TELEDYNE
ADVANCED POLLUTION INSTRUMENTATION
A Teledyne Technologies Company

MODBUS® INTERFACE OPERATION

ADDENDUM FOR

ALL T-SERIES AND E-SERIES ANALYZERS THAT SUPPORT MODBUS®

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ABOUT THIS MANUAL

MODBUS Interface Operation Addendum, Part Number 06276, is comprised of the following parts:

Part Number	Rev	Description
06276	C	MODBUS Addendum (this document)

Analyzer Firmware Rev		Appendices included:
T-Series	E-Series	
1.0.0	G.4	Appendix A T100, M100E Register Maps
1.0.0	C.6	Appendix B T101/102/108, M101E/102E/108E Register Maps
1.0.0	K.4	Appendix C T200, M200E Register Maps
1.0.0	C.0	Appendix D T201, M201E Register Maps
1.0.0	L.8	Appendix E T300, M300E Register Maps
1.0.0	E.3	Appendix F T400, M400E Register Maps
1.0.0	D.3	Appendix G T700, M700E Register Maps
1.0.0	A.2	Appendix H T80X, M80XE Register Maps

REVISION HISTORY

14 February 2011 to Rev C:

PN	Document	Change Description	S/W v. T/E series
06277	Text	Combine with "Title" document 06276 to make manual single document/single part number: 06276. Insert T-Series model names; add T-Series rear panel; obsolete PN 06277.	n/a
Summary: Eliminate the practice of assigning a separate part number for each Register Map by merging them into the manual as appendices of one document with a single part number 06276; obsolete other part numbers.			
06272	Appendix A	Merge into 06276; remains as Appendix A, MODBUS Register Map for model 100; insert T-Series model name; obsolete PN 06272	1.0.0/G.4
n/a	n/a	New addition: Appendix B, MODBUS Register Maps for models 101/102/108	1.0.0/C.6
06273	Appendix B	Merge into 06276 as Appendix C, MODBUS Register Map for model 200; insert T-Series model name; obsolete PN 06273	1.0.0/K.4
n/a	n/a	New addition: Appendix D, MODBUS Register Maps for model 201	1.0.0/C.0
06274	Appendix C	Merge into 06276 as Appendix E, MODBUS Register Map for model 300; insert T-Series model name; obsolete PN 06274	1.0.0/L.8
06275	Appendix D	Merge into 06276 as Appendix F, MODBUS Register Maps for model 400; insert T-Series model names; obsolete PN 06275	1.0.0/E.3
n/a	n/a	New addition: Appendix G, MODBUS Register Maps for T700, M700E	1.0.0/D.3
n/a	n/a	New addition: Appendix H, MODBUS Register Maps for T80X, M80XE	1.0.0/A.2

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PN	Document Name	Change Description
06277	Text	Fix pagination and cross-ref errors; delete “USER NOTES”
06272	Appendix A	Fix pagination; delete “USER NOTES”
06273	Appendix B	Fix pagination; delete “USER NOTES”
06274	Appendix C	Fix pagination; delete “USER NOTES”
06275	Appendix D	Fix pagination; delete “USER NOTES”

06/15/2009 06276 Rev A Initial Release

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1. INTRODUCTION

1.1. SAFETY MESSAGES

Your safety and the safety of others are very important. We have provided many important safety messages in this addendum. A safety message alerts you to potential hazards that could hurt you or others or cause damage to the instrument. Please read these messages carefully.

Each safety message is associated with a safety alert symbol. These symbols are found in this manual. The definition of these symbols is described below:

	**CAUTION** **GENERAL SAFETY HAZARD:** **Refers to the instructions for details on the specific hazard.**
	**CAUTION:** **HOT SURFACE HAZARD.**
	**CAUTION:** **ELECTRICAL SHOCK HAZARD.**
	**TECHNICIAN SYMBOL:** **All operations marked with this symbol are to be performed by qualified maintenance personnel only.**

NOTE

Technical assistance on the operation of

the MODBUS® can be obtained by:

Teledyne Instruments' Customer Service Department by telephone at 800-324-5190

or

Via the internet at http://www.Teledyne-API.com

1.2. MODBUS® OVERVIEW

When the MODBUS® is interfaced with the T-Series or E-Series Analyzers, two types of interaction can occur.

- The analyzer can report data directly to an external datalogger using MODBUS® protocol.

  When the appropriate data register(s) is queried by an external source (e.g. a datalogger or terminal emulation program), the analyzer outputs this data in the form of an ASCII data stream. The contents of all of the gas measurement data registers are available to be included in the data stream.

  Contents of gas measurement data registers are also available for viewing via the display/keyboard interface module.
- The analyzer can respond to commands that allow the user to perform the following functions:
  - Initiate or check the calibration
  - Certain setup and system configuration operations, or;
  - Query the current contents of any data register including those not part of the real time data stream.

The two types of interaction listed above are available from remote locations. Software commands can be activated and data can be requested by using either a terminal emulation program or Teledyne-API's APICOM interface. The analyzer system can be connected to both a datalogger and a terminal interface at the same time because it has two externally available I/O ports.

1.3. REFERENCE NUMBERING CONVENTION

Unless otherwise specified, chapter, section, figure and table reference numbers referred to within this text are relative to this document, P/N 06277

EXAMPLE: "Figure 2-1" refers to the figure, within this document, labeled as 2-1.

References to anything in the operation manual for your analyzer will be labeled as such.

EXAMPLE: "…your T-Series or E-Series Technical/Operator's Manual".

2. SPECIFICATIONS, APPROVALS AND WARRANTY

2.1. SPECIFICATIONS

The specifications for the T-Series or E-Series Analyzer with the MODBUS® option active are similar to those listed in the Specifications Section of the Technical/Operator's Manual for your T-Series or E-Series analyzer with the following exception.

Table 2-1: Basic Unit Specifications

MODBUS® Protocol	Configurable for either the MODBUS® RTU or ASCII protocols

2.2. EPA EQUIVALENCY DESIGNATION AND CE MARK COMPLIANCE

The MODBUS® interface does not affect the EPA Equivalency Designation and CE Mark Compliance of your T-Series or E-Series analyzer.

2.3. WARRANTY

WARRANTY POLICY (02024D)

Prior to shipment, TAPI equipment is thoroughly inspected and tested. Should equipment failure occur, TAPI assures its customers that prompt service and support will be available.

COVERAGE

After the warranty period and throughout the equipment lifetime, TAPI stands ready to provide on-site or in-plant service at reasonable rates similar to those of other manufacturers in the industry. All maintenance and the first level of field troubleshooting is to be performed by the customer.

NON-API MANUFACTURED EQUIPMENT

Equipment provided but not manufactured by TAPI is warranted and will be repaired to the extent and according to the current terms and conditions of the respective equipment manufacturers warranty.

GENERAL

During the warranty period, TAPI warrants each product manufactured by TAPI to be free from defects in material and workmanship under normal use and service. Expendable parts are excluded.

If a product fails to conform to its specifications within the warranty period, API shall correct such defect by, in API's discretion, repairing or replacing such defective product or refunding the purchase price of such product.

The warranties set forth in this section shall be of no force or effect with respect to any Product: (i) that has been altered or subjected to misuse, negligence or accident, or (ii) that has been used in any manner other than in accordance with the instruction provided by TAPI, or (iii) not properly maintained.

THE WARRANTIES SET FORTH IN THIS SECTION AND THE REMEDIES THEREFORE ARE EXCLUSIVE AND IN LIEU OF ANY IMPLIED WARRANTIES OF MERCHANTABILITY, FITNESS FOR PARTICULAR PURPOSE OR OTHER WARRANTY OF QUALITY, WHETHER EXPRESSED OR IMPLIED. THE REMEDIES

SET FORTH IN THIS SECTION ARE THE EXCLUSIVE REMEDIES FOR BREACH OF ANY WARRANTY CONTAINED HEREIN. API SHALL NOT BE LIABLE FOR ANY INCIDENTAL OR CONSEQUENTIAL DAMAGES ARISING OUT OF OR RELATED TO THIS AGREEMENT OF TAPI'S PERFORMANCE HEREUNDER, WHETHER FOR BREACH OF WARRANTY OR OTHERWISE.

3. FREQUENTLY ASK QUESTIONS AND GLOSSARY

3.1. FREQUENTLY ASK QUESTIONS AND GLOSSARY

Q: Why does the **INET SUBMENU** disappear from the **COMM** menu of your T-Series or E-Series Analyzer?

A: An inactivity timeout feature of the T-Series or E-Series firmware's internet driver automatically disconnects either of the two TCP ports if they are idle for the specified timeout period. This will allow the instrument to recover from an improperly terminated connection (see Section 5.1.3).

Check the connections between your instrument and the LAN. If these connections appear to be correct and there are no other problems with the LAN, contact Teledyne-API's Customer Service (see Section 8.3).

3.2. GLOSSARY

ADU – *Application Data Unit*. An application specific data unit that consist of a Protocol Data Unit (PDU) encapsulated with headers and suffixes used to route the data package properly.

APICOM – Name of a remote control program offered by Teledyne-API to its customers.

MBAP – *MODBUS® Application Protocol*.

CRC – *Cyclical Redundancy Checking*. A type of function that takes input data stream of any length and produces as output, a value of a certain fixed size.

CRLF – *Carriage Return - Line Feed*. When a transmitted character is received, each device decodes the next character until it detects the End-of-Frame Characters.

DCE –*Data Communications Equipment*. A MODBUS® device that communicates with a Data Terminal Equipment (DTE) device in RS-232C communications.

DTE – *Data Terminal Equipment*. A MODBUS® device that controls data flowing to or from a computer.

DHCP – *Dynamic Host Configuration Protocol.* A protocol used by LAN or Internet servers that automatically sets up the interface protocols between themselves and any other addressable device connected to the network.

LAN – *Local Area Network.*

LCR – *Longitudinal Redundancy Checking*. A system of error control based on the formation of block check, following preset rules.

MODBUS® – MODBUS® is an application layer, request/reply messaging protocol that provides client/server communication between devices connected on different types of buses or networks. There are three versions of MODBUS®:

- **MODBUS® RTU** - When devices communicate on a MODBUS® serial line using the RTU (Remote Terminal Unit) mode, each 8–bit byte in a message contains two 4–bit hexadecimal characters. The main advantage of this mode is that its greater character density allows better data throughput than ASCII mode for the same baud rate. Each message must be transmitted in a continuous stream of characters.
- **MODBUS® ASCII** - When devices are setup to communicate on a MODBUS® serial line using ASCII (American Standard Code for Information Interchange) mode, each 8–bit byte in a message is sent as two ASCII characters. This mode is used when the physical communication link or the capabilities of the device does not allow the conformance with RTU mode requirements regarding timer management.
- **MODBUS® TCP/IP** – A variant of the MODBUS® family that covers the use of MODBUS® messaging in an 'Intranet' or 'Internet' environment using the TCP/IP protocols. The most common use of this protocol

at this time is for Ethernet attachment of PLC's, I/O modules and 'gateways' to other simple field buses or I/O networks.

PDU – *Protocol Data Unit*. The basic data packet MODBUS® protocol communications.

RTU – *Remote Terminal Unit*. A device installed at a remote location that collects data, codes the data into a format that is transmittable and transmits the data back into the central station or master.

TAPI – *Teledyne Advanced Pollution Instrumentation*.

TCP/IP – *Transfer Control Protocol / Internet Protocol*. The standard communications protocol for Ethernet devices and the Internet.

VARS – *Variables*. The variables menu or settings of the system.

It provides client/server communication between devices connected on different types of buses or networks using a request/reply protocol. Client/Server communications is similar to Master/Slave type protocols in that:

- The **CLIENT** device is Master.
- The **SERVER** device is the Slave.

MODBUS® communications are handled as transactions where the Client issues **REQUESTS** to which the Server issues **RESPONSES** (see Figure 3-1). These transactions are considered either STATELESS or STATES. In a STATELESS transaction, the communications are momentary and short-term with no information. In a STATES transaction, the communications are remembered by either the Client or the Server from one transaction to the next. An example of a STATELESS transaction for a Client/Server protocol is HTTP.

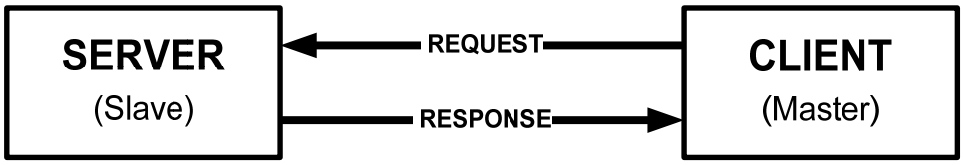

Figure 3-1. Typical MODBUS® Transaction

4. MODBUS® PROTOCOL: GENERAL INFORMATION

The MODBUS® protocol allows an easy communication within all types of network architectures. Every type of devices (PLC, HMI, Control Panel, Driver, Motion control, I/O Device…) can use MODBUS® protocol to initiate a remote operation. The same communication can be done as well on serial line as on an Ethernet TCP/IP networks. Gateways allow a communication between several types of buses or network using the MODBUS® protocol.

NOTE
This section assumes the operator has a functional familiarity with MODBUS®
It is not intended to be used as a detailed set of instructions
for the purpose of learning to operate the MODBUS®.
For more complete definitions of types of MODBUS® registers and the operations that are used to manipulate those registers, refer to the MODBUS® official website:
http://www.MODBUS-IDA.org

The MODBUS® ASCII and RTU protocols are described in the document:
MODBUS® over serial line specification and implementation guide V1.02.
The MODBUS® TCP/IP protocol is described in the document:
MODBUS® Messaging on TCP/IP Implementation Guide V1.0b

4.1. MODBUS® POSITION IN THE ISO/OSI NETWORK MODEL

The MODBUS® is a messaging protocol, positioned at layer 7 of the OSI network model (see Figure 4-1).

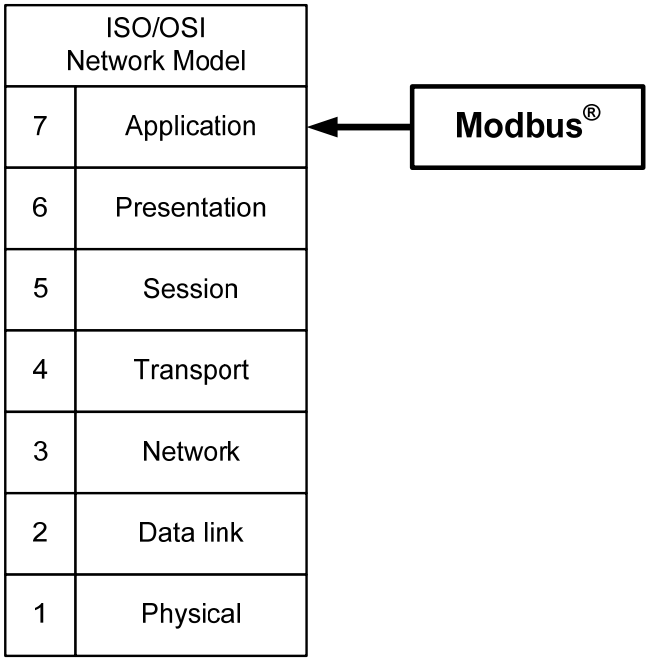

Figure 4-1: MODBUS® Positioning in ISO/OSI Model

4.2. PROTOCOL DATA UNITS (PDU)

The MODBUS® STATELESS communication transaction is based on a Protocol Data Unit (PDU) (see Figure 4-2, Figure 4-3, and Figure 4-4). This is a simple data package that combines a short section of Function Code that defines the **FUNCTION** of the PDU followed by a longer section containing Function Data that defines **DATA**. There are three types of PDU's:

- Request PDU: Used by the Client to issue a Request. Function codes are numbers between 1 and 127 (decimal) and are defined in the appropriate MODBUS® specification document .

Function Code (1 Byte)	**Function Data** (Variable)

Figure 4-2: MODBUS® Request PDU

- Response PDU: Used by the Server when responding to a Client Request.

Function Code (1 Byte)	**Response Data** (Variable)

Figure 4-3: MODBUS® Response PDU

- Exception Response PDU: used by the server when the Client's Request is not executable. In this case the Server responds with an Exception Response PDU containing an Error Code (a MODBUS® Function Code + 128) and the Exception Response Code defining the specific issues causing the error. Both the Error Codes and Exception Codes are defined in the MODBUS® specification.

Error Code (1 Byte)	**Exception Code** (1 Byte)

Figure 4-4: MODBUS® Exception Response PDU

4.2.1.1. MODBUS® Functions Codes Description

Standard function codes used on MODBUS® application layer protocol are described in detail in the MODBUS® Application Protocol Specification.

4.3. MODBUS® DATA REGISTERS

All MODBUS® data are organized according to the following four types (see Table 4-1), referred to as **MODBUS® REGISTERS**.

Table 4-1: Basic Types of MODBUS® Registers

NAME	SIZE	TYPE	COMMENTS
Input Registers	16-bit word[1]	Read-Only	This type of data can be provided by an I/O system. - EXAMPLE: A data register containing a measurement result such as gas concentration.
Holding Registers	16-bit word[1]	Read-Write	This type of data can be alterable by an application. - EXAMPLE: A storage place for a variable used to alter the manner in which a process operates such as a VAR.
Discrete Inputs	Single bit[2]	Read-Only	This type of data can be provided by an I/O system. - EXAMPLE: A Status Register.
Coils	Single bit[2]	Read-Write	This type of data can be alterable by an application program. - EXAMPLE: To turn OFF/ON an operating mode or initiate an action such as initiating the analyzers CAL mode.

