Analyze^{IT}

AO2000 Modbus and AO-MDDE

Technical Information

30/24-316 EN Rev. 1

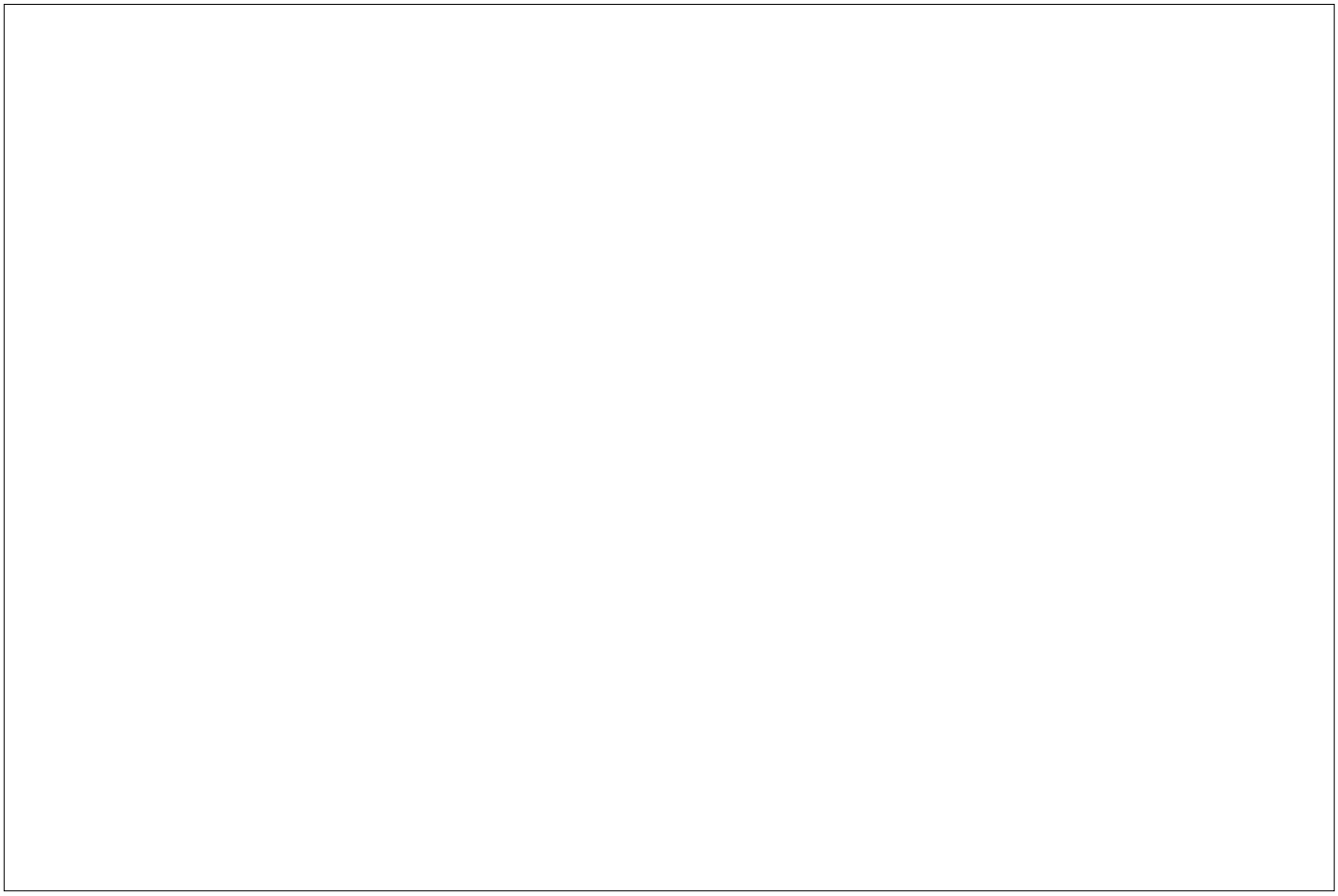

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ABB

Contents

Chapter 1 AO2000 Modbus

Description

Application

Information from the AO2000 gas analyzer can be transferred to a PC or DCS via the Modbus. Measurement values, status signals and also signals of analog and digital inputs and outputs are thus available for further usage.

Using the AO-MDDE server the signals can be integrated into standard software (e.g. Excel, Visual Basic or LabVIEW). For further information, see Chapter 3 “AO-MDDE Server and Demo Programs”, page 21.

AO-MDDE can be downloaded from the CD-ROM which is delivered together with each gas analyzer.

Modbus Slave Protocol with RTU Mode

This Technical Information is based on the Gould Modbus Protocol Reference Guide (January, 1985). The AO2000 gas analyzers support the Modbus slave protocol with RTU (Remote Terminal Unit) mode.

Interfaces and Connection Versions

The RS232 and the RS485 interface located on the RS232/RS485 module in AO2000 are supported, where only one can be operated at a time. Connection versions are described in Chapter 2 “Setting Modbus Parameters and Connection”, page 15.

Transferred Data	Read	Write	Example
Measurement Values	x	–	CO, NO, H_2, etc.
Analog Inputs	x	–	Indication of mA-values of external analyzers
Analog Outputs	x	–	Indication of mA-values of measurement values or calculated values (function block application)
Digital Inputs	x	–	Indication of external status signals
Digital Outputs	x	–	Measurement range feedback, indication of solenoid or pump controls
Bus Analog Inputs	x	x	Entering analog values into the function block application
Bus Analog Outputs	x	–	Outputting analog values from the function block application
Bus Digital Inputs	x	x	Control of functions such as auto calibration, measuring range control, etc. after function block configuration
Bus Digital Outputs	x	–	Indication of all functions integrated by function block configuration such as alarm signaling etc.
Modbus Configuration	x	–	Indication how many components, AOs, DOs, etc. have been configured or are in the gas analyzer
Status Signals	x	–	Indication of failure, maintenance mode, maintenance request

Modbus Frames and Functions

Data Transfer

For data transfer a combination of frames is used, that consists of 1/0 information, united to one or more telegrams.

