



Modbus Interface

T1000-10 Natural Gas Analyser

Revision: 23

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1. Modbus Information

The analyser is accessible as a Modbus slave on either Modbus RTU (over RS-485) or Modbus TCP (over Ethernet). Only two functions are supported:

- Read Holding Registers (0x03)
- Write Multiple Holding Registers (0x10)

All other Modbus functions are ignored.

1.1. Modbus RTU

The default parameters for Modbus RTU are shown in [Table 1](#). These can be changed from the Tunable Service Program, see MAN1014.

Table 1. Default Modbus RTU parameters

Transport	RS-485
Baud rate	9600
Data bits	8
Parity	None
Stop bits	2
Slave address	0x04

1.2. Modbus TCP

The parameters in [Table 2](#) are used for Modbus TCP. The IP can be changed from the Tunable Service Program, see MAN1014.

Table 2. Default Modbus TCP parameters

Transport	Ethernet
IP	192.168.9.2
Port	502

2. Analyser Operation

An overview of the analyser state machine is shown in [Figure 1](#). At powerup the analyser will automatically enter the IDLE state and wait for commands over Modbus. Different programs can be run by writing to the [CMD](#) register. The current state of the analyser can be read from the [STATE](#) register.

Any running program can be aborted by writing STOP to the [CMD](#) register. It may take a couple of seconds for analyser to abort the program and return to the IDLE state. During this time the [STATE](#) register will read STOPPING.

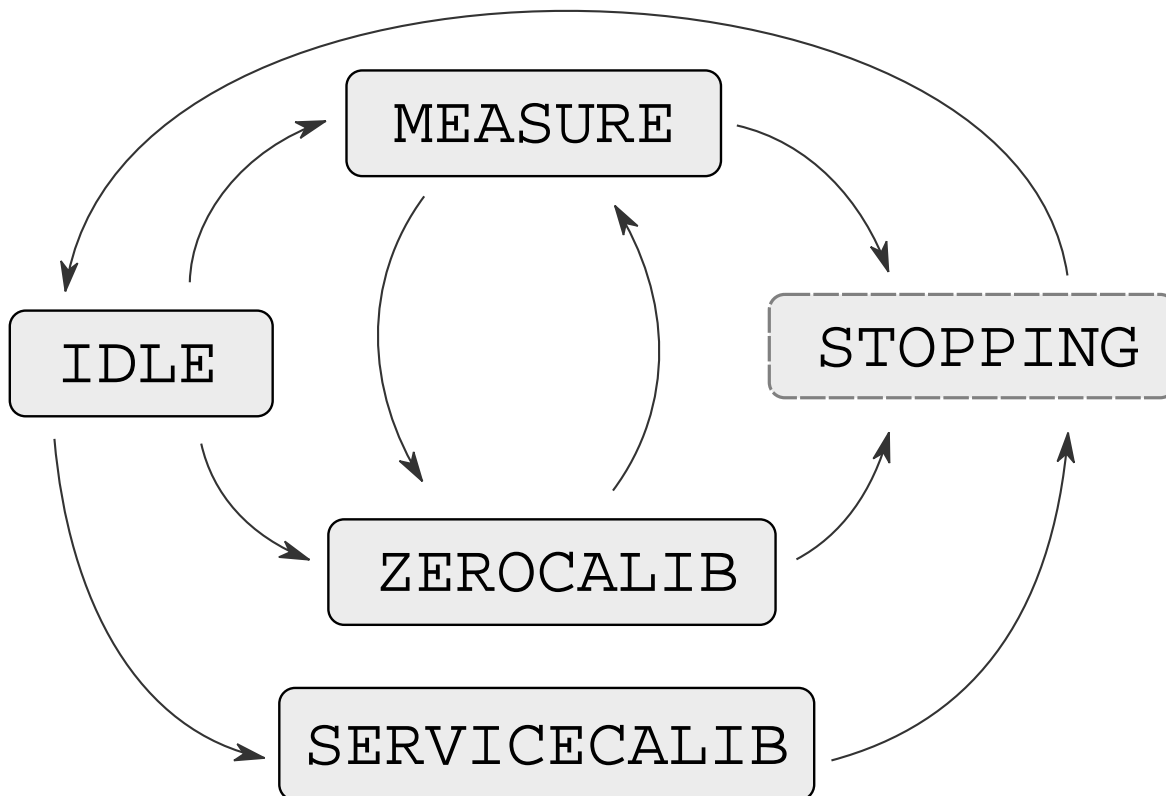


Figure 1. State Machine

2.1. Relay Control

Two relays intended for controlling solenoid valves can be controlled via the [RELAY_CFG](#) register. If the ENABLE bit in [RELAY_CFG](#) is LOW the relays are not controlled and will permanently stay OPEN. When the ENABLE bit is HIGH the relays are controlled either *manual* or *automatic* mode depending on the AUTOMATIC bit.

If the AUTOMATIC bit is LOW the relays are controlled by the [RELAY_CTRL](#) register, regardless of the analyser state.

If the AUTOMATIC bit is HIGH the relays are controlled automatically depending on the state of the analyser and the configuration in [RELAY_CFG](#). The R1_IDLE and R2_IDLE bits control the state of the relays in the IDLE state. The R1_MEASURE and R2_MEASURE bits control the state of the relays in the MEASURE state. The R1_ZEROCALIB and R2_ZEROCALIB bits control the state of the relays in the ZEROCALIB state.

The state of each relay can always be read from the [RELAY_STATE](#) register.

2.2. Measure Program

The analyser will start measuring after START_MEAS is written to the [CMD](#) register. To stop the analyser, write STOP to the [CMD](#) register. The analyser will then enter the IDLE state.

To run a *Finite Measurement*, first program the number of measurement cycles in [MEAS_CYCLES](#), then write START_FINITE_MEAS to the [CMD](#) register. The instrument will automatically return to IDLE when

the programmed number of measurement cycles are complete.

The current progression in a measurement cycle can be read through the [PROGRESSION](#) register. This register will go from 0 to 100 during each measurement cycle. When a measurement cycle finishes, the [MEAS_CNT](#) register will be increased by one.

2.3. Zero Calibration Program

The *Zero Calibration* program is run to remove drift due to reduced light intensity (e.g. from dirt on lenses). The *Zero Calibration* program is started by writing `START_ZEROCALIB` to the [CMD](#) register while the analyser is in the IDLE state. The [STATE](#) register will read `ZEROCALIB` while the *Zero Calibration* program is running. The analyser will automatically return to the IDLE state after the *Zero Calibration* program completes.

