EVVOS HTP PROBE USER'S MANUAL

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Contact Information

Email: sales@evvos.com
Company Address:

Evvos S.A.
65, rue des Bruyeres
L-1274 Howald
Luxembourg

Website: www.evvos.com

Document Revision

Document Revisions and Updates

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1.1	Updated compliance with SDI-12 v1.4	9-Mar-2023
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1. General Information

The Evvos HTP probe combines meteorological grade sensors for relative humidity, air temperature, and barometric pressure measurements. It is designed to provide high-quality environmental data, real-time measurements, and calculation of multiple derivative parameters. The Evvos HTP probe is also available in extended versions capable of extra measurements such as CO2-percentage (in air) compensated for relative humidity and air temperature.

Applications
- Environmental monitoring
- Weather forecasting solutions
- Industrial data acquisition
- Precision agriculture/farming
- Cold chain and HVAC applications
- Internet of Things (IoT)

Primary parameters
- Relative humidity
- Air temperature
- Barometric pressure
- CO2-percentage in air (HTP-CO_2 version only)

Secondary parameters
- Absolute humidity
- Dew point
- Wet-bulb temperature
- Vapour pressure
- Saturated vapour pressure
- Atmospheric pressure at sea level
- Heat index
- Mixing ratio
- Specific enthalpy
- Boiling point of water
- Speed of sound in air
- Water activity in air

1.1. Highlights

- Stainless steel enclosure and filter cap engineered to shield sensing elements in harsh environments.
- Waterproof protection, and internal electronics sealed in resin.
- Multiple electrical interfacing and data protocol options - SDI-12 (v.1.4), RS-485 (Modbus, NMEA0183), UART, USB.
- Low-power consumption suitable for battery-powered applications. On-board heater included.
- Extensive command sets for operational options and probe diagnostics.
- UV-protected and optional oil-resistant flexible cable.

1.2. Description

EHTP is a high-accuracy, digital probe for measuring multiple environmental parameters. Due to its low power consumption, versatile electrical interfacing options, and wide-range power supply, the probe is compatible with a variety of battery-operated dataloggers and industrial data acquisition systems. A stainless-steel enclosure in combination with weatherproof electronic circuitry ensures proper long-term operation even in harsh outdoor and demanding industrial conditions. All primary parameters are sensed by physical sensors. The secondary parameters are calculated, based on values measured by the probe's physical sensors. For optimal results in outdoor applications an EHTP probe must be installed in a solar shield.

1.3. Measured Parameters and Units

Table 1.1. EHTP: Environmental Parameters

Parameter	Unit	Description
air_ temperature	°C / °F	*Air Temperature (Dry-Bulb Temperature)*
relative_humidity	%	*Relative Humidity of Air*
barometric_pressure	hPa	*Barometric Pressure*
sea_level_pressure	hPa	*Reduced to Sea Level Atmospheric Pressure*
dew_point	°C	*Dew Point (Dew Temperature)*
absolute_humidity	g/m^3	*Absolute Humidity of Air*
vapor_pressure	hPa	*Vapor Pressure in Air*
saturated_vapor_pressure	hPa	*Saturated Vapor Pressure in Air*
heat_index	°C	*Heat Index*
speed_of_sound	m/s	*Speed of Sound in Air*
mixing_ratio	g/kg	*Mixing Ratio of Moisture in Air*
specific_enthalpy	kJ/kg	*Specific Enthalpy*
water_activity	-	*Water Activity in Air*
water_boiling_point	°C	*Boiling Point of Water*
wet_bulb_temperature	°C	*Wet-Bulb Temperature*
CO2_percentage	%	***HTP-CO_2 version only:*** *Percentage Concentration of CO2 in Air*

1.3.1. Primary Parameters

The primary environmental parameters are sampled by physical sensors within the probe. All primary parameters are sampled simultaneously to form a complete set of momentary values for a given measurement event. Each sampled value undergoes an in-range validity check before being used for calculating secondary parameters. The values which do not pass the validity check are discarded and a respective error flag is raised in *sensor_errors* (see *Diagnostics*). The accuracy of a primary parameter can be enhanced by applying an individual user calibration. Note that certain versions of EHTP are enabled to measure additional primary parameters.

1.3.2. Secondary Parameters

Secondary parameters are calculated by the EHTP probe only if the primary parameters have valid (in-range) values. The accuracy of a secondary parameter benefits indirectly from the optional user calibration of the primary parameters involved in its calculation (see *Table 1.2. EHTP: Secondary – Primary Parameters Functional Dependence*).

Table 2.2. EHTP: Secondary – Primary Parameters Functional Dependence

Secondary parameters	Primary parameters		
Parameter	*Air Temperature*	*Relative Humidity*	*Barometric Pressure*
Reduced to Sea Level Atmospheric Pressure[1]	•		•
Secondary parameters	**Primary parameters**		
Dew Point	•	•	
Absolute Humidity of Air	•	•	
Vapor Pressure in Air	•	•	
Saturated Vapor Pressure in Air	•		
Heat Index	•	•	
Speed of Sound in Air[2]	•	•	•
Mixing Ratio of Moisture in Air	•	•	•
Water Activity in Air	•	•	
Boiling Point of Water			•
Wet-Bulb Temperature	•	•	•

(1) Parameter also dependent on input by user (*height_above_sea_level, vertical_temp_coeff*)
(2) Slight dependence on barometric pressure

1.3.3. Calculating the Wet-Bulb Temperature

The secondary parameter of wet-bulb temperature is calculated through iterative solution of the wet-bulb thermodynamic equation. It is adjusted for the momentary values of the primary parameters air temperature, relative humidity, and barometric pressure. For fewer iterations the initial conditions are always modified based on the momentary values of *air_temperature* and *dew_point*. The number of performed iterations is stored in *wet_bulb_iterations*. To avoid an infinite loop the maximal count of iterations is limited to 1000. The value of *wet_bulb_iterations* can be used as a validity indicator: any value below 1000 indicates a valid calculation of the wet-bulb temperature.

1.3.4. Calculating the Sea Level Pressure

A protocol-specific set of commands enables the conversion of local barometric pressure to standard mean sea level atmospheric pressure as a means of migrating to worldwide standard atmospheric pressure value (see *Reduced to Sea Level Atmospheric Pressure*). Such conversion is valid in stationary installations only. Two user-input parameters are expected by the probe (see *Table 7.7.* EHTP: Calibration Parameters): exact altitude of the probe's installation point (mandatory, *height_above_sea_level*) and local vertical temperature coefficient (optional, *vertical_temp_coeff*). If no altitude is specified, then the default rule is followed by EHTP: *sea_level_pressure = barometric_pressure*. The input parameters must always be provided to the probe in their respective units as per *Table 3.3.* EHTP: Sea Level Pressure Input Parameters otherwise erroneous calculations will be performed. To store the user input values in the probe's non-volatile memory for permanent use a protocol-specific "save-to-EEPROM" command should be issued.

Table 3.3. EHTP: Sea Level Pressure Input Parameters

Parameter	R/W	Default	Unit	Description
height_above_sea_level	R/W	0	m	Height of installation point above sea level (for fixed installations only)
vertical_temp_coeff	R/W	0.6	°C/100m	Atmospheric vertical temperature gradient (a.k.a. temperature lapse rate)

NOTE: recommended range of height_above_sea_level [0-5000], recommended range of vertical_temp_coeff [0.5 – 0.65]

1.4. Statistics

This is an automatically performed special feature of EHTP for continually updating a set of basic statistical values for each primary and secondary parameter within any period of uninterrupted power supply for an EHTP. A statistical set consists of the following measured/calculated values in the period of continuous operation (see *Table 4.4.* EHTP: Statistical Environmental Parameters for naming convention and description of the statistical parameters):

- the minimal value of a given parameter within the statistical sample
- the maximal value of a given parameter within the statistical sample
- the first value of a given parameter within the statistical sample
- the last value of a given parameter within the statistical sample updated before reading the set
- the count of values for a given parameter processed within the statistical sample

The statistical sets are always updated after processing any new value of a given parameter. For any parameter, the maximal count of values within a statistical sample is 999999. No overflow to zero is performed in cases with an actual count greater than the maximal. The accumulation of statistical data is cleared and restarted after a power-up. Protocol-specific commands provide reading of the accumulated statistics as well as manual management of statistics collection for the individual parameters.

Table 4.4. EHTP: Statistical Environmental Parameters

Parameter	Unit	Description
MIN_air_temperature	°C	Minimal value of parameter within a statistical sample
MAX_air_temperature	°C	Maximal value of parameter within a statistical sample
FIRST_air_temperature	°C	First value of parameter within a statistical sample
LAST_air_temperature	°C	Last value of parameter within a statistical sample
COUNT_air_temperature	-	Count of values a statistical sample is based upon
MIN_relative_humidity	%	
MAX_relative_humidity	%	
FIRST_relative_humidity	%	
LAST_relative_humidity	%	
COUNT_relative_humidity	-	
MIN_barometric_pressure	hPa	
MAX_barometric_pressure	hPa	
FIRST_barometric_pressure	hPa	
LAST_barometric_pressure	hPa	
COUNT_barometric_pressure	-	
MIN_sea_level_pressure	hPa	
MAX_sea_level_pressure	hPa	
FIRST_sea_level_pressure	hPa	
LAST_sea_level_pressure	hPa	
COUNT_sea_level_pressure	-	
MIN_saturated_vapor_pressure	hPa	
MAX_saturated_vapor_pressure	hPa	
FIRST_saturated_vapor_pressure	hPa	
LAST_saturated_vapor_pressure	hPa	
COUNT_saturated_vapor_pressure	-	
MIN_heat_index	°C	
MAX_heat_index	°C	
FIRST_heat_index	°C	
LAST_heat_index	°C	
COUNT_heat_index	-	
MIN_speed_of_sound	m/s	
MAX_speed_of_sound	m/s	
FIRST_speed_of_sound	m/s	
LAST_speed_of_sound	m/s	
COUNT_speed_of_sound	-	
MIN_mixing_ratio	g/kg	
MAX_mixing_ratio	g/kg	
FIRST_mixing_ratio	g/kg	
LAST_mixing_ratio	g/kg	

COUNT_mixing_ratio	-	
MIN_specific_enthalpy	J/kg	
MAX_specific_enthalpy	J/kg	
FIRST_specific_enthalpy	J/kg	
LAST_specific_enthalpy	J/kg	
COUNT_specific_enthalpy	-	
Parameter	**Unit**	**Description**
MIN_water_activity	-	
MAX_water_activity	-	
FIRST_water_activity	-	
LAST_water_activity	-	
COUNT_water_activity	-	
MIN_water_boiling_point	°C	
MAX_water_boiling_point	°C	
FIRST_water_boiling_point	°C	
LAST_water_boiling_point	°C	
COUNT_water_boiling_point	-	
MIN_wet_bulb_temperature	°C	Minimal value of parameter within a statistical sample
MAX_wet_bulb_temperature	°C	Maximal value of parameter within a statistical sample
FIRST_wet_bulb_temperature	°C	First value of parameter within a statistical sample
LAST_wet_bulb_temperature	°C	Last value of parameter within a statistical sample
COUNT_wet_bulb_temperature	-	Count of values a statistical sample is based upon
MIN_CO2_percentage	%	Available only in EHTP-CO2 version of the probe
MAX_CO2_percentage	%	Available only in EHTP-CO2 version of the probe
FIRST_CO2_percentage	%	Available only in EHTP-CO2 version of the probe
LAST_CO2_percentage	%	Available only in EHTP-CO2 version of the probe
COUNT_CO2_percentage	-	Available only in EHTP-CO2 version of the probe

1.5. On-board Heater

The heater is used for removing condensed water drops on the humidity sensor in operating environments prone to condensation. The operation cycle is divided into 3 modes: HEATING, COOLING, OFF. The heater activation and status reading are performed by the master (controller/user) with a protocol-specific set of commands. Each command activates HEATING mode for a command-determined period (multiple of 10s). At the end of this period the probe enters automatically COOLING mode followed by automatic transition to OFF mode. If a new activation command is issued before the completion of the heater's operation cycle, then the cycle is restarted with the new parameters. This method is also applied for pre-term switching OFF (by issuing command for activation period = 0s). The default state of the heater is always OFF at probe's power-up. For valid results the probe's voltage supply must be kept uninterruptedly ON for at least the duration of the HEATING mode. During this mode a dedicated algorithm within the probe continually monitors the temperature of the humidity sensor and adjusts the heating power. The values of relative humidity, and barometric pressure are kept frozen while in HEATING and COOLING modes. During these modes any temperature values may be out of the nominal accuracy range for the probe. It is possible for an EHTP with activated heater to occasionally skip responding to valid commands by the master. In such a case repetition of the command is recommended. Excessive or prolonged use of the on-board heater may lead to permanent deterioration of the probe's accuracy and shorten its lifespan. Generally, the accumulated heater activation time (HEATING mode) should amount to no more than 10% of the total operation time of the probe.