Frame

The transfer values are decomposed in bytes (= 8 bit). Each of these bytes is completed by one start-bit, possibly one parity-bit (even number of “1”) and one stop-bit. In the following description the term “byte” will be used, even if ten or eleven bits will be transferred including the start-, stop- and parity-bits.

Telegrams

The Modbus telegrams consist of the following frames:
address (1 byte), function (1 byte), data (n bytes) and check sum (2 bytes).

The telegrams also take on the “shake-hands-function”: each telegram from master to slave must be responded, before a new telegram is allowed to be transmitted. The computer has to have in a adequate supervision, for excluding non answering bus participants (time-out-supervision).

Admissible Addresses

As addresses for the participants of the bus the numbers 1...255 are admitted.

The address 0 is the global address (broadcast-address). When this address will be used in a telegram, all participants accept this telegram without an acknowledgment to the master.

Functions

Code	Term	Function
01	Read coil status	Reading of binary values of type coil
02	Read input status	Reading of binary values of type status
03	Read holding registers	Reading of 16 bit holding-registers
04	Read input registers	Reading of 16 bit input-registers
05	Force single coil	Setting of a single binary value
06	Preset single register	Set of a single 16 bit-register; for DINT or REAL two telegrams are necessary
08	Loopback diagnostic test	Testing telegram for diagnostics of the communication capability of slave
15	Force multiple coils	Set of several successive binary values
16	Preset multiple registers	Set of several successive 16 bit-registers

Check Sum

The check sum is calculated over all bytes of one telegram without the start-, stop- and parity-bits.

Transfer Rules

The neutral position of the data line corresponds with the logical “1”.

A distance of more than 3.5 bytes, however at least 10 ms is defined as separation between two telegrams. For the beginning of the data transfer the neutral position of the data line must be observed.

IEEE 754-Format

Modbus-Protocol and IEEE 754-Format

The Modbus-protocol allows only 16-bit-registers as transfer values. Some of the AO2000 data is stored in the IEEE 754-Format (32 bit). For this reason the data must be processed by the interrogating device..

Construction of IEEE 754-Format

Term	Number of Bits	Meaning
S	1	Sign bit; explains the sign (0 = positive, 1 = negative)
E	8	Two's complement exponent. The true value is the exponent minus 127.
M	23	The "most significant bit" of the normalized mantissa before the decimal point is implicitly 1, but is not stored. The value range is also between 1.0 (included) and 2.0.

Example

The number –12.5 is stored as the hexadecimal value 0xC1480000. The following table shows the storage configuration:

Address	+0	+1	+2	+3
format	SEEEEEEE	EMMMMMMM	MMMMMMMM	MMMMMMMM
binary	11000001	01001000	00000000	00000000
hexadecimal	C1	48	00	00

Explanations

- The sign bit is 1, i.e. the value is negative.
- The exponent is 10000010 binary, which corresponds to the decimal value 130. Subtracting 127 from 130 leaves 3, which is the actual exponent.
- The stored mantissa value is 10010000000000000000000. Adding the non stored 1 before the decimal point gives the value 1.10010000000000000000000.
- After adjusting the mantissa to the exponent (moving it three places) the result is 1100.10000000000000000000. This binary number corresponds to the decimal value 12.5. Finally the sign bit needs to be taken into account. This makes the final value of –12.5.

Modbus Addresses and Data Format

Principle

The AO2000 series gas analyzers are modular and very flexible. A gas analyzer can consist of one or more analyzer modules which in itself can measure one or more components. It is also possible to connect different kinds of I/O-modules and I/O-boards to a device. For this reason the Modbus addressing schema is not static.

Data Format

There are five flexible groups, four configurable groups and two fixed length groups of information defined in a AO2000 gas analyzer.

The grouped information can be read through “Single Modbus Request”.

Flexible Groups

The flexible groups are:

- Measurement Values (see page 8)
- Analog Inputs (see page 8)
- Analog Outputs (see page 9)
- Digital Inputs (see page 9)
- Digital Output (see page 10)

Each flexible group has a fixed start address and a variable length of elements – depending on the system layout.

Configurable Groups

The configurable groups are:

- Bus Analog Inputs (see page 10)
- Bus Analog Outputs (see page 11)
- Bus Digital Inputs (see page 11)
- Bus Digital Outputs (see page 11)

Each configurable group has a start address and, depending on the user configuration, a variable number of elements.

Fixed Length Groups

The fixed length groups are:

- Configuration display (see page 12)
- Status (see page 12)

Continued on next page

Measurement Values

The measurement values are transmitted in the IEEE 32 bit standard floating point format. The floating point format is not a part of the Modbus specification. AO2000 devices use two word registers to represent a floating point value (high word, low word).

Modicon Modbus Address	Type	Register Number	Description/Name
30001	Input register	0	Measurement Component 1
30002		1	
30003	Input register	2	Measurement Component 2
30004		3	
30005	Input register	4	Measurement Component 3
30006		5	
30007	Input register	6	Measurement Component 4
30008		7	
30009	Input register	8	Measurement Component 5
30010		9	
30011	Input register	10	Measurement Component 6
30012		11	
			etc.

Analog Inputs

Analog inputs (AI) are transmitted in the IEEE 32 bit standard floating point format. The floating point format is not a part of the Modbus specification. AO2000 devices use two word registers to represent a floating point value (high word, low word).

Modicon Modbus Address	Type	Register Number	Description/Name
30100	Input register	99	Analog Input 1 V-in
30101		100	
30102	Input register	101	Analog Input 1 I-in
30103		102	
30104	Input register	103	Analog Input 2 V-in
30105		104	
30106	Input register	105	Analog Input 2 I-in
30107		106	
30108	Input register	107	Analog Input 3 V-in
30109		108	
30110	Input register	109	Analog Input 3 I-in
30111		110	
30112	Input register	111	Analog Input 4 V-in
30113		112	
30114	Input register	113	Analog Input 4 I-in
30115		114	
			etc.

Continued on next page

Analog Outputs

Analog outputs (AO) are transmitted in the IEEE 32 bit standard floating point format. The floating point format is not a part of the Modbus specification. AO2000 devices use two word registers to represent a floating point value (high word, low word).