[1] Word registers overlap bit registers. This means that you can read any data in either as a collection of 16-bit words, or as a collection of single bits.

[2] The addresses for the bit register commands are directly related to the word register addresses. To get the bit address for any data bit, take the word register address, multiply by 16 and then add the bit offset for that bit within the word register.

NOTE

THE TOP AND BOTTOM 16-BIT WORDS: [D1 D0 D3 D2] IN THE OLDER, MODICON STYLE MODBUS® IMPLEMENTATIONS ARE INTERCHANGEABLE. SUCH SYSTEMS ARE NOT COMPATIBLE WITH THE T-SERIES OR E-SERIES ANALYZER.

4.4. MODBUS® SERIAL INTERFACE OVERVIEW

The MODBUS® was originally intended for use over asynchronous serial networks (see Figure 4-5). In this case the application level protocol operates directly on top of a serial interface and serial communication standards.

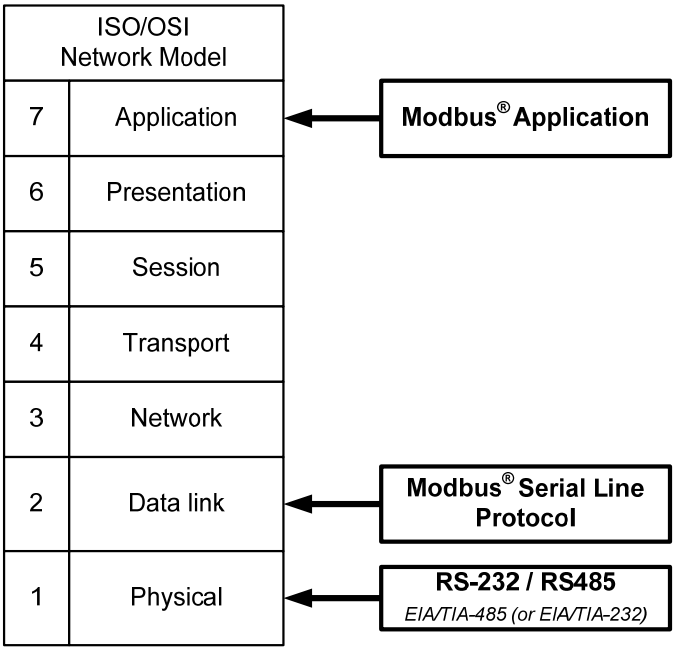

Figure 4-5: MODBUS® Implementation over Serial Networks

- RS232 is typically used for short distance point-to-point communication.
- RS485 is typically used for multipoint communication (i.e. multiple devices connected to the same signal cable), employing the Master-Slave paradigm (one master and fixed address slaves).

When using a MODBUS® over a serial network there can be only one Master unit which can be connected to 247 slave units.

- The slave units will never transmit data without receiving a request from the Master unit.
- The Master unit will initiate only one communication transaction at a time.

There are two request modes:

- **UNICAST MODE**: The Master addresses only one slave node, each of which must have a unique address between 1 and 247 inclusive.
- **BROADCAST MODE**: The Master initiates a transaction to all slave nodes. Broadcast requests are exclusively write commands where response is expected from the slave units. Address 0 is reserved for broadcast mode requests.

4.4.1. MODBUS® APPLICATION DATA UNIT (ADU)

The Application Data Unit (ADU) are serial communications that require additional fields be added to the basic MODBUS® PDU (see Figure 4-6). Specifically:

- An Address Header is added to the front of the PDU containing network address information for the Server device for which a specific communication REQUEST is generated.
  - Only Slave/Server
  - There can be 256 different MODBUS® addresses.
  - The 0 address is reserved for general broadcast that all Slave/Clients must recognize.
- A suffix field is added to the PDU that contains a checksum for the whole data unit.

The resulting Application Data Unit (ADU) has a maximum package size of 256 bytes.

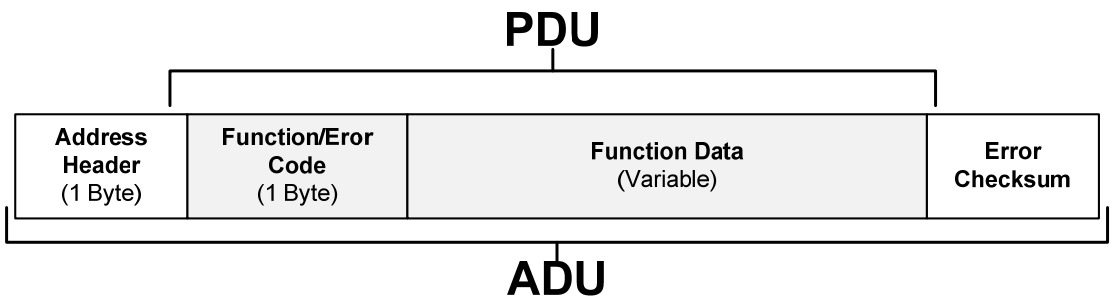

Figure 4-6: MODBUS® Application Data Unit (ADU)

Note

The maximum package size limitation of 256 bytes applies for all existing MODBUS® protocol implementations.

For transmission, the MODBUS® message (i.e. ADU) is placed into a frame that has a known beginning and ending point, allowing detection of the start and the end of a message. The exact nature of the frame depends on whether MODBUS® ASCII protocol or MODBUS® RTU protocol is being used.

NOTE

The transmission mode, ASCII or RTU must be the same for all units on a network if they are to be able to communicate/operate together. Default setup MUST be RTU.

4.4.2. MODBUS® REMOTE TERMIINAL UNIT (RTU)

The main advantage of the Remote Terminal Unit (RTU) is that it has a greater character density and data throughput than the ASCII mode at identical baud rates.

In the RTU mode the ADU conforms to the following format:

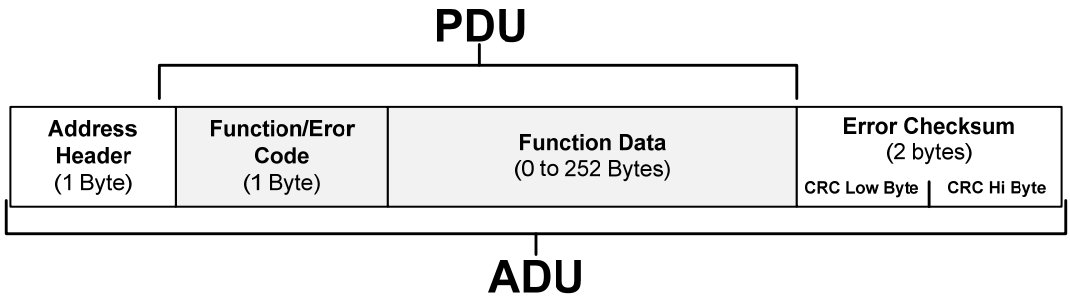

Figure 4-7: MODBUS® RTU Application Data Unit (ADU)

Messages are framed as follows:

- A silent period equal to 3.5 times the length of the characters in the transmission.
- The ADU
- An ending silent period also equal 3.5 times the transmissions character length.
- If more than 1.5 character times occurs between characters, the message is considered incomplete.

Each 8–bit byte in a message:

- Is preceded by one start bit.
- Contains two 4–bit hexadecimal characters.
  - These are transmitted Least Significant Bit first…Most Significant Bit last.
- Followed by either
  - One parity bit (default parity mode for the network MUST be **EVEN**) and one stop bit, or;
  - Two stop bits.
- Each message must be transmitted in a continuous stream of characters.

4.4.2.1. **Cyclical Redundancy Checking (CRC)**

The RTU mode includes an error–checking field that is based on a Cyclical Redundancy Checking (**CRC**) method. The CRC field checks the contents of the entire message and is applied regardless of any parity checking method used for the individual characters of the message.

The CRC field contains a 16–bit value implemented as two 8–bit bytes.

- A low–order byte of the field that is appended first, followed by a high–order byte.
- The CRC high–order byte is the last byte to be sent in the message.

A sending device calculates the CRC value by adding together successive 8-bit bytes of the messages to arrive at a checksum. The receiving device recalculates a CRC during receipt of the message, and compares the calculated value to the actual value it received in the CRC field. An error will occur if the two values are not equal.

- Start and stop bits, and the parity bit, do not apply to the CRC.

4.4.3. T-SERIES OR E-SERIES ANALYZER MODBUS® RTU INFORMATION

The MODBUS® RTU protocol for your T-Series or E-Series Analyzer's internal communications bus is a minor variation of the industry standard MODBUS® RTU protocol. The T-Series or E-Series Analyzer implements the MODBUS® protocol with the following options and exceptions:

- Some registers, primarily calibration registers, do not return command responses within the timeout interval specified by the MODBUS® protocol.
- In an T-Series or E-Series Analyzer, the 4 address spaces of the MODBUS® protocol all overlap at address 0 (not to be confused with device address 0).
  - This means that holding register 0 is exactly the same as input register 0, and all of the 16 bits of the holding register can be read out as coils or discrete inputs (0 - 15).
- The following MODBUS® function codes are not implemented in the T-Series or E-Series Analyzer:
  - 'Read exception status' (0x07),
  - 'Diagnostics' (0x08),
  - 'Get Comm Event Counter' (0x0B),
  - 'Get Comm Event Log' (0x0C),
  - 'Report Slave ID (0x11),
  - 'Read/Write File Record (0x14 & 0x15),
  - 'Mask Write Register' (0x16),
  - 'Read FIFO Queue' (0x18)

Note

MODBUS® supports at least two formats of floating point. We use the format that seems to be the most common, but some test programs call it an 'inverse float' format.

4.4.4. MODBUS® ASCII PROTOCOL

In MODBUS® ASCII Protocol, each 8–bit byte in a message is sent as two ASCII characters. It is less efficient than RTU mode because two characters are required for each byte. The ASCII Protocol is used when the timing management requirements of the network will not support RTU style communications.

In the RTU mode the ADU conforms to the following format:

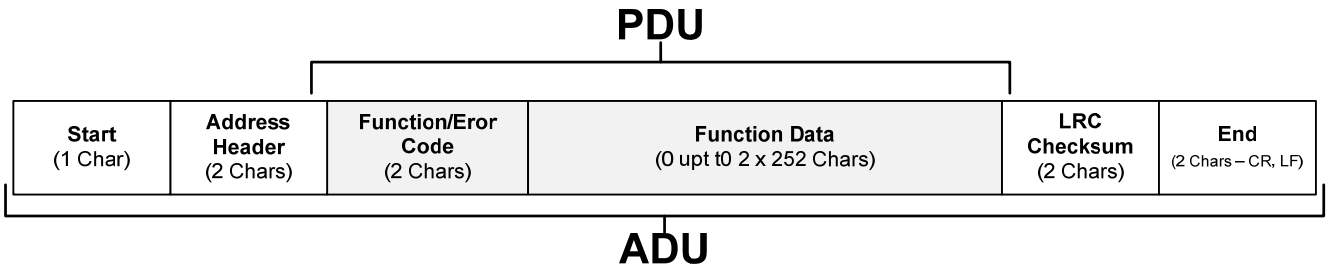

Figure 4-8: MODBUS® ASCII Protocol Application Data Unit (ADU)

Messages are framed as follows:

- The message MUST start with a colon.
- The allowable characters transmitted for all other fields are hexadecimal 0–9, A–F.
- When this character is received, each device decodes the next character until it detects the End-Of-Frame characters – “carriage return – line feed” (CRLF).
- The ADU
- Unless the network is otherwise configured, up to 1 second may elapse between characters without an error being declared.

The format for each byte in a ASCII message is:

- One start bit
- 7 data bits
  - These are transmitted Least Significant Bit first…Most Significant Bit last.
- Followed by either
  - One parity bit (default parity mode for the network MUST be **EVEN**) and one stop bit, or;
  - Two stop bits.

4.4.4.1. Longitudinal Redundancy Checking (LRC)

In ASCII mode, messages include an error–checking field that is based on a Longitudinal Redundancy Checking (**LRC**) calculation.

This error checking method ignores the beginning ‘colon’ and terminating CRLF pair characters used in ASCII mode messages, but it is applied regardless of any parity checking method used for the individual characters of the message.

A sending device calculates the LRC by adding together successive 8–bit bytes of the message, discarding any carries and then two’s, complementing the result. The resulting LRC is ASCII encoded into two bytes and placed at the end of the ASCII mode frame before the CRLF.

The receiving device recalculates an LRC during receipt of the message, and compares the calculated value to the actual value it received in the LRC field. An error will occur if the two values are not equal.

4.5. MODBUS® ETHERNET INTERFACE OVERVIEW

Unlike the MODBUS® Serial mode communications, when the MODBUS® is running over an Ethernet TCP/IP, the Client/Server communication transaction includes four types of messages.

- **Request:** A message sent on the network by the Client to initiate a transaction.
- **Indication:** A Request message received on the Server side.
- **Response:** A Response message sent by the Server.
- **Confirmation:** A Response Message received on the Client side.

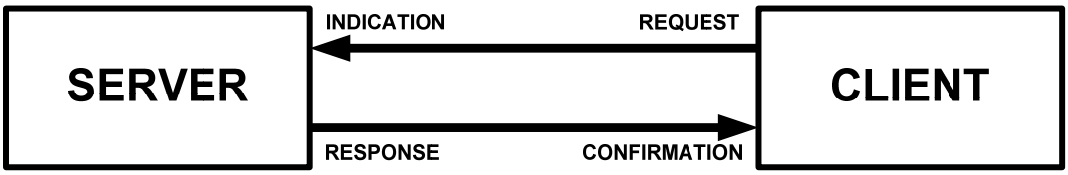

Figure 4-9: MODBUS® TCP/IP Transaction

A communicating system over MODBUS® TCP/IP may include different types of devices:

- A MODBUS® TCP/IP Client and Server device connected to a TCP/IP network
- Interconnection devices like a bridge, router or gateway for interconnection between the TCP/IP network and a serial line sub-network which permit connections of MODBUS® Serial line Client and Server end devices.

MODBUS® **CLIENT:** The MODBUS® Client allows the user application to explicitly control information exchange with a remote device. It builds a MODBUS® request from parameters contained in a demand sent by the user application via the Client Interface.

- The MODBUS® Client initiates a communication transaction by sending a REQUEST then waits for and processes the returning Confirmation.

A MODBUS® client can receive three events:

- A new demand from the user application to send a request.
- A response from the TCP management, in this case the client has to analyze the content of the response and send a confirmation.
- The expiration of a Time-out due to a non-response. A new retry can be sent on the network or a negative confirmation can be sent to the User Application.

MODBUS® **SERVER**: The role of a MODBUS® server is to provide access to application objects and services to remote MODBUS® clients. Once the TCP Port 502 receives a REQUEST from a Client node, this module activates a local action to read, to write or to achieve some other actions. The processing of these actions is done transparently for the application programmer.

A different kind of access may be provided depending on the user application:

- Simple access, such as get and set application objects attributes.
- Advanced access in order to trigger specific application services.

The MODBUS® server has:

- To map application objects onto readable and writable MODBUS® objects, in order to get or set application objects attributes.
- To provide a way to trigger services onto application objects.

- In run time the server has to analyze a received MODBUS® Request, to process the required action, and to send back a Response.

4.5.1. GENERAL TCP/IP IMPLEMENTATION RULES

- It is highly recommended to implement the automatic TCP connection management when connecting a Client or Server to the network.
- The TCP connection should be kept continuously open with remote devices and not opened and closed it for each MODBUS/TCP transaction.
  - However, the MODBUS® Client must be capable of accepting a close request from the server and closing the connection. The connection can be reopened when required.
  - A MODBUS® Client should be opened to a minimum of TCP connections with a remote server with the same IP address. One connection per application is preferrable.
  - If several MODBUS® transactions are activated simultaneously on the same TCP Connection, a MODBUS® transaction identifier must be used to uniquely identify the matching requests and responses.
  - It is necessary to open separate connections for the client data flow and for the server data flow when a bi-directional communication between two remote MODBUS® entities is being used.
  - Each TCP frame must transport only one MODBUS® ADU. Multiple MODBUS® requests or responses should not be sent on the same TCP PDU.

