Modbus Interface

T1000-10 Natural Gas Analyser

Revision: 15

Table of Contents

1. Modbus Information . . . 1
1.1. Modbus RTU . . . 1
1.2. Modbus TCP . . . 1
2. Analyser Operation . . . 1
2.1. Relay Control . . . 2
2.2. Measure Program . . . 2
2.3. Zero Calibration Program . . . 3
2.4. Span Calibration Program . . . 3
2.5. Stream Switching . . . 4
2.6. Service Calibration Program . . . 4
2.7. Measurement Data . . . 4
2.8. Service Indicators . . . 4
2.9. Live registers . . . 5
3. Interface Description . . . 5
3.1. Data Formats . . . 5
3.2. Memory Layout . . . 6
4. Register Map . . . 6
4.1. Register Descriptions . . . 9
5. Revisions . . . 25

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`.

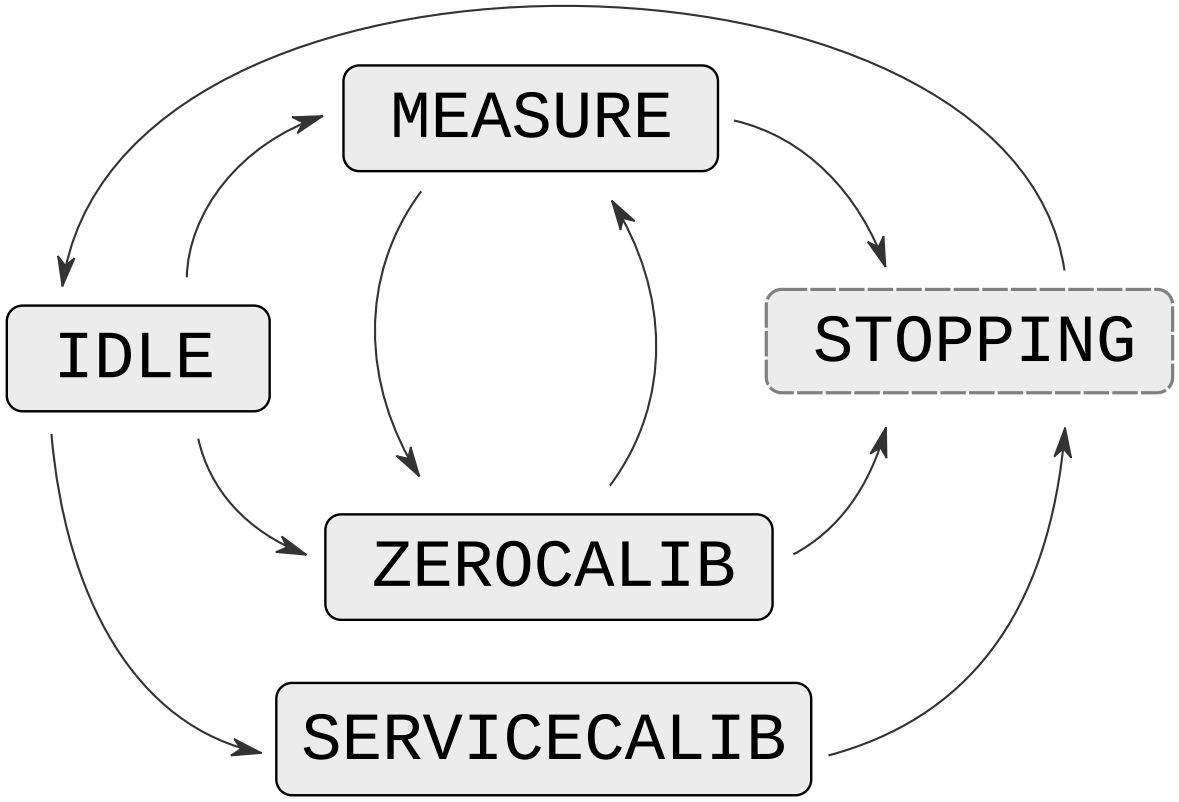

Figure 1. State Machine

2.1. Relay Control

Two relays intended for controlling soleniod 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 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_INCLUDE 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 inteded 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

Adress:	`0x8000`	`0x8001`	`0x80002`	`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

Adress 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.