Table 5.5. EHTP: On-board Heater Parameters

Parameter	R/W	Unit	Description
HEAT_mode	R	-	Indicator of the operational mode of the on-board heater: MANUAL, AUTO
HEAT_status	R	-	Indicator of the state of the heater cycle: ON, COOLING, OFF
HEAT_duty_cycle	R	-	Automatically set parameter for PWM control of the on-board heater

HEAT_set_time	R	s	User-defined ON time for the on-board heater (protocol-specific command)
HEAT_remaining_time	R	s	Self-updating remaining ON time for the on-board heater when enabled
HEAT_initial_temperature	R	°C	Temperature of the RH-sensor at the beginning of heater's ON state
HEAT_delta_temperature	R	°C	Increase of temperature of the RH-sensor during heating
COOL_remaining_time	R	s	Self-updating remaining COOLING time for the RH-sensor after heater automatically shuts OFF
Parameter	**R/W**	**Unit**	**Description**
COOL_initial_temperature	R	°C	The temperature of the RH-sensor at the end of heater's ON state
COOL_delta_temperature	R	°C	Decrease of temperature of the RH-sensor during cooling

1.6. Diagnostics

EHTP can perform auxiliary measurements for self-diagnostic purposes. Refer to *Table 6.6.* EHTP: Diagnostic Parameters for a list of all diagnostic parameters. Single measurements of the on-board voltages (*MCU_voltage*, *SEN_voltage*, *VIN_voltage*) are always performed at power-up automatically. The value of *reset_cause* is also updated on power-up and cannot be overridden. A self-calibration of the *MCU_temperature* is performed on power-up, too. The *sensor_errors* register is updated synchronously with the values of primary environmental parameters and keeps a record of any out-of-range occurrences. The *power_errors* and *MCU_errors* registers are updated on power-up. *power_errors* keeps a record of deviations in *MCU_voltage* greater than 7% during run-time. A manual diagnostic routine and update of all diagnostic values except for *reset_cause* can be performed with protocol-specific set of commands. Each detected occurrence of an error increments the value of *errors_count* (max value is 65535 without automatic overflow to zero). The values of *power_errors, sensor_errors*, *MCU_errors*, *errors_count* are always cleared before the power-up tests and before executing a request for manual diagnostics. Refer to the protocol-specific description of diagnostic commands for complete description of the diagnostic parameters.

Table 6.6. EHTP: Diagnostic Parameters

Parameter	R/W	Default	Unit	Description
MCU_voltage	R	-	mV	Internally regulated voltage supply for the on-board microcontroller
SEN_voltage	R	-	mV	Internally regulated voltage supply for the sensor circuits
VIN_voltage	R	-	mV	Unregulated voltage supply fed to the probe
MCU_temperature	R	-	°C	Temperature of the on-board microcontroller
MCU errors	R	0	-	A register of errors occurred in the MCU of a probe
reset_cause	R	0	-	A register of the most recent MCU reset cause code
power_errors	R	0	-	A register of error in the power circuitry of a probe
sensor_errors	R	0	-	A register of errors occurred during sensing
errors_count	R	0	-	Total count of errors occurred in a probe
wet_bulb_iterations	R	-	-	Count of iterations to solve the equation for wet_bulb_temperature

1.7. Test Aid

A built-in feature that returns fixed values/messages with known content to help a developer/integrator validate the integration between a Master system and a HTP. The fixed messages can be used to test and debug encoding/decoding algorithms and communication settings. They can also be useful validation tools for periodic communication tests during run time. The messages/values are formatted as per the conventions of the specific interface(s) implemented in a HTP probe.

1.8. Single-Wire Auxiliary Interface

A low-power multipurpose digital interface that is available in all versions of HTP. Its primary use is compatibility with the data acquisition products by Evvos. It is also reserved for future upgrades and functional enhancements.
The single-wire interface is disabled at voltage supply greater than 6 Vdc to improve the electromagnetic immunity of the probe.

EVVOS

1.9. User Calibration

1.9.1. Description

Optional user-defined multipoint calibrations for each of the primary parameters (air temperature, relative humidity, and barometric pressure). Increased accuracy of all parameters is achieved through second-order polynomial calibrating formulas over the values of the primary parameters always applied before calculating the secondary parameters. For calculation of the calibration coefficients a set of no less than 3 reference measurements is required. Additional reference measurements will enhance the calibration accuracy. A protocol-specific set of commands provides individual calibration management for each primary parameter:

- run-time enabling/disabling of individual calibration rules
- in-probe calibration test mode for error analysis

Table 7.7. EHTP: Calibration Parameters

Parameter	R/W	Default	Unit	Description
CAL_temperature_A	R/W	0.000000	-	Calibration coefficient A for air temperature
CAL_temperature_B	R/W	1.000000	-	Calibration coefficient B for air temperature
CAL_temperature_C	R/W	0.000000	-	Calibration coefficient C for air temperature
CAL_temperature_date	R/W	0	-	User-defined date of the most recent air temperature calibration
CAL_temperature_status	R/W	0		Calibration state (ON=1/OFF=0) for air temperature
TEST_temperature_value	R/W	-	°C/°F	User-defined temperature value for manual test and evaluation of the air temperature calibration
CAL_humidity_A	R/W	0.000000	-	Calibration coefficient A for relative humidity
CAL_humidity_B	R/W	1.000000	-	Calibration coefficient B for relative humidity
CAL_humidity_C	R/W	0.000000	-	Calibration coefficient C for relative humidity
CAL_humidity_date	R/W	0	-	User-defined date of the most recent relative humidity calibration
CAL_humidity_status	R/W	0		Calibration state (ON=1/OFF=0) for relative humidity
TEST_humidity_value	R/W	-	%	User-defined temperature value for manual test and evaluation of the relative humidity calibration
CAL_pressure_A	R/W	0.000000	-	Calibration coefficient A for barometric pressure
CAL_pressure_B	R/W	1.000000	-	Calibration coefficient B for barometric pressure
CAL_pressure_C	R/W	0.000000	-	Calibration coefficient C for barometric pressure
CAL_pressure_date	R/W	0	-	User-defined date of the most recent barometric pressure calibration
CAL_pressure_status	R/W	0		Calibration state (ON=1/OFF=0) for relative humidity
TEST_pressure_value	R/W	-	hPa	User-defined temperature value for manual test and evaluation of the barometric pressure calibration

1.9.2. Application

- Improvement of measurement accuracy in a local range of interest
- Minimization of probe-to-probe errors
- Optimization of measurement performance
- Point-by-point validation and analysis of calibration quality in demanding applications

1.9.3. Calibration Equation

The general form of the calibration equation programmed in EHTP allows multipoint calibration for reduction of errors in global or local measurement range:

$$x_{cal} = Ax^2 + Bx + C$$

There are three types of measurement errors that can be significantly reduced using this 2-order calibration equation above: offset, gain, and nonlinearity.

Whenever A = 0, the calibration equation can be used in its simplified linearization form, allowing 2-point calibration in global or local measurement range:

$$x_{cal} = Bx + C$$

Where:

x_{cal} – calibrated value of a primary parameter:

air_temperature $_{cal}$ or
relative_himidity $_{cal}$ or
barometrc_pressure $_{cal}$

x – measured (uncalibrated) value of a primary parameter:

air_temperature or
relative_himidity or
barometrc_pressure

A, B, C – user-defined set of calibration coefficients for a primary parameter:

CAL_temperature_A, CAL_temperature_B, CAL_temperature_C or
CAL_humidity_A, CAL_humidity_B, CAL_humidity_C or
CAL_pressure_A, CAL_pressure_B, CAL_pressure_C

This simplified linear equation can be applied to reduce offset and gain errors.

1.9.4. Calculation of Calibration Coefficients

The word "parameter" refers to any of the primary parameters, measured by an EHTP probe: air temperature, relative humidity, and barometric pressure. The steps are valid for the general form of the calibration equation (A≠0).

1. For a selected parameter, perform multiple measurements of at least 3 reference values to gather a table of multipoint reference data.
2. Enter the reference data into the least square algorithm (e.g. ***Error! Reference source not found.***) to calculate c alibration coefficients A, B, C for the selected parameter
3. Enter the calibration coefficients in the EHTP probe
4. Optional: write calibration date(s) in the EHTP probe
5. Enable calibration routine for a primary parameter in the EHTP
6. Optional: perform a manual test/verification in the EHTP with a known value
7. Save all calibration data in the EHTP to EEPROM

1.9.5. MATLAB Script for Calculating Calibration Coefficients

Table 8.8. MATLAB Script for Calculating Calibration Coefficients

```
clear all; close all;

%----- USER-PERFORMED INPUT of reference data:
USER_DATA =
[
     reference_value_1, corresponding_measured_value_1;
     reference_value_2, corresponding_measured_value_2;
     reference_value_3, corresponding_measured_value_3;
          …
     reference_value_N, corresponding_measured_value_N;
];
order = 2;                          % order of calibration equation:
                                    %(order=2 => A is a non-zero value,
                                    % order=1 => A = 0)

%----- Calculation of calibration coefficients:
x_cal = USER_DATA (:,1);                 % reference value contained in vector (x_cal)
x = USER_DATA (:,2);                     % measured values contained in vector (x)
[CAL] = polyfit(x_cal, x, order);       % calibration of coefficients A, B, C

%----- Displaying of calibration coefficients:
CAL_A = CAL(1)            % Coeff A displayed in MATLAB Command Window
CAL_B = CAL(2)            % Coeff B displayed in MATLAB Command Window
```

```
CAL_C = CAL(3)             % Coeff C displayed in MATLAB Command Window

%----- OPTIONAL: manual testing with calibration data
TEST_value = ???                      % USER-PERFORMED INPUT of test value
CAL_value = polyval(CAL, TEST_value)  % CAL_value displayed in MATLAB Command Window
```

