward to the master station. In this way data can be read with complete transparency. Therefore all values from 00h through FFh can be transmitted.

The data block received from the terminal equipment is inserted into a radio message frame and transmitted by the TRM-700/S1U to the master station.

5.1.4.5 Master Station Modem: Send Data To Host System

When the master station modem has received data over the radio channel, it forwards the data in ASCII format to the host system. The word “HALLO” (48h - 41h - 4Ch - 4Ch - 4Fh) is transferred by the modem to the host system through the serial interface as follows:

Communication: master station radio modem to the host system:

42_h	32_h	30_h	30_h	30_h	31_h	30_h	30_h	30_h	30_h	30_h	31_h
B2		00		01		00		00		01	

34_h	38_h	34_h	31_h	34_h	43_h	34_h	43_h	34_h	46_h
48		41		4C		4C		4F	

5.1.4.6 Simplification

The steps in 5.1.4.3 and 5.1.4.4 (two-way data exchange via the serial interface of the TRM-700/S1U) were described separately for purposes of clarity. In practice, these steps can be combined into a single step using the function code 31 (see 5.1.4.1), with which the timeout byte is simply set to a suitable value greater than 0. This way, the TRM-700/S1U outputs the data via its serial interface and is immediately ready to receive return data within the specified timeout limit. This return data is inserted in a message frame with the acknowledgement function code B1 with the record counter set to 1, and immediately transmitted to the master station.

5.1.5 Summary

In short, communication between the master station and a TRM-700/S1U is divided into 3 steps:

5.1.5.1 Transmission Of Data To The TRM-700/S1U

The data is transferred by the host system to the master station radio modem with the function code set to 31, and then onward over the radio channel to the TRM-700/S1U. This modem then transfers the data out through its serial port, using the appropriate Layer 1 protocol, and sets its internal record counter register to zero. If the timeout is set to a value greater than 0, the TRM-700/S1U is immediately thereafter ready to receive return data. This return data is then transmitted to the master station. In other words, by using the function code 31, transmission of data from the master station is combined with reading in of data by the TRM-700/S1U via its serial interface, as described in 5.1.4.3.

5.1.5.2 TRM-700/S1U: Forward Received Data To Master Station

When a message frame with the function code 32 is received by a TRM-700/S1U, it gets set to receive data during the immediately following time period “t”. During this period, its CTS line is activated, thereby signaling to the connected terminal equipment that the modem is ready to receive data. The period “t” is determined by the master station, in 25 ms units.

The CTS line of the TRM-700/S1U is deactivated at the end of this timeout period if no data is received via the serial interface up to that point, and an acknowledgement message frame without user data is returned to the master station. This message frame would have the acknowledgement function code (B2), the address block, record counter value set to 0, and no data block after that.

If the TRM-700/S1U receives a data block via its serial interface within this timeout period, it deactivates CTS line immediately after receiving the data block, and transmits this data to the master station.

5.1.5.3 Repeat Transmission Of The Last Data Block

Occasionally, a data block transmitted to the master station can be lost. This can happen due to various reasons, including radio interference or expiry of a time slot. The master station detects this situation when it fails to receive a complete and valid acknowledgement from the TRM-700/S1U.

To ensure that the data received by the TRM-700/S1U is not lost, the host system will request the same data block by sending the function code 33 in the next message frame. In this case the record counter is not incremented, and the TRM-700/S1U does not read new data from the terminal equipment connected to its serial interface. The TRM-S1U retains the last data block received from the connected terminal equipment until it is transmitted to the master station, and an explicit request is received from the master station for a new data block to be fetched.

5.2 S2U Mode Operation

TRM-700/U radio modems that operate in the S2U mode can link up distributed front-end controllers, data acquisition modules, instruments, and computers in a radio network, with a master station operating in the ZZT mode.