4. Register Map

The register map is given in Table 5.

Table 5. Register Map

Address	Name	Access	Data type
Data Section			
0x0000	METHANE	R	float32
0x0002	ETHANE	R	float32
0x0004	PROPANE	R	float32
0x0006	BUTANE	R	float32
0x0008	ISOBUTANE	R	float32
0x000A	C5TOT	R	float32
0x000C	NITROGEN	R	float32
0x0020	GAS_PRESSURE	R	float32

Address	Name	Access	Data type
0x0022	GAS_TEMP	R	float32
0x0024	BOARD_TEMP	R	float32
0x0026	FP_TEMP	R	float32
0x0028	FP_HUMID	R	float32
0x0030	HHV_MASS	R	float32
0x0032	LHV_MASS	R	float32
0x0034	HHV_VOLUME	R	float32
0x0036	LHV_VOLUME	R	float32
0x0038	GROSS_WOBBE	R	float32
0x003A	NET_WOBBE	R	float32
0x003C	DENSITY	R	float32
0x003E	REL_DENSITY	R	float32
0x0040	MEAS_CNT	R	uint32
0x0042	MEAS_FLAGS	R	uint32
0x0044	TIMESTAMP	R	uint32
0x0046	MEAS_OOR	R	uint32
0x0048	MEAS_STREAM	R	uint16
0x0050	METHANE_NUMBER	R	float32
0x0052	COMPRESSIBILITY	R	float32
0x0200	STATE	R	uint16
0x0202	ERROR_CODE	R	uint32
0x0204	PROGRESSION	R	uint16
0x0205	RELAY_STATE	R	uint16
0x0300	ABS_TRANS	R	uint16
0x0301	REL_TRANS	R	uint16
0x0420	LIVE_GAS_PRESSURE	R	float
0x0422	LIVE_GAS_TEMP	R	float
0x0424	LIVE_BOARD_TEMP	R	float
0x0426	LIVE_FP_TEMP	R	float
0x0428	LIVE_FP_HUMID	R	float
Control Section			
0x1000	CMD	W	uint16
0x1001	RELAY_CTRL	W	uint16

Address	Name	Access	Data type
0x1010	REBOOT	W	uint16
Configuration Section			
0x2000	AUTOSTART	RW	uint16
0x2001	AUTOZERO	RW	uint16
0x2002	AUTOZERO_PERIOD	RW	float32
0x2004	RELAY_CFG	RW	uint16
0x200A	MEAS_CYCLES	RW	uint32
0x200C	AVG_FILTER	RW	uint32
0x2030	MANUAL_STREAM_SELECT	RW	uint16
0x2031	AUTOMATIC_STREAM_SWITCH	RW	uint16
0x2032	STREAM_SWITCH_INCLUDE	RW	uint16
0x2034	STREAM_1_MEASURE_TIME	RW	float32
0x2036	STREAM_2_MEASURE_TIME	RW	float32
0x2038	STREAM_3_MEASURE_TIME	RW	float32
0x2100	SPANTARGET_METHANE	RW	float32
0x2102	SPANTARGET_ETHANE	RW	float32
0x2104	SPANTARGET_PROPANE	RW	float32
0x2106	SPANTARGET_BUTANE	RW	float32
0x2108	SPANTARGET_ISOBUTANE	RW	float32
0x210A	SPANTARGET_C5TOT	RW	float32
0x2200	SPANFACTOR_METHANE	R	float32
0x2202	SPANFACTOR_ETHANE	R	float32
0x2204	SPANFACTOR_PROPANE	R	float32
0x2206	SPANFACTOR_BUTANE	R	float32
0x2208	SPANFACTOR_ISOBUTANE	R	float32
0x220A	SPANFACTOR_C5TOT	R	float32
0x2300	SPANCALIB_INCLUDE	RW	uint16
Information Section			
0x7000	MAPTYPE	R	uint16
0x7001	MAPREV	R	uint16
0x7002	MANUFACTURER	R	uint16
0x7003	DEVTYPE	R	uint16
0x7004	HWPLATFORM	R	uint16