Modicon Modbus Address	Type	Register Number	Description/Name
30300	Input register	299	Analog Output 1
30301		300	
30302	Input register	301	Analog Output 2
30303		302	
30304	Input register	303	Analog Output 3
30305		304	
30306	Input register	305	Analog Output 4
30307		306	
30308	Input register	307	Analog Output 5
30309		308	
30310	Input register	309	Analog Output 6
30311		310	
30312	Input register	311	Analog Output 7
30313		312	
30314	Input register	313	Analog Output 8
30315		314	
			etc.

Digital Inputs

The Modbus master has only read access to digital input values (DI).

Modicon Modbus Address	Type	Input Number	Description/Name
10016	input status	15	Syscon DI purge
10017	input status	16	Digital Input 1
10018	input status	17	Digital Input 2
10019	input status	18	Digital Input 3
10020	input status	19	Digital Input 4
10021	input status	20	Digital Input 5
10022	input status	21	Digital Input 6
10023	input status	22	Digital Input 7
10024	input status	23	Digital Input 8
			etc.

Continued on next page

Digital Outputs

The Modbus master has only read access to digital output values (DO).

Modicon Modbus Address	Type	Input Number	Description/Name
11036	input status	1035	Digital Output 1
11037	input status	1036	Digital Output 2
11038	input status	1037	Digital Output 3
11039	input status	1038	Digital Output 4
11040	input status	1039	Digital Output 5
11041	input status	1040	Digital Output 6
11042	input status	1041	Digital Output 7
11043	input status	1042	Digital Output 8
			etc.

Bus Analog Inputs

Bus analog inputs (Bus AI) are transmitted in the IEEE 32 bit standard floating point format. The floating point format is not a part of the Modbus specification. AO2000 devices use two word registers to represent a floating point value (high word, low word).

Bus AIs can be read and written by the Modbus Master. They can be used like physical ("real") AIs when configuring function blocks [1)]. The Master has access to the configured variables (holding register) and uses function code 3 to read them. Due to the 32-bit register, the variables can only be written using function code 16. A maximum of 50 Bus AIs can be configured.

A waiting period of 250 msec per analog input should be observed after writing the Bus AIs.

Modicon Modbus Address	Type	Register Number	Description/Name
40001	Holding Register	0	Bus AI 1
40002		1	
40003	Holding Register	2	Bus AI 2
40004		3	
...	Holding Register	...	Bus AI ...
40099	Holding Register	98	Bus AI 50
40100		99	

1) Detailed information on function block configuration can be found in the AO2000 Continuous Gas Analyzers operator's manual.

Continued on next page

Bus Analog Outputs

Bus analog outputs (Bus AO) are transmitted in the IEEE 32 bit standard floating point format. The floating point format is not a part of the Modbus specification. AO2000 devices use two word registers to represent a floating point value (high word, low word).

Bus AOs can be used like physical ("real") AOs when configuring function blocks. A maximum of 50 Bus AOs can be configured.

Modicon Modbus Address	Type	Register Number	Description/Name
30600	Input register	599	Bus AO 1
30601		600	
30602	Input register	601	Bus AO 2
30603		602	
...	Input register	...	Bus AO ...
30698	Input register	697	Bus AO 50
30699		698	

Bus Digital Inputs

Bus digital inputs (Bus DI) are bit variables in the gas analyzer. The Modbus master has read and write access to these variables.

Bus DIs can be used like physical ("real") DIs when configuring function blocks. The master has access to all configured variables and uses function code 1 to read and 5 or 15 to write the variables. A maximum of 50 Bus DIs can be configured.

Modicon Modbus Address	Type	Coil Number	Description/Name
1	Coil status	0	Bus DI 1
2	Coil status	1	Bus DI 2
3	Coil status	2	Bus DI 3
...	Coil status	...	Bus DI ...
50	Coil status	49	Bus DI 50

Bus Digital Outputs

Bus digital outputs (Bus DO) are bit variables in the gas analyzer which can only be read by the Modbus master.

Bus DOs can be used like physical ("real") DOs when configuring function blocks. A maximum of 50 Bus DOs can be configured.

Modicon Modbus Address	Type	Input Number	Description/Name
12060	input status	2059	Modbus DO 1
12061	input status	2060	Modbus DO 2
12062	input status	2061	Modbus DO 3
...	input status	...	Modbus DO ...
12109	input status	2108	Modbus DO 50

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Configuration

The Modbus has read access to the configuration register. By means of the this register, a Master can determine how many components, AIs, AOs, etc. have been installed in the gas analyzer. The data are represented as 16-bit integers.

Modicon Modbus Address	Type	Register Number	Description/Name
30500	input register	499	Number of components
30501	input register	500	Number of AIs
30502	input register	501	Number of AOs
30503	input register	502	Number of DIs
30504	input register	503	Number of DOs
30505	input register	504	Number of Modbus AIs
30506	input register	505	Number of Modbus AOs
30507	input register	506	Number of Modbus DIs
30508	input register	507	Number of Modbus DOs

Status

The Modbus has read access to the three status values.

Modicon Modbus Address	Type	Input Number	Description/Name
10001	input status	0	Failure
10002	input status	1	Maintenance Mode
10003	input status	2	Maintenance Request

Modbus Address Assignment

Assigning Input and Output Signals to Modbus Addresses

The assignment of input and output signals to Modbus addresses depends on
- the number of input and output signals available on the I/O modules and I/O boards in the gas analyzer and
- the sequence in which the I/O modules and I/O boards have been registered in the gas analyzer.

All existing inputs and outputs are mapped to the Modbus irrespective of their assignment to signals.

Note: The Modbus address assignment does not depend on the slot on which the I/O modules and I/O boards are installed.

Procedure

In principle proceed as follows to assign input and output signals to Modbus addresses:

Step	Action
1	Determine the sequence of the I/O modules and I/O boards.
2	Determine the respective numbers of the input and output signals.
3	Assign input and output signals to Modbus addresses.