In this type of a radio network, data transmission is transparent. Unlike with ZZ-S1U networks, here no special message frame headers or station addresses need to be transmitted. Data sent by the host system (using the appropriate Layer 1 protocol) to the ZZT-mode master station radio modem is broadcast to all the S2U slave stations on the network. In this type of a network, all slave stations will have a common address which is 1 higher then the master station address (e.g., if the master station is assigned the address 1, all slave stations on that network will have the address 2). Each slave station transfers data received over the radio channel to the connected terminal equipment via its serial interface.

The exchange of user data with the connected terminal equipment is effected using the Layer 1 protocol for which the S2U slave station has been set up.

The ZZT-mode station has a 4-bit address, which can be set in the range 0 - 14. This address is the basis for a group address for the S2U slave stations on the same network. The S2U slave stations are assigned an address that must be 1 higher than the master station address. For example, if the master station is assigned the address “0”, the S2U slave stations must have the address “1”. If several ZZ- or ZZT-mode stations are operating in the same area, where one or more of them can receive signals from slave stations in other neighboring networks, then the slave stations in each network must have an address that is different from the addresses of the slave station of the other networks. This is necessary to ensure that a ZZ-mode master station does not accept and process a message frame from a slave station that is not on its own network.. In addition, each network in the same area should be given a unique slave station (group) address and frequency channel.

All radio modules of one customer are pre-programmed with a unique customer address, which takes precedence over network station addresses (see section 4.3). Therefore it is not possible for stations of one customer’s network to communicate accidentally with stations of another customer’s network, even if they are within radio range of each other.

A detailed description of data communication in ZZT-S1U networks is given in section 4.3 (“ZZT” Operating Mode).

5.3 T1X Mode Operation

The T1X mode allows the operation of a peer-to-peer radio network, without involving a master station. Each T1X slave station can receive and send data via its serial interface at any time. Data can be received by any of the TRM-700H/U-T1X modems from any of the other stations on the network, which have the same user address and operate on the same frequency. Each modem then forwards this data via their serial interfaces to its connected terminal equipment. The message frame header excludes destination station or group addresses. The station address (which in this case relates to the terminal equipment instead of the radio modem) is included in the user data block. The terminal equipment therefore must be programmed to detect whether its own address is present or not in the user data block, and thereby accept or reject the data block. Neither time slot operation nor repeater stations are supported by T1X-mode radio modems.

For these reasons, T1X mode operation may be used on frequency channels applicable for restricted radio data transmission (using the time slot method) only if external timing and logic control can be provided at each TRM-700H/T1X to ensure operation in accordance with time-slot operating norms.

6 Set-Up And Connections

6.1 DIP Switch Settings

Parameters of TRM-700 radio modems are set through DIP switches. These parameters include: serial interface data communication parameters, transmitting power, Layer 1 protocol, and operating frequency. Programming is done at one of 4 levels.

The operating frequency can be set without entering programming mode, using DIP switches 1 - 7. DIP switch 8 is intended for the programming mode.

DIP Switches							
1	2	3	4	5	6	7	8
F0	F1	F2	F3	F4	F5	F6	P

Operating Frequency Setting							
1	2	3	4	5	6	7	DIP Switch
F0	F1	F2	F3	F4	F5	F6	Radio Channel
0	0	0	0	0	0	0	0
1	0	0	0	0	0	0	1
0	1	0	0	0	0	0	2
1	1	0	0	0	0	0	3
0	0	1	0	0	0	0	4
1	0	1	0	0	0	0	5
...	...	...	...	...	...	...	...
0	1	1	1	1	1	1	126
1	1	1	1	1	1	1	127

This table indicates that 128 channels are available for selection. For most frequency bands, however, so many frequency channels are not permitted. Therefore, in general, fewer radio channels in a frequency band are actually available, depending on local regulations.

Allocation of radio frequencies to radio channels in different frequency bands is shown in the following tables. Radio modems with adjustable frequency have the frequency band marked on the rear of the modem (except for radio modems intended for time-slot operation, which have a fixed frequency).