4.5.2. MODBUS® TCP/IP APPLICATION DATA UNIT (ADU)

The format for a MODBUS® TCP/IP Application Data Unit (ADU) is:

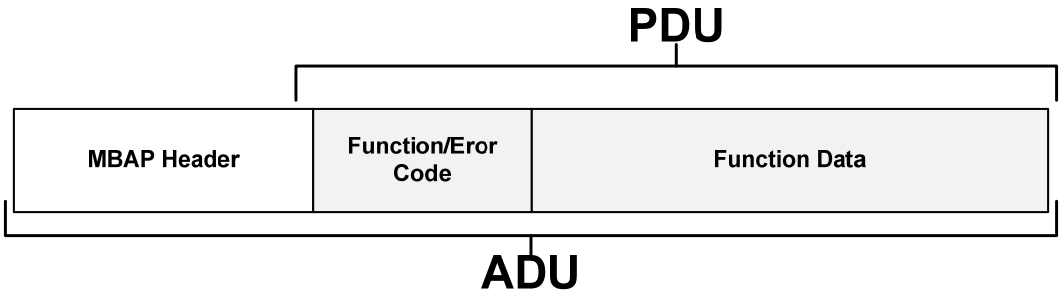

Figure 4-10: MODBUS® TCP/IP Application Data Unit (ADU)

The MODBUS® Application Protocol (MBAP) Header includes several differences when compared to the MODBUS® RTU application data unit used in the Serial I/O version of MODBUS®:

- The MODBUS® 'Slave Address' field usually used on MODBUS® Serial Line is replaced by a single byte 'Unit Identifier' within the MBAP Header.
  - The 'Unit Identifier' is used to communicate via devices such as bridges, routers and gateways that use a single IP address to support multiple independent MODBUS® end units.
- All MODBUS® requests and responses are designed in such a way that the recipient can verify that a message is finished.
  - For function codes where the MODBUS® PDU has a fixed length, the function code alone is sufficient.
  - For function codes carrying a variable amount of data in the request or response, the data field includes a byte count.
- When the MODBUS® is carried over TCP, additional length information is carried in the MBAP Header to allow the recipient to recognize message boundaries even if the message has been split into multiple packets for transmission.

- The existence of explicit and implicit length rules, and use of a CRC-32 error check code (on Ethernet) means that there is a very small chance of undetected errors being transmitted.

4.5.2.1. **MBAP Header description**

The MBAP Header is seven bytes long and contains the following four fields:

- **Transaction Identifier** - It is used to match future responses with initial requests, the MODBUS® server copies in the response the transaction identifier of the request.
  - This identifier must be unique
- **Protocol Identifier** – It is used for intra-system multiplexing. The MODBUS® protocol is identified by the value 0.
- **Length** - The length field is a byte count of the following fields, including the Unit Identifier and data fields.
- **Unit Identifier** – This field is used for intra-system routing purpose. It is typically used to communicate to a MODBUS+ or a MODBUS® Serial Line Slave through a gateway between an Ethernet TCP/IP network and a MODBUS® Serial Line. This field is set by the MODBUS® Client in the request and must be returned with the same value in the response by the server.
  - On TCP/IP networks, the MODBUS® server is addressed using its IP address. Therefore, the MODBUS® Unit Identifier is useless. The value 0xFF has to be used.

Table 4-2: MODBUS® TCP/IP MBAP Header Field Definitions

FIELDS	LENGTH	DESCRIPTION -	CLIENT	SERVER
TRANSACTION IDENTIFIER	2 Bytes	Identification of a MODBUS® Request / Response transaction.	Initialized by the client	Recopied by the server from the received request
PROTOCOL IDENTIFIER	2 Bytes	0 = MODBUS® Protocol	Initialized by the client	Recopied by the server from the received request
LENGTH	2 Bytes	Number of following bytes	Initialized by the client (request)	Initialized by the server (Response)
UNIT IDENTIFIER	1 Byte	Identification of a remote slave connected on a serial line or on other buses.	Initialized by the client	Recopied by the server from the received

4.5.3. MODBUS® TCP/IP CONNECTION MANAGEMENT

4.5.3.1. **Establishing a Connection**

The MODBUS® Messaging Service must provide a listening socket on Port 502, which permits to accept a new connection and to exchange data with other devices.

- When the Messaging Service needs to exchange data with a remote server, it must open a new client connection with a remote Port 502 in order to exchange data with this distant.
- The local port must be higher than 1024 and different for each client connection.

4.5.3.2. **Data Transfer**

Request must be sent on an already opened TCP connection. The IP address of the remote is used to find that TCP connection.

- In case of multiple TCP connections opened with the same remote, one connection has to be chosen to send the MODBUS® Message, different choice criteria can be used like the oldest one, the first one.

- The connection has to remain open during all the MODBUS® communications.
- A Client can initiate several MODBUS® transactions with a server without waiting the ending of the previous one.

4.5.3.3. **Closing a Connection**

- When MODBUS® communications are ended between a Client and a Server, the client has to initiate a connection closing of the connection used for these communications. If not the server will continue to consider the connection open.
- If the number of client and server connections is greater than the number of authorized connections, the oldest unused connection is closed. The access control mechanism can be activated to check if the IP address of the remote client is authorized. If there is no authorization, the new connection is refused.

4.5.4. BUILDING A MODBUS® REQUEST

Following the reception of a demand from the user application, the client has to build a MODBUS® request and to send it to the TCP management. This is split into several sub-tasks:

- The initiation of a MODBUS® transaction that enables the Client to memorize all required information in order to match a later the response to the request and to send the confirmation to the user application.
- The encoding of the MODBUS® request (PDU + MPAB header). The application that initiates the demand has to provide all required information to enable the Client to encode the request.
  - The MODBUS® PDU is encoded according to the MODBUS® Application Protocol Specification [1]. (MB function code, associated parameters and application data).
  - All fields of the MBAP Header are filled.
  - Then the MODBUS® request ADU is built prefixing the PDU with the MBAP Header.
- The requested ADU is sent to the TCP management module which is in charge of finding the right TCP socket towards the remote Server.
  - In addition to the MODBUS® ADU the Destination IP address must also be passed.

4.5.5. PROCESS MODBUS® CONFIRMATION

When a response frame is received on a TCP connection, the Transaction Identifier carried in the MBAP header is used to associate the response with the original request previously sent on that TCP connection:

- If the Transaction Identifier does not refer to any pending transaction, the response is discarded.
- If the Transaction Identifier refers to a pending transaction, the response must be parsed in order to send a Confirmation to the initiating user application.
  - This can be either a positive or negative confirmation.

Parsing the response consists of verifying the MBAP Header and the PDU response.

4.5.5.1. **MBAP Header**

After verifying that the Protocol Identifier is 0x0000, the length of the Protocol Identifier gives the size of the Response.

- If the response comes from a server device directly connected to the TCP/IP network, the TCP connection identification is sufficient to the server. Therefore the Unit Identifier is discarded.
- If the remote server is connected on a Serial Line sub-network and the response comes from a bridge, a router or a gateway, then the Unit Identifier identifies the remote server that sent the response.

4.5.5.2. **MODBUS® Response PDU**

The function code is verified and the Response confirmation are as follows:

- If the function code is the same as the one used in the request, and if the response format is correct, a Positive Confirmation Response is given to the user application.
- If the function code is an Exception code the Exception Response is given to the user application as a Positive Confirmation Response.
- If the function code is different from the one used in the request or if the format of the response is incorrect, then an error is signaled by giving a Negative Confirmation Response to the user application..

NOTE

A Positive Confirmation is a confirmation that the command was received and responded to by the server.

It does not imply that the server was able to successfully act on the command.

Failure to successfully act on the command will be indicated by the Server issuing an Exception response.

4.5.6. TIME-OUT MANAGEMENT

There is deliberately no specification of required response time for a transaction over MODBUS® TCP/IP. This is because it is expected to be used in the widest possible variety of communication situations, from I/O scanners expecting sub-millisecond timing to long distance radio links with delays of several seconds.

From a client perspective, the timeout must take into account the expected transport delays across the network, to determine a 'reasonable' response time. Such transport delays might be milliseconds for a switched Ethernet, or hundreds of milliseconds for a wide area network connection.

Any 'timeout' period used to initiate an application retry should be larger than the expected maximum 'reasonable' response time.

- If this is not followed, there is a potential for significant congestion on the network, which may cause further errors.
- For your T-Series or E-Series Analyzer the time out period is user configurable (see Section 5.1.30).

4.5.7. MODBUS® PDU CHECKING

When the Protocol Identifier field is checked:

- If it is different from protocol type, the indication is simply discarded.
- If it is correct (= MODBUS® protocol type; value 0x00), a MODBUS® transaction is initiated.

The maximum number of MODBUS® transactions the server can initiate is limited by the maximum number of transactions your particular system can handle. If no more transactions are available, the server builds a MODBUS® Exception Response (Exception code 6 : Server Busy).

If a MODBUS® transaction is available, it is initialized in order to memorize the following information:

- The TCP connection identifier used to send the indication (given by the TCP Management).
- The MODBUS® Transaction ID (given in MBAP Header).
- The Unit Identifier (given in MBAP Header).

Then the MODBUS® PDU is parsed. The function code is first controlled :

- In case of invalidity, a MODBUS® Exception Response is built (Exception code 1 : Invalid function).

- If the function code is accepted, the server initiates the "MODBUS® Service Processing" activity.

4.5.8. MODBUS® RESPONSE BUILDING

Once the request has been processed, the Server has to build the response using the adequate server transaction and has to send it to the TCP/IP management component.

Depending on the result of the processing, two types of responses can be built :

- A positive MODBUS® Response: In this case, the response function code will be the same as request function code.
- A MODBUS® Exception Response: In this case, the client will be provided with relevant information concerning the error detected.
  - The response Function Code = the Request Function Code but with the most significant bit set to “1”;
  - An Exceptions Code is provided to indicate the reason of the error.

Table 4-3: MODBUS® TCP\IP Exception Codes

EXCEPTION CODE	MODBUS® NAME	COMMENTS
01	**Illegal Function Code**	The function code is unknown by the server.
02	**Illegal Data Address**	Dependant on the request.
03	**Illegal Data Value**	Dependant on the request.
04	**Server Failure**	The server failed during the execution.
05	**Acknowledge**	The server accepted the service invocation but the service requires a relatively long time to execute. The server therefore returns only an acknowledgement of the service invocation receipt.
06	**Server Busy**	The server was unable to accept the MB Request PDU. The client application has the responsibility of deciding if and when to re-send the request.
0A	**Gateway problem**	Gateway paths not available.
0B	**Gateway problem**	The targeted device failed to respond. The gateway generates this exception.

- Unit Identifier: The Unit Identifier is copied as it was given within the received MODBUS® Request and memorized in the transaction context.
- Length: The server calculates the size of the MODBUS® PDU plus the Unit Identifier byte. This value is set in the "Length" field.
- Protocol Identifier: The Protocol Identifier field is set to 0x0000 as it was given within the received Request.
- Transaction Identifier: This field is set to the "Transaction Identifier" value that was associated with the original request and memorized in the transaction context.

The Response is returned to the correct Client using the TCP connection memorized in the transaction context. When the Response is sent, the transaction context must be free.

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5. MODBUS® SETUP

The MODBUS® communication can be accomplished:

- Via RS-232 by connecting to the COM B port on the back of the analyzer, or;
- Via the internet by connecting through an optional Ethernet card available for your T-Series or E-Series Analyzer.

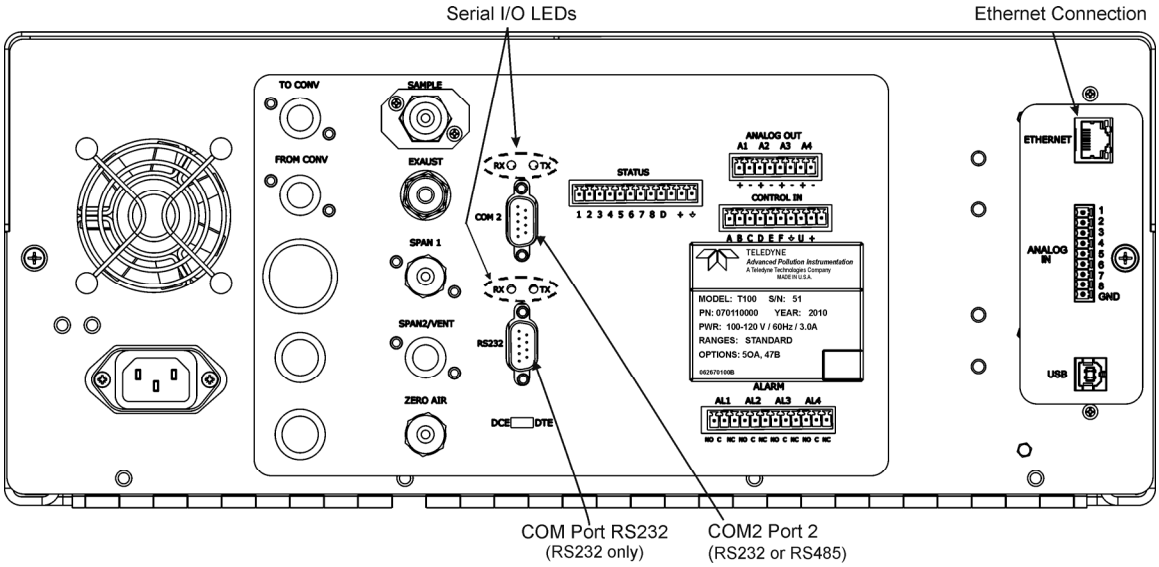


Figure 5-1: Typical T-Series Analyzer Rear Panel

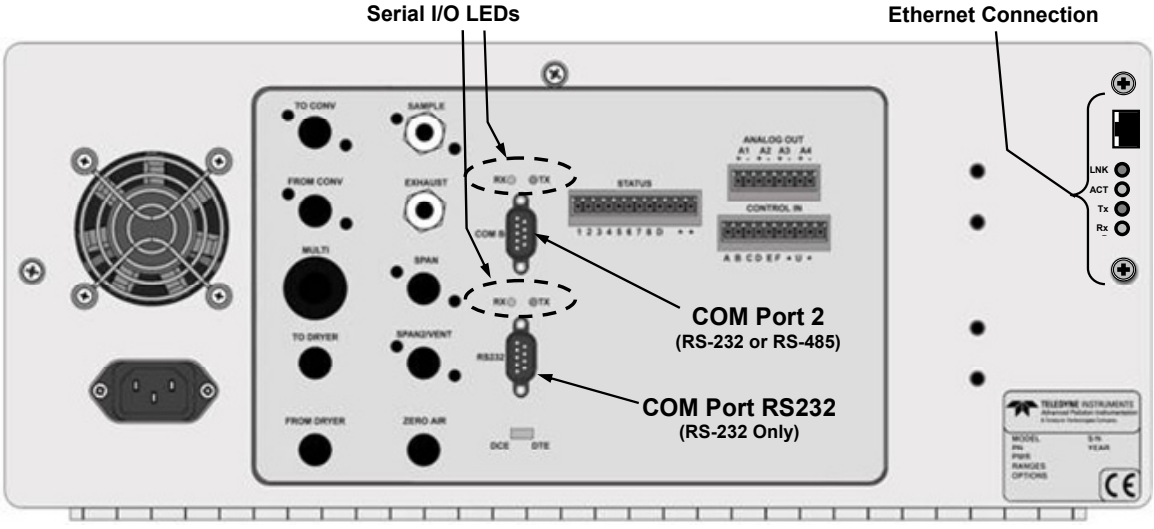


Figure 5-2: Typical E-Series Analyzer Rear Panel Layout

5.1.1. USING MODBUS® OVER THE SERIAL PORTS

Your T-Series or E-Series Analyzer is equipped with two serial communication ports these are accessible via two DB-9 connectors on the back panel of the instrument (See Figure 5-2).

- COM Port A (referred to as COM1 by the T-Series or E-Series firmware) connector is a male DB-9 connector. It can be configured to operate in single or multidrop mode.

- COM Port B (referred to as COM2 by the T-Series or E-Series firmware) is a female DB9 connector. It can be configured for standard RS-232 operation or half-duplex RS-485 communication. This is the COMM channel used by the MODBUS® interface.

NOTE

The COM B port connector is wired for Data Terminal Equipment (DTE) type connections only. The Data Communications Equipment (DCE) / DTE switch located on the back of the instrument does not affect this connector.

To assist in properly connecting the serial ports to either a computer or a modem, there are activity indicators just above the RS-232 port. Once a cable is connected between the analyzer and a computer or modem, both the red and green LEDs should be on.

- If both LEDs are still not illuminated, ensure that the cable is properly constructed.

5.1.1.1. Electronic Connections for RS-232 MODBUS® Communications

Attach a standard, shielded, RS-232 compatible cable terminated with a straight-through DB-9F connector to the COM Port B connector on the back of the instrument.

Teledyne-API offers two mating cables, one of which should be applicable for your use (see Figure 5-3).

- Part number WR000077, a DB-9 female to DB-9 female cable, 6 feet long. Allows connection of the serial ports of most personal computers.
- Part number WR000024, a DB-9 female to DB-25 male cable. Allows connection to the most common styles of modems (e.g. Hayes-compatible) and code activated switches.

Both cables are configured with straight-through wiring and should require no additional adapters.

NOTE

Cables that appear to be compatible because of matching connectors may incorporate internal wiring that make the link inoperable. Check cables acquired from sources other than Teledyne-API for pin assignments before using.

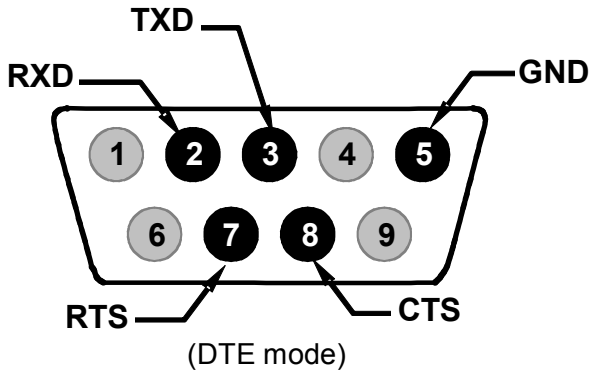


Figure 5-3: Connector Pin-Outs for I/O Port RS-232 connector.