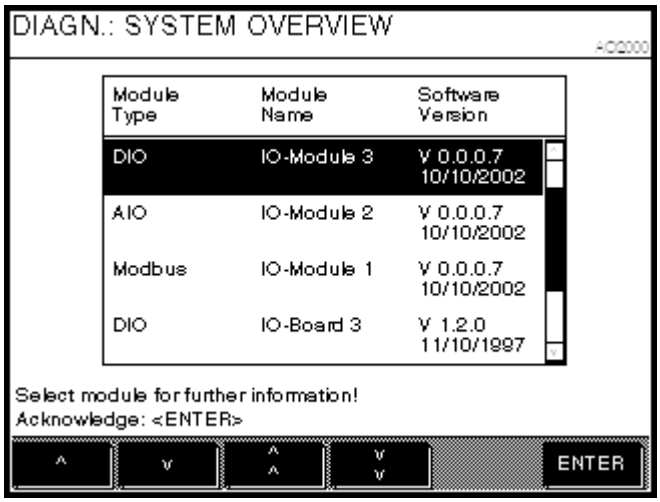
Step 1: Determine the Sequence of the I/O Modules and I/O Boards.

Use the system overview menu item to determine the sequence in which the I/O modules and I/O boards have been registered in the gas analyzer (see Fig. 1).

Menu path: **MENU → Diagnostic/Information → System overview**

Figure 1

System Overview (Example)



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Step 2:
Determine the Numbers of the Input and Output Signals

The numbers of the input and output signals can be obtained from the digital and analog input and output function block lists.

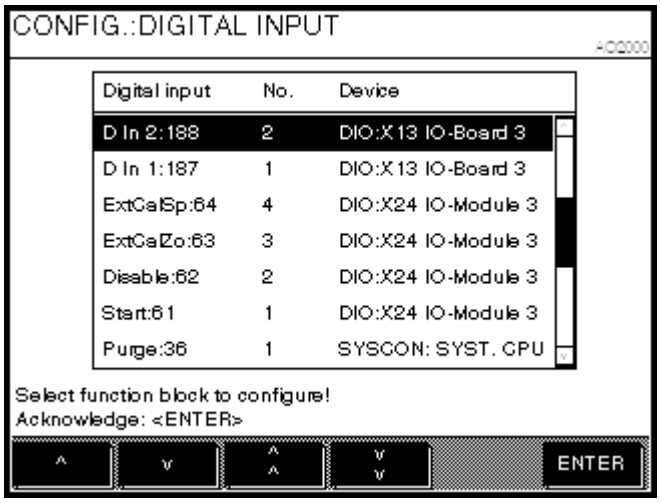
Menu path (example, see also Fig. 2): **MENU → Configure → Function blocks → Inputs → Digital input**

The inputs and outputs are listed in the registration sequence from the bottom up. Enumerate the list accordingly from the bottom up to determine the number of an input or output signal.

In the example shown in Fig. 2, digital input 2 on digital I/O board 3 has the consecutive number 7.

Figure 2

Digital Input Function Blocks
(Example)



Step 3:
Assign Input and Output Signals to Modbus Addresses

Assign the number determined in step 2 to a Modbus address in that Modbus address list which corresponds to the input or output signal type. Enumerate this list top down to determine the address.

In the digital input address list (see page 9), Modbus address 10022 is assigned to number 7 determined in the above example.

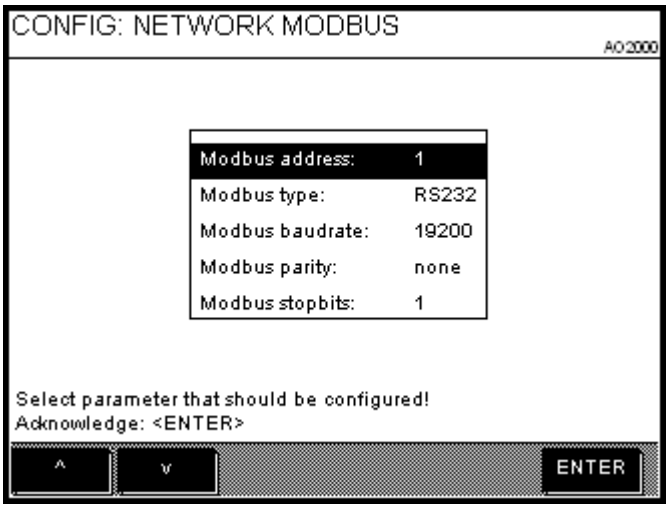
Modbus Parameters

Menu Path

`MENU → Configure → System → Network → Modbus`

Figure 3

Modbus Configuration in AO2000



Function

The gas analyzer can be connected to a network with Modbus protocol via the RS232 or the RS485 interface.

The RS232/RS485 module must be installed in the gas analyzer. Only then the `Modbus` menu item is displayed.

Parameters

The `Modbus address` can be set in the 1-255 range.

For `Modbus type`, select the interface which connects the gas analyzer to the Modbus network (RS232 or RS485).

The data transfer default settings are shown in Figure 3.

Request interval

The request response of AO2000 is < 500 ms. Therefore the times for the time-out-supervision in the master should be > 500 ms (recommendation: 1 s). Between two faultless requests a minimum waiting time of ≥ 100 ms need be to kept.

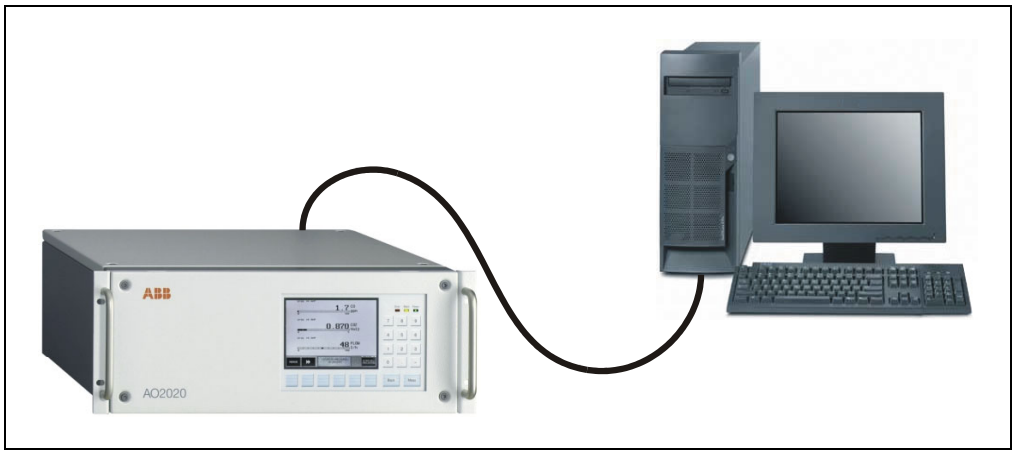
Connection via the RS232 Interface

Connecting

Connect the Modbus master to the RS232 interface of the gas analyzer. This connection only provides a point to point access (e.g. AO2000 and a PC, see Fig. 4).