ISM Band Label Marking: ISM	
Radio Channel	**Frequency (MHz)**
0	433.100
1	433.125
2	433.150
3	433.175
4	433.200
5	433.225
6	433.250
7	433.275
8	433.300
9	433.325
10	433.350
11	433.375
12	433.400
13	433.425
14	433.450
15	433.475
16	433.500
17	433.525
18	433.550
19	433.575
20	433.600
21	433.625
22	433.650
23	433.675
24	433.700
25	433.725
26	433.750
27	433.775
28	433.800
29	433.825
30	433.850
31	433.875

ISM Band (continued) Label Marking: ISM	
Radio Channel	**Frequency (MHz)**
32	433.900
33	433.925
34	433.950
35	433.975
36	434.000
37	434.025
38	434.050
39	434.075
40	434.100
41	434.125
42	434.150
43	434.175
44	434.200
45	434.225
46	434.250
47	434.275
48	434.300
49	434.325
50	434.350
51	434.375
52	434.400
53	434.425
54	434.450
55	434.475
56	434.500
57	434.525
58	434.550
59	434.575
60	434.600
61	434.625
62	434.650
63	434.675

England Label Marking GB	
Radio Channel	**Frequency (MHz)**
0	458.5000
1	458.5125
2	458.5250
3	458.5375
4	458.5500
5	458.5625
6	458.5750
7	458.5875
8	458.6000
9	458.6125
10	458.6250
11	458.6375
12	458.6500
13	458.6625
14	458.6750
15	458.6875
16	458.7000
17	458.7125
18	458.7250
19	458.7375
20	458.7500
21	458.7625
22	458.7750
23	458.7875
24	458.8000
25	458.8125
26	458.8500
27	458.8625
28	458.8750
29	458.8875
30	458.9125
31	458.9250

Irland Label Marking: IR	
Radio Channel	**Frequency (MHz)**
0	446,00625
1	446,01875
2	446,03125
3	446,04375
4	446,05625
5	446,06875
6	446,08125
7	446,09375

Malaysia Label Marking: MY	
Radio Channel	**Frequency (MHz)**
0	450.6250
1	451.3750
2	452.1250
3	452.8750
4	453.6250
5	454.3750
6	455.1250
7	455.8750
8	456.6250
9	457.3750
10	458.1250
11	458.8750
12	459.6250
13	460.3750
14	461.1250
15	461.9750

6.2 Entering The Programming Mode

To put the TRM-700 into programming mode, switch off (or disconnect) the power supply. Then set DIP switches 1 - 7 all to "OFF" (0) position, and DIP switch 8 to "ON" (1) position.

DIP Switches							
1	2	3	4	5	6	7	8
0	0	0	0	0	0	0	1

The power supply is switched on again. The "OK" LED should blink slowly.

After entering the programming mode, DIP switches 6 and 7 are used for selecting the programming level. DIP switches 1 - 5 are used for parameter setting, while DIP switch 8 is used for making the new settings effective.

6.3 Setting RF Power Output

TRM-700 radio modems are available either as high power units (RF power output capacity up to 4 W) or medium power units (RF power output capacity up to 500 mW). Actual output power limit can be set at one of 8 levels in the respective power range. To set the output power limit level, the unit first has to be put into programming mode.

DIP Switches							
1	2	3	4	5	6	7	8
P0	P1	P2	-	-	0	0	1

Effective Radiated Power (ERP) With 0dB, 3dB, 7dB and 10dB Antenna High Power Unit (4 Watts Max. RF Power Output Capacity)						
1	**2**	**3**	**DIP Switches**			
P0	**P1**	**P2**	**0dB**	**3dB**	**7dB**	**10dB**
0	0	0	100 mW	200mW	500mW	1W
1	0	0	250 mW	500mW	1.25W	2.5W
0	1	0	500 mW	1W	2.5W	5W
1	1	0	1 W	2W	5W	10W
0	0	1	1.5 W	3W	7.5W	15W
1	0	1	2 W	4W	10W	20W
0	1	1	3 W	6W	15W	30W
1	1	1	4 W	8W	20W	40W