Table 5-1: RS-232 Pin Definitions

GND	Ground
CTS	Clear To Send
RTS	Ready To Send
RxD	Received Data
TxD	Transmitted Data

5.1.1.2. Firmware Setup for RS-232 MODBUS® Communications

To use MODBUS® communications over your T-Series or E-Series Analyzer's Com B port (COM2) several of the COM port Communication Modes must be activated.

Table 5-2: COM Port Communication Modes

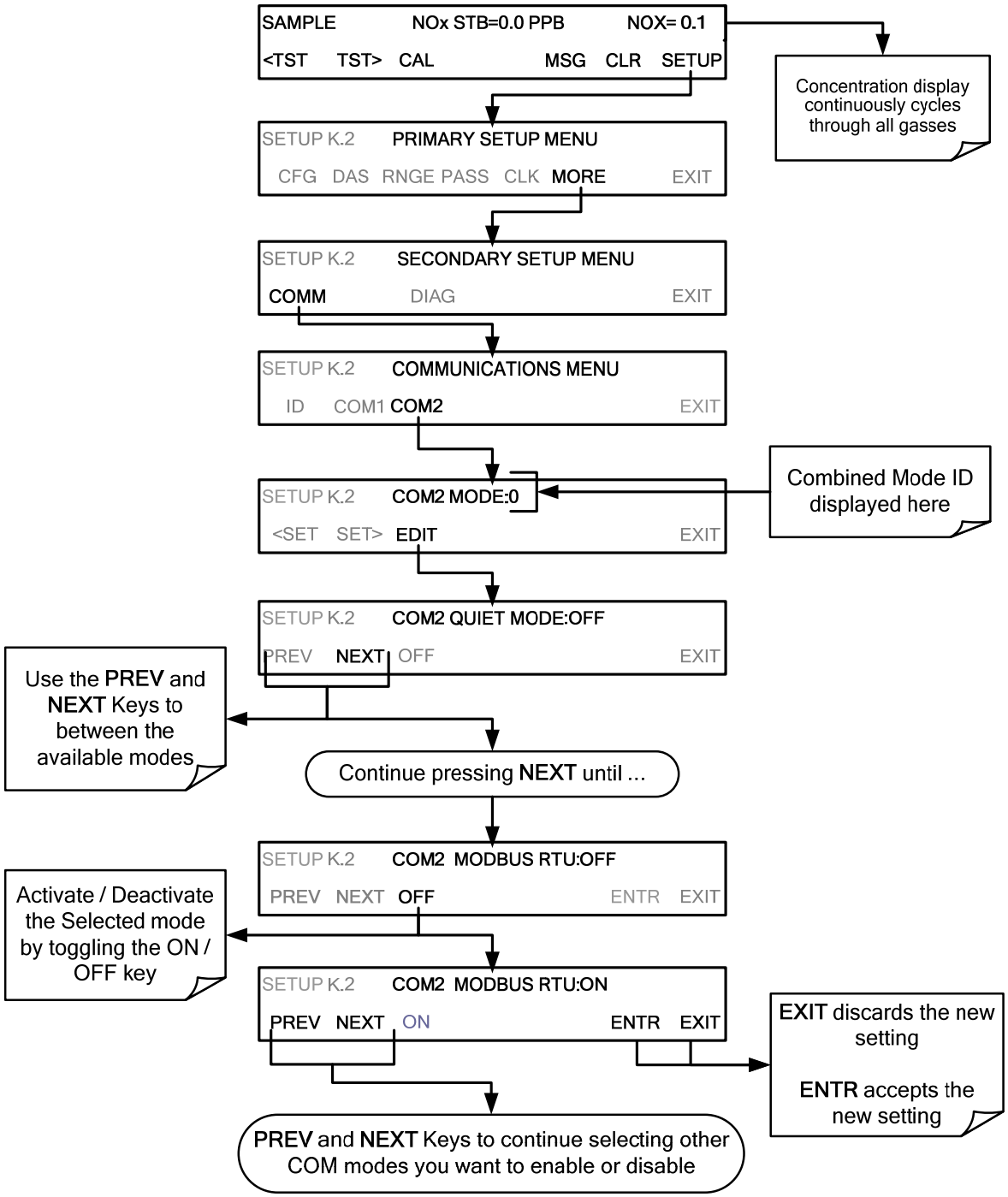
MODE[1]	ID	DESCRIPTION	MODBUS® SETTING
QUIET	**1**	Quiet mode suppresses any feedback from the analyzer (such as warning messages) to the remote device and is typically used where such intermittent messages might cause communication problems.	***OFF***
COMPUTER	**2**	Computer mode inhibits echoing of typed characters	***OFF***
HESSEN PROTOCOL	**16**	This MODE is not available when the MODBUS® interface is active.	***N/A***
E, 8, 1	**8192**	When turned on this mode switches the **COM** port settings from ● **NO PARITY;** 8 data bits; 1 stop bit to **EVEN PARITY**; 8 data bits; 1 stop bit.	***Set as required for your application.***
MODBUS® ASCII[2]	**16384**	This mode sets the firmware to utilize ***MODBUS® ASCII*** protocol in applications where the communication does not allow the conformance with RTU mode requirements regarding timer management.	***ON for ASCII mode.*** ***OFF for RTU***
MODBUS® RTU[2]	**32678**	This mode sets the firmware to utilize ***MODBUS® RTU*** protocol. RTU mode allows character density and better data throughput than ASCII mode for the same baud rate. ● Each message must be transmitted in a continuous stream of characters.	***OFF for ASCII mode.*** ***ON for RTU***
E, 7, 1	**2048**	When turned on this mode switches the **COM** port settings from ● **NO PARITY; 8 DATA BITS**; 1 stop bit to **EVEN PARITY; 7 DATA BITS**; 1 stop bit.	***Set as required for your application.***
RS-485	**1024**	Configures the **COM2** Port for RS-485 communication.	***OFF***
SECURITY	**4**	When enabled, the serial port requires a password before it will respond.	***OFF***
MULTIDROP PROTOCOL	**32**	Multidrop protocol allows a multi-instrument configuration on a single communications channel.	***OFF***
ENABLE MODEM	**64**	Enable to send a modem initialization string at power-up.	***Set as required for your application.***
ERROR CHECKING[3]	**128**	Fixes certain types of parity errors.	***ON***
XON/XOFF HANDSHAKE[3]	**256**	Disables XON/XOFF data flow control also known as software handshaking.	***ON***
HARDWARE HANDSHAKE	**8**	Enables CTS/RTS style hardwired transmission handshaking. This style of data transmission handshaking is commonly used with modems or terminal emulation protocols as well as by Teledyne-API's APICOM software.	***OFF***
HARDWARE FIFO[3]	**512**	Disables the **HARDWARE FIFO** (First In – First Out), When FIFO is enabled it improves data transfer rate for that COM port.	***ON***
COMMAND PROMPT	**4096**	Enables a command prompt when in terminal mode.	***OFF***

[1] Modes are listed in the order in which they appear in the **SETUP → MORE → COMM → COM[1 OR 2] → MODE** menu

[2] Only one of these modes may be set to on at one time.

[3] The default setting for this feature is **ON.** Do not disable unless instructed to by Teledyne-API's Customer Service personnel.

In the following example, the MODBUS® RTU mode is enabled on a 200 by pressing the following:



NOTE

Other settings for COM2, such as Baud Rate should be set as applicable for your application by following the instructions found in the Technical/Operator's manual for your T-Series or E-Series Analyzer.

5.1.2. USING MODBUS® VIA THE ETHERNET

MODBUS® communications can be utilized via the internet if your E-Series Analyzer is equipped with the optional Ethernet card. (Ethernet is standard in the T-Series analyzers. With the Ethernet interface, the analyzer can be connected to any standard 10 or 100Base-T Ethernet network via low-cost network hubs, switches or routers.

In a standard T-Series or E-Series Analyzer, the interface operates as a standard TCP/IP device on port 3000. For analyzers with the MODBUS® Interface activated, a second TCP port is also present on Port 502, which is the default for MODBUS® TCP/IP according to the MODBUS® specifications.

The firmware on the Ethernet card automatically sets the communication modes and baud rate (115,200 kBaud) for the **COM2** port. Once the Ethernet option is installed and activated, the **COM2** submenu is replaced by a new submenu, **INET**. This submenu is used to manage and configure the Ethernet interface with your LAN or Internet Server(s).

The Ethernet interface operates in ”polled” mode with a polling period that ranges from between 250ms and 2 seconds.

- When there is port activity, the polling rate is the minimum, 250ms.
- When port activity is quiet, the polling rate lengthens up to 2-seconds to reduce the burden on the instrument’s CPU.

NOTE

To ensure a reliable operation, commands should not be issued faster than twice a second.

5.1.2.1. Electronic Connections for RS-232 MODBUS® Communications

For an Ethernet connection, plug one end into the 7’ CAT5 cable supplied with the option into the appropriate place on the back of the analyzer and the other end into any nearby Ethernet access port. Please refer to for E-Series Ethernet, and refer to for T-Series Ethernet.

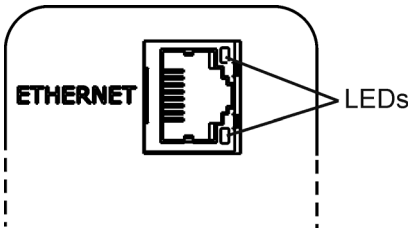


Figure 5-4: T-Series Rear Panel Ethernet Connector

The T-Series rear panel Ethernet connector has two LEDs indicating the Ethernet’s current operating status (please see):

Table 5-3: T-Series Ethernet Status Indicators

LED	FUNCTION
amber (link)	On when connection to the LAN is valid
green (activity)	Flickers during any activity on the LAN

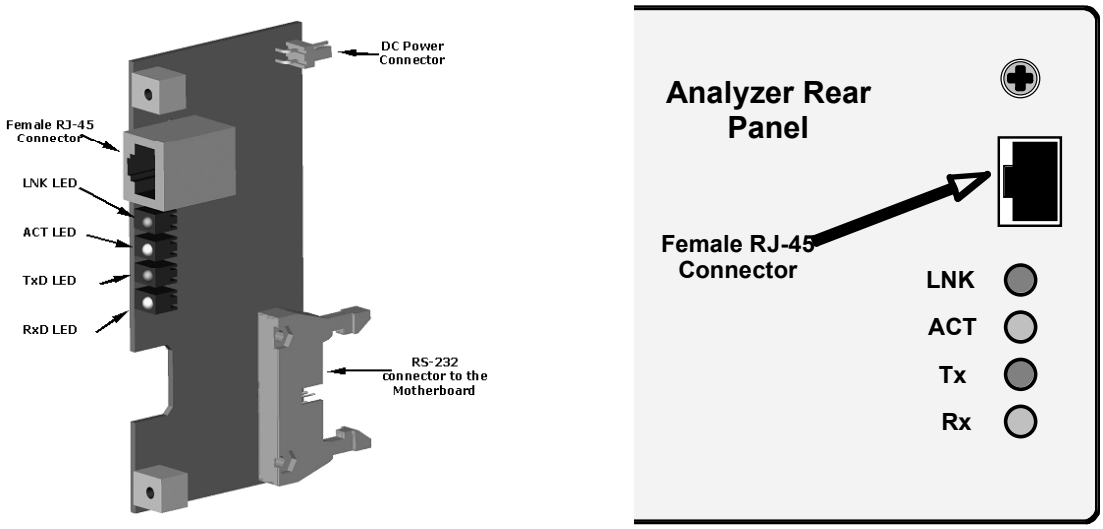


Figure 5-5: E-Series Ethernet PCA and Status Indicators

The E-Series Ethernet card has four LEDs that are visible on the rear panel of the analyzer indicating its current operating status. provides information on what each LED indicates.

Table 5-4: Ethernet Status Indicators

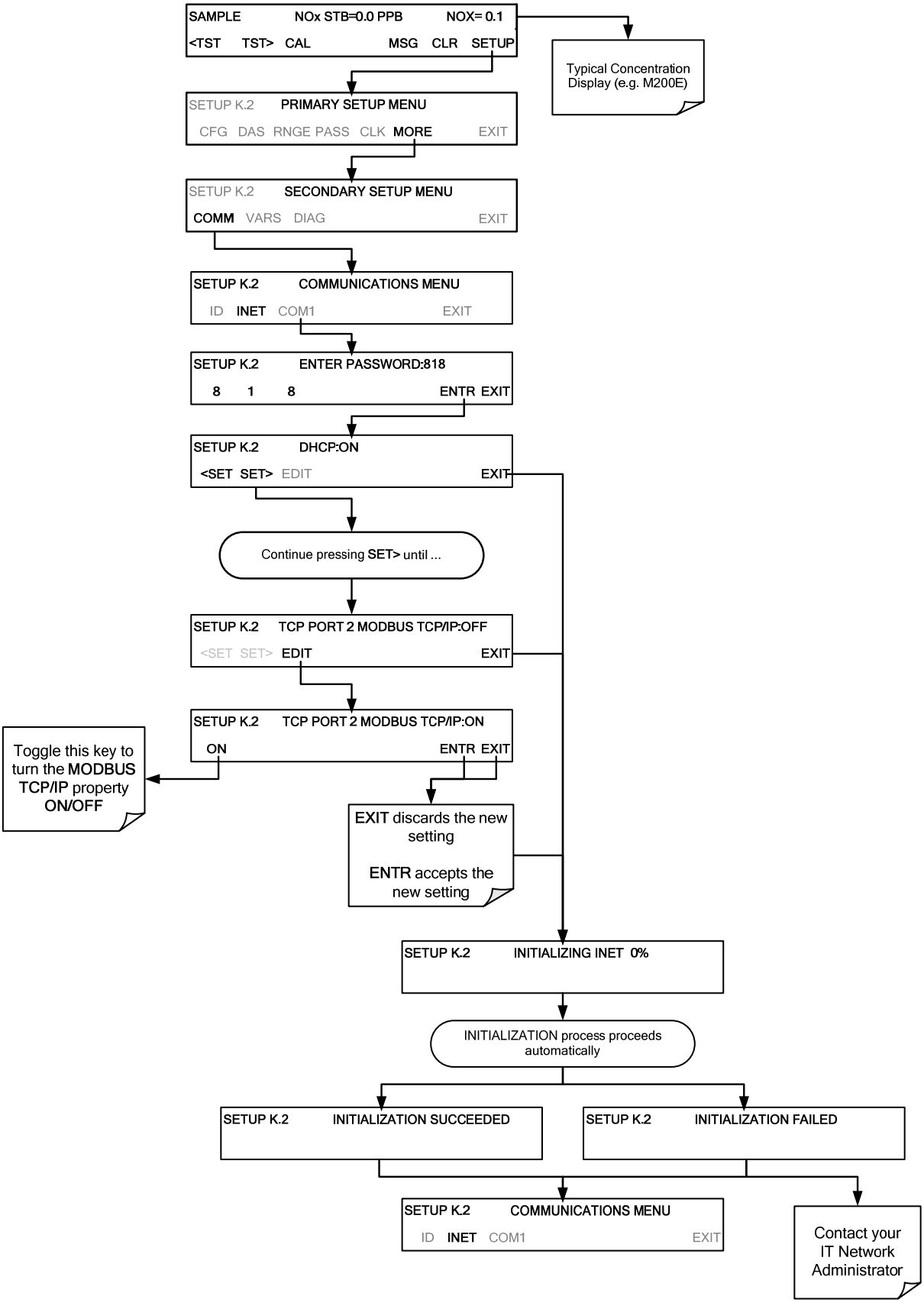
LED	FUNCTION
LNK (green)	ON when connection to the LAN is valid.
ACT (yellow)	Flickers on any activity on the LAN.
TxD (green)	Flickers when the ethernet port is transmitting data.
RxD (yellow)	Flickers when the ethernet port is receiving data.

5.1.2.2. Firmware Setup for Ethernet MODBUS® Communications

To activate MODBUS® TCP/IP protocol the following firmware properties must be activated:

1. Verify that the **ONLINE** property located under the **INET** submenu is set to **ON**.
2. Turn on the **TCP PORT 2** MODBUS® **TCP/IP** property also located under the **INET** submenu.

To perform these two actions press:



5.1.2.3. Configuring the MODBUS® Connection

The Ethernet option for your T-Series or E-Series Analyzer uses Dynamic Host Configuration Protocol (DHCP) to configure its interface with your LAN automatically. This requires your network servers also be running DHCP.

- The analyzer will do this the first time you turn the instrument on after it has been physically connected to your network.

  Once the instrument is connected and turned on, it will appear as an active device on your network without any extra set up steps or lengthy procedures.
- If your network does not support DHCP, see the instructions found in the Technical/Operator's Manual of your T-Series or E-Series Analyzer for manually configuring the LAN connection.
- Ensure that the Internet Configuration Properties that appear under the INET submenu match those listed in the following table.