Table 9.9. EHTP: Example of Using the MATLAB Script for Calibration of Barometric Pressure

USER-PERFORMED INPUT of reference data	
MATLAB Script	**Description**
USER_DATA = [950, 949.3; 1000, 1000.2; 1010, 1010.3; 1015, 1015.9;];	4-point reference data set manually inputted in the script by the user: reference_value_1 = 950 hPa, corresponding_measured_value_1 = 949.3 hPa reference_value_2 = 1000 hPa, corresponding_measured_value_2 = 1000.2 hPa reference_value_3 = 1010 hPa, corresponding_measured_value_3 = 1010.3 hPa reference_value_4 = 1015 hPa, corresponding_measured_value_4 = 1015.9 hPa
order = 2;	Calculating calibration coefficients for 2-order equation: $x_{cal} = Ax^2 + Bx + C$
Displaying of calibration coefficients	
MATLAB Command Window	**Description**
CAL_A = 4.2018e-04	CAL_pressure_A = 0.0004218 to be inputted to EHTP
CAL_B = 0.1968	CAL_pressure_B = 0.1968 to be inputted to EHTP
CAL_C = 383.1403	CAL_pressure_C = 383.1403 to be inputted to EHTP
OPTIONAL: manual testing with calibration data	
MATLAB Command Window	**Description**
TEST_value = 981.3000	Uncalibrated value = 981.3 hPa (manually inputted in the script by the user)
CAL_value = 980.8627	Calibrated value = 980.86 hPa

1.10. Maintenance

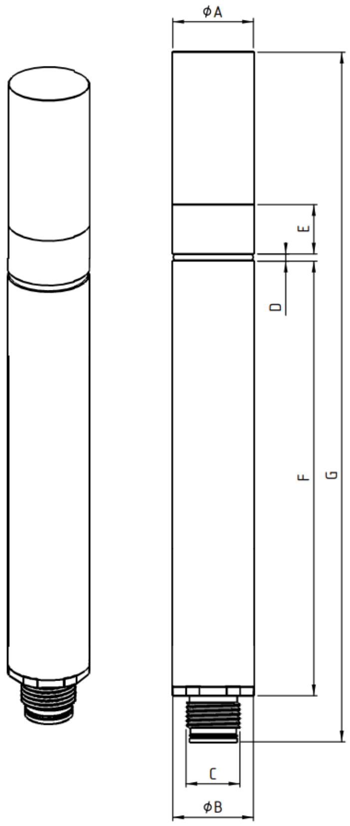
Yearly re-calibration is recommended for optimal quality of data. Installations in dusty environments may suffer from deposits on the sintered filter cap leading to reduced sensitivity to changes in relative humidity. The sintered filter cap should be cleaned with compressed air only when unscrewed from the body of the probe. Otherwise, damage to electronic and sensing components may occur. Cleaning of probe's enclosure should be performed with a soft cloth. Do not submerge the probe into a liquid (may it be water or detergent). The electrical pins in the M12 connector of the probe may be cleaned with ethanol. When the filter cap is removed, the exposed electronic components are at risk of damage by ESD events.

1.11. Environmental

This product contains substances that may be harmful to the environment if not disposed of properly.
At the end of its life cycle, this product must be disposed of as electronic waste.
Refer to your local authority's relevant regulations regarding disposal of electronic waste.

1.12. Disposal

The product contains substances and materials that may be harmful to the environment if not disposed of in accordance with local regulations. Please, consult the prescription of your local government regarding disposal of electronic and mechanical parts at the end of their life cycle.



1.13. Dimensions

Table 10.10. EHTP: Geometry

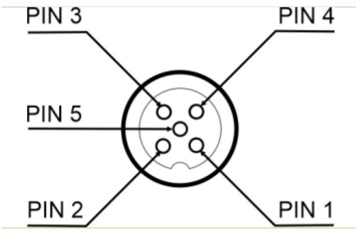
Dimension	Min	Nom	Max	Unit
A	17.9	18	18.1	mm
	0.705	0.709	0.713	in
B	17.9	18	18.1	mm
	0.705	0.709	0.713	in
C	-	M12x1.5	-	mm
	-	-	-	in
D	1.2	1.5	1.8	mm
	0.047	0.059	0.071	in
E	9.9	109.9	10.1	mm
	3.898	3.934	3.976	in
F	97.2	97.3	97.4	mm
	3.827	3.831	3.835	in
G	144.2	144.5	144.8	mm
	5.677	5.689	5.701	in

1.14. Optional Patch Cable

All versions of the HTP probe are equipped with a standard industrial M12, 5-pin, A-coded male waterproof connector. The patch cable is equipped with the complementary M12x5-pin, female, A-coded, straight connector on one end and free bare wires on the other end. The waterproof rating of the probe is preserved in mated state. The optional cable is suitable for EHTP versions with SDI-12, single-wire, UART interfaces. Although not complying with the Modbus cabling specifications, it can be used as a service cable with EHTP Modbus versions enabling the user to take advantage of the AUX pin.

Table 11.11. EHTP: Pinout of the Optional Patch Cable

M12 cable connector (front view)	Cable wires (free end)	Pin Number	Note
	Brown	Pin 1	Mated to Pin 1 of the probe's connector
	White	Pin 2	Mated to Pin 2 of the probe's connector
	Blue	Pin 3	Mated to Pin 3 of the probe's connector



Black	Pin 4	Mated to Pin 4 of the probe's connector
Green/yellow	Pin 5	Mated to Pin 5 of the probe's connector

1.15. Brief Definitions of the Physical Parameters

1.15.1. Air Temperature (Dry-Bulb Temperature)

A thermodynamic parameter, quantifying the kinetic motion of gas molecules contained in air. In macroscopic scale this motion is translated in the degree of how cold or hot air is. Also, known as dry-bulb temperature, this is the parameter measured by a conventional thermometer.

1.15.2. Relative Humidity of Air

The amount of water vapour in air, expressed as a percentage of the total possible (saturation) amount of water vapour at the same temperature. This parameter is important for many types of thermodynamic systems including all living organisms.

1.15.3. Barometric Pressure

The total weight of gas molecules exerted in the atmosphere at a given point on Earth. It is a fundamental environmental parameter for prediction of weather changes for hours in advance. In environmental measurements, it can also be found under the name "station pressure".

1.15.4. Reduced to Sea Level Atmospheric Pressure

Equivalent atmospheric pressure at sea level, introduced globally to eliminate dependence of barometric pressure values on installation height (station elevation) of a weather station. This is the parameter reported in weather forecasts.

1.15.5. Dew Point (Dew Temperature)

The temperature at which water vapours in air begins condensing into water. This parameter finds valuable applications in industrial processes and agriculture.

1.15.6. Absolute Humidity of Air

The mass of water vapour present in a unit volume of air.

1.15.7. Vapor Pressure in Air

The pressure exerted by vapours that are in thermodynamic equilibrium with their solid or liquid form in air.

1.15.8. Saturated Vapor Pressure in Air

Under each given set of environmental conditions, saturated vapour pressure is the maximal vapour pressure exerted by vapours in thermodynamic equilibrium with their solid or liquid form.

1.15.9. Heat Index

An equivalent raised value of air temperature, perceived by a human body due to the presence of relative humidity in air. The heat index is a valuable indicator for heat stroke prevention in activities involving people exposed to high levels of relative humidity – both indoors and outdoors.

1.15.10. Speed of Sound in Air

The distance travelled per unit of time by a sound wave in air. Speed of sound changes with air temperature and relative humidity.

1.15.11. Mixing Ratio of Moisture in Air

A measure of atmospheric humidity defining the ratio of mass of water vapor contained in air to mass of dry air. Also known as specific humidity.

1.15.12. Specific Enthalpy

The total thermal energy (sensible heat + latent heat), contained in a unit mass of mixture of dry air and water vapour.

1.15.13. Water Activity in Air

A dimensionless parameter of how efficiently the water amount present in air can take part in a reaction or in a physical process.

1.15.14. Boiling Point of Water

The temperature at which the water vapour pressure equals the barometric pressure thus causing the visual effect of boiling water at temperatures other than the accepted standard of 100°C.

1.15.15. Wet-Bulb Temperature

Under each given set of environmental conditions, wet-bulb temperature is the lowest temperature that can be reached through cooling by means of evaporating water (e.g. human perspiration). It is an important parameter in many industrial thermal processes as well as in agriculture and farming.

1.15.16. Percentage Concentration of CO_2 in Air

Abnormally high concentration of CO_2 that may be reached in an enclosed space during fire burning or because of biological or technological processes. The percentage of CO_2 in the air is often monitored in safety applications.

1.15.17. Height Above Sea Level

Also referred to as "station elevation", this is the vertical distance above mean sea level at which a meteorological station (a HTP probe) is installed. This elevation is adopted as the reference datum level for all measurements of reduced to sea level atmospheric pressure by the station (by the HTP probe). The parameter is used in the calculation of *Reduced to Sea Level Atmospheric Pressure*.

1.15.18. Vertical Temperature Coefficient

The rate of temperature drop for every 100 meters of vertical elevation above sea level. The parameter is used in the calculation of *Reduced to Sea Level Atmospheric Pressure*

2. SDI-12 INTERFACE

Table 12.1. SDI-12: Special Features of EHTP Supported in the SDI-12 Version(s)

Secondary Parameters	Sea-level Pressure	Wet-Bulb Temperature	User Calibration	Heater Control	Statistics	Diagnostics	Test Aid
•	•	•	•	•	•	•	•

2.1. SDI-12 Organization

SDI-12 is a standard electrical interface and data protocol for digital environmental probes. It is a master-slave communication type where the master is the data logging device, and the slave is the EHTP probe. The master always issues commands first and the slave replies. More information about SDI-12 here: https://sdi-12.org/

2.2. Minor Deviations in EHTP from the Standard SDI-12 Protocol

1. Some EHTP-specific command sets may return stings longer than 35 characters.
2. Some EHTP-specific commands may delay their output for up to 200 ms.
3. Aborting the execution of a command is not supported by EHTP.