Address	Name	Access	Data type
0x8000	SERIAL	R	string
0x8100	OS_VER	R	string
0x8200	FW_VER	R	string
0x8300	FPGA_VER	R	string

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 (0x000C, 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. FP_HUMID Register

Table 17. FP_HUMID register (0x0028, float32, R)

Unit	Description
RH	Fabry-Perot filter humidity

4.1.13. HHV_MASS Register

Table 18. HHV_MASS register (0x0030, float32, R)

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

4.1.14. LHV_MASS Register

Table 19. LHV_MASS register (0x0032, float32, R)

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

4.1.15. HHV_VOLUME Register

Table 20. HHV_VOLUME register (0x0034, float32, R)

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

4.1.16. LHV_VOLUME Register

Table 21. LHV_VOLUME register (0x0036, float32, R)

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

4.1.17. GROSS_WOBBE Register

Table 22. GROSS_WOBBE register (0x0038, float32, R)

Unit	Description
MJ/m3	Gross Wobbe Index

4.1.18. NET_WOBBE Register

Table 23. NET_WOBBE register (0x003A, float32, R)

Unit	Description
MJ/m3	Net Wobbe Index

4.1.19. DENSITY Register

Table 24. DENSITY register (0x003C, float32, R)

Unit	Description
kg/m3	Gas density

4.1.20. REL_DENSITY Register

Table 25. REL_DENSITY register (0x003E, float32, R)

Unit	Description
-	Relative density

4.1.21. MEAS_CNT Register

Table 26. MEAS_CNT register (0x0040, uint32, R)

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

4.1.22. MEAS_FLAGS Register

Table 27. 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 high 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 warning
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

Bit	Name	Description
9	MEASUREMENT_OUT_OF_RANGE	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.

4.1.23. TIMESTAMP Register

Table 28. TIMESTAMP register (0x0044, uint32, R)

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

4.1.24. MEAS_OOR Register

Table 29. 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.

Bit	Name	Description
6	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 calulation valid according to ISO23306. 1: Methane number calculation not valid.

4.1.25. MEAS_STREAM Register

Table 30. MEAS_STREAM register (0x0048, uint16, R)

Value	Name	Description
0	N/A	N/A
1	STREAM_1	Measure Stream 1
2	STREAM_2	Measure Stream 2
3	STREAM_3	Measure Stream 3

4.1.26. METHANE_NUMBER Register

Table 31. METHANE_NUMBER register (0x0050, float32, R)

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

4.1.27. COMPRESSIBILITY Register

Table 32. COMPRESSIBILITY register (0x0052, float32, R)

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

4.1.28. STATE Register

Table 33. 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)

Value	Name	Description
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	Analyzer in process of starting a measurement

4.1.29. ERROR_CODE Register

Table 34. ERROR_CODE register (0x0202, uint32, R)

Value	Name	Description
0	NONE	No error
1	GENERIC	Unspecified error
2	CONFIG	Configuration error
3	DATABASE	Database error
4	FPGA	FPGA error
5	IRDRV	IR driver error
6	IRDET	IR detector error
7	FILTER	IR filter error
10	DMA	DMA error
11	FILTERTEMP	Filter temperature sensor error
12	GASTEMP	Gas temperature sensor error
13	GASPRESSURE	Gas pressure sensor error
14	FILTERHUMID	Filter humidity sensor error
15	SELFTEST	Selftest failed
17	WATCHDOG	Watchdog error
18	MODBUS	Modbus error
19	FILTERCALIB	Filter calibration error
20	RELAYCTRL	Error in relay ctrl
22	HEALTHCHECK	Errur during healthcheck
24	IRDETCLIP	IR detector clipping
26	COMPUTE	Internal computation error
29	SPANCALIB	Span calibration failed
33	FPDACCLIP	FP DAC clip (internal error)
34	HIGHFPTEMP	Filter temperature too high