Table 5-5: T-Series or E-Series MODBUS® TCP/IP Property Settings

PROPERTY	DEFAULT STATE	DESCRIPTION
DHCP STATUS	On	This displays whether the DHCP is turned ON or OFF.
INSTRUMENT IP ADDRESS	Configured by DHCP	This string of four packets of 1 to 3 numbers each (e.g. 192.168.76.55) is the address of the analyzer itself.
GATEWAY IP ADDRESS	Configured by DHCP	A string of numbers very similar to the Instrument IP address (e.g. 192.168.76.1) that is the address of the computer used by your LAN to access the Internet.
SUBNET MASK	Configured by DHCP	Also, a string of four packets of 1 to 3 numbers each (e.g. 255.255.252.0) that defines that identifies the LAN to which the device is connected. All addressable devices and computers on a LAN must have the same subnet mask.
TCP PORT1[1]	**3000**	TSP listening port 1. This port is used for standard Ethernet communications. The number defines the terminal control port by which the instrument is addressed by terminal emulation software, such as Teledyne-API's APICOM.
TCP PORT2[1]	**520**	TSP listening port 2. The setting for this port is specified by MODBUS® specifications.
TCP PORT2 MODBUS TCP/IP	**ON**	Enables or disables the T200, M200E's two TCP Ports. The TCP ports are inactive when this is set to **OFF.**
HOST NAME	**XXXX**[2]	The name by which your analyzer will appear when addressed from other computers on the LAN or via the Internet. While the default setting for all Teledyne-API's analyzers is "Txxx" or "MxxxE", the host name may be changed to fit customer needs.
ONLINE	**ON**	Enables or disables the analyzer's two TCP Ports. The TCP ports are inactive when this is set to to to **OFF.**

[1] Do not change the setting for this property unless instructed to by Teledyne-API's Customer Service personnel.
[2] Appears only if DHCP enabled. Exact name depends on instrument model.

NOTE

It is recommended to check the INET settings the first time you power up your analyzer after it has been physically connected to the LAN/Internet to ensure that the DHCP has successfully downloaded the appropriate information from you network server(s).

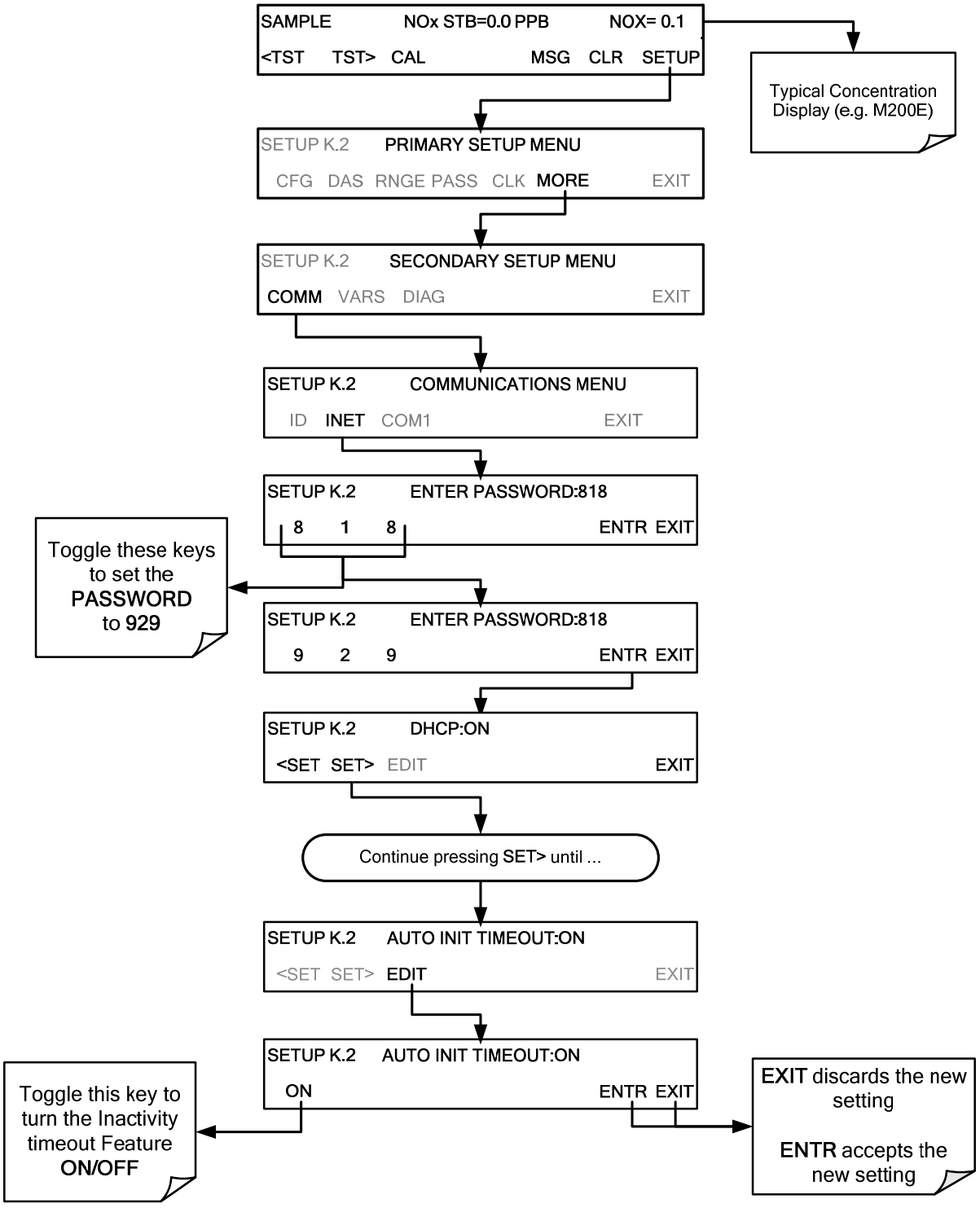
The Ethernet configuration properties are viewable via the analyzer's front panel.

5.1.3. CONFIGURING THE INET INACTIVITY TIMER

An undesirable side effect of the collision detection method used by Ethernet protocol is that if the Ethernet connection of a client or server on the network is improperly terminated (i.e. ended without following the required protocol) the Ethernet driver can freeze. Typically this occurs if the cable physically connecting the instrument to the network is unplugged or breaks. Symptomatically this can be indistinguishable from long periods of inactivity such as might occur if an error occurs in a MODBUS® transaction request causing the requesting device to sit idle for long periods of time waiting for a response that will never come.

The Ethernet version of the T-Series or E-Series Analyzer firmware includes a feature that automatically disconnects and re-initializes either of the two TCP ports if they are idle for the specified timeout period (default value = 60 min), saving the user from having to manually reinitialize the connection from the instrument's front panel.

5.1.3.1. **Enabling/Disabling the Inactivity Timer**

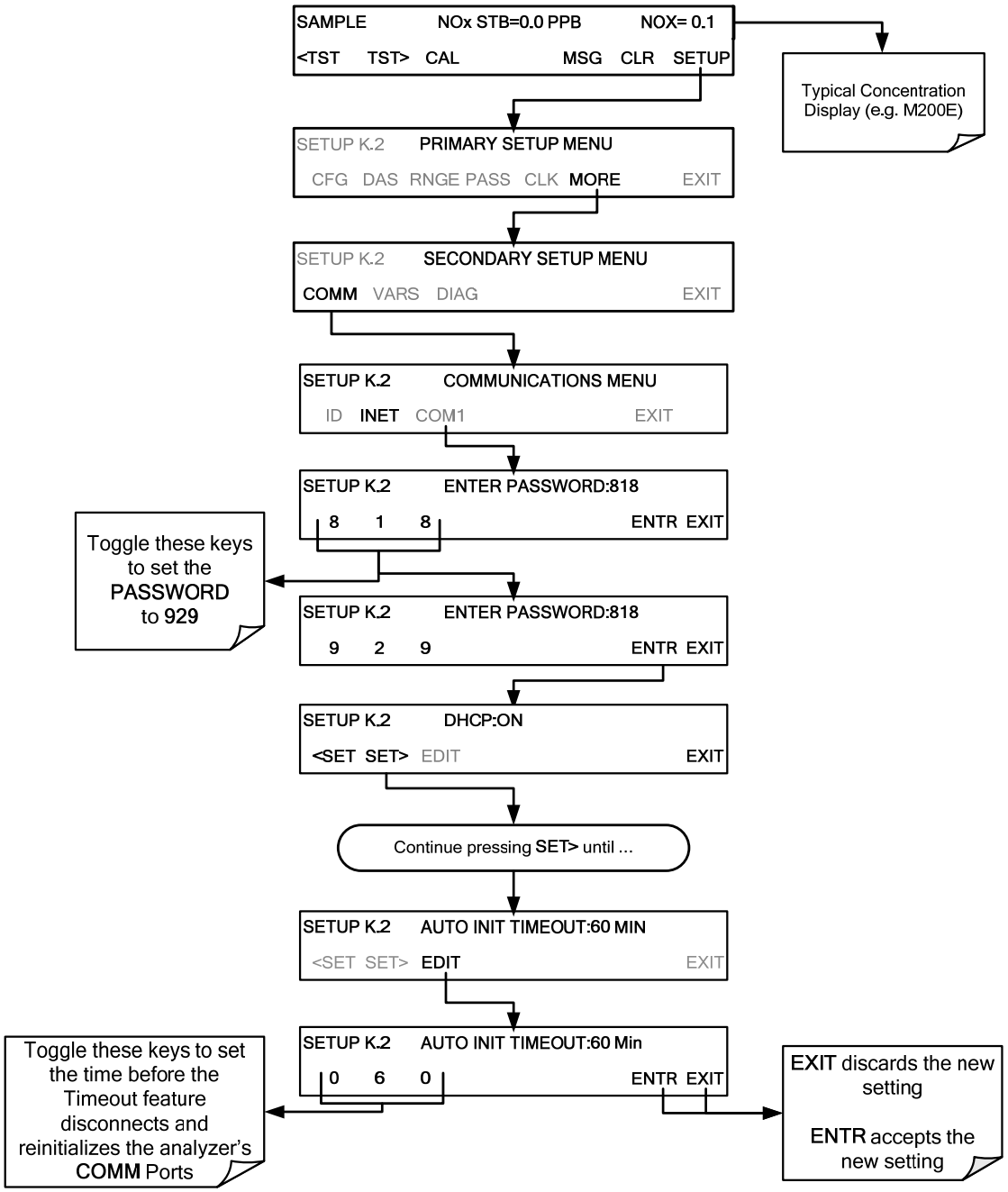


5.1.3.2. **Setting the Inactivity Period**

If your Ethernet network is running DHCP, it is important that the INET Inactivity Timeout period NOT be LONGER than the DHCP Lease Duration for your network. If it is, and there is no activity between the analyzer and the network for a period longer than the DHCP lease duration, the network server may release and reassign the IP address originally given to the instrument. This is particularly important if IP address dependent software, such as APICOM, is being used to interface with the analyzer over the INET connection.

NOTE

The default value of the T-Series or E-Series Inactivity Timer is 60 minutes



6. MODBUS® CALIBRATION PROCEDURES

Calibration operations are Initiated by setting one of the analyzers Coil Register to ON. In the T-Series or E-Series Analyzers, Coil Registers associated with calibration usually have decimal address of 20 through 29 (see the appropriate Appendix for an exact list of applicable Coil Registers).

6.1. CALIBRATION QUALITY ANALYSIS

The values for Slope and Offset of the analyzers various measurement ranges are available by reading the contents of several Floating Point Input Registers (see the appropriate Appendix for an exact list of applicable Input Registers).

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7. MODBUS® AND ALARMS

Alarm related I/O signals do not appear in the MODBUS® versions of the firmware. This is because they are defined as MODBUS® coil registers.

There is a separate MODBUS® discrete input register for each gas and alarm (see the appropriate Appendix for an exact list of applicable Registers) .

- If an alarm is set, its corresponding discrete input register is set to 1.
- The MODBUS® discrete input registers are self clearing.
- If an alarm is cleared, then its corresponding MODBUS® discrete input register is set to 0.

Table 7-1: MODBUS® Alarm Outputs

Alarm outputs, U21, J1009, pins 1–12 = bits 4–7, default I/O address 325 hex	
MB_RELAY_36	Controlled by MODBUS® coil register
MB_RELAY_37	Controlled by MODBUS® coil register
MB_RELAY_38	Controlled by MODBUS® coil register
MB_RELAY_39	Controlled by MODBUS® coil register

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8. GENERAL MODBUS® TROUBLESHOOTING & REPAIR

8.1. WARNING MESSAGES

Warning messages are stored by the MODBUS® interface as the contents of Discreet Input Registers (see the appropriate Appendix for an exact list of applicable Registers). When the contents of the register is set to ON the Warning is active.

8.2. SIGNAL I/O

The analyzer's various Signal I/O functions are available as the contents of Floating Point and input Registers (see the appropriate Appendix for an exact list of applicable Registers).

8.3. TECHNICAL ASSISTANCE

If this addendum and its trouble-shooting / repair sections do not solve your problems, technical assistance may be obtained from:

Teledyne Instruments
Advanced Pollution Instrumentation Division
(TAPI)
Customer Service
9480 Carroll Park Drive
San Diego, California 92121-5201USA

Toll-free Phone: 800-324-5190
Phone: 858-657-9800
Fax: 858-657-9816
Email: API-CustomerService@Teledyne.com
Website: http://www.Teledyne-API.com

Before you contact Teledyne Instruments' Customer service, fill out the problem report form in Appendix C, which is also available online for electronic submission at http://www.Teledyne-API.com/forms/p-fmapicom.asp.

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APPENDIX A: T100, M100E MODBUS® Register Maps

Firmware Revisions, T-Series: 1.0.0, E-Series: G.4

T100, M100E MODBUS Register Map		
MODBUS Register Address (dec., 0-based)	**Description**	**Units**
MODBUS Floating Point Input Registers (32-bit IEEE 754 format; read in high-word, low-word order; read-only)		
0	PMT detector reading	mV
2	UV lamp intensity reading	mV
4	UV lamp ratio of calibrated intensity	%
6	PMT electrical offset	mV
8	UV lamp electrical offset	mV
10	SO_2 slope for range #1	—
12	SO_2 slope for range #2	—
14	SO_2 offset for range #1	mV
16	SO_2 offset for range #2	mV
18	SO_2 concentration for range #1 during zero/span calibration, just before computing new slope and offset	PPB, PPM [2]
20	SO_2 concentration for range #2 during zero/span calibration, just before computing new slope and offset	PPB
22	SO_2 concentration for range #1	PPB
24	SO_2 concentration for range #2	PPB
26	Concentration stability	PPB
28	Stray light reading	PPB
30	Reaction cell temperature	°C
32	PMT temperature	°C
34	Sample pressure	“Hg
36	Internal box temperature	°C
38	High voltage power supply output	Volts
40	Diagnostic test input (TEST_INPUT_8)	mV
42	Diagnostic temperature input (TEMP_INPUT_5)	°C
44	Diagnostic temperature input (TEMP_INPUT_6)	°C
46	Ground reference (REF_GND)	mV
48	4096 mV reference (REF_4096_MV)	mV
50	Sample flow	cc/m
52 [1]	IZS temperature	°C
54 [2]	Vacuum pressure	“Hg
56 [1]	Pre-amplified UV lamp intensity reading	mV
100 [10]	O_2 concentration	%
102 [10]	O_2 concentration during zero/span calibration, just before computing new slope and offset	%

T100, M100E MODBUS Register Map		
MODBUS Register Address (dec., 0-based)	**Description**	**Units**
104 [10]	O_2 slope	—
106 [10]	O_2 offset	%
108 [10]	O_2 sensor cell temperature	°C
110 [12]	SO_2 concentration for range #1, with O_2 correction	PPB
112 [12]	SO_2 concentration for range #2, with O_2 correction	PPB
130 [14]	External analog input 1 value	Volts
132 [14]	External analog input 1 slope	eng unit /V
134 [14]	External analog input 1 offset	eng unit
136 [14]	External analog input 2 value	Volts
138 [14]	External analog input 2 slope	eng unit /V
140 [14]	External analog input 2 offset	eng unit
142 [14]	External analog input 3 value	Volts
144 [14]	External analog input 3 slope	eng unit /V
146 [14]	External analog input 3 offset	eng unit
148 [14]	External analog input 4 value	Volts
150 [14]	External analog input 4 slope	eng unit /V
152 [14]	External analog input 4 offset	eng unit
154 [14]	External analog input 5 value	Volts
156 [14]	External analog input 5 slope	eng unit /V
158 [14]	External analog input 5 offset	eng unit
160 [14]	External analog input 6 value	Volts
162 [14]	External analog input 6 slope	eng unit /V
164 [14]	External analog input 6 offset	eng unit
166 [14]	External analog input 7 value	Volts
168 [14]	External analog input 7 slope	eng unit /V
170 [14]	External analog input 7 offset	eng unit
172 [14]	External analog input 8 value	Volts
174 [14]	External analog input 8 slope	eng unit /V
176 [14]	External analog input 8 offset	eng unit
200 [11]	CO_2 concentration	%
202 [11]	CO_2 concentration during zero/span calibration, just before computing new slope and offset	%
204 [11]	CO_2 slope	—
206 [11]	CO_2 offset	%
MODBUS Floating Point Holding Registers (32-bit IEEE 754 format; read/write in high-word, low-word order; read/write)		
0	Maps to *SO2_SPAN1* variable; target conc. for range #1	Conc. units
2	Maps to *SO2_SPAN2* variable; target conc. for range #2	Conc. units
100 [10]	Maps to *O2_TARG_SPAN_CONC* variable	%
200 [11]	Maps to *CO2_TARG_SPAN_CONC* variable	%

T100, M100E MODBUS Register Map		
MODBUS Register Address (dec., 0-based)	**Description**	**Units**
MODBUS Discrete Input Registers (single-bit; read-only)		
0	PMT detector warning	
1	UV detector warning	
2	Dark calibration warning	
3	Box temperature warning	
4	PMT temperature warning	
5	Reaction cell temperature warning	
6	Sample pressure warning	
7	HVPS warning	
8	System reset warning	
9	Rear board communication warning	
10	Relay board communication warning	
11	Front panel communication warning	
12	Analog calibration warning	
13	Dynamic zero warning	
14	Dynamic span warning	
15	Invalid concentration	
16	In zero calibration mode	
17	In span calibration mode	
18	In multi-point calibration mode	
19	System is OK (same meaning as *SYSTEM_OK* I/O signal)	
20	Sample flow warning	
21 [1]	IZS temperature warning	
22 [2]	In low span calibration mode	
23 [2]	Vacuum pressure warning	
24 [3]	SO_2 concentration alarm limit #1 exceeded	
25 [3]	SO_2 concentration alarm limit #2 exceeded	
26	In Hessen manual mode	
100 [10]	In O_2 calibration mode	
101 [10]	O_2 cell temperature warning	
102 [10+3]	O_2 concentration alarm limit #1 exceeded	
103 [10+3]	O_2 concentration alarm limit #2 exceeded	
200 [11]	In CO_2 calibration mode	
201 [11+3]	CO_2 concentration alarm limit #1 exceeded	
202 [11+3]	CO_2 concentration alarm limit #2 exceeded	

T100, M100E MODBUS Register Map		
MODBUS Register Address (dec., 0-based)	**Description**	**Units**
MODBUS Coil Registers (single-bit; read/write)		
0	Maps to relay output signal 36 (*MB_RELAY_36* in signal I/O list)	
1	Maps to relay output signal 37 (*MB_RELAY_37* in signal I/O list)	
2	Maps to relay output signal 38 (*MB_RELAY_38* in signal I/O list)	
3	Maps to relay output signal 39 (*MB_RELAY_39* in signal I/O list)	
20 [13]	Triggers zero calibration of range #1 (on enters cal.; off exits cal.)	
21 [13]	Triggers span calibration of range #1 (on enters cal.; off exits cal.)	
22 [13]	Triggers zero calibration of range #2 (on enters cal.; off exits cal.)	
23 [13]	Triggers span calibration of range #2 (on enters cal.; off exits cal.)	