2.3. EHTP Quick Start (SDI-12 Version)

Table 13.2. SDI-12: Symbols and Parameters

Parameter	Description
a, <addr>	SDI-12 address of a probe
new_addr	New SDI-12 address when changing probe's address
n	Count of parameters to be returned by a probe
ttt	Time (in seconds) between issuing Start measurement Command and Read Measurement Command
±	Positive/negative sign of a numerical value
<CR>	Carriage return ASCII character as per SDI-12 convention
<LF>	Line feed ASCII character as per SDI-12 convention

Table 14.3. SDI-12: Quick Start: Example of Reading Environmental Data

Sequence of Commands	Description	Issued by
0M!	Issue a Start Measurement Command aM! (a = EHTP's SDI-12 address[1]). It starts measurements of all environmental parameters except *wet_bulb_temperature*	user
00023 (or 00024)	Wait for 2-3 sec. while the aM!- command is being executed within the probe.	probe
0D0!	Issue Read Data Commands[2] starting with aD0!	user
0+26.67+58.23+997.51 (or 0+26.67+58.23+997.51+1.21)	<addr>±<air_temperature>+<relative_humidity>+<barometric_pressure> (or <addr>±<air_temperature>+<relative_humidity>+<barometric_pressure>+<CO2_percentage>)	probe
0D1! (optional)	Keep issuing aDx!-commands to read more parameters (optional)	user
0+2660+5820+99750 (or 0+2660+5820+99750+120)	Compatibility mode integer format: <addr>±<air_temperature>+<relative_humidity>+<barometric_pressure> (or <addr>±<air_temperature>+<relative_humidity>+<barometric_pressure>+<CO2_percentage>)	probe
0D2! (optional)	Keep issuing aDx!-commands to read more parameters (optional)	user
0+26.67+17.76+28.00+80.01	<addr>±<air_temperature°C>±<dew_point>±<heat_index>±<air_temperature°F>	probe
0D3! (optional)	Keep issuing aDx!-commands to read more parameters (optional)	user
0+58.23+14.706+12.953	<addr>+<relative_humidity>+<absolute_humidity>+<mixing_ratio>	probe
0D4! (optional)	Keep issuing aDx!-commands to read more parameters (optional)	user
0+997.51+20.35+34.96	<addr>+<sea_level_pressure>+<vapor_pressure>+<saturated_vapor_pressure>	probe
0D5! (optional)	Keep issuing aDx!-commands to read more parameters (optional).	user
0+348.77+59.849+0.5820+99.56	<addr>+<speed_of_sound>+<specific_enthalpy>+<water_activity>+<water_boiling_point>	probe

(1) Default SDI-12 address for EHTP probes is 0 (zero)

(2) additional values may be returned to 0D0!-command for extended model probes (e.g. EHTP-CO2)

NOTE: units available in "Measured Parameter and Units" Table

Table 15.4. SDI-12: Quick Start: Example of Reading Wet-bulb Temperature

Sequence of Commands	Description	Issued by
0M6!	Issue a Start Measurement Command aM6! to start the calculation of *wet_bulb_temperature*	user

00054	Wait for 5 sec. conversion time while the 0M6! command is being executed. Service request will be generated by the probe at the moment data is ready (before the end of the 5-sec interval)	probe
0D0!	Issue Read Data Command aD0! to read *wet_bulb_temperature*	user
0+20.50+26.73+17.57+159	<addr>±<wet_boulb_temperature>±<air_temperature°C>±<dew_point>+<wet_bulb_iterations>	probe

NOTE: units available in "Measured Parameter and Units" Table

2.4. EHTP Electrical and Timing Specification (SDI-12 Version)

Table 16.5. SDI-12: EHTP Electrical and Timing Specification

Parameter	Condition	Min	Typ	Max	Unit
Supply voltage (Vin)	Complying with SDI-12 specifications	5	12	24	Vdc
Current consumption (normal mode)	Vin = 12Vdc. Heater OFF. During measurement. **Wired for SDI-12 or single-wire interface.**	3.2	3.5	5.0	mA
Current consumption (sleep mode)	Vin = 12Vdc. Heater OFF. Disabled Continuous Statistic. **Wired for SDI-12 only.**	200	300	400	uA
SDI-12 logic high input		3.5	5	5.5	V
SDI-12 logic high output	Vin = 12Vdc	4.7	4.8	5.0	V
SDI-12 logic low input		0.3	0.5	0.6	V
SDI-12 logic low output	Vin = 12Vdc	0.05	0.1	0.2	V
Power-up time	-	1700	2000	2200	ms
EHTP internal fixed sampling rate	Available in Continuous Statistics mode only	-	1	-	S/s

2.5. EHTP Communication Configuration (SDI-12 Version)

Table 17.6. SDI-12: Communication Configuration

Parameter	Setting
Baud Rate (fixed)	1200
Start Bits (fixed)	1
Data Bits (fixed)	7 (LSB first)
Parity Bits (fixed)	1 (even)
Stop Bits (fixed)	1
Logic type	Inverted (active low)
EHTP default address	0
EHTP address range	0-9
SDI-12 break symbol duration generated by the SDI-12 master	9-100 ms (recommended: 12 ms)
Probe response timeout to be programmed in the SDI-12 master	Recommended: 200 ms (for ***Error! Reference source not found.***) Standard: 16 ms (only for ***Error! Reference source not found.***)
Power-up time to be programmed in the SDI-12 master	Recommended: 2200 ms

Table 18.7. SDI-12: Absolute Maximal Length of SDI-12 Output String Returned by EHTP

Command Set	Command	Max String Length (characters)
Statistical Control Command Set	aXSC2!	46
User Calibration Management Set	aXLD?	37
All remaining command sets	-	35

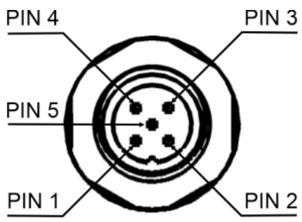
NOTE: the total count of characters includes <addr>, <CRC>, <CR>, <LF>.

2.6. Wiring

2.6.1. EHTP Connector (SDI-12 Version)

The SDI-12 version of the EHTP probe is equipped with dual interfacing – along with the main SDI-12, there is an auxiliary single-wire interface used mainly for compatibility with other Evvos products.

Table 19.8. SDI-12: Pinout of the M12-connector on EHTP probe

Probe's connector (front view)	Pin function	Pin number	Note
	System power supply (Vin)	Pin 1	
	System ground (GND)	Pin 2	Internally connected to casing.
	SDI-12 DATA	Pin 3	SDI-12 interface bidirectional DATA-port. **Connect to GND when single-wire mode is in use.**
	Unused	Pin 4	Unused wire. Leave floating. Do not connect to any electrical potential.
	Auxiliary (AUX)	Pin 5	Single-wire interface bidirectional DATA-pin. **Connect to GND when SDI-12 mode is in use.**

NOTE: older hardware versions of EHTP have SDI-12 DATA on pin 5 and AUX on pin 3.

2.6.2. Grounding

The metal casing of the probe is internally connected to GND.

2.6.3. Wiring for SDI-12 Interface

Table 20.9. SDI-12: Wiring of EHTP for SDI-12 Interface

Probe's Connector (front view)	Wires of the Optional Patch Cable	Electrical Connection
Pin 1	Brown	Vin
Pin 2	White	GND
Pin 3	Blue	GND or left floating
Pin 4	Black	Left floating
Pin 5	Green/yellow	SDI-12 comm pin

NOTE: it is recommended to connect the unused Pin 3 to GND, else occasional errors in communication may occur.

2.6.4. Wiring for Single-Wire Interface (SDI-12 Version)

Table 21.10. SDI-12: Wiring of EHTP (SDI-12 Version) for Single-Wire Interface

Probe's Connector (front view)	Wires of the Optional Patch Cable	Electrical Connection
Pin 1	Brown	Vin
Pin 2	White	GND
Pin 3	Blue	GND
Pin 4	Black	Left floating
Pin 5	Green/yellow	AUX (Single-wire comm pin)

NOTE: older hardware versions of EHTP have SDI-12 DATA on pin 5 (to be connected to GND) and AUX on pin 3.

2.7. Summary of Command Set

Table 22.11. SDI-12: Standard Commands

Command	Description	Note
?!	**Address Query Command** Probe returns its currently assigned SDI-12 address. This command is not address-specific and using it on buses where multiple SDI-12 probes are connected should be avoided (all probes trying to respond simultaneously may cause contention of the bus).	
Command	**Description**	**Note**
aI!	**Identification Command** Probe returns formatted identification and traceability data (model, manufacturer, revisions for hardware and firmware).	
aAb!	**Change Address Command** Command is used to change or reassign the SDI-12 address of a probe.	a - current addr b - new addr
aV! aVC!	**Verification Command** Command initiates thorough self-diagnostics including bitwise test of on-board RAM. Measurements of all on-board voltages are performed. Once the self-diagnostics is over the probe returns Service Request. Read Data Command is used to read the results of the self-diagnostics along with the values of error registers that EHTP continually updates. Error registers are cleared on power-up and reset.	
aM! aMC! aMx! aMCx!	**Start Measurement Command Set** Probe starts data collection/calculation of value sets of environmental parameters (sets dependent on the specific format of the command). M-commands are used primarily in applications with a single probe per a SDI-12 bus. A Service Request is sent by the probe once values are available. aDy-command is used to read the results.	x=1÷9
aC! aCC! aCx! aCCx!	**Start Concurrent Measurement Command Set** Probe starts data collection/calculation of value sets of environmental parameters (sets dependent on the specific format of the command). C-commands are used primarily in applications with multiple probes per a SDI-21 bus. C-commands are equivalent to the M-commands with the exception that no Service Request is sent by the probe once values are available. aDy-command is used to read the results.	x=1÷9
aRx! aRCx!	**Read Continuous Measurement Command Set** Probe starts data collection/calculation of value sets of environmental parameters (sets dependent on the specific format of the command). Results are transmitted by the probe over the SDI-12 interface as soon as made available. No Read Data Command is required to read the results. R-commands are used primarily in applications with a single probe per SDI-12 bus. By default, R-commands are disabled in EHTP. The R-commands are made accessible only when Continuous Statistics is enabled (using command aXSN!) and are disabled when Continuous Statistics is disabled (using command aXSF!).	x=0÷14 for standard EHTP version. Extended versions may have greater count
aHA! aHB!	**High Volume Command Set** Probe starts data collection/calculation of value sets of all environmental parameters. Sequence of aDy-commands is used to read the results. In an EHTP probe aHA-command provides a means of automated bulk reading of all supported parameters at once.	
aDx!	**Read Data Command Set** Probe returns results from the most recently initiated Measurement or Verification commands. Value sets selectable by the specific format of the initiated aDx-command.	x=0÷9
aIM! aIMx! aIMCx! aIC! aICx! aICC! aICCx! aIHA! aIHB! aIV!	**Identify Measurement Command Set** Metadata commands, introduced in version 1.4 of the SDI-12 Specification, providing ways to getting response to any M-, MC-, C-, CC-, H-, V- commands, without starting data collection/calculation.	As per SDI-12 specification v1.4 x=1÷9

Table 23.12. SDI-12: EHTP-specific Commands

Command	Description	Note
aXR!	**Master Reset Command** User-triggered software master reset of the EHTP probe. All unsaved to EEPROM data is lost as well as accumulated statistical data. Correct reception of XR-command is indicated by EHTP with issuing Service Request before the actual reset takes place. Probe returns to normal operation after a power-up sequence.	aXR!

aXH! aXH? aXHx!	**Heater Control Command Set** XH-command set is used to manage the on-board heater. Heater is used at very high humidity levels for removing condensed water drops on the humidity sensor. Special algorithm smooths the errors in the measured temperature values for the duration of the heating/cooling cycle. It is recommended the SDI-12 master be programmed for 200 ms response timeout.	x=0÷9