Figure 4

Connection via the RS232 Interface

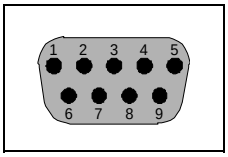


Materials Needed

A cable with two 9-pin female Sub-D connectors, pins 2 and 3 twisted pair, is needed for connecting.

Figure 5

Pin Configuration of the AO2000 RS232 Interface



2 RxD
3 TxD
5 GND

Type: 9-pin male Sub-D connector

Connection via the RS485 Interface

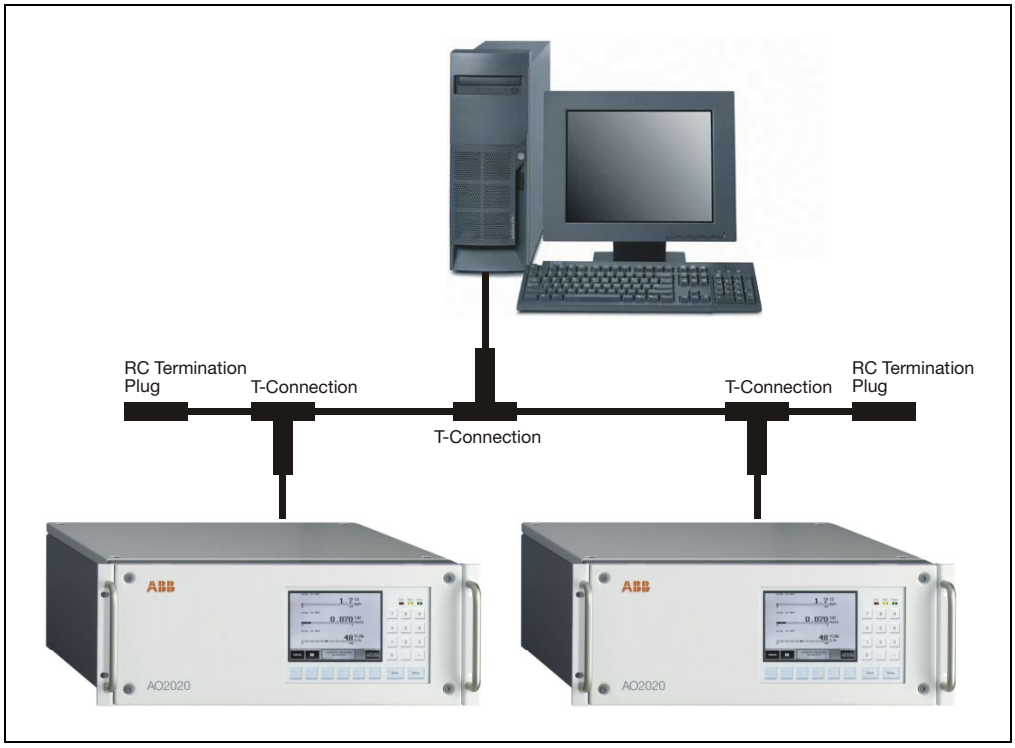
Connecting

In a network up to 32 gas analyzers may be connected to a PC via the RS485 interface.

The network uses a bus topology which needs to be terminated via a RC termination plugs (see Figure 6). This is also true for a point to point connection.

Figure 6

Connection via the RS485 Interface

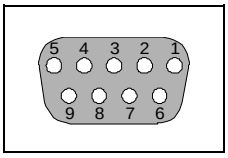


Materials Needed

See Section “Components for RS485 Connection”, page 19.

Figure 7

Pin configuration of the AO2000 RS485 Interface



2 RTxD–
3 RTxD+
5 GND

Type: 9-pin female Sub-D connector

Cable Type

A three lines twisted pair cable e.g. Thomas & Betts Type LiYCY, 0.25 mm^2 is used for the Modbus connection. The max. cable length is limited to 1200 m.

Signal Converter

If the PC has no RS485 interface, an RS232/RS485 signal converter must be linked between the PC and the Modbus network.

Continued on next page

Technical details are depicted in Fig. 8. Note the input circuit of a Modbus slave.

Any internal termination need to be disconnected. AC termination is only allowed at the cable ends using the RC termination plugs.

You can also use other cables and connectors as long as they correspond to the specifications in Fig. 8.