[1] T100, M100E
[2] T100H, M100EH.
[3] Concentration alarm option.
[10] O_2 option.
[11] CO_2 option.
[12] SO_2 with O_2 correction option.
[13] Set *DYN_ZERO* or *DYN_SPAN* variables to *ON* to enable calculating new slope or offset. Otherwise a calibration check is performed.
[14] T-Series external analog input option.

APPENDIX B: T101/102/108, M101E/102E/108E MODBUS® Register Maps

Firmware Revisions, T-Series: 1.0.0, E-Series: G.4

T101/102/108, M101E/102E/108E MODBUS Register Map		
MODBUS Register Address (dec., 0-based)	**Description**	**Units**
MODBUS Floating Point Input Registers (32-bit IEEE 754 format; read in high-word, low-word order; read-only)		
0	PMT detector reading	mV
2	UV lamp intensity reading	mV
4	UV lamp ratio of calibrated intensity	%
6	PMT electrical offset	mV
8	UV lamp electrical offset	mV
10	SO_2 slope for range #1	PPB/mV
12	SO_2 slope for range #2	PPB/mV
14	H_2S/TRS slope for range #1	PPB/mV
16	H_2S/TRS slope for range #2	PPB/mV
18	SO_2 offset for range #1	mV
20	SO_2 offset for range #2	mV
22	H_2S/TRS offset for range #1	mV
24	H_2S/TRS offset for range #2	mV
26	SO_2 concentration for range #1 during zero/span calibration, just before computing new slope and offset	PPB
28	SO_2 concentration for range #2 during zero/span calibration, just before computing new slope and offset	PPB
30	H_2S/TRS concentration for range #1 during zero/span calibration, just before computing new slope and offset	PPB
32	H_2S/TRS concentration for range #2 during zero/span calibration, just before computing new slope and offset	PPB
34	SO_2 concentration for range #1	PPB
36	SO_2 concentration for range #2	PPB
38	H_2S/TRS concentration for range #1	PPB
40	H_2S/TRS concentration for range #2	PPB
42	Concentration stability #1	PPB
44	Stray light reading	PPB
46	Reaction cell temperature	°C
48	IZS temperature	°C
50	PMT temperature	°C
52	Converter efficiency factor for range #1	—
54	Converter efficiency factor for range #2	—
56	Sample flow rate	cc/m
58	Sample pressure	“Hg

T101/102/108, M101E/102E/108E MODBUS Register Map		
MODBUS Register Address (dec., 0-based)	**Description**	**Units**
60	Internal box temperature	°C
62	High voltage power supply output	Volts
64	Diagnostic test input (TEST_INPUT_8)	mV
66	Diagnostic test input (TEST_INPUT_11)	mV
68	Diagnostic temperature input (TEMP_INPUT_4)	°C
70	Diagnostic temperature input (TEMP_INPUT_5)	°C
72	Diagnostic temperature input (TEMP_INPUT_6)	°C
74	Ground reference (REF_GND)	mV
76	4096 mV reference (REF_4096_MV)	mV
78	Pre-amplified UV lamp intensity reading	mV
80 [1]	Converter temperature	°C
82 [5]	Oxygenator flow rate	cc/m
84 [6]	Concentration stability #2	PPB
86 [7]	UV lamp stability	mV
100 [4]	TRS slope for range #1	PPB/mV
102 [4]	TRS slope for range #2	PPB/mV
104 [4]	TRS offset for range #1	mV
106 [4]	TRS offset for range #2	mV
108 [4]	TRS concentration for range #1 during zero/span calibration, just before computing new slope and offset	PPB
110 [4]	TRS concentration for range #2 during zero/span calibration, just before computing new slope and offset	PPB
112 [4]	TRS concentration for range #1	PPB
114 [4]	TRS concentration for range #2	PPB
116 [4]	TRS converter efficiency factor for range #1	—
118 [4]	TRS converter efficiency factor for range #2	—
130 [8]	External analog input 1 value	Volts
132 [8]	External analog input 1 slope	eng unit /V
134 [8]	External analog input 1 offset	eng unit
136 [8]	External analog input 2 value	Volts
138 [8]	External analog input 2 slope	eng unit /V
140 [8]	External analog input 2 offset	eng unit
142 [8]	External analog input 3 value	Volts
144 [8]	External analog input 3 slope	eng unit /V
146 [8]	External analog input 3 offset	eng unit
148 [8]	External analog input 4 value	Volts
150 [8]	External analog input 4 slope	eng unit /V
152 [8]	External analog input 4 offset	eng unit
154 [8]	External analog input 5 value	Volts

T101/102/108, M101E/102E/108E MODBUS Register Map		
MODBUS Register Address (dec., 0-based)	**Description**	**Units**
156 [8]	External analog input 5 slope	eng unit /V
158 [8]	External analog input 5 offset	eng unit
160 [8]	External analog input 6 value	Volts
162 [8]	External analog input 6 slope	eng unit /V
164 [8]	External analog input 6 offset	eng unit
166 [8]	External analog input 7 value	Volts
168 [8]	External analog input 7 slope	eng unit /V
170 [8]	External analog input 7 offset	eng unit
172 [8]	External analog input 8 value	Volts
174 [8]	External analog input 8 slope	eng unit /V
176 [8]	External analog input 8 offset	eng unit
MODBUS Floating Point Holding Registers (32-bit IEEE 754 format; read/write in high-word, low-word order; read/write)		
0	Maps to *SO2_SPAN1* variable; target conc. for range #1	Conc. units
2	Maps to *SO2_SPAN2* variable; target conc. for range #2	Conc. units
4	Maps to *H2S_SPAN1* variable; target conc. for range #1	Conc. units
6	Maps to *H2S_SPAN2* variable; target conc. for range #2	Conc. units
100 [4]	Maps to *TRS_SPAN1* variable; target conc. for range #1	Conc. units
102 [4]	Maps to *TRS_SPAN2* variable; target conc. for range #2	Conc. units
MODBUS Discrete Input Registers (single-bit; read-only)		
0	PMT detector warning	
1	UV detector warning	
2	Dark calibration warning	
3	Box temperature warning	
4	PMT temperature warning	
5	Reaction cell temperature warning	
6	Sample pressure warning	
7	HVPS warning	
8	System reset warning	
9	Rear board communication warning	
10	Relay board communication warning	
11	Front panel communication warning	
12	Analog calibration warning	
13	Dynamic zero warning	
14	Dynamic span warning	
15	Invalid concentration	
16	In zero calibration mode	
17	In span calibration mode	

T101/102/108, M101E/102E/108E MODBUS Register Map		
MODBUS Register Address (dec., 0-based)	**Description**	**Units**
18	In multi-point calibration mode	
19	System status is OK (same meaning as *SYSTEM_OK* I/O signal)	
20	Sample flow warning	
21	IZS temperature warning	
22 [1]	Converter temperature warning	
23 [5]	Oxygenator flow warning	
24 [2]	SO_2 concentration alarm limit #1 exceeded	
25 [2]	SO_2 concentration alarm limit #2 exceeded	
26 [2]	H_2S/TRS concentration alarm limit #1 exceeded	
27 [2]	H_2S/TRS concentration alarm limit #2 exceeded	
28 [2+4]	TRS concentration alarm limit #1 exceeded	
29 [2+4]	TRS concentration alarm limit #2 exceeded	
MODBUS Coil Registers (single-bit; read/write)		
0	Maps to relay output signal 36 (*MB_RELAY_36* in signal I/O list)	
1	Maps to relay output signal 37 (*MB_RELAY_37* in signal I/O list)	
2	Maps to relay output signal 38 (*MB_RELAY_38* in signal I/O list)	
3	Maps to relay output signal 39 (*MB_RELAY_39* in signal I/O list)	
20 [3]	Triggers zero calibration of range #1 (on enters cal.; off exits cal.)	
21 [3]	Triggers span calibration of range #1 (on enters cal.; off exits cal.)	
22 [3]	Triggers zero calibration of range #2 (on enters cal.; off exits cal.)	
23 [3]	Triggers span calibration of range #2 (on enters cal.; off exits cal.)	

[1] T101, M101E.
[2] Concentration alarm option.
[3] Set *DYN_ZERO* or *DYN_SPAN* variables to *ON* to enable calculating new slope or offset. Otherwise a calibration check is performed.
[4] Triple-gas option.
[5] T108, M108E.
[6] T108U, M108EU.
[7] Optional.
[8] T-Series external analog input option.

APPENDIX C: T200, M200E MODBUS® Register Maps

Firmware Revisions, T-Series: 1.0.0, E-Series: K.4

T200, M200E MODBUS Register Map		
MODBUS Register Address (decimal, 0-based)	**Description [10]**	**Units**
MODBUS Floating Point Input Registers (32-bit IEEE 754 format; read in high-word, low-word order; read-only)		
0	Instantaneous PMT detector reading	mV
2	NO_X slope for range #1	—
4	NO_X slope for range #2	—
6	NO slope for range #1	—
8	NO slope for range #2	mV
10	NO_X offset for range #1	mV
12	NO_X offset for range #2	mV
14	NO offset for range #1	mV
16	NO offset for range #2	mV
18	NO_X concentration for range #1 during zero/span calibration, just before computing new slope and offset	PPB
20	NO_X concentration for range #2 during zero/span calibration, just before computing new slope and offset	PPB
22	NO concentration for range #1 during zero/span calibration, just before computing new slope and offset	PPB
24	NO concentration for range #2 during zero/span calibration, just before computing new slope and offset	PPB
26	NO_2 concentration for range #1 during zero/span calibration, just before computing new slope and offset	PPB
28	NO_2 concentration for range #2 during zero/span calibration, just before computing new slope and offset	PPB
30	NO_X concentration for range #1	PPB
32	NO_X concentration for range #2	PPB
34	NO concentration for range #1	PPB
36	NO concentration for range #2	PPB
38	NO_2 concentration for range #1	PPB
40	NO_2 concentration for range #2	PPB
42	Concentration stability	PPB
44	Auto zero offset (range de-normalized) Pre React [11]	mV
46	Ozone flow rate	cc/m
48	Reaction cell pressure	"Hg
50	Reaction cell temperature	°C

T200, M200E MODBUS Register Map		
MODBUS Register Address (decimal, 0-based)	**Description [10]**	**Units**
52	Manifold temperature	°C
54	Converter efficiency factor for range #1	—
56	Converter efficiency factor for range #2	—
58	Converter temperature	°C
60	PMT temperature	°C
62	Sample flow rate	cc/m
64	Sample pressure	“Hg
66	Internal box temperature	°C
68	High voltage power supply output	Volts
70	Ground reference (REF_GND)	mV
72	4096 mV reference (REF_4096_MV)	mV
74	Diagnostic test input (TEST_INPUT_13)	mV
76	Diagnostic temperature input (TEMP_INPUT_6)	°C
78	IZS temperature	°C
80 [9]	Sample restrictor temperature	°C
82 [9]	Remote box temperature	°C
80	Diagnostic test input (TEST_INPUT_11)	mV
82	Diagnostic temperature input (TEMP_INPUT_5)	°C
84 [1]	Raw PMT detector reading for NO_X	mV
86 [1]	Raw PMT detector reading for NO	mV
100 [3]	NO_X slope for range #3	—
102 [3]	NO slope for range #3	mV
104 [3]	NO_X offset for range #3	mV
106 [3]	NO offset for range #3	mV
108 [3]	NO_X concentration for range #3 during zero/span calibration, just before computing new slope and offset	PPB
110 [3]	NO concentration for range #3 during zero/span calibration, just before computing new slope and offset	PPB
112 [3]	NO_2 concentration for range #3 during zero/span calibration, just before computing new slope and offset	PPB
114 [3]	NO_X concentration for range #3	PPB
116 [3]	NO concentration for range #3	PPB
118 [3]	NO_2 concentration for range #3	PPB
120 [3]	Converter efficiency factor for range #3	—
130 [12]	External analog input 1 value	Volts
132 [12]	External analog input 1 slope	eng unit /V
134 [12]	External analog input 1 offset	eng unit
136 [12]	External analog input 2 value	Volts
138 [12]	External analog input 2 slope	eng unit /V

T200, M200E MODBUS Register Map		
MODBUS Register Address (decimal, 0-based)	**Description [10]**	**Units**
140 [12]	External analog input 2 offset	eng unit
142 [12]	External analog input 3 value	Volts
144 [12]	External analog input 3 slope	eng unit /V
146 [12]	External analog input 3 offset	eng unit
148 [12]	External analog input 4 value	Volts
150 [12]	External analog input 4 slope	eng unit /V
152 [12]	External analog input 4 offset	eng unit
154 [12]	External analog input 5 value	Volts
156 [12]	External analog input 5 slope	eng unit /V
158 [12]	External analog input 5 offset	eng unit
160 [12]	External analog input 6 value	Volts
162 [12]	External analog input 6 slope	eng unit /V
164 [12]	External analog input 6 offset	eng unit
166 [12]	External analog input 7 value	Volts
168 [12]	External analog input 7 slope	eng unit /V
170 [12]	External analog input 7 offset	eng unit
172 [12]	External analog input 8 value	Volts
174 [12]	External analog input 8 slope	eng unit /V
176 [12]	External analog input 8 offset	eng unit
200 [5]	O_2 concentration	%
202 [5]	O_2 concentration during zero/span calibration, just before computing new slope and offset	%
204 [5]	O_2 slope	—
206 [5]	O_2 offset	%
208 [5]	O_2 sensor cell temperature	°C
300 [6]	CO_2 concentration	%
302 [6]	CO_2 concentration during zero/span calibration, just before computing new slope and offset	%
304 [6]	CO_2 slope	—
306 [6]	CO_2 offset	%
308 [6]	CO_2 sensor cell temperature	°C

T200, M200E MODBUS Register Map		
MODBUS Register Address (decimal, 0-based)	**Description [10]**	**Units**
MODBUS Floating Point Holding Registers (32-bit IEEE 754 format; read/write in high-word, low-word order; read/write)		
0	Maps to *NOX_SPAN1* variable; target conc. for range #1	Conc. units
2	Maps to *NO_SPAN1* variable; target conc. for range #1	Conc. units
4	Maps to *NOX_SPAN2* variable; target conc. for range #2	Conc. units
6	Maps to *NO_SPAN2* variable; target conc. for range #2	Conc. units
100 [3]	Maps to *NOX_SPAN3* variable; target conc. for range #3	Conc. units
102 [3]	Maps to *NO_SPAN3* variable; target conc. for range #3	Conc. units
200 [5]	Maps to *O2_TARG_SPAN_CONC* variable; target conc. for range O_2 gas	%
300 [6]	Maps to *CO2_TARG_SPAN_CONC* variable; target conc. for range CO_2 gas	%
MODBUS Discrete Input Registers (single-bit; read-only)		
0	Manifold temperature warning	
1	Converter temperature warning	
2	Auto-zero warning	
3	Box temperature warning	
4	PMT detector temperature warning	
5	Reaction cell temperature warning	
6	Sample flow warning	
7	Ozone flow warning	
8	Reaction cell pressure warning	
9	HVPS warning	
10	System reset warning	
11	Rear board communication warning	
12	Relay board communication warning	
13	Front panel communication warning	
14	Analog calibration warning	
15	Dynamic zero warning	
16	Dynamic span warning	
17	Invalid concentration	
18	In zero calibration mode	
19	In span calibration mode	
20	In multi-point calibration mode	
21	System is OK (same meaning as *SYSTEM_OK* I/O signal)	
22	Ozone generator warning	
23	IZS temperature warning	
24 [8]	In low span calibration mode	

T200, M200E MODBUS Register Map		
MODBUS Register Address (decimal, 0-based)	**Description [10]**	**Units**
25 [7]	NO concentration alarm limit #1 exceeded	
26 [7]	NO concentration alarm limit #2 exceeded	
27 [7]	NO_2 concentration alarm limit #1 exceeded	
28 [7]	NO_2 concentration alarm limit #2 exceeded	
29 [7]	NO_X concentration alarm limit #1 exceeded	
30 [7]	NO_X concentration alarm limit #2 exceeded	
200 [5]	Calibrating O_2 gas	
201 [5]	O_2 sensor cell temperature warning	
202 [5+7]	O_2 concentration alarm limit #1 exceeded	
203 [5+7]	O_2 concentration alarm limit #2 exceeded	
300 [6]	Calibrating CO_2 gas	
301 [6]	CO_2 sensor cell temperature warning	
302 [6+7]	CO_2 concentration alarm limit #1 exceeded	
303 [6+7]	CO_2 concentration alarm limit #2 exceeded	
MODBUS Coil Registers (single-bit; read/write)		
0	Maps to relay output signal 36 (*MB_RELAY_36* in signal I/O list)	
1	Maps to relay output signal 37 (*MB_RELAY_37* in signal I/O list)	
2	Maps to relay output signal 38 (*MB_RELAY_38* in signal I/O list)	
3	Maps to relay output signal 39 (*MB_RELAY_39* in signal I/O list)	
20 [2]	Triggers zero calibration of NO_X range #1 (on enters cal.; off exits cal.)	
21 [2]	Triggers span calibration of NO_X range #1 (on enters cal.; off exits cal.)	
22 [2]	Triggers zero calibration of NO_X range #2 (on enters cal.; off exits cal.)	
23 [2]	Triggers span calibration of NO_X range #2 (on enters cal.; off exits cal.)	