Note



During *Zero Calibration* the analyser measurement cell must be filled with nitrogen gas.^[1] Running *Zero Calibration* with a different gas may affect subsequent measurement results.

If both the `ENABLE` and `AUTOMATIC` bits in [RELAY_CFG](#) register are set, the relays are controlled according to the settings in `R1_ZEROCALIB` and `R2_ZEROCALIB` in [RELAY_CFG](#).

2.4. Span Calibration Program

The *Span Calibration* program can be used to correct gain-offsets by calibrating against a known reference.

Before starting a span calibration, first check that the [STATE](#) registers reads `IDLE` and the [ERROR_CODE](#) registers read `NONE`.

Write the target values for each component in the corresponding registers (e.g. write the `METHANE` concentration to the [SPANTARGET_METHANE](#) register). Set the bits in [SPANCALIB_INCLUDES](#) for each component that should be calibrated. Only include components that are between 60% and 100% of full range.

Fill the measurement cell with span gas and write `START_SPANCALIB` to the [CMD](#) register to start the span calibration. The instrument will return to `IDLE` automatically when span calibration is complete. Check that the [ERROR_CODE](#) register still reads `NONE` to verify that the span calibration completed successfully.

When the span calibration completes, the instrument will store *span factors* for each component that is used to adjust the component accordingly in future measurements. The span factors can be read out via separate registers (e.g. span factor for `METHANE` is read from the [SPANFACTOR_METHANE](#) register).

Note



Do not include components without a set span target or with very low target concentrations. Doing so will result in poor performance in subsequent

measurements. Please ensure that all components that are included in span calibration are above 60% of full range for the instrument.

Span calibration factors can be cleared (reset to 1.0) by writing CLEAR_SPAN_FACTORS to the `CMD` register. This will reset the calibration to factory default.

2.5. Stream Switching

It is possible to set the instrument up to measure multiple streams and automatically switch between them. If `AUTOMATIC_STREAM_SWITCH` is enabled, the instrument will measure *Stream 1* for the time specified in `STREAM_1_MEASURE_TIME`, then switch to *Stream 2* etc. If `AUTOMATIC_STREAM_SWITCH` is disabled, the user can manually switch streams by writing to the `MANUAL_STREAM_SELECT` register. The stream that was measured for each measurement cycle can be read from the `MEAS_STREAM` register.

2.6. Service Calibration Program

The service calibration program is intended to be run after cleaning lenses. This program creates a new reference point for light intensity levels. The program should be run with nitrogen gas^[1] in the measurement cell. To run the program, write `START_SERVICECALIB` while the analyser is in the IDLE state. The analyser automatically returns to IDLE after the program completes.

If both the `ENABLE` and `AUTOMATIC` bits in `RELAY_CFG` register are set, the relays are controlled according to the settings in `R1_SERVICECALIB` and `R2_SERVICECALIB` in `RELAY_CFG`.

2.7. Measurement Data

The measurement data registers (addresses below `0x0080`) are guaranteed to be updated atomically. This means that if these registers are read together in a single Modbus transaction, they are guaranteed to belong to the same measurement cycle.

The `MEAS_CNT` register indicates the last completed measurement cycle, and can be used to check when a new measurement cycle is finished.

Timestamps



Timestamps recorded in the `TIMESTAMP` register depend on persistent connection to an NTP (Network Time Protocol) server. If the instrument does not have access to an NTP server, these timestamps will be wrong.

2.8. Service Indicators

The service indicator registers, `ABS_TRANS` and `REL_TRANS`, give information about the current condition of the instrument. They are updated during zero calibration.

The `ABS_TRANS` register holds the current optical transmission relative to the level during production with N₂ to in the measurement cell. The `REL_TRANS` register gives the current light intensity relative to the level during the last service calibration. The service calibration routine can be run by writing `START_SERVICECALIB` while the instrument is in the IDLE state.



Intensity Values

Light intensity values are affected by the gas present in the measurement cell. Make sure to analyze these values with a known gas composition.

2.9. Live registers

The *live sensor registers* (e.g. `LIVE_GAS_PRESSURE`) give out sensor readings regardless if the instrument is measuring or not. These can be used to check temperature and pressure readings when the instrument is IDLE.

3. Interface Description

3.1. Data Formats

Four different data types are used in the Modbus register map:

- uint16 (2 bytes)
- uint32 (4 bytes)
- float32 (4 bytes)
- string (n bytes)

Values labelled uint16 contain unsigned 16-bit integers.

Values labelled uint32 contain unsigned 32-bit integers. They thus span two Modbus registers. Data is stored in big-endian format (most significant byte at lowest memory address).

Values labelled float32 contain 32-bit floating point numbers. The format corresponds to the IEEE 754 standard. They thus span two Modbus registers. Data is stored in big-endian format (most significant byte at lowest memory address).

strings are stored as zero-terminated ASCII byte arrays with a prepended size field. The size field is of type uint16 and does *not* include the zero-termination character. [Table 3](#) shows the memory layout if the string "TUNE" was stored at 0x8000 (x = undefined).

Table 3. String Example

Address:	0x8000	0x8001	0x8002	0x8003
Value (hex):	0x0004	0x5455	0x4E45	0x00xx
Value:	4	"TU"	"NE"	"\0"

3.2. Memory Layout

The register map is divided in four sections. [Table 4](#) shows the layout of the Modbus memory.

Table 4. Memory Layout

Section Name	Start Address	End Address
Data	0x0000	0x0FFF
Control	0x1000	0x1FFF
Configuration	0x2000	0x2FFF
Information	0x8000	0x8FFF



Address Values

Address values given in this document refers to the data address used in Modbus messages. The Modbus specification has an alternative method of specifying addresses where the first Holding Register is numbered 40001 (decimal). This notation is *not* used in this document.

The *Data Section* contains measurement results as well as status information.

The *Control Section* contains registers for controlling analyser behavior: starting/stopping measurements, performing Zero-Point Calibration, etc.

The *Configuration Section* contains configuration settings.

The *Information Section* contains information about the device.

3.3. Modbus Emulation Mode

By logging in with the Service User in the Service Program on the analyser, it is possible to access the Modbus Emulation Mode. This mode is a tool for debugging modbus communication issues during installation and commissioning of the analyser.