Figure 8

Cable Ends with RC Termination Plugs

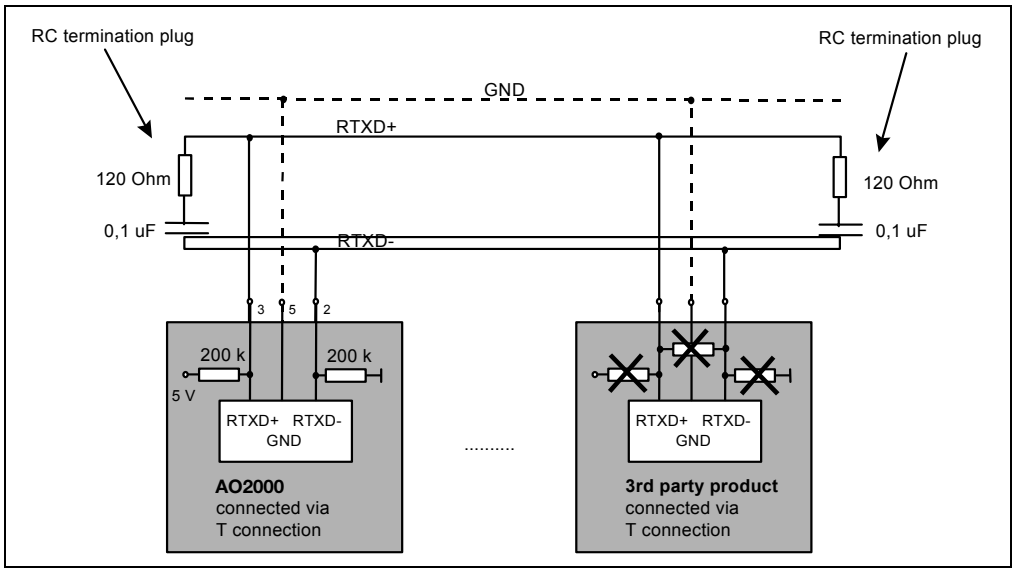
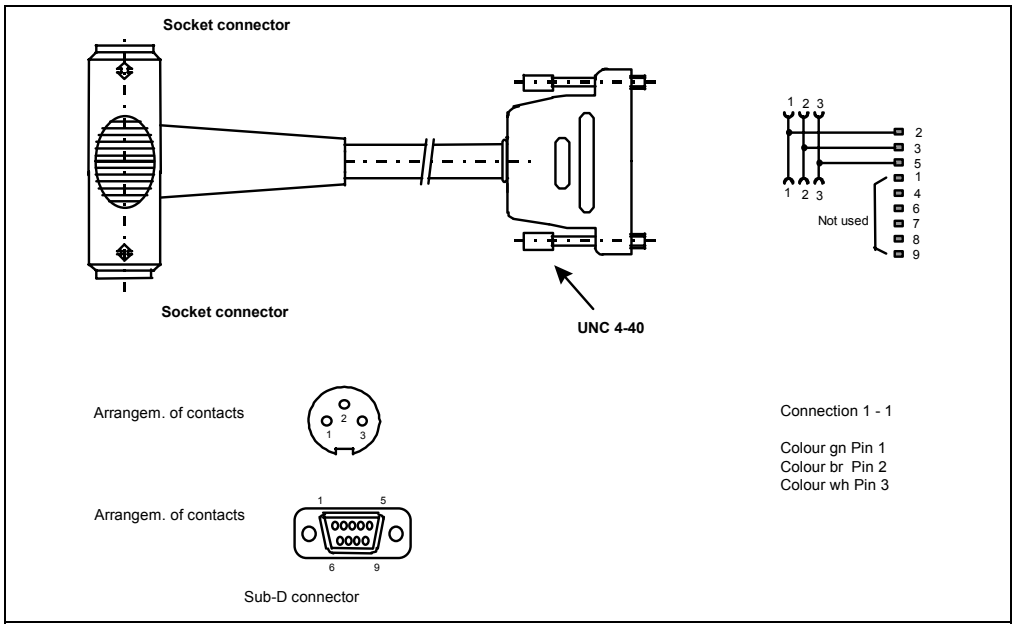


Figure 9

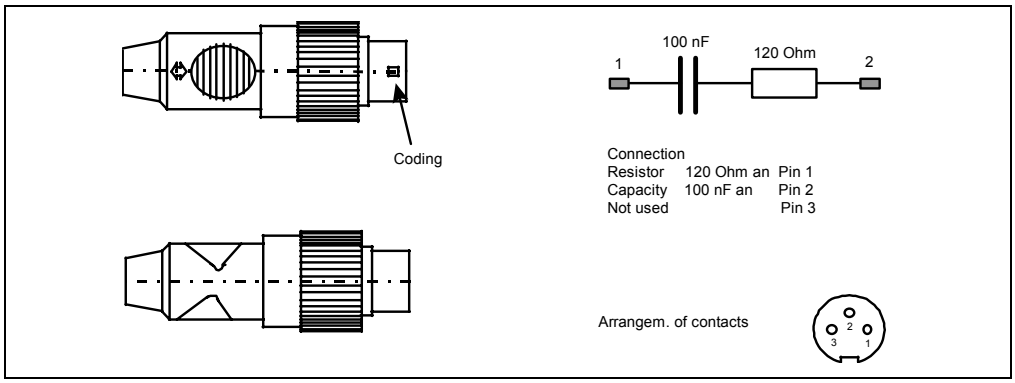
T-connection



Catalog No. 24009-4-0746617

Figure 10

RC Termination Plug



Catalog No. 24009-4-0746616

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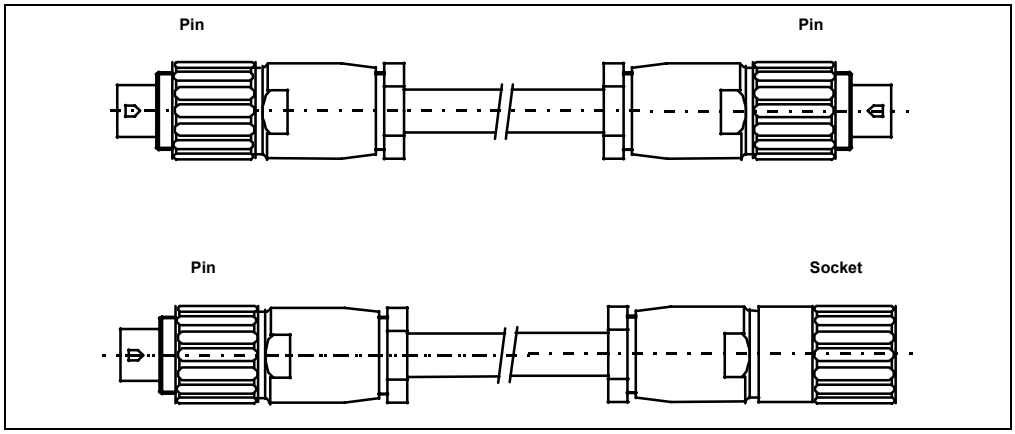
Modbus Connections with User Defined Cable Length

When using this type of cable one has to specify the desired length. Furthermore the connectors and the cable come as a set that need to be assembled. Two types of cables can be assembled.