Command	Description	Note
aXSx! aXSCx! aXSN! aXSN? aXSF! aXSF? aXSR!	**Statistics Control Command Set** The XS-command set manages the Statistics feature of EHTP. There are two modes for collection of statistical data in a SDI-12-enabled EHTP probe: Continuous Statistics and Triggered Statistics (default). With Continuous Statistics ON, the environmental parameters are measured at 1S/s sample rate and R-commands are accessible. The probe does not enter a sleep cycle, and its power consumption remains constantly high. Wet-bulb temperature is not calculated in Continuous Statistics mode. Triggered Statistics is the default mode of operation enabling data collection triggered by issuing M- or C-command. This mode does not affect the sleep cycle of the probe. The XS-commands are not standard commands for the SDI-12 protocol. It is recommended the SDI-12 master be programmed for 200 ms response timeout.	x=0÷14* * Valid for the conventional EHTP versions. Extended versions may have additional parameters
aXT! aXT?	**Test Data Command** XT-commands provide means to test and verify SDI-12 communication between master and a probe. They are useful test tool during development of SDI-12 communication routines or for periodic communication test during run time. Depending on the selected command-mode a probe returns: • a fixed test string formatted as per SDI-12 protocol (address + fixed data + CRC) • currently signed SDI-12 address, and the duration of the Break symbol (start of data transfer) as measured by the probe.	
aXPH:<value>! aXPV:<value>! aXPH? aXPV? aXPS! aXPR!	**Sea-Level-Pressure Configuration Command Set** XP-command set enables the conversion of local barometric pressure to standard mean sea level atmospheric pressure as a means of migrating to worldwide standard atmospheric pressure value. Such a conversion is valid in stationary installations only.	
aXLTA:<value>! aXLTB:<value>! aXLTC:<value>! aXLXT:<value>! aXLT? aXLD0:<value>! aXLN0! aXLF0! aXLHA:<value>! aXLHB:<value>! aXLHC:<value>! aXLXH:<value>! aXLH? aXLD1:<value>! aXLN1! aXLF1! aXLPA:<value>! aXLPB:<value>! aXLPC:<value>! aXLXP:<value>! aXLH? aXLD2:<value>! aXLN2! aXLF2! aXLD? aXLN! aXLN? aXLF! aXLF? aXLS! aXLR!	**User Calibration Command Set** The XL-command set provides the means to manage individual multipoint calibrations for each of the primary parameters (air temperature, relative humidity, barometric pressure) measured by an EHTP probe. Increased accuracy of all parameters is achieved through the second-order polynomial calibrating formulas applied over the values of the primary parameters before calculating the secondary parameters. For calculation of the calibration coefficients a set of no less than 3 referent measurements is required. Additional referent measurements will enhance the calibration accuracy. Fine error analysis for demanding applications is enabled with the aXLXy!-commands. Any datalogger that supports Transparent SDI-12 Mode (manual mode) can be used for writing/reading the calibration data to an EHTP probe.	<value> is user-inputted value

2.8. SDI-12 Command Set for EHTP

2.8.1. Service Request

Some commands indicate they have performed their designated function by sending a service request to the master on the SDI-12 bus. The format of the service request is "<addr><CR><LF>".

2.8.2. Address Query Command (?!)

Table 24.13. SDI-12: Implementation of Address Query Command

?!	Probe returns its currently assigned SDI-12 address. This command is not address-specific and using it on buses where multiple SDI-12 probes are connected, should be avoided (all sensors trying to respond simultaneously may cause contention of the bus). <addr><CR><LF>

Table 25.14. SDI-12: Example of Address Query Command

?!
0

2.8.3. Identification Command (aI)

Table 26.15. SDI-12: Implementation of Identification Command

aI**!**	Probe returns formatted identification and traceability data (model, manufacturer, revisions for hardware and firmware). <addr><llccccccccmmmmmmvvvxxx . . . xxx ><CR><LF> Where: a - the sensor's address ll - the SDI-12 version number, indicating SDI-12 version compatibility; for example, version 1.4 is encoded as 14 cccccccc - an 8-character vendor identification, usually a company name or its abbreviation mmmmmm - 6 characters specifying the sensor model number vvv - 3 characters specifying the sensor version xxx . . . xx - an optional field, up to 13 characters, used for a serial number or other specific sensor information that is not relevant for operation of the master

Table 27.16. SDI-12: Example of Identification Command

0I!
013EVVOS HTP-S011010/032001

2.8.4. Change Address Command (aAb)

Table 28.17. SDI-12: Implementation of Change Address Command

aAb!	Command is used to change or reassign the SDI-12 address of a probe. a = current address, b = new address Input: <addr>A<new_addr>!

Table 29.18. SDI-12: Example of Change Address Command

?!
0
0A1!
1
?!
1

2.8.5. Verification Command (aV)

Refer to *Diagnostics*
for details on the operation.

Table 30.19. SDI-12: Implementation of Verification Command

aV! aVC!	Command initiates thorough self-diagnostics including bitwise test of on-board RAM and measurements of all on-board voltages are performed. After the self-diagnostic is over the probe returns Service Request. Read Data Command is used to read the results of the self-diagnostics along with the values of error registers that EHTP continually updates. Error registers are cleared on power-up and reset. Values of registers returned in DEC-format. <atttn><CR><LF>
0D0!	<addr>+<reset_cause>+<MCU_errors>+<power_errors>+<sensor_errors>+<errors_count><CRC><CR><LF> Where: reset_cause (on-board MCU reset cause): 0 = unknown reset cause 1 = normal power up 2 = brownout reset 3 = master reset from sleep 4 = WDT timeout 5 = WDT from sleep 6 = interrupt from sleep 7 = master reset from runt 8 = software reset 9 = stack overflow 10 = stack underflow 11 = WDT window violation MCU_errors: Bit 0 (LSb) – write-to-EEPROM error detected Bit 1 – on-board MCU's RAM error detected during self-test Bit 2 – on-board MCU's oscillator error detected power_errors (errors in on-board supply voltages): Bit 0 (LSb) – Vin supply voltage out-of-range event detected Bit 1 – MCU supply voltage out-of-range event detected Bit 2 – sensing circuitry supply voltage out-of-range event detected Bit 4 – master voltage regulator error sensor_errors (errors in the values of primary parameters): Bit 0 (LSb) – out-of-range value detected in air temperature measurements Bit 1 – out-of-range value detected in relative humidity measurements Bit 2 – out-of-range value detected barometric pressure measurements

Table 31.20. SDI-12: Example of Verification Command

0V!
00045 → service request
0D0!
0+1+0+0+0+0

2.8.6. Differences between aM-, aC-, aR, aHA-Command Sets

These command sets perform similar functions (start/read measurements) but differ in the ways they operate.

Table 32.21. SDI-12: Differences between aM-, aC-, aR, aH-Command Sets

	aM!	aMC!	aMx!	aMCx!	aC!	aCC!	aCx!	aCCx!	aRx!	aRCx!	aHA!
Generates Service Request when output available	•	•	•	•							
Generates CRC in the output		•		•		•		•		•	
Starts measurement only (output read with aDx!-command)	•	•	•	•	•	•	•	•			•
Start-and-Read with a single command									•	•	
Starts measurements of all environmental parameters simultaneously (excluding wet-bulb temperature)	•	•			•	•					
Starts measurements of all environmental parameters simultaneously (including wet-bulb temperature)											•
Always accessible	•	•	•	•	•	•	•	•			•

NOTE: x = 1÷9 for aMx!, aMCx!, aCx!, aCCx!; x = 0÷9 for aRx!, aRCx!

2.8.7. Start Measurement Command Set + Reading (aM, aC + aD)

Table 33.22. SDI-12: Implementation of Start Measurement (aM!, aC!) Command Sets + Reading output (aD!)

aM! aMC! (aCC! aC!)	Start measurements of all environmental parameters except wet bulb temperature. Values are returned in standard SDI-12 format. Additionally, the formatted outputs of commands aM1 to aM9 (excluding aM6!) are also made available for reading with optional issuing of aD1! to aD9!. NOTE: *model_specific_parameter* is present only with the extended models e.g. EHTP+CO2. <atttn><CR><LF> (or <atttnn><CR><LF>)
aD0!	<addr>±<air_temperature°C>+<relative_humidity>+<barometric_pressure><±model_specific_parameter><CRC><CR><LF>
aM1! aMC1! (aC1! aCC1!)	Starts measurements of relative humidity, air temperature and atmospheric pressure. Values are converted to integers for compatibility reasons. NOTE: *model_specific_parameter* is present only with the extended models e.g. EHTP+CO2. <atttn><CR><LF> (or <atttnn><CR><LF>)

aD0!	<addr>±<air_temperature°C>+<relative_humidity>+<barometric_pressure><±model_specific_parameter><CRC><CR><LF>
aM2! aMC2! (aC2! aCC2!)	Starts measurements of relative air temperature, dew point, heat index, air temperature (Fahrenheit). Values are returned in standard SDI-12 format. <atttn><CR><LF> (or <atttnn><CR><LF>)
aD0!	<addr>±<air_temperature°C>±<dew_point>±<heat_index>±<air_temperature°F><CRC><CR><LF>

SDI-12: Start Measurement (aM!, aC!) Command Sets + Reading output (aD!) Implementation (continued)

aM3! aMC3! (aC3! aCC3!)	Starts measurements of relative humidity, absolute humidity, mixing ratio. Values are returned in standard SDI-12 format. <atttn><CR><LF> (or <atttnn><CR><LF>)
aD0!	<addr>+<relative_humidity>+<absolute_humidity>+<mixing_ratio><CRC><CR><LF>
aM4! aMC4! (aC4! aCC4!)	Starts measurements of barometric pressure, vapour pressure, saturated vapour pressure. Values are returned in standard SDI-12 format. NOTE: *sea_level_pressure* is equal to *barometric_pressure* for the default value of *height_above_sea_level.* <atttn><CR><LF> (or <atttnn><CR><LF>)
aD0!	<addr>+<sea_level_pressure>+<vapor_pressure>+<saturated_vapor_pressure><CRC><CR><LF>
aM5! aMC5! (aC5! aCC5!)	Start measurements of speed of sound, specific enthalpy water activity and boiling point of water. Values are returned in standard SDI-12 format. <atttn><CR><LF> (or <atttnn><CR><LF>)
aD0!	<addr>+<speed_of_sound>+<specific_enthalpy>+<water_activity>+<water_boiling_point><CRC><CR><LF>
aM6! aMC6! (aC6! aCC6!)	Starts measurement of wet bulb temperature. Values are returned in standard SDI-12 format. If *wet_bulb_iterations* = 0, then the value of *wet_bulb_temperature* is invalid. <atttn><CR><LF> (or <atttnn><CR><LF>)
aD0!	<addr>±<wet_bulb_temperature>±<air_temperature°C>±<dew_point>+<wet_bulb_iterations><CRC><CR><LF>
aM7! aMC7! (aC7! aCC7!)	Starts measurements of relative humidity, air temperature and barometric pressure. Results are raw ADC integer values. NOTE: *ADC_model_specific* is present only with the extended models e.g. EHTP+CO2. <atttn><CR><LF> (or <atttnn><CR><LF>)
aD0!	<addr>+<ADC1>+<ADC2>+<ADC3><±ADC_model_specific><CRC><CR><LF>
aM8! aMC8! (aC8! aCC8!)	Starts measurements of the on-boards supply voltages (Vmcu, Vsen, Vin) and the MCU temperature and the air temperature. <atttn><CR><LF> (or <atttnn><CR><LF>)
aD0!	<addr>+<MCU_voltage>+<SEN_voltage>+<VIN_voltage>+<MCU_temperature>+<air_temperature°C><CRC><CR><LF>
aM9! aMC9! (aC9! aCC9!)	Starts quick update of the system status registers. <atttn><CR><LF> (or <atttnn><CR><LF>)

aD0!	<addr>+<reset_cause>+<MCU_errors>+<power_errors>+<sensor_error>+<errors_count><CRC><CR><LF> Where: See aV!-command for description of reset_cause, MCU_errors, power_errors, sensor_error

Table 34.23. SDI-12: Examples aM- and aCC-Commands

Example of aM-Command	Example of aCC-Command
0M!	0CC!
00023 → service request	000203
0D0!	0D0!
24.05+45.35+953.03	24.05+45.35+953.03Bcx
0D1! (optional)	0D1! (optional)
0+2400+4530+95300	0+2400+4530+95300NUj
0D2! (optional)	0D2! (optional)
0+24.05+11.48+24.00+75.29	0+24.05+11.48+24.00+75.29OZA
0D3! (optional)	0D3! (optional)
0+45.35+9.886+8.977	0+45.35+9.886+8.977KG|
0D4! (optional)	0D4! (optional)
0+953.03+13.55+29.92	0+953.03+13.55+29.92@wa
0D5! (optional)	0D5! (optional)
0+346.94+47.028+0.4532+98.28	0+346.94+47.028+0.4532+98.28A]^
0D6! (optional)	0D6! (optional)
0AP@	0AP@
0D7! (optional)	0D7! (optional)
0+25861+29722+3903681+2320	0+25861+29722+3903681+2320BeB
0D8! (optional)	0D8! (optional)
0+4766+2810+9460+23.50+24.05	0+4766+2810+9460+23.50+24.05KHw
0D9! (optional)	0D9! (optional)
0+2+0+0+0+0	0+2+0+0+0+0E[`

NOTE: issuing aD6! after aM!, aMC!, aC!, aCC! always returns <addr><CRC><CR><LF>.