The Modbus Emulation Mode sets static emulated values on most of the modbus registers, which can be read out to ensure that the registers are accessed correctly. The value emulated for each register is given in the last column in the [Table 5](#). The value N/A means that the register is not emulated, and is therefore not affected by the mode.

4. Register Map

The register map is given in [Table 5](#).

Table 5. Register Map

Address	Name	Access	Data type	Emulated value
<i>Data Section</i>				
0x0000	METHANE	R	float32	90.0
0x0002	ETHANE	R	float32	18.0
0x0004	PROPANE	R	float32	18.0
0x0006	BUTANE	R	float32	4.5

Address	Name	Access	Data type	Emulated value
0x0008	ISOBUTANE	R	float32	4.5
0x000A	C5TOT	R	float32	4.5
0x000C	RESERVED	R	float32	0
0x000E	NITROGEN	R	float32	90.0
0x0020	GAS_PRESSURE	R	float32	1.01325
0x0022	GAS_TEMP	R	float32	25
0x0024	BOARD_TEMP	R	float32	50
0x0026	FP_TEMP	R	float32	27
0x0030	HHV_MASS	R	float32	54
0x0032	LHV_MASS	R	float32	49
0x0034	HHV_VOLUME	R	float32	39
0x0036	LHV_VOLUME	R	float32	35
0x0038	GROSS_WOBBE	R	float32	51
0x003A	NET_WOBBE	R	float32	46
0x003C	DENSITY	R	float32	0.75
0x003E	REL_DENSITY	R	float32	0.65
0x0040	MEAS_CNT	R	uint32	17
0x0042	MEAS_FLAGS	R	uint32	892652235
0x0044	TIMESTAMP	R	uint32	1735718400
0x0046	MEAS_OOR	R	uint32	892652235
0x0048	MEAS_STREAM	R	uint32	3
0x0050	METHANE_NUMBER	R	float32	83
0x0052	COMPRESSIBILITY	R	float32	0.97
0x0200	STATE	R	uint16	34
0x0202	ERROR_CODE	R	uint32	18
0x0204	PROGRESSION	R	uint16	49
0x0205	RELAY_STATE	R	uint16	3
0x0300	ABS_TRANS	R	uint16	90
0x0301	REL_TRANS	R	uint16	95
0x0304	ABS_TRANS_FLOAT	R	float32	90.4
0x0306	REL_TRANS_FLOAT	R	float32	94.8
0x0420	LIVE_GAS_PRESSURE	R	float32	1.01325
0x0422	LIVE_GAS_TEMP	R	float32	25

Address	Name	Access	Data type	Emulated value
0x0424	LIVE_BOARD_TEMP	R	float32	50
0x0426	LIVE_FP_TEMP	R	float32	27
0x0500	ZERO_CHECK_METHANE	R	float32	0.2
0x0502	ZERO_CHECK_ETHANE	R	float32	0.04
0x0504	ZERO_CHECK_PROPANE	R	float32	0.04
0x0506	ZERO_CHECK_BUTANE	R	float32	0.01
0x0508	ZERO_CHECK_ISOBTANE	R	float32	0.01
0x050A	ZERO_CHECK_C5TOT	R	float32	0.01
0x050E	ZERO_CHECK_NITROGEN	R	float32	0.2
0x0520	SPAN_CHECK_METHANE	R	float32	99.8
0x0522	SPAN_CHECK_ETHANE	R	float32	19.96
0x0524	SPAN_CHECK_PROPANE	R	float32	19.96
0x0526	SPAN_CHECK_BUTANE	R	float32	4.99
0x0528	SPAN_CHECK_ISOBTANE	R	float32	4.99
0x052A	SPAN_CHECK_C5TOT	R	float32	4.99
<i>Control Section</i>				
0x1000	CMD	W	uint16	N/A
0x1001	RELAY_CTRL	W	uint16	N/A
0x1010	REBOOT	W	uint16	N/A
<i>Configuration Section</i>				
0x2000	AUTOSTART	RW	uint16	1
0x2001	AUTOZERO	RW	uint16	1
0x2002	AUTOZERO_PERIOD	RW	uint16	72
0x2004	RELAY_CFG	RW	uint16	51915
0x200A	MEAS_CYCLES	RW	uint32	17
0x200C	AVG_FILTER	RW	uint32	5
0x2030	MANUAL_STREAM_SELECT	RW	uint16	2
0x2031	AUTOMATIC_STREAM_SWITCH	RW	uint16	1
0x2032	STREAM_SWITCH_INCLUDES	RW	uint16	6
0x2034	STREAM_1_MEAS_TIME	RW	float32	0.25
0x2036	STREAM_2_MEAS_TIME	RW	float32	0.5
0x2038	STREAM_3_MEAS_TIME	RW	float32	0.75
0x2100	SPANTARGET_METHANE	RW	float32	98.0

Address	Name	Access	Data type	Emulated value
0x2102	SPANTARGET_ETHANE	RW	float32	19.6
0x2104	SPANTARGET_PROPANE	RW	float32	19.6
0x2106	SPANTARGET_BUTANE	RW	float32	4.9
0x2108	SPANTARGET_ISOBTANE	RW	float32	4.9
0x210A	SPANTARGET_C5TOT	RW	float32	4.9
0x2200	SPANFACTOR_METHANE	R	float32	0.99
0x2202	SPANFACTOR_ETHANE	R	float32	0.991
0x2204	SPANFACTOR_PROPANE	R	float32	0.992
0x2206	SPANFACTOR_BUTANE	R	float32	0.993
0x2208	SPANFACTOR_ISOBTANE	R	float32	0.994
0x220A	SPANFACTOR_C5TOT	R	float32	0.995
0x2300	SPANCALIB_INCLUDES	RW	uint16	892652235
0x2400	TIME_YEAR	RW	uint16	2025
0x2401	TIME_MONTH	RW	uint16	1
0x2402	TIME_DAY	RW	uint16	1
0x2403	TIME_HOUR	RW	uint16	8
0x2404	TIME_MINUTE	RW	uint16	0
0x2405	TIME_SECOND	RW	uint16	0
0x2410	ENABLE_ZERO_CHECK	RW	uint16	0
0x2411	ZERO_CHECK_SAMPLES	RW	uint16	10
0x2412	ENABLE_SPAN_CHECK	RW	uint16	1
0x2413	SPAN_CHECK_SAMPLES	RW	uint16	10
Information Section				
0x7000	MAPTYPE	R	uint16	N/A
0x7001	MAPREV	R	uint16	N/A
0x7002	MANUFACTURER	R	uint16	N/A
0x7003	DEVTYPE	R	uint16	N/A
0x7004	HWPLATFORM	R	uint16	N/A
0x8000	SERIAL	R	string	N/A
0x8100	OS_VER	R	string	N/A
0x8200	FW_VER	R	string	N/A
0x8300	FPGA_VER	R	string	N/A