- connection between two T-connections (pin connectors at each end)
- extension cord (pin and socket connector)

Figure 11

Variable Connections



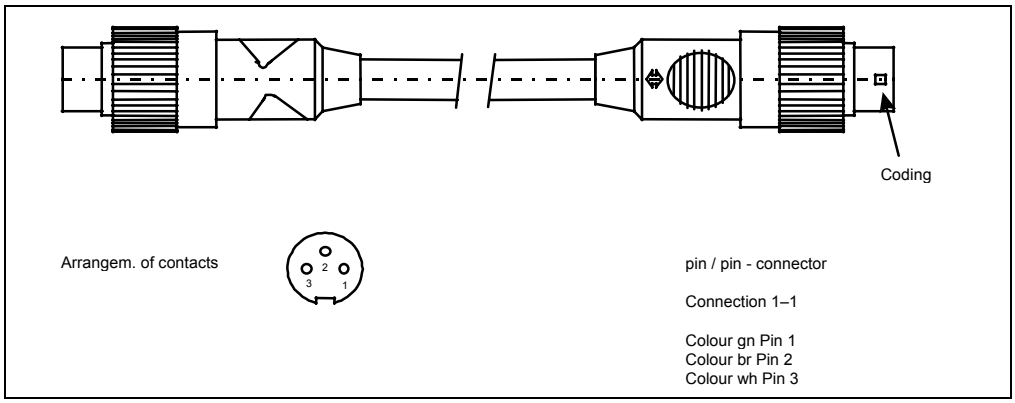
	Catalog No.
Cable with variable length	24009-4-0746622
Pin connector	24009-4-0746318
Socket connector	24009-4-0746471

Cables with Predefined Length

This option allows ordering cables of three different lengths. The cable can be used to connect two T-connections.

Figure 12

Cables with Predefined Length



Length	Catalog No.
1,0 m	24009-4-0746619
2,0 m	24009-4-0746620
5,0 m	24009-4-0746621

Chapter 3 AO-MDDE Server and Demo Programs

Description

Application

The AO-MDDE server is an effective and easy-to-use tool for integrating AO2000 signals into standard software through the RS232 or the RS485 interface.

AO-MDDE can be downloaded from the CD-ROM which is delivered together with each gas analyzer.

Program Files

OPTIMDDE.EXE	DDE server
OPTIMDDE.HLP	Help file for DDE server
AODEF.DDB	Device description for AO2000 with SW Version 3.0
AODEF_KOMP20.DDB	Device description for AO2000 with SW Version 3.0 for integration into existing Modbus applications for Advance Optima with SW Versions ≤ 2.0
AO-DDESE.XLS	Demo program based on Excel
AOMDDEMO.EXE	Demo program based on LabVIEW
LVWUTIL32.DLL	Program file for LabVIEW demo program

Both demo programs are intended to show by example how AO2000 can be linked to standard PC programs. Neither the transfer nor the storage of data can be regarded as fail-safe.

Modbus knowledge is not necessary for demo program operation.

Transferred Data	Read	Write	Example
Measurement Values	x	–	CO, NO, H_2, etc.
Analog Inputs	x	–	Indication of mA-values of external analyzers
Analog Outputs	x	–	Indication of mA-values of measurement values or calculated values (function block application)
Digital Inputs	x	–	Indication of external status signals
Digital Outputs	x	–	Measurement range feedback, indication of solenoid or pump controls
Bus Analog Inputs	x	x	Entering analog values into the function block application
Bus Analog Outputs	x	–	Outputting analog values from the function block application
Bus Digital Inputs	x	x	Control of functions such as auto calibration, measuring range control, etc. after function block configuration
Bus Digital Outputs	x	–	Indication of all functions integrated by function block configuration such as alarm signaling etc.
Modbus Configuration	x	–	Indication how many components, AOs, DOs, etc. have been configured or are in the gas analyzer
Status Signals	x	–	Indication of failure, maintenance mode, maintenance request

Installation

Installing AO-MDDE

Step	Action
1	Insert the CD-ROM with the AO-MDDE program.
2	Run the “AO_MDDEE.EXE” file.
3	Follow the instructions of the installation program. Accept the recommendation of the installation program for the name of the folder in which AO-MDDE shall be installed. All Analyze^{IT} software tools are installed in this folder.

Start

AO-MDDE Start

Start the AO-MDDE server in the Start menu or by running the program OPTIMDDE.EXE. Please refer to the integrated help function for further information about AO-MDDE.

Check that the bus transfer rates on the gas analyzer and the PC are identical.

Open the device description AODEF.DDB or AODEF_KOMP20.DDB and select the desired variables (see Figure 13). After this the data are transferred (see Figure 14).

Figure 13

Selection of Variables (Example)