2.8.8. Reading Wet-Bulb Temperature

Refer to *Calculating the Wet-Bulb Temperature*
for detailed description. Reading the wet-bulb temperature requires the following steps:
Step 1: Issue an aM6!-command (alternatively aMC6!, aC6!, or aCC6!) to measure the momentary values of the primary parameters and, based on them, calculate the value of wet-bulb temperature.
Step 2: Issue aD0!-command to read the calculated value of wet_bulb_temperature.

Table 35.24. SDI-12: Example of Wet-bulb Temperature Measurement with aM- and aCC-Commands

Wet-bulb Temperature Example of aM-Command	Wet-bulb Temperature Example of aCC-Command
0M6!	0CC6!
00054 → service request	000504
0D0!	0D0!
0+18.60+25.98+14.78+182	0+18.60+25.98+14.78+182Mzg

2.8.9. Read Continuous Measurement Command Set (aR)

Probe starts data collection/calculation of value sets of environmental parameters (sets dependent on the specific format of the command). Results are transmitted by the probe, over the SDI-12 interface within 15 ms. No Read Data Command is required to read the results. R-commands are used primarily in applications with a single probe per SDI-12 bus. By default, R-commands are disabled in EHTP. **The R-commands are made accessible only when Continuous Statistics is enabled** (using command aXSN!) and are disabled when Continuous Statistics is disabled (using command aXSF!).

Table 36.25. SDI-12: Implementation of aR-/aRC-commands

aR0!	aRC0!	Output same as with aD0 after aM! (aMC!) or aC! (aCC!)
aR1!	aRC1!	Output same as with aD0 after aM1! (aMC1!) or aC1! (aCC1!)
aR2!	aRC2!	Output same as with aD0 after aM2! (aMC2!) or aC2! (aCC2!)
aR3!	aRC3!	Output same as with aD0 after aM3! (aMC3!) or aC3! (aCC3!)
aR4!	aRC4!	Output same as with aD0 after aM4! (aMC4!) or aC4! (aCC4!)
aR5!	aRC5!	Output same as with aD0 after aM5! (aMC5!) or aC5! (aCC5!)
aR6!	aRC6!	<addr><CRC><CR><LF> (measurement not supported)
aR7!	aRC7!	<addr><CRC><CR><LF> (measurement not supported)
aR8!	aRC8!	<addr><CRC><CR><LF> (measurement not supported)
aR9!	aRC9!	<addr><CRC><CR><LF> (measurement not supported)

NOTE 1: in case aR-commands are not enabled all aRx-requests will be replied with *<addr><CRC><CR><LF>* (measurement not supported)
NOTE 2: CRC-value is returned only for the aRCx!-commands.

Table 37.26. SDI-12: Example of aR-commands

0XSN! (enabling aR-commands)
0 (aR-commands enabled successfully)
0R2!
0+25.68+16.97+26.00+78.22
0R3!
0+58.78+14.052+12.327
0R4!
0+997.20+19.43+33.00
0R5!
0+348.16+57.387+0.5893+99.54

2.8.10. Identify Measurement Command Set (aIM, aIC, aIH, aIV)

Table 38.27. SDI-12: Implementation of Identify Measurement Command Set (aIM!, aIMC!, aIC!, aICC!, aIHA!, aIV!)

aIM! aIMx! aIMC! aIMCx! aIV!	aIC! aICx! aICC! aICCx!	aIHA! aIHB!	Metadata commands, introduced in version 1.4 of the SDI-12 Specification, providing means to getting the response to any M-, MC-, C-, CC-, H-, V- commands, without starting data collection/calculation. x = 1÷ 9. <atttn><CR><LF> (for IM, IV-commands) <atttnn><CR><LF> (for IC-commands) <atttnnn><CR><LF> (for IH-commands)

Table 39.28. SDI-12: Example of Identify Measurement Command Set (aIM!, aIMC!, aIC!, aICC!, aIHA!, aIV!)

0IM!
00023
0IC!
000203
0IHA!
0008024

2.8.11. High Volume Command Set (aHA, aHB)

Probe starts data collection/calculation of value sets of all environmental parameters. A sequence of aDy-commands is used to read the results. The high-volume commands, introduced in version 1.4 of the SDI-12 Specification, expand the concurrent measurement commands to allow up to 999 parameters to be returned from a probe. In an EHTP probe aHA-command provides a means of automated bulk reading of all supported parameters at once.

Table 40.29. SDI-12: High Volume Command Set + Reading output (aD!) Implementation

aHA!	Starts measurements of all supported environmental parameters. Values with aD0!, aD2!, aD3!, aD4!, aD5!, aD6! are returned in standard SDI-12 ASCII format. Values with aD1! are returned in integer format for compatibility reasons. All outputs have CRC as standard feature for aHA-command in SDI-12 specification v1.4 NOTE: *model_specific_parameter* is present only with the extended models e.g. EHTP+CO2. <atttnnn><CR><LF>
aD0!	<addr>±<air_temperature°C>+<relative_humidity>+<barometric_pressure><±model_specific_parameter><CRC><CR><LF>
aD1!	<addr>±<air_temperature°C>+<relative_humidity>+<barometric_pressure><±model_specific_parameter><CRC><CR><LF>
aD2!	<addr>±<air_temperature°C>±<dew_point>±<heat_index>±<air_temperature°F><CRC><CR><LF>
aD3!	<addr>+<relative_humidity>+<absolute_humidity>+<mixing_ratio><CRC><CR><LF>
aD4!	<addr>+<sea_level_pressure>+<vapor_pressure>+<saturated_vapor_pressure><CRC><CR><LF>
aD5!	<addr>+<speed_of_sound>+<specific_enthalpy>+<water_activity>+<water_boiling_point><CRC><CR><LF>
aD6!	<addr>±<wet_bulb_temperature>±<air_temperature°C>±<dew_point>+<wet_bulb_iterations><CRC><CR><LF>
aHB!	No data is processed for reading with aHB-command. <a000000><CR><LF>

Table 41.30. SDI-12: Examples aHA-Command

0HA!
0008024
0D0!
0+22.26+48.43+953.66I{D
0D1!
0+2220+4840+95360G]q
0D2!
0+22.26+10.82+22.00+72.07BOn
0D3!
0+48.43+9.535+8.595JQX
0D4!
0+953.66+13.00+26.85G\}
0D5!
0+345.84+44.228+0.4841+98.29K_p
0D6!
0+15.23+22.26+10.82+161Ilq

2.8.12. Heater Control Command Set (aXH)

Refer to *On-board Heater*
for detailed description of the heater operation. XH-command set is used to manage the on-board heater over SDI-12. The XS-commands are not standard commands for the SDI-12 protocol. For proper use of the on-board heater, the SDI-12 master must be programmed for the recommended response timeout as per ***Error! Reference source not found.***.

NOTE: enabling the heater may occasionally cause the EHTP probe to skip detecting a valid incoming command. Make sure the logging device is enabled to repeat a command should a timeout occur.

Table 42.31. SDI-12: Implementation of Heater Control Command Set

aXH?	Reads status of the heater. <addr>+<HEAT_status>+<HEAT_mode>+<remaining_time>+<set_time>±<delta_temperature>±<initial_temperature>+<HEAT_duty_cycle>+<VIN_voltage><CR><LF> Where: HEAT_status = 0 (OFF default state): remaining_time = 0 set_time = 0 delta_temperature = 0 initial_temperature = air_temperature HEAT_status = 1 (HEATING): remaining_time = HEAT_remaining_time set_time = HEAT_set_time delta_temperature = HEAT_delta_temperature initial_temperature = HEAT_initial_temperature HEAT_status = 2 (COOLING): remaining_time = COOL_remaining_time set_time = COOL_set_time delta_temperature = COOL_delta_temperature initial_temperature = COOL_initial_temperature

	HEAT_mode = 0 (MANUAL): heater under manual control by the user HEAT_mode = 1 (AUTOMATIC): heater operation is controller automatically by the probe (firmware version dependent)

Implementation of Heater Control Command Set (continued)

aXH0!	Turns heater OFF. Overrides remaining time by previously issued aXH(1-9) command. Stops COOLING state if active. <addr><CR><LF>
aXH1!	Heater is ON for 10 sec → Automatic OFF → Cooling time 30 sec. <addr><CR><LF>
aXH2!	Heater is ON for 20 sec → Automatic OFF → Cooling time 60 sec. <addr><CR><LF>
aXH3!	Heater is ON for 30 sec → Automatic OFF → Cooling time 90 sec. <addr><CR><LF>
aXH4!	Heater is ON for 40 sec → Automatic OFF → Cooling time 120 sec. <addr><CR><LF>
aXH5!	Heater is ON for 50 sec → Automatic OFF → Cooling time 150 sec. <addr><CR><LF>
aXH6!	Heater is ON for 60 sec → Automatic OFF → Cooling time 180 sec. <addr><CR><LF>

SDI-12: Implementation of Heater Control Command Set (continued)

aXH7!	Heater is ON for 70 sec → Automatic OFF → Cooling time 210 sec. <addr><CR><LF>
aXH8!	Heater is ON for 80 sec → Automatic OFF → Cooling time 240 sec. <addr><CR><LF>
aXH9!	Heater is ON for 90 sec → Automatic OFF → Cooling time 270 sec. <addr><CR><LF>

Table 43.32. SDI-12: Example of Heater Control

Example	**Comment**
0XH1!	Turns heater ON for 10 sec.
0	Probe replies. The command is executed
0XH?	Read status of the heater
0+1+0+9+10+0.51+25.14+29+9570	Heater is ON, 9 out of 10 sec. ON time remaining
0XH? (Issued more than 9 sec. later than the previous command)	Read status of the heater
0+2+0+6+30-3.82+32.56+0+9570	Heater is COOLING, 6 out of 30 sec. cooling time remaining
0XH? (Issued more than 6 sec. later than the previous command)	Read status of the heater
0+0+0+0+0+0.00+24.98+0+9570 (heater OFF)	Heater is OFF, current *air_temperature* = 24.98˚C

NOTE 1: when heater is ON measurements of air temperature may be affected during the ON+COOLING period.
NOTE 2: supply voltage (VIN_voltage) may reduce the efficiency of the heater at extremely low temperatures. In such applications it is recommended the probe be powered with 12Vdc or more.