4.1. Register Descriptions

4.1.1. METHANE Register

Table 6. METHANE register (0x0000, float32, R)

Unit	Description
mol-%	METHANE concentration

4.1.2. ETHANE Register

Table 7. ETHANE register (0x0002, float32, R)

Unit	Description
mol-%	ETHANE concentration

4.1.3. PROPANE Register

Table 8. PROPANE register (0x0004, float32, R)

Unit	Description
mol-%	PROPANE concentration

4.1.4. BUTANE Register

Table 9. BUTANE register (0x0006, float32, R)

Unit	Description
mol-%	BUTANE concentration

4.1.5. ISOBUTANE Register

Table 10. ISOBUTANE register (0x0008, float32, R)

Unit	Description
mol-%	ISOBUTANE concentration

4.1.6. C5TOT Register

Table 11. C5TOT register (0x000A, float32, R)

Unit	Description
mol-%	C5TOT concentration

4.1.7. NITROGEN Register

Table 12. NITROGEN register (0x000E, float32, R)

Unit	Description
mol-%	NITROGEN concentration

4.1.8. GAS_PRESSURE Register

Table 13. GAS_PRESSURE register (0x0020, float32 , R)

Unit	Description
bar	Gas pressure

4.1.9. GAS_TEMP Register

Table 14. GAS_TEMP register (0x0022, float32 , R)

Unit	Description
C	Gas temperature

4.1.10. BOARD_TEMP Register

Table 15. BOARD_TEMP register (0x0024, float32 , R)

Unit	Description
C	Board temperature

4.1.11. FP_TEMP Register

Table 16. FP_TEMP register (0x0026, float32 , R)

Unit	Description
C	Fabry-Perot filter temperature

4.1.12. HHV_MASS Register

Table 17. HHV_MASS register (0x0030, float32 , R)

Unit	Description
MJ/kg	Higher Heating Value (Calorific Value), mass basis

4.1.13. LHV_MASS Register

Table 18. LHV_MASS register (0x0032, float32 , R)

Unit	Description
MJ/kg	Lower Heating Value (Calorific Value), mass basis

4.1.14. HHV_VOLUME Register

Table 19. HHV_VOLUME register (0x0034, float32 , R)

Unit	Description
MJ/m3	Higher Heating Value (Calorific Value), volume basis

4.1.15. LHV_VOLUME Register

Table 20. LHV_VOLUME register (0x0036, float32 , R)

Unit	Description
MH/m3	Lower Heating Value (Calorific Value), volume basis

4.1.16. GROSS_WOBBE Register

Table 21. GROSS_WOBBE register (0x0038, float32 , R)

Unit	Description
MJ/m3	Gross Wobbe Index

4.1.17. NET_WOBBE Register

Table 22. NET_WOBBE register (0x003A, float32 , R)

Unit	Description
MJ/m3	Net Wobbe Index

4.1.18. DENSITY Register

Table 23. DENSITY register (0x003C, float32 , R)

Unit	Description
kg/m3	Gas density

4.1.19. REL_DENSITY Register

Table 24. REL_DENSITY register (0x003E, float32 , R)

Unit	Description
-	Relative density

4.1.20. MEAS_CNT Register

Table 25. MEAS_CNT register (0x0040, uint32 , R)

Unit	Description
-	Counter increased by 1 each time a new measurement cycle finishes.

4.1.21. MEAS_FLAGS Register

Table 26. MEAS_FLAGS register (0x0042, uint32 , R)

Bit	Name	Description
0	DATAREADY	Indicates if data registers are ready (contains measurement data). 0: Data registers are not ready. 1: Data registers are ready.
1	FP_TEMP_HIGH	Fabry Perot filter temperature high warning. 0: No warning. 1: Fabry Perot filter temperature too high.
2	FP_TEMP_LOW	Fabry Perot filter temperature low warning. 0: No warning. 1: Fabry Perot filter temperature too low.
3	GAS_TEMP_HIGH	Gas temperature high warning. 0: No warning. 1: Gas temperature too high.
4	GAS_TEMP_LOW	Gas temperature low warning. 0: No warning. 1: Gas temperature too low.
5	GAS_PRESSURE_HIGH	Gas pressure high warning. 0: No warning. 1: Gas pressure too high.
6	GAS_PRESSURE_LOW	Gas pressure low warning. 0: No warning. 1: Gas pressure too low.
7	ZERO_FLUSHING	Indicates whether instrument is flushing with zero gas. 0: No flushing in progress. 1: Flushing in progress.
8	PROCESS_FLUSHING	Indicates whether instrument is flushing with process gas. 0: No flushing in progress. 1: Flushing in progress.
9	MEAS_OOR	One or more measurements outside calibrated range warning. 0: No warning. 1: One or more measured quantities outside of calibrated ranges, check the MEAS_OOR register for per-quantity warnings.

4.1.22. TIMESTAMP Register

Table 27. *TIMESTAMP* register (0x0044, uint32, R)

Unit	Description
s	Unix timestamp (seconds since 1 Jan 1970 00:00:00).

4.1.23. MEAS_OOR Register

Table 28. MEAS_OOR register (0x0046, uint32_t, R)

Bit	Name	Description
0	METHANE_OOR	Indicates if the METHANE concentration is within calibrated range. 0: Concentration within calibrated range. 1: Concentration outside of calibrated range.
1	ETHANE_OOR	Indicates if the ETHANE concentration is within calibrated range. 0: Concentration within calibrated range. 1: Concentration outside of calibrated range.
2	PROPANE_OOR	Indicates if the PROPANE concentration is within calibrated range. 0: Concentration within calibrated range. 1: Concentration outside of calibrated range.
3	BUTANE_OOR	Indicates if the BUTANE concentration is within calibrated range. 0: Concentration within calibrated range. 1: Concentration outside of calibrated range.
4	ISOBUTANE_OOR	Indicates if the ISOBUTANE concentration is within calibrated range. 0: Concentration within calibrated range. 1: Concentration outside of calibrated range.
5	C5TOT_OOR	Indicates if the C5TOT concentration is within calibrated range. 0: Concentration within calibrated range. 1: Concentration outside of calibrated range.
7	NITROGEN_OOR	Indicates if the NITROGEN concentration is within calibrated range. 0: Concentration within calibrated range. 1: Concentration outside of calibrated range.
16	METHANE_NUMBER_OOR	Indicates if the methane number calculation is within calibrated range. 0: Methane number calculation valid according to ISO23306. 1: Methane number calculation not valid.