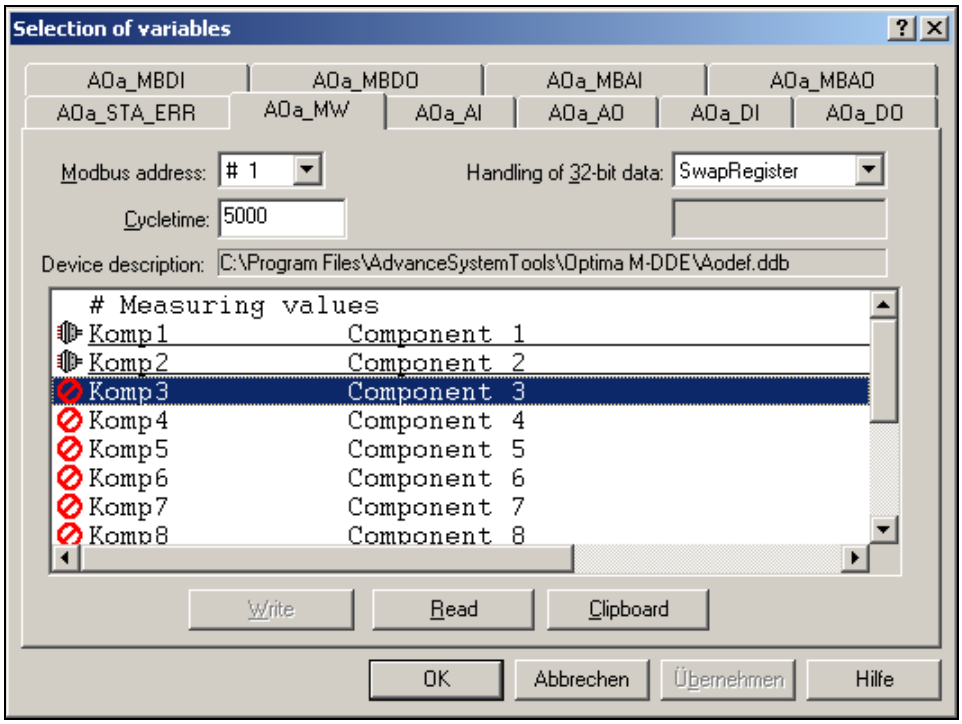


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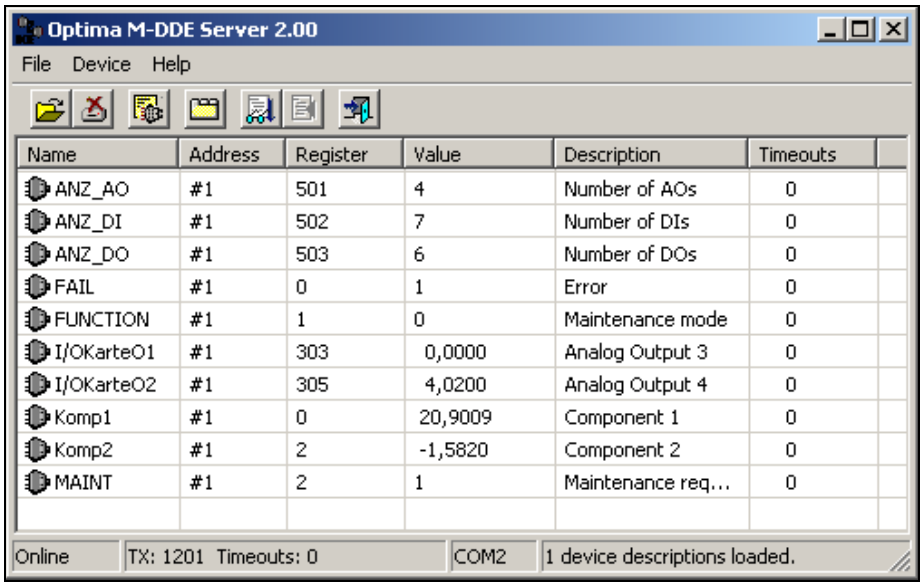
Figure 14

Device Description
(Example)



LabVIEW Demo Program

Application

The LabVIEW demo program presents a possible digital and trend display for data visualization.

LabVIEW Demo Program Start

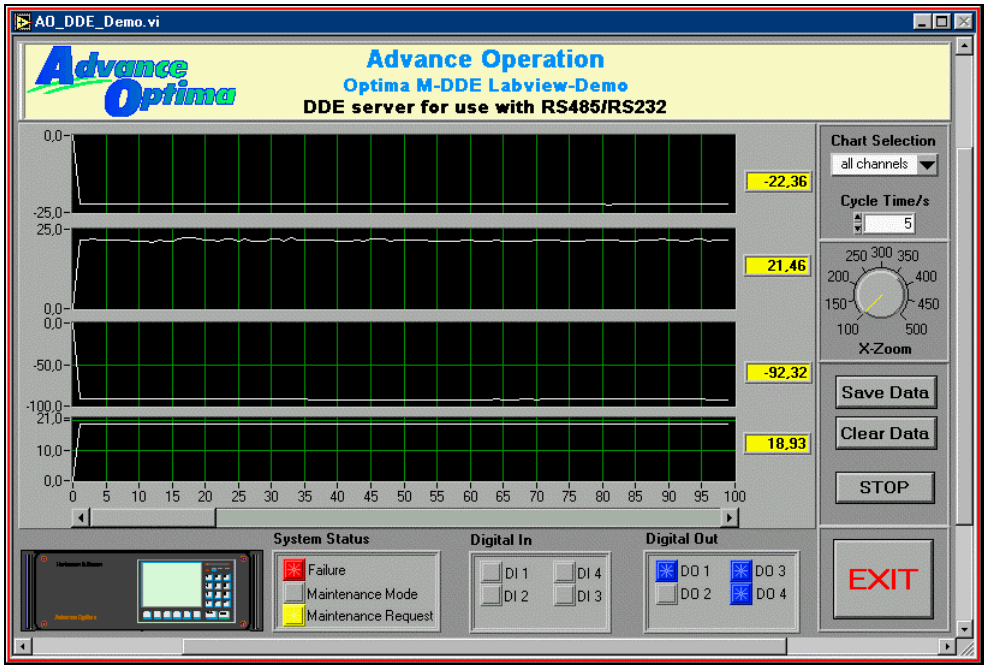
Start the demo program in the Start menu or by opening the file AOMDDEMO.EXE on your PC. The AO-MDDE server is started automatically by the demo program.

Basic Settings in AO-MDDE-Server

- In the “File → Open device description...” menu: Open the device description file “aodef.ddb”.
- In the “Device → Communication parameters...” menu: Deactivate the function “Bundle couple of registers” on the “Protocol” tab.

Figure 15

LabVIEW Demo Program (Example)



Excel Demo Program

Excel Demo Program Start

Start the demo program in the Start menu or by opening the file AO-DDESE.XLS on your PC. The AO-MDDE server is started automatically by the demo program.

Basic Settings in AO-MDDE-Server

- In the “File → Open device description...” menu: Open the device description file “aodef.ddb”.
- In the “Device → Communication parameters...” menu: Deactivate the function “Bundle couple of registers” on the “Protocol” tab.

Figure 16

Excel Demo Program (Example)

Integration of Information

The integration of information into standard software such as Microsoft Excel is straightforward: Select the required data field in AO-MDDE (see Fig. 13), copy it to the clipboard, select the required program, paste – and the data should appear and be ready for further processing. Please refer to the integrated help function for further information about AO-MDDE.

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