2.8.13. Statistics Control Command Set (aXS)

Refer to *Statistics*
for detailed description of the feature. XS-command set manages the Statistics feature of EHTP. There are two modes for collection of statistical data in a SDI-12-enabled EHTP probe: Continuous Statistics and Triggered Statistics (default). With Continuous Statistics ON, the environmental parameters are measured at a fixed sample rate (see ***Error! Reference source not found.***) and R-commands are made accessible. The probe does not enter a sleep cycle, and its power consumption remains constantly high. Wet-bulb temperature is not calculated in Continuous Statistics mode. Triggered Statistics is the default mode of operation enabling data collection triggered by issuing M- or C-command. This mode does not affect the sleep cycle of the probe. The XS-commands are not standard commands for the SDI-12 protocol. For proper use of the Statistics feature, the SDI-12 master must be programmed for the recommended response timeout as per ***Error! Reference source not found.***.

NOTE: enabling Continuous Statistics may occasionally cause the EHTP probe to skip detecting a valid incoming command. Make sure the logging device is enabled to repeat a command should a timeout occur.

Table 44.33. SDI-12: Statistics Data Output Commands

aXS0! aXSC0!	Reads statistical data for air temperature (+CRC) <addr>±<MIN_air_temperature>±<MAX_air_temperature>±<FIRST_air_temperature>±<LAST_air_temperature>+<COUNT_air_temperature><CRC><CR><LF>
aXS1! aXSC1!	Reads statistical data for relative temperature (+CRC) <addr>+<MIN_relative_humidity>+<MAX_relative_humidity>+<FIRST_relative_humidity>+<LAST_relative_humidity>+<COUNT_relative_humidity><CRC><CR><LF>
aXS2! aXSC2!	Reads statistical data for barometric pressure (+CRC) <addr>+<MIN_barometric_pressure>+<MAX_barometric_pressure>+<FIRST_barometric_pressure>+<LAST_barometric_pressure>+<COUNT_barometric_pressure><CRC><CR><LF>
aXS3! aXSC3!	Reads statistical data for dew point (+CRC) <addr>±<MIN_dew_point>±<MAX_dew_point>±<FIRST_dew_point>±<LAST_dew_point>+<COUNT_dew_point><CRC><CR><LF>
aXS4! aXSC4!	Reads statistical data for heat index (+CRC) <addr>±<MIN_heat_index>±<MAX_heat_index>±<FIRST_heat_index>±<LAST_heat_index>+<COUNT_heat_index><CRC><CR><LF>
aXS5! aXSC5!	Reads statistical data for absolute humidity (+CRC) <addr>+<MIN_absolute_humidity>+<MAX_absolute_humidity>+<FIRST_absolute_humidity>+<LAST_absolute_humidity>+ <COUNT_absolute_humidity><CRC><CR><LF>
aXS6! aXSC6!	Reads statistical data for vapor pressure (+CRC) <addr>+<MIN_vapor_pressure>+<MAX_vapor_pressure>+<FIRST_vapor_pressure>+<LAST_vapor_pressure>+<COUNT_vapor_pressure><CRC><CR><LF>
aXS7! aXSC7!	Reads statistical data for saturated vapor pressure (+CRC) <addr>+<MIN_saturated_vapour_pressure>+<MAX_saturated_vapour_pressure>+<FIRST_saturated_vapour_pressure>+<LAST_saturated_vapour_pressure>+<COUNT_vapour_pressure><CRC><CR><LF>
aXS8! aXSC8!	Reads statistical data for speed of sound (+CRC) <addr>+<MIN_speed_of_sound>+<MAX_speed_of_sound>+<FIRST_speed_of_sound>+<LAST_speed_of_sound>+<COUNT_speed_of_sound><CRC><CR><LF>
aXS9! aXSC9!	Reads statistical data wet bulb temperature (+CRC). Data sampled only in Trigger Statistics (see "Reading Wet-Bulb Temperature"). <addr>±<MIN_wet_bulb_temperature>±<MAX_wet_bulb_temperature>±<FIRST_wet_bulb_temperature>±<LAST_wet_bulb_temperature>+<COUNT_wet_bulb_temperature ><CRC><CR><LF>
aXS10! aXSC10!	Reads statistical data for sea level pressure (+CRC). At least parameter *height_above_sea_level* must be configured by the user (see aXP-commands). Else *sea_level_pressure = barometric_pressure*. <addr>+<MIN_sea_level_pressure>+<MAX_sea_level_pressure>+<FIRST_sea_level_pressure>+ <LAST_sea_level_pressure>+<COUNT_sea_level_pressure><CRC><CR><LF>
aXS11!	Reads statistical data for mixing ratio (+CRC)

aXSC11!	<addr>+<MIN_mixing_ratio>+<MAX_mixing_ratio>+<FIRST_mixing_ratio>+<LAST_mixing_ratio>+ <COUNT_mixing_ratio><CRC><CR><LF>
SDI-12: Statistics Data Output Commands (continued)	
aXS12! aXSC12!	Reads statistical data for specific enthalpy (+CRC) <addr>+<MIN_specific_enthalpy>+<MAX_specific_enthalpy>+<FIRST_specific_enthalpy>+ <LAST_specific_enthalpy>+<COUNT_specific_enthalpy><CRC><CR><LF>
aXS13! aXSC13!	Reads statistical data for water activity (+CRC) <addr>+<MIN_water_activity>+<MAX_water_activity>+<FIRST_water_activity>+<LAST_water_activity>+ <COUNT_water_activity><CRC><CR><LF>
aXS14! aXSC14!	Reads statistical data for boiling point of water (+CRC) <addr>+<MIN_water_boiling_point>+<MAX_water_boiling_point>+<FIRST_water_boiling_point>+ <LAST_water_boiling_point>+<COUNT_water_boiling_point><CRC><CR><LF>
aXS15! aXSC15!	Reads statistical data for CO2-percentage in air (+CRC) NOTE: command valid only in HTP-CO2 version of the probe. <addr>+<MIN_CO2_percentage>+<MAX_CO2_percentage>+<FIRST_CO2_percentage>+<LAST__CO2_percentage>+ <COUNT_CO2_percentage><CRC><CR><LF>

Table 45.34. SDI-12: Statistics Control Commands

aXSN!	Continuous Statistics is ON. The probe does not enter sleep mode. R-commands are accessible. <addr><CR><LF>
aXSF!	Continuous Statistics is OFF (Triggered Statistics is ON – default state). Entering sleep mode is enabled. R-commands are not accessible. Statistical data is collected triggered by aMy!-, aMCy!-commands. <addr><CR><LF>
aXSN? aXSF?	Status of Statistics (Continuous/Triggered). <addr>+<STAT_status>+<STAT_mode><CR><LF> Where: STAT_status = 0 (Triggered Statistics) STAT_status = 1 (Continuous Statistics) STAT_mode = 2 (Fixed value)

Table 46.35. SDI-12: Statistics Reset Commands

aXSR!	Resets accumulated statistics for all monitored parameters. <addr><CR><LF>
aXSR0!	Resets accumulated statistics for air temperature. <addr><CR><LF>
aXSR1!	Resets accumulated statistics for relative humidity. <addr><CR><LF>
aXSR2!	Resets accumulated statistics for barometric pressure. <addr><CR><LF>
aXSR3!	Resets accumulated statistics for dew point. <addr><CR><LF>
aXSR4!	Resets accumulated statistics for heat index. <addr><CR><LF>
aXSR5!	Resets accumulated statistics for absolute humidity. <addr><CR><LF>
aXSR6!	Resets accumulated statistics for vapour pressure. <addr><CR><LF>
aXSR7!	Resets accumulated statistics for saturated vapour pressure <addr><CR><LF>
aXSR8!	Resets accumulated statistics for speed of sound. <addr><CR><LF>
aXSR9!	Resets accumulated statistics for wet-bulb temperature. <addr><CR><LF>
aXSR10!	Resets accumulated statistics for sea level pressure.

	<addr><CR><LF>
SDI-12: Statistics Reset Commands (continued)	
aXSR11!	Resets accumulated statistics for mixing ratio. <addr><CR><LF>
aXSR12!	Resets accumulated statistics for specific enthalpy. <addr><CR><LF>
aXSR13!	Resets accumulated statistics for water activity. <addr><CR><LF>
aXSR14!	Resets accumulated statistics for CO2-percentage in air. NOTE: command valid only in HTP-CO2 version of the probe. <addr><CR><LF>

Table 47.36. SDI-12: Example of Resetting Statistics

0XSN!
0
0XSN?
0+1+2
0XS0!
0+25.05+26.96+25.41+26.95+239
0XS1!
0+57.87+59.90+59.81+57.89+242
0XS2!
0+995.94+997.25+997.15+996.03+254
0XS3!
0+16.18+18.05+17.02+17.85+256

2.8.14. Test Data Command (aXT)

Refer to *Test Aid*

for a detailed description of the feature. The XT-commands provide means to test and verify SDI-12 communication between master and a probe. They are useful test tools during development of SDI-12 communication routines or for periodic communication tests during run time.

Table 48.37. SDI-12: Implementation of Test Data Command

aXT!	Returns a fixed string of values with CRC. <addr>-<constant_1>+<constant_2>-<constant_3>+<constant_4><CRC><CR><LF>
aXT?	Probe measures and returns the SDI-12 Break symbol duration generated by the SDI-12 master in microseconds. <addr>+<break_duration><CR><LF>

NOTE: during normal SDI-12 operation the on-board MCU enters low-power state and turns its internal oscillator circuit. The break symbol wakes the MCU and some time is required for the oscillator to stabilize. Thus, break duration detected by a HTP probe may be shorter than the actual value. For maximal accuracy of break duration detection, it is recommended the Continuous Statistics be enabled.

Table 49.38. SDI-12: List of All Test Data Command Outputs

Command	SDI-12 Address	Fixed String	CRC
0XT!	0	0-0.1+23.45-678.987+6543.21	CtY
1XT!	1	1-0.1+23.45-678.987+6543.21	K g
2XT!	2	2-0.1+23.45-678.987+6543.21	Gcf
3XT!	3	3-0.1+23.45-678.987+6543.21	OhX
4XT!	4	4-0.1+23.45-678.987+6543.21	K[g
5XT!	5	5-0.1+23.45-678.987+6543.21	CPY
6XT!	6	6-0.1+23.45-678.987+6543.21	OLX
7XT!	7	7-0.1+23.45-678.987+6543.21	GGf
8XT!	8	8-0.1+23.45-678.987+6543.21	Fkf
9XT!	9	9-0.1+23.45-678.987+6543.21	N`X

NOTE: The probe will accept the command only if issued with the correct SDI-12 address. For test purposes the SDI-12 address can be changed multiple times by issuing aAb-command.

Table 50.39. SDI-12: Example of Test Data Command

?!
0
0XT!
0-0.1+23.45-678.987+6543.21CtY
0XT?
0+11.920 (actual break duration generated by the master is 12 ms)

2.8.15. Sea Level Pressure Configuration Command Set (aXP)

Refer to Test Aid
for a detailed description of the feature. XP-command set enables the conversion of local barometric pressure to standard mean sea level atmospheric pressure.