Effective Radiated Power (ERP) With 0dB, 3dB, 7dB and 10dB Antenna Medium Power Unit (500 mW Max. RF Power Output Capacity)						
1	**2**	**3**	**DIP Switches**			
P0	**P1**	**P2**	**0dB**	**3dB**	**7dB**	**10dB**
0	0	0	10mW	20mW	50mW	100mW
1	0	0	100mW	200mW	500mW	1W
0	1	0	250mW	500mW	1.25W	2.5W
1	1	0	500mW	1W	2.5W	5W

Note: RF power must not exceed the value stipulated by local regulations for the appropriate location and type of application! Cable and connector losses should be compensated.

The required RF power output level is set through DIP switches 1 - 3. For the programmed values to become effective, DIP switch 8 must be set to the “OFF“ (0) position. The “OK” LED will now blink at double rate, indicating that the new adjustment has been successfully implemented.

After this, further programming can be carried out (by setting DIP switch #8 to position 1), or the programming is treated as completed.

6.4 Setting Serial Data Interface Parameters

At this programming level, the baud rate and other parameters of the serial data interface can be set. For this, the TRM-700 must be in programming mode

DIP Switches							
1	2	3	4	5	6	7	8
BR 0	BR 1	PE	PS	DL	1	0	1

Serial Data Interface Parameters					
1	**2**	**3**	**4**	**5**	**DIP Switches**
BR0	**BR1**	**PE**	**PS**	**DL**	**Setting**
0	0	x	x	x	2400 bps
1	0	x	x	x	4800 bps
0	1	x	x	x	9600 bps
1	1	x	x	x	19200 bps
x	x	0	x	x	8 data bits, no parity
x	x	1	0	0	7 data bits, even parity
x	x	1	1	0	7 data bits, odd parity
x	x	1	0	1	8 data bits, even parity
x	x	1	1	1	8 data bits, odd parity

The interface parameters are set through DIP switches 1 - 5. For the programmed values to become effective, DIP switch 8 must be set to the “OFF“ (0) position. The “OK” LED will now blink at double rate, indicating that the new adjustment has been successfully implemented.

After this, further programming can be carried out (by setting DIP switch #8 to position 1), or the programming is treated as completed.

6.5 Operating Mode And Layer 1 Protocol Selection

The operating mode of the TRM-700 (ZZ o ZZT for master station units; S1U, S2U, T1X for slave units) and the Layer 1 protocol (3964R, ASCII, or timeout) are selectable in programming level 3.

DIP Switches							
1	2	3	4	5	6	7	8
P0	P1	P2	B0	B1	0	1	1

Layer 1 Protocol			
1	2	3	DIP Switches
P0	**P1**	**P2**	**Setting**
0	0	0	3964R
1	0	0	ASCII
0	1	0	Timeout
1	1	0	Timeout with RTS

TRM-700H/M Operating Mode		
4	5	DIP Switches
B0	**B1**	**Setting**
0	0	ZZ
1	0	ZZT
0	1	ZZ, backward compatible (*Z1 instead of *Zs1)

TRM-700H/U Operating		
4	**5**	DIP Switches
B0	**B1**	**Setting**
0	0	S1U
1	0	S2U
0	1	T1X

For the programmed values to become effective, DIP switch 8 must be set to the "OFF" (0) position. The "OK" LED will now blink at double rate, indicating that the new adjustment has been successfully implemented.

After this, further programming can be carried out (by setting DIP switch #8 to position 1), or the programming is treatd as completed.

6.6 Station Address

The station address is set in programming level 4. Up to 32 address values are selectable on the 5 DIP switches. Addresses can be selected for the TRM-700H/M in the range 0 - 14; for the TRM-700H/U in S1U mode in the range 1-31; and for the TRM-700H/U in S2U mode in the range 1-15.