4.1.24. MEAS_STREAM Register

Table 29. MEAS_STREAM register (0x0048, uint32_t, R)

Bit	Name	Description
0	N/A	N/A

Bit	Name	Description
1	STREAM_1	Measure Stream 1
2	STREAM_2	Measure Stream 2
3	STREAM_3	Measure Stream 3

4.1.25. METHANE_NUMBER Register

Table 30. METHANE_NUMBER register (0x0050, float32 , R)

Unit	Description
-	Methane number calculated according to ISO 23306:2020 Annex A

4.1.26. COMPRESSIBILITY Register

Table 31. COMPRESSIBILITY register (0x0052, float32 , R)

Unit	Description
-	Compressibility factor calculated according to ISO 6976:2016 section 6.2

4.1.27. STATE Register

Table 32. STATE register (0x0200, uint16 , R)

Value	Name	Description
0	IDLE	Analyser is idle.
1	MEASURE	Analyser is measuring gas.
2	ZEROCALIB	Analyser is performing Zero-Point Calibration.
7	STOPPING	Analyser is in process of stopping (returning to IDLE state).
13	SERVICECALIB	Analyser is performing service calibration.
16	SPANCALIB	Analyser is performing Span Calibration.
18	ZERO_FLUSHING	Analyser is flushing with zero gas.
19	PROCESS_FLUSHING	Analyser is flushing with process gas.
24	STARTING	Analyser is process of starting a measurement.

4.1.28. ERROR_CODE Register

Table 33. ERROR_CODE register (0x0202, uint32 , R)

Value	Name	Description
0	NoError	No error
1	Generic	Generic error
2	DeviceConfig	Error in device configuration

Value	Name	Description
3	Database	Database error
4	Fpga	FPGA error
5	IrDrv	IR driver communication error
6	IrDet	IR detector communication error
7	Pcap	PCAP error
8	LsrDrv	Laser driver communication error
9	LsrDet	Laser detector communication error
10	DataSpi	DMA error
11	FilterTemp	Error reading filter temperature
12	GasTemp	Error reading gas temperature
13	GasPressure	Error reading gas pressure
14	FilterHumid	Error reading filter humidity
15	Selftest	Error in selftest
16	MicPressure	Error reading microphone pressure
17	Watchdog	Watchdog error
18	Modbus	Modbus error
19	FilterCalib	Error with filter calibration
20	RelayCtrl	Relay control error
21	Calculation	Calculation error
22	HealthCheck	Error during health check
23	MeasureConfig	Measurement configuration error
24	IrDetClip	Possible IR detector clipping
25	LsrDetClip	Possible laser detector clipping
26	Compute	Computation error
27	CtrlSpi	Control SPI link error
28	RefCalib	Error with reference calibration
29	SpanCalib	Span calibration error
30	MembraneTemp	Error reading membrane temperature
31	PcapDetect	No PCAP detected
32	PcapMeasure	Error with PCAP measurement
33	FilterDacClip	Filter DAC drive clipping
34	FilterTempHigh	Filter temperature high
35	FilterTempLow	Filter temperature low

Value	Name	Description
36	GasTempHigh	Gas temperature high
37	GasTempLow	Gas temperature low
38	GasPressureHigh	Gas pressure high
39	GasPressureLow	Gas pressure low
41	RefCalibTempHigh	Filter temperature above reference calibration
42	RefCalibTempLow	Filter temperature below reference calibration
43	CalorificValue	Error during calorific value calculation
44	MethaneNumber	Error during methane number calculation
45	Onnx	Error with estimation model
46	SublockinMeasureConfig	Error with sub-lockin measurement config
47	InvalidHw	Invalid HW
48	McuSpi	Error with MCU SPI link
49	Gpio	GPIO error
50	Bmp388	Error with BMP388 sensor
51	I2C	I2C error
52	McuSerial	MCU serial error
53	FpgaDeviceFieldUpgrade	Error with FPGA DFU
54	Sht30	Error with SHT30 sensor
55	Sht3xI2C	Error with I2C SHT3x sensor
56	ClampNormalize	Error during clamp/normalize
57	Tircp	Tircp protocol error
58	Te89bsd	Error with TE89BSD sensor
59	Dps500	Error with DPS5000 sensor
60	Max31865	Error with MAX31865 sensor
61	Dac8571	Error with DAC8571
62	Tirdata	Error with tirdata
63	ZeroCalib	Zero calibration failed
64	DacTrim	Dac trimming failed

4.1.29. PROGRESSION Register

Table 34. PROGRESSION register (0x0204, uint16, R)

Unit	Description
%	Measurement cycle progression

4.1.30. RELAY_STATE Register

Table 35. RELAY_STATE register (0x0205, uint16, R)

Bit	Name	Description
0	R1	0: R1 is OPEN. 1: R1 is CLOSED.
1	R2	0: R2 is OPEN. 1: R2 is CLOSED.

4.1.31. ABS_TRANS Register

Table 36. ABS_TRANS register (0x0300, uint16, R)

Unit	Description
%	Last background transmission, compared to factory values.

4.1.32. REL_TRANS Register

Table 37. REL_TRANS register (0x0301, uint16, R)

Unit	Description
%	Last background transmission, compared to last service calibration.

4.1.33. ABS_TRANS_FLOAT Register

Table 38. ABS_TRANS_FLOAT register (0x0304, float32, R)

Unit	Description
%	Last background transmission as float, compared to factory values.

4.1.34. REL_TRANS_FLOAT Register

Table 39. REL_TRANS_FLOAT register (0x0306, float32, R)

Unit	Description
%	Last background transmission as float, compared to last service calibration.

4.1.35. LIVE_GAS_PRESSURE Register

Table 40. LIVE_GAS_PRESSURE register (0x0420, float32, R)

Unit	Description
bar	Live gas pressure.