Value	Name	Description
35	LOWFPTEP	Filter temperature too low
36	HIGHGASTEMP	Gas temp too high
37	LOWGASTEMP	Gas temp too low
38	HIGHGASPRESS	Gas pressure too high
39	LOWGASPRESS	Gas pressure too low
40	HIGHREFCALIBTEMP	Temperature above calibration
41	LOWREFCALIBTEMP	Temperature below calibration
42	CVFAIL	Failed to calculate Calorific Value
44	MNFAIL	Failed to calculate Methane Number
45	MODELERR	Error in estimation model
63	ZEROFAIL	Zero caliberation failed

4.1.30. PROGRESSION Register

Table 35. PROGRESSION register (0x0204, uint16, R)

Unit	Description
%	Measurement cycle progression

4.1.31. RELAY_STATE Register

Table 36. 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.

4.1.32. ABS_TRANS Register

Table 37. ABS_TRANS Register (0x0300, uint16, R)

Unit	Description
%	Absolute transmission

4.1.33. REL_TRANS Register

Table 38. REL_TRANS Register (0x0301, uint16, R)

Unit	Description
%	Relative transmission

4.1.34. LIVE_GAS_PRESSURE Register

Table 39. LIVE_GAS_PRESSURE register (0x0420, float32, R)

Unit	Description
bar	Live gas pressure

4.1.35. LIVE_GAS_TEMP Register

Table 40. LIVE_GAS_TEMP register (0x0422, float32, R)

Unit	Description
C	Live gas temperature

4.1.36. LIVE_BOARD_TEMP Register

Table 41. LIVE_BOARD_TEMP register (0x0424, float32, R)

Unit	Description
C	Live board temperature

4.1.37. LIVE_FP_TEMP Register

Table 42. LIVE_FP_TEMP register (0x0426, float32, R)

Unit	Description
C	Live Fabry-Perot filter temperature

4.1.38. LIVE_FP_HUMID Register

Table 43. LIVE_FP_HUMID register (0x0428, float32, R)

Unit	Description
RH	Fabry-Perot filter humidity

4.1.39. CMD Register

Table 44. 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 Calibration.
8	START_SERVICECALIB	Start Service Calibration
9	START_SPANCALIB	Start Span Calibration

Value	Name	Description
10	CLEAR_SPAN_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.

4.1.40. RELAY_CTRL Register

Table 45. 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.

4.1.41. REBOOT Register

Table 46. REBOOT register (0x1010, uint16, W)

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

4.1.42. AUTOSTART Register

Table 47. AUTOSTART register (0x2000, uint16, RW)

Value	Name	Description
0	FALSE	Enter IDLE state on start-up
1	TRUE	Start measurements on start-up

4.1.43. AUTOZERO Register

Table 48. AUTOZERO register (0x2001, uint16, RW)

Value	Name	Description
0	FALSE	Do not run automatic zero-point calibrations
1	TRUE	Run zero-point calibrations automatically

4.1.44. AUTOZERO_PERIOD Register

Table 49. AUTOZERO_PERIOD register (0x2002, float32, RW)

Unit	Description
h	Time between zero-point calibrations

4.1.45. RELAY_CFG Register

Table 50. RELAY_CFG register (0x2004, uint32, RW)

Bit	NAME	Description
0	ENABLE	0: Relay control is DISABLED. 1: Relay controls 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.
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.

4.1.46. MEAS_CYCLES Register

Table 51. MEAS_CYCLES Register (0x200A, uint32, RW)

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

4.1.47. AVG_FILTER Register

Table 52. AVG_FILTER Register (0x200C, uint32, RW)

Unit	Description
-	Size of averaging filter in number of measurement cycles.