Since the address range of S1U-mode TRM-700H/U radio modems (1 - 31) is smaller than that of RTU-700 radio remote I/O modules, in mixed networks which include both types of stations, addresses up to 31 only should be assigned to the TRM-700 stations, while higher addresses can be asigned to the RTU-700 stations.

DIP Switches							
1	2	3	4	5	6	7	8
A0	A1	A2	A3	A4	1	1	1

Station Addresses					
1	**2**	**3**	**4**	**5**	DIP Switches
A0	**A1**	**A2**	**A3**	**A4**	**Setting**
0	0	0	0	0	0 (Master only)
1	0	0	0	0	1
0	1	0	0	0	2
1	1	0	0	0	3
0	0	1	0	0	4
1	0	1	0	0	5
...	...	...	...	...	...
0	1	1	1	1	30
1	1	1	1	1	31

For the programmed values to become effective, DIP switch 8 must be set to the “OFF” (0) position. The “OK” LED will now blink at double rate, indicating that the new adjustment has been successfully implemented.

After this, further programming can be carried out (by setting DIP switch #8 to position 1), or the programming is treated as completed.

6.7 Exiting The Programming Mode

To exit the programming mode, set DIP switch #8 to to the "OFF" (0) position. This has the effect of replacing the previous settings with the new programmed settings. The "OK" LED will now blink at double rate. Power supply to the unit is then switched off for at least 3 seconds, and then switched on again. The TRM-700 now operates with the new settings.

After exiting the programming mode, if the unit is a type with adjustable frequency, do not forget to re-set the operating frequency to the appropriate value (main DIP switch programming level).

6.8 TRM-700 Serial Interface Connector: Pin-Outs

RS-232 interface:

Pin:	Designation
2	TxD Transmit data: TRM-700 → terminal equipment
3	RxD Receive data: TRM-700 ← terminal equipment
4	DTR Shorted to pin #6
5	GND Ground
6	DSR Shorted to pin #4
7	RTS Handshake: TRM-700 ← terminal equipment
8	CTS Handshake: TRM-700 → terminal equipment

RS-485 interface (optional):

Pin:	Designation
3	B Signal
5	GND Ground / shield
8	A Signal

6.9 PC Serial Interface Connectors: Pin-Outs

PC RS-232 connector: 9-pin

Pin:	Designation
1	Carrier Detect
2	RxD Receive data
3	TxD Transmit data
4	DTR Data terminal ready
5	GND Ground
6	DSR Data set ready
7	RTS Request to send (handshake)
8	CTS Clear to send (handshake)
9	Ring indicator

PC RS-232 connector: 25-pin

Pin:	Designation
8	Carrier Detect
3	RxD Receive data
2	TxD Transmit data
20	DTR Data terminal ready
7	GND Ground
6	DSR Data set ready
4	RTS Request to send (handshake)
5	CTS Clear to send (handshake)
22	Ring indicator

For connecting a TRM-700 with a PC, always use a 1:1 cable.

6.10 Power Supply Connector: Pin-Outs

Front view:

Pin:	Designation
Outer	Earth
Middle	+12 VDC / +24 VDC
Inner	0 V

7 Specifications

Function:	Radio modem
Serial interface:	RS-232, optionally RS-485
Bit rate:	2400 - 19200 bps
Protocol:	ASCII, 3964R, transparent timeout (any one; user programmable)
Radio network topology:	Point-to-point (master-slave), point-to-multiple-points (master-to-multiple-slaves), or peer-to-peer (multiple points, no master)
Frequency:	403 - 470 MHz (UHF)
Channel occupation:	Continuous transmitting or time-slot method
RF power output (UHF):	100 mW to 4 W
Supply voltage:	12 - 24 VDC
Operating temperature:	-20 to +70 °C (ambient)
Housing:	Coated aluminium with plastic sides. DIN rail mounting. Conforms to per DIN 43880
Dimensions:	Approx. 162 mm x 80 mm x 62 mm (without BNC plug and plug-in terminal block)