4.1.36. LIVE_GAS_TEMP Register

Table 41. LIVE_GAS_TEMP register (0x0422, float32, R)

Unit	Description
C	Live gas temperature.

4.1.37. LIVE_BOARD_TEMP Register

Table 42. LIVE_BOARD_TEMP register (0x0424, float32, R)

Unit	Description
C	Live board temperature.

4.1.38. LIVE_FP_TEMP Register

Table 43. LIVE_FP_TEMP register (0x0426, float32, R)

Unit	Description
C	Live Fabry-Perot temperature.

4.1.39. ZERO_CHECK_METHANE Register

Table 44. ZERO_CHECK_METHANE register (0x0500, float32, R)

Unit	Description
mol-%	Last zero check value for METHANE.

4.1.40. ZERO_CHECK_ETHANE Register

Table 45. ZERO_CHECK_ETHANE register (0x0502, float32, R)

Unit	Description
mol-%	Last zero check value for ETHANE.

4.1.41. ZERO_CHECK_PROPANE Register

Table 46. ZERO_CHECK_PROPANE register (0x0504, float32, R)

Unit	Description
mol-%	Last zero check value for PROPANE.

4.1.42. ZERO_CHECK_BUTANE Register

Table 47. ZERO_CHECK_BUTANE register (0x0506, float32, R)

Unit	Description
mol-%	Last zero check value for BUTANE.

4.1.43. ZERO_CHECK_ISOBUTANE Register

Table 48. ZERO_CHECK_ISOBUTANE register (0x0508, float32, R)

Unit	Description
mol-%	Last zero check value for ISOBUTANE.

4.1.44. ZERO_CHECK_C5TOT Register

Table 49. ZERO_CHECK_C5TOT register (0x050A, float32, R)

Unit	Description
mol-%	Last zero check value for C5TOT.

4.1.45. ZERO_CHECK_NITROGEN Register

Table 50. ZERO_CHECK_NITROGEN register (0x050E, float32, R)

Unit	Description
mol-%	Last zero check value for NITROGEN.

4.1.46. SPAN_CHECK_METHANE Register

Table 51. SPAN_CHECK_METHANE register (0x0520, float32, R)

Unit	Description
mol-%	Last span check value for METHANE.

4.1.47. SPAN_CHECK_ETHANE Register

Table 52. SPAN_CHECK_ETHANE register (0x0522, float32, R)

Unit	Description
mol-%	Last span check value for ETHANE.

4.1.48. SPAN_CHECK_PROPANE Register

Table 53. SPAN_CHECK_PROPANE register (0x0524, float32, R)

Unit	Description
mol-%	Last span check value for PROPANE.

4.1.49. SPAN_CHECK_BUTANE Register

Table 54. SPAN_CHECK_BUTANE register (0x0526, float32, R)

Unit	Description
mol-%	Last span check value for BUTANE.

4.1.50. SPAN_CHECK_ISOBUTANE Register

Table 55. SPAN_CHECK_ISOBUTANE register (0x0528, float32, R)

Unit	Description
mol-%	Last span check value for ISOBUTANE.

4.1.51. SPAN_CHECK_C5TOT Register

Table 56. SPAN_CHECK_C5TOT register (0x052A, float32, R)

Unit	Description
mol-%	Last span check value for C5TOT.

4.1.52. CMD Register

Table 57. CMD register (0x1000, uint16, W)

Value	Name	Description
0	NOOP	No operation. This command is ignored.
1	START_MEAS	Start measurements.
2	STOP	Stop measurement activity. Return to IDLE state.
3	START_ZEROCALIB	Start Zero-Point Calibration.
8	START_SERVICECALIB	Start Service Calibration.
9	START_SPANCALIB2	Start Span Calibration.
10	CLEAR_SPANCALIB2_FACTORS	Reset Span Calibration Factors to 1.
11	CLEAR_ERROR	Clears the ERROR_CODE register.
12	START_FINITE_MEAS	Starts a Finite Measurement. See also MEAS_CYCLES
13	START_SWEEP	Starts a Sweep Measurement.

4.1.53. RELAY_CTRL Register

Table 58. RELAY_CTRL register (0x1001, uint16, W)

Bit	Name	Description
0	R1	0: R1 is OPEN. 1: R1 is CLOSED.
1	R2	0: R2 is OPEN. 1: R2 is CLOSED.

4.1.54. REBOOT Register

Table 59. REBOOT register (0x1010, uint16, W)

Value	Name	Description
0xDEAD	REBOOTCMD	Triggers a reboot of the instrument. All other values are ignored.

4.1.55. AUTOSTART Register

Table 60. AUTOSTART register (0x2000, uint16, RW)

Value	Name	Description
0	False	Enter IDLE on power-up.
1	True	Start measurements on power-up.

4.1.56. AUTOZERO Register

Table 61. AUTOZERO register (0x2001, uint16, RW)

Value	Name	Description
0	False	Do not run automatic zero-point calibrations.
1	True	Run zero-point calibrations automatically.

4.1.57. AUTOZERO_PERIOD Register

Table 62. AUTOZERO_PERIOD register (0x2002, uint16, RW)

Unit	Description
h	Time between zero-point calibrations.

4.1.58. RELAY_CFG Register

Table 63. RELAY_CFG register (0x2004, uint16, RW)

Bit	Name	Description
0	ENABLE	0: Relay control is DISABLED. 1: Relay control is ENABLED.
1	AUTOMATIC	0: Relay control is MANUAL. 1: Relay control is AUTOMATIC.
2	R1_IDLE	0: R1 is OPEN in IDLE state. 1: R1 is CLOSED in IDLE state.
3	R2_IDLE	0: R2 is OPEN in IDLE state. 1: R2 is CLOSED in IDLE state.
4	R1_MEASURE	0: R1 is OPEN in MEASURE state. 1: R1 is CLOSED in MEASURE state.
5	R2_MEASURE	0: R2 is OPEN in MEASURE state. 1: R2 is CLOSED in MEASURE state.
6	R1_ZEROCALIB	0: R1 is OPEN in ZEROCALIB state. 1: R1 is CLOSED in ZEROCALIB state.
7	R2_ZEROCALIB	0: R2 is OPEN in ZEROCALIB state. 1: R2 is CLOSED in ZEROCALIB state.