[1] Engineering firmware only.
[2] Set *DYN_ZERO* or *DYN_SPAN* variables to *ON* to enable calculating new slope or offset. Otherwise a calibration check is performed.
[3] Triple-range option.
[4] Optional.
[5] O_2 option.
[6] CO_2 option.
[7] Concentration alarm option.
[8] Low span option.
[9] M200EUP.
[10] All NO_X references become NO_y for M200EU_NO_y.
[11] T200U, T200U_NO_x, M200EU and M200EU_NO_y.
[12] T-Series external analog input option.

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APPENDIX D: T201, M201E MODBUS® Register Maps

Firmware Revisions, T-Series: 1.0.0, E-Series: C.0

T201, M201E MODBUS Register Map		
MODBUS Register Address (dec., 0-based)	**Description**	**Units**
MODBUS Floating Point Input Registers (32-bit IEEE 754 format; read in high-word, low-word order; read-only)		
0	Instantaneous PMT detector reading	mV
2	TNX slope for range #1	mV
4	TNX slope for range #2	mV
6	NO_X slope for range #1	—
8	NO_X slope for range #2	—
10	NO slope for range #1	—
12	NO slope for range #2	—
14	TNX offset for range #1	mV
16	TNX offset for range #2	mV
18	NO_X offset for range #1	mV
20	NO_X offset for range #2	mV
22	NO offset for range #1	mV
24	NO offset for range #2	mV
26	TNX concentration for range #1 during zero/span calibration, just before computing new slope and offset	PPB
28	TNX concentration for range #2 during zero/span calibration, just before computing new slope and offset	PPB
30	NH3 concentration for range #1 during zero/span calibration, just before computing new slope and offset	PPB
32	NH3 concentration for range #2 during zero/span calibration, just before computing new slope and offset	PPB
34	NO_X concentration for range #1 during zero/span calibration, just before computing new slope and offset	PPB
36	NO_X concentration for range #2 during zero/span calibration, just before computing new slope and offset	PPB
38	NO concentration for range #1 during zero/span calibration, just before computing new slope and offset	PPB
40	NO concentration for range #2 during zero/span calibration, just before computing new slope and offset	PPB
42	NO_2 concentration for range #1 during zero/span calibration, just before computing new slope and offset	PPB
44	NO_2 concentration for range #2 during zero/span calibration, just before computing new slope and offset	PPB
46	TNX concentration for range #1	PPB
48	TNX concentration for range #2	PPB
50	NH3 concentration for range #1	PPB
52	NH3 concentration for range #2	PPB
54	NO_X concentration for range #1	PPB

T201, M201E MODBUS Register Map		
MODBUS Register Address (dec., 0-based)	**Description**	**Units**
56	NO_X concentration for range #2	PPB
58	NO concentration for range #1	PPB
60	NO concentration for range #2	PPB
62	NO_2 concentration for range #1	PPB
64	NO_2 concentration for range #2	PPB
66	Auto zero offset (range de-normalized)	mV
68	Ozone flow rate	cc/m
70	Reaction cell pressure	"Hg
72	Reaction cell temperature	°C
74	Bypass or dilution manifold temperature	°C
76	Orifice block temperature	°C
78	Converter efficiency factor for range #1	—
80	Converter efficiency factor for range #2	—
82	Converter temperature	°C
84	PMT temperature	°C
86	Sample flow rate	cc/m
88	Sample pressure	“Hg
90	Internal box temperature	°C
92	High voltage power supply output	Volts
94	Ground reference (REF_GND)	mV
96	4096 mV reference (REF_4096_MV)	mV
98	Diagnostic test input (TEST_INPUT_11)	mV
100	Diagnostic test input (TEST_INPUT_13)	mV
102	Diagnostic temperature input (TEMP_INPUT_5)	°C
104 [3]	TN concentration for range #1 during zero/span calibration, just before computing new slope and offset	PPB
106 [3]	TN concentration for range #2 during zero/span calibration, just before computing new slope and offset	PPB
108 [3]	TN concentration for range #1	PPB
110 [3]	TN concentration for range #2	PPB
112 [1]	Concentration stability	PPB
130 [5]	External analog input 1 value	Volts
132 [5]	External analog input 1 slope	eng unit /V
134 [5]	External analog input 1 offset	eng unit
136 [5]	External analog input 2 value	Volts
138 [5]	External analog input 2 slope	eng unit /V
140 [5]	External analog input 2 offset	eng unit
142 [5]	External analog input 3 value	Volts
144 [5]	External analog input 3 slope	eng unit /V
146 [5]	External analog input 3 offset	eng unit

T201, M201E MODBUS Register Map		
MODBUS Register Address (dec., 0-based)	**Description**	**Units**
148 [5]	External analog input 4 value	Volts
150 [5]	External analog input 4 slope	eng unit /V
152 [5]	External analog input 4 offset	eng unit
154 [5]	External analog input 5 value	Volts
156 [5]	External analog input 5 slope	eng unit /V
158 [5]	External analog input 5 offset	eng unit
160 [5]	External analog input 6 value	Volts
162 [5]	External analog input 6 slope	eng unit /V
164 [5]	External analog input 6 offset	eng unit
166 [5]	External analog input 7 value	Volts
168 [5]	External analog input 7 slope	eng unit /V
170 [5]	External analog input 7 offset	eng unit
172 [5]	External analog input 8 value	Volts
174 [5]	External analog input 8 slope	eng unit /V
176 [5]	External analog input 8 offset	eng unit
MODBUS Floating Point Holding Registers (32-bit IEEE 754 format; read/write in high-word, low-word order; read/write)		
0	Maps to *TNX_SPAN1* variable; target conc. for range #1	Conc. units
2	Maps to *NOX_SPAN1* variable; target conc. for range #1	Conc. units
4	Maps to *NO_SPAN1* variable; target conc. for range #1	Conc. units
6	Maps to *TNX_SPAN2* variable; target conc. for range #2	Conc. units
8	Maps to *NOX_SPAN2* variable; target conc. for range #2	Conc. units
10	Maps to *NO_SPAN2* variable; target conc. for range #2	Conc. units
MODBUS Discrete Input Registers (single-bit; read-only)		
0	Bypass or dilution manifold temperature warning	
1	Converter temperature warning	
2	Auto-zero warning	
3	Orifice block temperature warning	
4	Box temperature warning	
5	PMT detector warning	
6	Reaction cell temperature warning	
7	Sample flow warning	
8	Ozone flow warning	
9	Reaction cell pressure warning	
10	HVPS warning	
11	System reset warning	
12	Rear board communication warning	
13	Relay board communication warning	
14	Front panel communication warning	
15	Analog calibration warning	

T201, M201E MODBUS Register Map		
MODBUS Register Address (dec., 0-based)	**Description**	**Units**
16	Dynamic zero warning	
17	Dynamic span warning	
18	Invalid concentration	
19	In zero calibration mode	
20	In span calibration mode	
21	In multi-point calibration mode	
22	System is OK (same meaning as *SYSTEM_OK* I/O signal)	
23	Ozone generator warning	
24 [4]	TNX concentration alarm limit #1 exceeded	
25 [4]	TNX concentration alarm limit #2 exceeded	
26 [4]	NH_3 concentration alarm limit #1 exceeded	
27 [4]	NH_3 concentration alarm limit #2 exceeded	
28 [4]	NO_X concentration alarm limit #1 exceeded	
29 [4]	NO_X concentration alarm limit #2 exceeded	
30 [4]	NO concentration alarm limit #1 exceeded	
31 [4]	NO concentration alarm limit #2 exceeded	
32 [4]	NO_2 concentration alarm limit #1 exceeded	
33 [4]	NO_2 concentration alarm limit #2 exceeded	
34 [3+4]	TN concentration alarm limit #1 exceeded	
35 [3+4]	TN concentration alarm limit #2 exceeded	
MODBUS Coil Registers (single-bit; read/write)		
0	Maps to relay output signal 36 (*MB_RELAY_36* in signal I/O list)	
1	Maps to relay output signal 37 (*MB_RELAY_37* in signal I/O list)	
2	Maps to relay output signal 38 (*MB_RELAY_38* in signal I/O list)	
3	Maps to relay output signal 39 (*MB_RELAY_39* in signal I/O list)	
20 [2]	Triggers zero calibration of NO_X range #1 (on enters cal.; off exits cal.)	
21 [2]	Triggers span calibration of NO_X range #1 (on enters cal.; off exits cal.)	
22 [2]	Triggers zero calibration of NO_X range #2 (on enters cal.; off exits cal.)	
23 [2]	Triggers span calibration of NO_X range #2 (on enters cal.; off exits cal.)	
24 [2]	Triggers zero calibration of TNX range #1 (on enters cal.; off exits cal.)	
25 [2]	Triggers span calibration of TNX range #1 (on enters cal.; off exits cal.)	
26 [2]	Triggers zero calibration of TNX range #2 (on enters cal.; off exits cal.)	
27 [2]	Triggers span calibration of TNX range #2 (on enters cal.; off exits cal.)	

[1] Engineering firmware only.
[2] Set *DYN_ZERO* or *DYN_SPAN* variables to *ON* to enable calculating new slope or offset. Otherwise a calibration check is performed.
[3] Optional.
[4] Concentration alarm option.
[5] T-Series external analog input option.

APPENDIX E: T300, M300E MODBUS® Register Maps

Firmware Revisions, T-Series: 1.0.0, E-Series: L.8

T300, M300E MODBUS Register Map		
MODBUS Register Address (dec., 0-based)	**Description**	**Units**
MODBUS Floating Point Input Registers (32-bit IEEE 754 format; read in high-word, low-word order; read-only)		
0	Detector measure reading	mV
2	Detector reference reading	mV
4	M/R ratio.	none
6	Slope for range #1	none
8	Slope for range #2	none
10	Offset for range #1	none
12	Offset for range #2	none
14	Concentration for range #1 during zero/span calibration, just before computing new slope and offset	PPM
16	Concentration for range #2 during zero/span calibration, just before computing new slope and offset	PPM
18	Concentration for range #1	PPM
20	Concentration for range #2	PPM
22	Concentration stability	PPM
24	Bench temperature	°C
26	Bench temperature control duty cycle	Fraction (0.0 = off, 1.0 = on full)
28	Wheel temperature	°C
30	Wheel temperature control duty cycle	Fraction (0.0 = off, 1.0 = on full)
32 [11]	Sample temperature	°C
34	Sample pressure	“Hg
36	Internal box temperature	°C
38	Photometer detector temperature drive	mV
40	Diagnostic test input (TEST_INPUT_7)	mV
42	Diagnostic test input (TEST_INPUT_8)	mV
44	Diagnostic temperature input (TEMP_INPUT_4)	°C
46	Diagnostic temperature input (TEMP_INPUT_5)	°C
48	Ground reference (REF_GND)	mV
50	4096 mV reference (REF_4096_MV)	mV
52 [1]	Purge pressure	PSIG
54 [1]	Sample flow	cc/m
56 [1]	Vacuum pressure	"Hg

T300, M300E MODBUS Register Map		
MODBUS Register Address (dec., 0-based)	**Description**	**Units**
58 [1]	Internal box temperature #2/oven	°C
60 [1]	Internal box temperature #2/oven control duty cycle	Fraction (0.0 = off, 1.0 = on full)
62 [1]	Auto-zero reading	M/R
100 [2]	O_2 concentration	%
102 [2]	O_2 concentration during zero/span calibration, just before computing new slope and offset	%
104 [2]	O_2 slope	—
106 [2]	O_2 offset	%
108 [2]	O_2 sensor cell temperature	°C
130 [10]	External analog input 1 value	Volts
132 [10]	External analog input 1 slope	eng unit /V
134 [10]	External analog input 1 offset	eng unit
136 [10]	External analog input 2 value	Volts
138 [10]	External analog input 2 slope	eng unit /V
140 [10]	External analog input 2 offset	eng unit
142 [10]	External analog input 3 value	Volts
144 [10]	External analog input 3 slope	eng unit /V
146 [10]	External analog input 3 offset	eng unit
148 [10]	External analog input 4 value	Volts
150 [10]	External analog input 4 slope	eng unit /V
152 [10]	External analog input 4 offset	eng unit
154 [10]	External analog input 5 value	Volts
156 [10]	External analog input 5 slope	eng unit /V
158 [10]	External analog input 5 offset	eng unit
160 [10]	External analog input 6 value	Volts
162 [10]	External analog input 6 slope	eng unit /V
164 [10]	External analog input 6 offset	eng unit
166 [10]	External analog input 7 value	Volts
168 [10]	External analog input 7 slope	eng unit /V
170 [10]	External analog input 7 offset	eng unit
172 [10]	External analog input 8 value	Volts
174 [10]	External analog input 8 slope	eng unit /V
176 [10]	External analog input 8 offset	eng unit
200 [3]	CO_2 concentration	%
202 [3]	CO_2 concentration during zero/span calibration, just before computing new slope and offset	%
204 [3]	CO_2 slope	—
206 [3]	CO_2 offset	%

T300, M300E MODBUS Register Map		
MODBUS Register Address (dec., 0-based)	**Description**	**Units**
MODBUS Floating Point Holding Registers (32-bit IEEE 754 format; read/write in high-word, low-word order; read/write)		
0	Maps to *CO_SPAN1* variable; target conc. for range #1	Conc. units
2	Maps to *CO_SPAN2* variable; target conc. for range #2	Conc. units
100 [2]	Maps to *O2_TARG_SPAN_CONC* variable	%
200 [3]	Maps to *CO2_TARG_SPAN_CONC* variable	%
MODBUS Discrete Input Registers (single-bit; read-only)		
0	Source warning	
1	Box temperature warning	
2	Bench temperature warning	
3	Wheel temperature warning	
4 [11]	Sample temperature warning	
5	Sample pressure warning	
6	Photometer detector temperature warning	
7	System reset warning	
8	Rear board communication warning	
9	Relay board communication warning	
10	Front panel communication warning	
11	Analog calibration warning	
12	Dynamic zero warning	
13	Dynamic span warning	
14	Invalid concentration	
15	In zero calibration mode	
16	In span calibration mode	
17	In multi-point calibration mode	
18	System is OK (same meaning as *SYSTEM_OK* I/O signal)	
19 [1]	Purge pressure warning	
20 [1]	Sample flow warning	
21 [1]	Internal box temperature #2/oven warning	
22 [1]	Concentration limit 1 exceeded	
23 [1]	Concentration limit 2 exceeded	
24 [1]	Auto-zero warning	
25 [1]	Sync warning	
26 [1]	In Hessen manual mode	
100 [2]	In O_2 calibration mode	
101 [2]	O_2 cell temperature warning	
102 [1,2]	O_2 concentration limit 1 exceeded	
103 [1,2]	O_2 concentration limit 2 exceeded	
200 [3]	In CO_2 calibration mode	

T300, M300E MODBUS Register Map		
MODBUS Register Address (dec., 0-based)	**Description**	**Units**
201 [1,3]	CO_2 concentration limit 1 exceeded	
202 [1,3]	CO_2 concentration limit 2 exceeded	
MODBUS Coil Registers (single-bit; read/write)		
0	Maps to relay output signal 36 (*MB_RELAY_36* in signal I/O list)	
1	Maps to relay output signal 37 (*MB_RELAY_37* in signal I/O list)	
2	Maps to relay output signal 38 (*MB_RELAY_38* in signal I/O list)	
3	Maps to relay output signal 39 (*MB_RELAY_39* in signal I/O list)	
20 [4]	Triggers zero calibration of range #1 (on enters cal.; off exits cal.)	
21 [4]	Triggers span calibration of range #1 (on enters cal.; off exits cal.)	
22 [4]	Triggers zero calibration of range #2 (on enters cal.; off exits cal.)	
23 [4]	Triggers span calibration of range #2 (on enters cal.; off exits cal.)	