4.1.48. MANUAL_STREAM_SELECT Register

Table 53. 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

4.1.49. AUTOMATIC_STREAM_SWITCH Register

Table 54. 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

4.1.50. STREAM_SWITCH_INCLUDE Register

Table 55. STREAM_SWITCH_INCLUDE register (0x2032, uint16, RW)

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

4.1.51. STREAM_1_MEASURE_TIME Register

Table 56. STREAM_1_MEASURE_TIME register (0x2034, float32, RW)

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

4.1.52. STREAM_2_MEASURE_TIME Register

Table 57. STREAM_2_MEASURE_TIME register (0x2036, float32, RW)

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

4.1.53. STREAM_3_MEASURE_TIME Register

Table 58. STREAM_3_MEASURE_TIME register (0x2038, float32, RW)

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

4.1.54. SPANTARGET_METHANE Register

Table 59. SPANTARGET_METHANE register (0x2100, float32, RW)

Description
Span calibration target for METHANE

4.1.55. SPANTARGET_ETHANE Register

Table 60. SPANTARGET_ETHANE register (0x2102, float32, RW)

Description
Span calibration target for ETHANE

4.1.56. SPANTARGET_PROPANE Register

Table 61. SPANTARGET_PROPANE register (0x2104, float32, RW)

Description
Span calibration target for PROPANE

4.1.57. SPANTARGET_BUTANE Register

Table 62. SPANTARGET_BUTANE register (0x2106, float32, RW)

Description
Span calibration target for BUTANE

4.1.58. SPANTARGET_ISOBUTANE Register

Table 63. SPANTARGET_ISOBUTANE register (0x2108, float32, RW)

Description
Span calibration target for ISOBUTANE

4.1.59. SPANTARGET_C5TOT Register

Table 64. SPANTARGET_C5TOT register (0x210A, float32, RW)

Description
Span calibration target for C5TOT

4.1.60. SPANFACTOR_METHANE Register

Table 65. SPANFACTOR_METHANE register (0x2200, float32, R)

Description
Span calibration factor for METHANE

4.1.61. SPANFACTOR_ETHANE Register

Table 66. SPANFACTOR_ETHANE register (0x2202, float32, R)

Description
Span calibration factor for ETHANE

4.1.62. SPANFACTOR_PROPANE Register

Table 67. SPANFACTOR_PROPANE register (0x2204, float32, R)

Description
Span calibration factor for PROPANE

4.1.63. SPANFACTOR_BUTANE Register

Table 68. SPANFACTOR_BUTANE register (0x2206, float32, R)

Description
Span calibration factor for BUTANE

4.1.64. SPANFACTOR_ISOBUTANE Register

Table 69. SPANFACTOR_ISOBUTANE register (0x2208, float32, R)

Description
Span calibration factor for ISOBUTANE

4.1.65. SPANFACTOR_C5TOT Register

Table 70. SPANFACTOR_C5TOT register (0x220A, float32, R)

Description
Span calibration factor for C5TOT

4.1.66. SPANCALIB_INCLUDE Register

Table 71. SPANCALIB_INCLUDE register (0x2300, uint32, 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	ISOBUTANE	Indicates if next span calibration should include ISOBUTANE. 0: Do not include 1: Include
5	C5TOT	Indicates if next span calibration should include C5TOT. 0: Do not include 1: Include

4.1.67. MAPTYPE Register

Identifies the register map type.

Table 72. MAPTYPE register (0x7000, uint16, R)

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

4.1.68. MAPREV Register

Identifies the register map revision.

Table 73. MAPREV register (0x7001, uint16, R)

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

4.1.69. MANUFACTURER Register

Identifies the manufacturer.

Table 74. MANUFACTURER register (0x7002, uint16, R)

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

4.1.70. DEVTYPE Register

Identifies the device type.

Table 75. DEVTYPE register (0x7003, uint16, R)

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

4.1.71. HWPLATFORM Register

Identifies the hardware platform.

Table 76. HWPLATFORM register (0x7004, uint16, R)

Description
Number representing the hardware platform

4.1.72. SERIAL Register

Table 77. SERIAL Register (0x8000, string, R)

Description
Serial number of device.

4.1.73. OS_VER Register

Table 78. OS_VER Register (0x8100, string, R)

Description
OS version

4.1.74. FW_VER Register

Table 79. FW_VER Register (0x8200, string, R)

Description
FW version

4.1.75. FPGA_VER Register

Table 80. FPGA_VER Register (0x8300, string, R)

Description
FPGA version

5. Revisions

Table 81. Document Revisions

Rev.	Date	Description
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 *Finite Measurement* 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.
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.