Bit	Name	Description
8	R1_SERVICECALIB	0: R1 is OPEN in SERVICECALIB state. 1: R1 is CLOSED in SERVICECALIB state.
9	R2_SERVICECALIB	0: R2 is OPEN in SERVICECALIB state. 1: R2 is CLOSED in SERVICECALIB state.
10	R1_MEASURE2	0: R1 is OPEN in MEASURE STREAM 2 state. 1: R1 is CLOSED in MEASURE STREAM 2 state.
11	R2_MEASURE2	0: R2 is OPEN in MEASURE STREAM 2 state. 1: R2 is CLOSED in MEASURE STREAM 2 state.
12	R1_MEASURE3	0: R1 is OPEN in MEASURE STREAM 3 state. 1: R1 is CLOSED in MEASURE STREAM 3 state.
13	R2_MEASURE3	0: R2 is OPEN in MEASURE STREAM 3 state. 1: R2 is CLOSED in MEASURE STREAM 3 state.
14	R1_SPANCALIB	0: R1 is OPEN in SPANCALIB state. 1: R1 is CLOSED in SPANCALIB state.
15	R2_SPANCALIB	0: R2 is OPEN in SPANCALIB state. 1: R2 is CLOSED in SPANCALIB state.

4.1.59. MEAS_CYCLES Register

Table 64. MEAS_CYCLES register (0x200A, uint32 , RW)

Unit	Description
-	Number of measurement cycles to run for a Finite Measurement .

4.1.60. AVG_FILTER Register

Table 65. AVG_FILTER register (0x200C, uint32 , RW)

Unit	Description
-	Size of moving average filter in number of measurement cycles.

4.1.61. MANUAL_STREAM_SELECT Register

Table 66. MANUAL_STREAM_SELECT register (0x2030, uint16 , RW)

Value	Name	Description
1	STREAM_1	Select stream 1.
2	STREAM_2	Select stream 2.
3	STREAM_3	Select stream 3.

4.1.62. AUTOMATIC_STREAM_SWITCH Register

Table 67. AUTOMATIC_STREAM_SWITCH register (0x2031, uint16 , RW)

Value	Name	Description
0	FALSE	Disable automatic switch of measurement streams.
1	TRUE	Enable automatic switch of measurement streams.

4.1.63. STREAM_SWITCH_INCLUDES Register

Table 68. STREAM_SWITCH_INCLUDES register (0x2032, uint16 , RW)

Bit	Name	Description
0	INCLUDE_STREAM_1	Indicates of measurement stream 1 will be included on the automatic stream switching. 0: Do not include, 1: Include.
1	INCLUDE_STREAM_2	Indicates of measurement stream 2 will be included on the automatic stream switching. 0: Do not include, 1: Include.
2	INCLUDE_STREAM_3	Indicates of measurement stream 3 will be included on the automatic stream switching. 0: Do not include, 1: Include.

4.1.64. STREAM_1_MEAS_TIME Register

Table 69. STREAM_1_MEAS_TIME register (0x2034, float32 , RW)

Unit	Description
h	Time to measure stream 1 when automatic stream switching is enabled.

4.1.65. STREAM_2_MEAS_TIME Register

Table 70. STREAM_2_MEAS_TIME register (0x2036, float32 , RW)

Unit	Description
h	Time to measure stream 2 when automatic stream switching is enabled.

4.1.66. STREAM_3_MEAS_TIME Register

Table 71. STREAM_3_MEAS_TIME register (0x2038, float32 , RW)

Unit	Description
h	Time to measure stream 3 when automatic stream switching is enabled.

4.1.67. SPANTARGET_METHANE Register

Table 72. SPANTARGET_METHANE register (0x2100, float32, RW)

Unit	Description
mol-%	Span calibration target for METHANE

4.1.68. SPANTARGET_ETHANE Register

Table 73. SPANTARGET_ETHANE register (0x2102, float32, RW)

Unit	Description
mol-%	Span calibration target for ETHANE

4.1.69. SPANTARGET_PROPANE Register

Table 74. SPANTARGET_PROPANE register (0x2104, float32, RW)

Unit	Description
mol-%	Span calibration target for PROPANE

4.1.70. SPANTARGET_BUTANE Register

Table 75. SPANTARGET_BUTANE register (0x2106, float32, RW)

Unit	Description
mol-%	Span calibration target for BUTANE

4.1.71. SPANTARGET_ISOBTANE Register

Table 76. SPANTARGET_ISOBTANE register (0x2108, float32, RW)

Unit	Description
mol-%	Span calibration target for ISOBTANE

4.1.72. SPANTARGET_C5TOT Register

Table 77. SPANTARGET_C5TOT register (0x210A, float32, RW)

Unit	Description
mol-%	Span calibration target for C5TOT

4.1.73. SPANFACTOR_METHANE Register

Table 78. SPANFACTOR_METHANE register (0x2200, float32, R)

Unit	Description
-	Span calibration factor for METHANE

4.1.74. SPANFACTOR_ETHANE Register

Table 79. SPANFACTOR_ETHANE register (0x2202, float32, R)

Unit	Description
-	Span calibration factor for ETHANE

4.1.75. SPANFACTOR_PROPANE Register

Table 80. SPANFACTOR_PROPANE register (0x2204, float32, R)

Unit	Description
-	Span calibration factor for PROPANE

4.1.76. SPANFACTOR_BUTANE Register

Table 81. SPANFACTOR_BUTANE register (0x2206, float32, R)

Unit	Description
-	Span calibration factor for BUTANE

4.1.77. SPANFACTOR_ISOBTANE Register

Table 82. SPANFACTOR_ISOBTANE register (0x2208, float32, R)

Unit	Description
-	Span calibration factor for ISOBTANE

4.1.78. SPANFACTOR_C5TOT Register

Table 83. SPANFACTOR_C5TOT register (0x220A, float32, R)

Unit	Description
-	Span calibration factor for C5TOT

4.1.79. SPANCALIB_INCLUDES Register

Table 84. SPANCALIB_INCLUDES register (0x2300, uint16, RW)

Bit	Name	Description
0	METHANE	Indicates if next span calibration should include METHANE. 0: Do not include, 1: Include.
1	ETHANE	Indicates if next span calibration should include ETHANE. 0: Do not include, 1: Include.
2	PROPANE	Indicates if next span calibration should include PROPANE. 0: Do not include, 1: Include.
3	BUTANE	Indicates if next span calibration should include BUTANE. 0: Do not include, 1: Include.
4	ISOBTANE	Indicates if next span calibration should include ISOBTANE. 0: Do not include, 1: Include.