[1] Optional
[2] O_2 option
[3] CO_2 option
[4] Set *DYN_ZERO* or *DYN_SPAN* variables to *ON* to enable calculating new slope or offset. Otherwise a calibration check is performed.
[10] T-Series external analog input option.
[11] Except T300U2, T320U, M300EU2 and M320EU configurations.

APPENDIX F: T400, M400E MODBUS® Register Maps

Firmware Revisions, T-Series: 1.0.0, E-Series: E.3

T400, M400E MODBUS Register Map		
MODBUS Register Address (dec., 0-based)	**Description**	**Units**
MODBUS Floating Point Input Registers (32-bit IEEE 754 format; read in high-word, low-word order; read-only)		
0	Photometer detector measure reading	mV
2	Photometer detector reference reading	mV
4	Photometer lamp stability	%
6	Slope for range #1	—
8	Slope for range #2	—
10	Offset for range #1	PPB
12	Offset for range #2	PPB
14	Concentration for range #1 during zero/span calibration, just before computing new slope and offset	PPB
16	Concentration for range #2 during zero/span calibration, just before computing new slope and offset	PPB
18	Concentration for range #1	PPB
20	Concentration for range #2	PPB
22	Concentration stability	PPB
24	Ozone generator reference detector reading	mV
26	Ozone generator lamp drive	mV
28	Ozone generator lamp temperature	°C
30	Ozone scrubber temperature	°C
32	Ozone scrubber temperature duty cycle	Fraction (1.0 = 100%)
34	Photometer lamp temperature	°C
36	Photometer lamp temperature duty cycle	Fraction (1.0 = 100%)
38	Sample temperature	°C
40	Sample flow rate	cc/m
42	Sample pressure	Inches Hg
44	Internal box temperature	°C
46	Diagnostic test input (TEST_INPUT_7)	mV
48	Diagnostic test input (TEST_INPUT_8)	mV
50	Diagnostic temperature input (TEMP_INPUT_6)	°C
52	Diagnostic temperature input (TEMP_INPUT_7)	°C
54	Ground reference	mV
56	Precision 4.096 mV reference	mV
130 [10]	External analog input 1 value	Volts
132 [10]	External analog input 1 slope	eng unit /V

T400, M400E MODBUS Register Map		
MODBUS Register Address (dec., 0-based)	**Description**	**Units**
134 [10]	External analog input 1 offset	eng unit
136 [10]	External analog input 2 value	Volts
138 [10]	External analog input 2 slope	eng unit /V
140 [10]	External analog input 2 offset	eng unit
142 [10]	External analog input 3 value	Volts
144 [10]	External analog input 3 slope	eng unit /V
146 [10]	External analog input 3 offset	eng unit
148 [10]	External analog input 4 value	Volts
150 [10]	External analog input 4 slope	eng unit /V
152 [10]	External analog input 4 offset	eng unit
154 [10]	External analog input 5 value	Volts
156 [10]	External analog input 5 slope	eng unit /V
158 [10]	External analog input 5 offset	eng unit
160 [10]	External analog input 6 value	Volts
162 [10]	External analog input 6 slope	eng unit /V
164 [10]	External analog input 6 offset	eng unit
166 [10]	External analog input 7 value	Volts
168 [10]	External analog input 7 slope	eng unit /V
170 [10]	External analog input 7 offset	eng unit
172 [10]	External analog input 8 value	Volts
174 [10]	External analog input 8 slope	eng unit /V
176 [10]	External analog input 8 offset	eng unit
MODBUS Floating Point Holding Registers (32-bit IEEE 754 format; read/write in high-word, low-word order; read/write)		
0	Maps to *O3_TARG_ZERO1* variable; target zero concentration for range #1	Conc. units
2	Maps to *O3_SPAN1* variable; target span concentration for range #1	Conc. units
4	Maps to *O3_TARG_ZERO2* variable; target zero concentration for range #2	Conc. units
6	Maps to *O3_SPAN2* variable; target span concentration for range #2	Conc. units
MODBUS Discrete Input Registers (single-bit; read-only)		
0	O_3 generator reference detector warning	
1	O_3 generator lamp intensity warning	
2	O_3 generator lamp temperature warning	
3	O_3 scrubber temperature warning	
4	Photometer reference warning	
5	Photometer lamp stability warning	
6	Photometer lamp temperature warning	
7	Box temperature warning	

T400, M400E MODBUS Register Map		
MODBUS Register Address (dec., 0-based)	**Description**	**Units**
8	Sample temperature warning	
9	Sample flow warning	
10	Sample pressure warning	
11	System reset warning	
12	Rear board communication warning	
13	Relay board communication warning	
14	O_3 generator or photometer lamp I^2C driver chip communication warning	
15	Front panel communication warning	
16	Analog calibration warning	
17	Dynamic zero warning	
18	Dynamic span warning	
19	Invalid concentration	
20	In zero calibration mode	
21	In low span calibration mode	
22	In span calibration mode	
23	In multi-point calibration mode	
24	System is OK (same meaning as *SYSTEM_OK* I/O signal)	
25 [3]	O_3 concentration alarm limit #1 exceeded	
26 [3]	O_3 concentration alarm limit #2 exceeded	
MODBUS Coil Registers (single-bit; read/write)		
0	Maps to relay output signal 36 (*MB_RELAY_36* in signal I/O list)	
1	Maps to relay output signal 37 (*MB_RELAY_37* in signal I/O list)	
2	Maps to relay output signal 38 (*MB_RELAY_38* in signal I/O list)	
3	Maps to relay output signal 39 (*MB_RELAY_39* in signal I/O list)	
20 [1]	Triggers zero calibration of O_3 range #1 (on enters cal.; off exits cal.)	
21 [2]	Triggers low span calibration of O_3 range #1 (on enters cal.; off exits cal.)	
22 [1]	Triggers span calibration of O_3 range #1 (on enters cal.; off exits cal.)	
23 [1]	Triggers zero calibration of O_3 range #2 (on enters cal.; off exits cal.)	
24 [2]	Triggers low span calibration of O_3 range #2 (on enters cal.; off exits cal.)	
25 [1]	Triggers span calibration of O_3 range #2 (on enters cal.; off exits cal.)	

[1] Set *DYN_ZERO* or *DYN_SPAN* variables to *ON* to enable calculating new slope or offset. Otherwise a calibration check is performed.

[2] O_3 generator or zero/span valve factory options must be enabled.

[3] Concentration alarm option.

[10] T-Series external analog input option.

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APPENDIX G: T700, M700E MODBUS® Register Maps

Firmware Revisions, T-Series: 1.0.0, E-Series: D.3

T700, M700E MODBUS Register Map		
MODBUS Register Address (dec., 0-based)	**Description**	**Units**
MODBUS Floating Point Input Registers (32-bit IEEE 754 format; read in high-word, low-word order; read-only)		
0	Actual cal. gas flow rate	LPM
2	Actual diluent flow rate	LPM
4	Photometer measured ozone concentration	PPB
6	Ozone generator reference detector reading	mV
8	Ozone generator flow rate	LPM
10	Ozone generator lamp drive	mV
12	Ozone generator lamp temperature	°C
14	Cal. gas pressure	PSIG
16	Diluent pressure	PSIG
18	Regulator pressure	PSIG
20	Internal box temperature	°C
22	Permeation tube #1 temperature [3]	°C
24	Permeation tube flow rate [3]	LPM
26	Photometer detector measure reading	mV
28	Photometer detector reference reading	mV
30	Photometer sample flow rate	LPM
32	Photometer lamp temperature	°C
34	Photometer sample pressure	Inches Hg
36	Photometer sample temperature	°C
38	Photometer slope computed during zero/span bench calibration	—
40	Photometer offset computed during zero/span bench calibration	PPB
42	Ground reference	mV
44	Precision 4.096 mV reference	mV
46	Permeation tube #2 temperature [1]	°C
48	Ozone Gen Fraction [2]	—
MODBUS Discrete Input Registers (single-bit; read-only)		
0	System reset warning	
1	Box temperature warning	
2	Photometer lamp temperature warning	
3	O_3 generator lamp temperature warning	
4	Permeation tube #1 temperature warning [3]	
5	Photometer reference warning	
6	Photometer lamp stability warning	

T700, M700E MODBUS Register Map		
MODBUS Register Address (dec., 0-based)	**Description**	**Units**
7	O_3 generator reference detector warning	
8	Regulator pressure warning	
9	Any MFC pressure outside of warning limits	
10	Any MFC drive less than 10% of full scale or greater than full scale	
11	Any MFC sensor offset greater than allowable limit	
12	Rear board communication warning	
13	Relay board communication warning	
14	Valve board communication warning	
15	O_3 generator or photometer lamp I^2C driver chip communication warning	
16	Front panel communication warning	
17	Firmware is unable to communicate with any MFC	
18	Analog calibration warning	
19	System is OK (same meaning as *SYSTEM_OK* I/O signal)	
20	O_3 generator not yet stabilized	
21	Permeation tube #2 temperature warning [1]	
MODBUS Coil Registers (single-bit; read/write)		
00-99	Trigger execution of sequence whose name begins with “00” - “99”. Turning a coil on executes a sequence. Turning a coil off does nothing. When reading coils, the value indicates which sequence is executing. If a coil is on, the sequence is executing; if off the sequence is not executing. Supports nested sequences, so multiple sequence coils may be on simultaneously.	
100	Turning coil on turns on purge. Turning coil off does nothing. When reading coil, the value indicates whether purge is active. If on, purge is active; if off, purge is not active. Purge may be invoked within a sequence, so purge coil may be on at the same time as a sequence coil.	
101	Turning coil on puts instrument in standby. Turning coil off does nothing. When reading coil, the value indicates whether instrument is in standby mode. If on, instrument is in standby; if off, instrument is not in standby.	
200-211	Connected to the control outputs (CONTROL_OUT_1– CONTROL_OUT_12). These coils may be turned both on and off. Reading the coils indicates the current state.	

[1] Dual permeation tube option.
[2] Low range option.
[3] Permeation tube option.

APPENDIX H: T80X, M80XE MODBUS® Register Maps

Firmware Revisions, T-Series: 1.0.0, E-Series: A.2

T80X, M80XE MODBUS Register Map		
MODBUS Register Address (dec., 0-based)	**Description**	**Units**
MODBUS Floating Point Input Registers (32-bit IEEE 754 format; read in high-word, low-word order; read-only)		
0 [4]	O_2 slope for range 1	—
2 [6]	O_2 slope for range 2	—
4 [4]	O_2 offset for range 1	%
6 [6]	O_2 offset for range 2	%
8 [4]	O_2 concentration for range 1 during zero/span calibration, just before computing new slope and offset	%
10 [6]	O_2 concentration for range 2 during zero/span calibration, just before computing new slope and offset	%
12 [4]	O_2 concentration for range 1	%
14 [6]	O_2 concentration for range 2	%
16 [4]	O_2 sensor cell temperature	°C
18 [4]	O_2 sensor cell temperature control duty cycle	Fraction
20	Concentration stability	%
22	Sample flow	cc/m
24	Sample pressure	“Hg
26	Internal box temperature	°C
28	Ground reference (REF_GND)	mV
30	4096 mV reference (REF_4096_MV)	mV
100 [1]	CO_2 slope for range 1	—
102 [5]	CO_2 slope for range 2	—
104 [1]	CO_2 offset for range 1	%
106 [5]	CO_2 offset for range 2	%
108 [1]	CO_2 concentration for range 1 during zero/span calibration, just before computing new slope and offset	%
110 [5]	CO_2 concentration for range 2 during zero/span calibration, just before computing new slope and offset	%
112 [1]	CO_2 concentration for range 1	%
114 [5]	CO_2 concentration for range 2	%
116 [1]	CO_2 sensor cell temperature	°C
118 [1]	CO_2 sensor cell temperature control duty cycle	Fraction
130 [7]	External analog input 1 value	Volts
132 [7]	External analog input 1 slope	eng unit /V
134 [7]	External analog input 1 offset	eng unit
136 [7]	External analog input 2 value	Volts
138 [7]	External analog input 2 slope	eng unit /V

T80X, M80XE MODBUS Register Map		
MODBUS Register Address (dec., 0-based)	**Description**	**Units**
140 [7]	External analog input 2 offset	eng unit
142 [7]	External analog input 3 value	Volts
144 [7]	External analog input 3 slope	eng unit /V
146 [7]	External analog input 3 offset	eng unit
148 [7]	External analog input 4 value	Volts
150 [7]	External analog input 4 slope	eng unit /V
152 [7]	External analog input 4 offset	eng unit
154 [7]	External analog input 5 value	Volts
156 [7]	External analog input 5 slope	eng unit /V
158 [7]	External analog input 5 offset	eng unit
160 [7]	External analog input 6 value	Volts
162 [7]	External analog input 6 slope	eng unit /V
164 [7]	External analog input 6 offset	eng unit
166 [7]	External analog input 7 value	Volts
168 [7]	External analog input 7 slope	eng unit /V
170 [7]	External analog input 7 offset	eng unit
172 [7]	External analog input 8 value	Volts
174 [7]	External analog input 8 slope	eng unit /V
176 [7]	External analog input 8 offset	eng unit
MODBUS Floating Point Holding Registers (32-bit IEEE 754 format; read/write in high-word, low-word order; read/write)		
0 [4]	Maps to *O2_TARG_SPAN1* variable; target conc. for range 1	%
2 [6]	Maps to *O2_TARG_SPAN2* variable; target conc. for range 2	%
100 [1]	Maps to *CO2_TARG_SPAN1* variable; target conc. for range 1	%
102 [5]	Maps to *CO2_TARG_SPAN2* variable; target conc. for range 2	%
MODBUS Discrete Input Registers (single-bit; read-only)		
0	Box temperature warning	
1 [4]	O_2 cell temperature warning	
2	Sample flow warning	
3	Sample pressure warning	
4	System reset warning	
5	Rear board communication warning	
6	Relay board communication warning	
7	Front panel communication warning	
8	Analog calibration warning	
9	Dynamic zero warning	
10	Dynamic span warning	
11	Invalid concentration	

T80X, M80XE MODBUS Register Map		
MODBUS Register Address (dec., 0-based)	**Description**	**Units**
12 [4]	In O_2 zero calibration mode	
13 [4]	In O_2 span calibration mode	
14 [4]	In O_2 multi-point calibration mode	
15	System is OK (same meaning as *SYSTEM_OK* I/O signal)	
16	O_2 concentration alarm limit #1 exceeded	
17	O_2 concentration alarm limit #2 exceeded	
18	In Hessen manual mode	
100 [1]	CO_2 cell temperature warning	
101 [1]	In CO_2 zero calibration mode	
102 [1]	In CO_2 span calibration mode	
103 [1]	In CO_2 multi-point calibration mode	
104 [1]	CO_2 concentration alarm limit #1 exceeded	
105 [1]	CO_2 concentration alarm limit #2 exceeded	
MODBUS Coil Registers (single-bit; read/write)		
0	Maps to relay output signal 36 (*MB_RELAY_36* in signal I/O list)	
1	Maps to relay output signal 37 (*MB_RELAY_37* in signal I/O list)	
2	Maps to relay output signal 38 (*MB_RELAY_38* in signal I/O list)	
3	Maps to relay output signal 39 (*MB_RELAY_39* in signal I/O list)	
20 [3,4]	Triggers O_2 zero calibration of range 1 (on enters cal.; off exits cal.)	
21 [3,4]	Triggers O_2 span calibration of range 1 (on enters cal.; off exits cal.)	
22 [6,4]	Triggers O_2 zero calibration of range 2 (on enters cal.; off exits cal.)	
23 [6,4]	Triggers O_2 span calibration of range 2 (on enters cal.; off exits cal.)	
24 [1,3]	Triggers CO_2 zero calibration of range 1 (on enters cal.; off exits cal.)	
25 [1,3]	Triggers CO_2 span calibration of range 1 (on enters cal.; off exits cal.)	
26 [5,3]	Triggers CO_2 zero calibration of range 2 (on enters cal.; off exits cal.)	
27 [5,3]	Triggers CO_2 span calibration of range 2 (on enters cal.; off exits cal.)	

1 T801, T803, T802 with CO_2 option, M801E, M803E or M802E with CO_2 option.
2 future.
3 Set *DYN_ZERO* or *DYN_SPAN* variables to *ON* to enable calculating new slope or offset. Otherwise a calibration check is performed.
4 T802, T803, M802E or M803E.
5 T801, T803, M801E or M803E.
6 T802 or M802E only.
7 T-Series external analog input option.