Bit	Name	Description
5	C5TOT	Indicates if next span calibration should include C5TOT. 0: Do not include, 1: Include.

4.1.80. TIME_YEAR Register

Table 85. TIME_YEAR register (0x2400, uint16 , RW)

Unit	Description
Year	Current year. All datetime registers must be written to simultaneously to set new date.

4.1.81. TIME_MONTH Register

Table 86. TIME_MONTH register (0x2401, uint16 , RW)

Unit	Description
Month (1-12)	Current month. All datetime registers must be written to simultaneously to set new date.

4.1.82. TIME_DAY Register

Table 87. TIME_DAY register (0x2402, uint16 , RW)

Unit	Description
Day of month (1-31)	Current day. All datetime registers must be written to simultaneously to set new date.

4.1.83. TIME_HOUR Register

Table 88. TIME_HOUR register (0x2403, uint16 , RW)

Unit	Description
Hour (0-23)	Current hour. All datetime registers must be written to simultaneously to set new date.

4.1.84. TIME_MINUTE Register

Table 89. TIME_MINUTE register (0x2404, uint16 , RW)

Unit	Description
Minute (0-59)	Current minute. All datetime registers must be written to simultaneously to set new date.

4.1.85. TIME_SECOND Register

Table 90. TIME_SECOND register (0x2405, uint16 , RW)

Unit	Description
Second (0-59)	Current second. All datetime registers must be written to simultaneously to set new date.

4.1.86. ENABLE_ZERO_CHECK Register

Table 91. ENABLE_ZERO_CHECK register (0x2410, uint16, RW)

Value	Name	Description
0	FALSE	Disable automatic zero check.
1	TRUE	Enable automatic zero check.

4.1.87. ZERO_CHECK_SAMPLES Register

Table 92. ZERO_CHECK_SAMPLES register (0x2411, uint16, RW)

Unit	Description
-	Number of samples to average in automatic zero check.

4.1.88. ENABLE_SPAN_CHECK Register

Table 93. ENABLE_SPAN_CHECK register (0x2412, uint16, RW)

Value	Name	Description
0	FALSE	Disable automatic span check.
1	TRUE	Enable automatic span check.

4.1.89. SPAN_CHECK_SAMPLES Register

Table 94. SPAN_CHECK_SAMPLES register (0x2413, uint16, RW)

Unit	Description
-	Number of samples to average in automatic span check.

4.1.90. MAPTYPE Register

Table 95. MAPTYPE register (0x7000, uint16, R)

Value	Description
12	Always reads this value. Indicates that the register map corresponds to the description in this document.

4.1.91. MAPREV Register

Table 96. MAPREV register (0x7001, uint16, R)

Value	Description
10	Always reads this value. Indicates that the register map matches this documentation.

4.1.92. MANUFACTURER Register

Table 97. MANUFACTURER register (0x7002, uint16, R)

Value	Description
0x5455	Always reads this value. Indicates that this is a Tunable AS instrument.

4.1.93. DEVTYPE Register

Table 98. DEVTYPE register (0x7003, uint16, R)

Value	Description
2	Always reads this value. Indicates that this is a T1000-10 instrument.

4.1.94. HWPLATFORM Register

Table 99. HWPLATFORM register (0x7004, uint16, R)

Value	Description
1	BB platform.
2	VD platform.

4.1.95. SERIAL Register

Table 100. SERIAL register (0x8000, string, R)

Unit	Description
-	Serial number of device

4.1.96. OS_VER Register

Table 101. OS_VER register (0x8100, string, R)

Unit	Description
-	OS version

4.1.97. FW_VER Register

Table 102. FW_VER register (0x8200, string, R)

Unit	Description
-	FW version

4.1.98. FPGA_VER Register

Table 103. FPGA_VER register (0x8300, string, R)

Unit	Description
-	FPGA version

5. Revisions

Table 104. Document Revisions

Rev.	Date	Description
23	05.03.2026	Added Start Sweep to register CMD.
22	06.02.2026	Fixed datatype typo for register SPANCALIB_INCLUDES.
21	12.12.2025	Updated some descriptions and fixed typos.
20	21.10.2025	Added new registers for zero and span check values and configurations.
19	26.09.2025	Added emulated values in Table 5 for Modbus Emulation Mode. Changed generation template for manual, some changes in register descriptions as a result.
18	25.06.2025	Added new registers DATETIME_REGS .
17	14.05.2025	Added new registers ABS_TRANS_FLOAT and REL_TRANS_FLOAT .
16	07.11.2024	Fixed wrong address for NITROGEN register.
15	21.08.2024	Updated documentation for ERROR_CODE register.
14	25.04.2024	Split manual for T1000-10 and T1000-20 in two documents. Added MANUFACTURER , DEVTYPE and HWPLATFORM registers. Increased MAPREV to 10.
13	13.02.2024	Added Rx_SPANCALIB bits to RELAY_CFG register. Increased MAPREV to 9.
12	15.11.2023	Fixed wrong values for SERVICECALIB and SPANCALIB in STATE register. Added STARTING state.
11	27.10.2023	Added LIVE_ registers. Added <i>Finite Measurement</i> command. Changed MAPREV to 8.
10	21.09.2023	Added stream switch registers. Changed MAPREV to 7.
09	30.05.2023	Added MEASUREMENT_OUT_OF_RANGE flag to MEAS_FLAGS register. Added MEAS_OOR register. Added COMPRESSIBILITY register. Changed MAPREV to 6.
08	02.08.2022	Added NOOP command to CMD register. Changed MAPREV to 5.
07	06.07.2022	Renamed FLUSHING flag to ZERO_FLUSHING. Added PROCESS_FLUSHING flag. Added ZERO_FLUSHING and PROCESS_FLUSHING states to the STATE register. Changed MAPREV to 4.
06	14.05.2022	Added FLUSHING flag to MEAS_FLAGS. Added DENSITY and REL_DENSITY registers. Added CLEAR_ERROR command to CMD register. Changed MAPREV to 3.

Rev.	Date	Description
05	21.01.2022	Added methane number. Added span calibration registers. Removed FACTORY_RESET register.
04	04.10.2021	Fixed wrong revision in header
03	26.04.2021	Fixed wrong data type for RELAY_CFG
02	11.01.2021	Changed document number
01	26.11.2020	Initial release

[1] A suitable inert gas like helium or argon may be used instead of nitrogen.