Table 51.40. SDI-12: Implementation of Sea Level Pressure Command Set

aXPH?	Reads the value of height above sea level set by the user. <addr>±<height_above_sea_level><CR><LF>
aXPH:<value>!	Writes height above/below sea level (meters). Input: <addr>XPH:<height_above_sea_level>! Reply: <addr><CR><LF>
aXPV?	Reads vertical temperature coefficient. <addr>+<vertical_tem_coeff>
aXPV:<value>!	Writes vertical temperature coefficient (°C/100 m). Input: <addr>XPV:<vertical_temp_coeff>! Reply: <addr><CR><LF>
aXPS!	Saves settings to EEPROM. Else data will not be preserved after probe reset/power down. This command must be executed to enable calculations with the user-defined values of height_above_sea_level and vertical_temp_coeff Input: <addr>XPS! Reply: <addr><CR><LF>
aXPR!	Resets to default the values of height_above_sea_level and vertical_temp_coeff. Disables calculation of sea_level_pressure Input: <addr>XPS! Reply: <addr><CR><LF>

Table 52.41. SDI-12: Example of Sea Level Pressure Configuration

0XPH?
0+0.00
0XPH:340.5!
0
0XPH?
0+340.50
0XPV?
0+0.60
0XPS! (Important line)
0
0M!
00023
0D4!
0+1005.00+19.97+29.85

2.8.16. Master Reset Command (aXR)

Table 53.42. SDI-12 Implementation of Master Reset Command

aXR!	User-triggered software master reset of the EHTP probe. All unsaved to EEPROM data is lost as well as the accumulated statistical data. Correct reception of XR-command is indicated by EHTP with issuing Service Request before the actual reset takes place. Probe returns to normal operation after a power-up sequence. <addr><CR><LF>

Table 54.43. SDI-12: Example of Master Rest Command

0XR!
0
(reset takes place)

2.9. User Calibration

2.9.1. Description

Refer to *Test Aid*
for a detailed description of the feature. The XL-command set provides the means to manage the Calibration feature of EHTP. Fine error analysis for demanding applications is enabled with the aXLXy!-commands. Any datalogger that supports Transparent SDI-12 Mode (manual mode) can be used for writing/reading the calibration data to an EHTP probe.

2.9.2. Calculation of Calibration Coefficients

The word "parameter refers to any of the primary parameters, measured by an EHTP probe: air temperature, relative humidity, and barometric pressure. The steps are valid for the general form of the calibration equation (A≠0).

1. For a selected parameter, perform multiple measurements of at least 3 reference values to gather a table of multipoint reference data.
2. Enter the reference data into the least square algorithm (e.g. the provided MATLAB script) to calculate calibration coefficients A, B, C for the selected parameter
3. Enter the calibration coefficients in the EHTP probe using the aXL_A, aX_B, aXL_C commands
4. Optional: write calibration date(s) in the EHTP probe using a respective aXLD_ command
5. Enable calibration routine for a primary parameter in the EHTP using a respective aXLN_ command
6. Optional: perform a manual test/verification in the EHTP with a known value using the aXLX_ commands

7. Save all calibration data in the EHTP to EEPROM using the aXLS-command

2.9.3. User Calibration Command Set (aXL)

Table 55.44. SDI-12: Implementation of Air Temperature Calibration Commands

aXLTA:<value>!	Writes value for temperature calibration coefficient A Input: <addr>XLTA: <CAL_temperature_A>! Reply: <addr><CR><LF>
aXLTB:<value>!	Writes value for temperature calibration coefficient B Input: <addr>XLTB: <CAL_temperature_B>! Reply: <addr><CR><LF>
aXLTC:<value>!	Writes value for temperature calibration coefficient C Input: <addr>XLTC: <CAL_temperature_C>! Reply: <addr><CR><LF>
aXLT?	Reads values for temperature calibration coefficients A, B, C <addr>±<CAL_temperature_A>±<CAL_temperature_B>±<CAL_temperature_C>
aXLD0:<value>!	Writes string for the most recent temperature calibration date (max 10 characters) Input: <addr>XLD0:<CAL_temperature_date>! Reply: <addr><CR><LF>
aXLN0!	Enables calibration routine over the temperature measurements <addr><CR><LF>
aXLF0!	Disables calibration routine over the temperature measurements <addr><CR><LF>
aXLXT:<value>!	Manual Test&Evaluation command for temperature calibration. Input value independent on measurement unit Input: <addr>XLXH: ±<TEST_temperature_value>! Reply: <addr>±<TEST_temperature_value>±<CAL_temperature_value>+<CAL_temperature_status><CR><LF>

Table 56.45. SDI-12: Implementation of Relative Humidity Calibration Commands

aXLHA:<value>!	Writes value for humidity calibration coefficient A Input: <addr>XLHA:<CAL_humidity_A>! Reply: <addr><CR><LF>
aXLHB:<value>!	Writes value for humidity calibration coefficient B Input: <addr>XLHB:<CAL_humidity_B>! Reply: <addr><CR><LF>
aXLHC:<value>!	Writes value for humidity calibration coefficient C Input: <addr>XLHC:<CAL_humidity_C>! Reply: <addr><CR><LF>
aXLH?	Reads values for humidity calibration coefficients A, B, C <addr>±<CAL_humidity_A>±<CAL_humidity_B>±<CAL_humidity_C><CR><LF>
aXLD1:<value>!	Writes string for the most recent humidity calibration date (max 10 characters) Input: <addr>XLD1:<CAL_humidity_date>! Reply: <addr><CR><LF>
aXLN1!	Enables calibration routine over the humidity measurements <addr><CR><LF>
aXLF1!	Disables calibration routine over the humidity measurements <addr><CR><LF>
aXLXH:<value>!	Manual Test&Evaluation command for humidity calibration Input: <addr>XLXH: +<TEST_humidity_value>! Reply: <addr>+<TEST_humidity_value>+<CAL_humidity_value>+<CAL_humidity_status><CR><LF>

Table 57.46. SDI-12: Implementation of Barometric Pressure Calibration Commands

aXLPA:<value>!	Writes value for pressure calibration coefficient A Input: <addr>XLPA:<CAL_pressure_A>! Reply: <addr><CR><LF>
aXLPB:<value>!	Writes value for pressure calibration coefficient B Input: <addr>XLPB:<CAL_pressure_B>! Reply: <addr><CR><LF>
aXLPC:<value>!	Writes value for pressure calibration coefficient C Input: <addr>XLPC:<CAL_pressure_C>! Reply: <addr><CR><LF>
aXLP?	Reads values for pressure calibration coefficients A, B, C <addr>±<CAL_pressure_A>±<CAL_pressure_B>±<CAL_pressure_C><CR><LF>
aXLD2:<value>!	Writes string for the most recent pressure calibration date (max 10 characters) Input: <addr>XLD2:<CAL_pressure_date>! Reply: <addr><CR><LF>
aXLN2!	Enables calibration routine over the pressure measurements <addr><CR><LF>
aXLF2!	Disables calibration routine over the pressure measurements <addr><CR><LF>
aXLXP:<value>!	Manual Test&Evaluation command for pressure calibration Input: <addr>XLXP:+<TEST_pressure_value>! Reply: <addr>+<TEST_pressure_value>+<CAL_pressure_value>+<CAL_pressure_status><CR><LF>

NOTE 1: user calibrations of temperature, relative humidity, and barometric pressure (wherever/if enabled) will be applied prior to calculation of all secondary parameters.
NOTE 2: user calibration of barometric pressure (if enabled) will be applied to the barometric_pressure value prior to calculation of sea_level_pressure
NOTE 3: using the dedicated commands the user can turn ON or OFF calibrations during run time

Table 58.47. SDI-12: Implementation of Auxiliary Calibration Commands

aXLD?	Reads strings for the most recent calibration dates for temperature, humidity, and pressure <addr>+<CAL_temperature_date>+<CAL_humidity_date>+<CAL_pressure_date><CR><LF>
aXLN!	Enables calibration routine over temperature, humidity, pressure measurements <addr><CR><LF>
aXLF!	Disables calibration routine over temperature, humidity, pressure measurements <addr><CR><LF>
aXLN?	Gets status flags of temperature, humidity, pressure measurements calibrations: enabled/disabled <addr>+<CAL_temperature_status>+<CAL_humidity_status>+<CAL_pressure_status><CR><LF> Where <CAL_..._status>: 0 – calibration is OFF (not applied) for the respective environmental parameter 1 – calibration is ON (applied) for the respective environmental parameter
aXLF?	The same as “aXLN?” <addr>+<CAL_temperature_status>+<CAL_humidity_status>+<CAL_pressure_status><CR><LF>
aXLS!	Saves all calibration data to EEPROM. Else data will not be preserved after probe reset/power down <addr><CR><LF>
aXLR!	Resets all calibration data to default and saves to EEPROM <addr><CR><LF>

2.9.4. Example for Inputting Calibration Data in the Probe

Table 59.48. SDI-12: Example of Inputting Calibration Data in EHTP

Calibration Input Sequence	Comments
aXLR!	Optional: reset all calibration data to default
0	
0XLTC:-0.2!	CAL_temperature_C = -0.2, the other calibration coefficients remain with default values
0	
0XLXT:30.5!	Optional: TEST_temperature_value = 30.5°C/°F
0+30.50+30.30+0	
0XLXT:-10.8!	Optional: TEST_temperature_value = -10.8°C/°F
0-10.80-10.99+0	
0XLD0:15/09/22!	Optional: set CAL_temperature_date=15/09/22
0	
0XLD?	
0+15/09/22+0+0	Date changed only for air_temperature.
0XLN0!	Enables calibration only for air_temperature
0	
0XLN?	
0+1+0+0	Calibration enabled only for air_temperature
aXLS!	(Important line) Save to EEPROM CAL_temperature_C = -0.2, CAL_temperature_date=15/09/22, CAL_temperature_status=1
0	Successful save confirmed

2.10. CRC Algorithm

The cyclic redundancy check (CRC) is an error-detecting code used to determine if a block of digital data has been corrupted during transmission/reception. CRC is an integral component in the SDI-12 protocol - it is formatted as 3 ASCII symbols concatenated at the end of the SDI-12 message. Many SDI-12 commands have dedicated versions that request/generate CRC along with the main block of data. More information on the topic can be found in the official SDI-12 specification v1.4. EHTP implements the following algorithm that complies with the standard CRC algorithm for SDI-12 protocol. The CRC script is provided in C-code:

Table 60.49. SDI-12: CRC Algorithm Implemented in EHTP

```
struct SDI_SPECIFIC
{
    unsigned int16  CRC_INT_VALUE;  //CRC value in integer format
    char CRC_CHAR_VALUE[3];         //3-character string of CRC
    char ANY_out[50];               //any transmitted/received SDI-12 string (CRC not included)
}sdi_OUT;

//=======================================================
unsigned int16 SDI_CRC16_algorithm(unsigned int16 crc, char *buffer, unsigned int16 mask, unsigned int16 len)
//=======================================================
{
    unsigned int8 i;
    while (len--)
    {
        crc ^= (*buffer++);
        for(i=0;i<8;i++)
        {
            if(crc&0x0001)
            {
                 crc >>= 1;
                 crc ^= mask;
            }
            else{ crc >>= 1;  }
        }
    }
    return(crc);
}

//=======================================================
void SDI_CRC_format(char *crc_formatted[], unsigned int16 crc)
//=======================================================
{
    crc_formatted[0] = (0x40|(crc>>12));
    crc_formatted[1] = (0x40|((crc>>6)&0x3F));
    crc_formatted[2] = (0x40|(crc&0x3F));
}

//=======================================================
unsigned int16 SDI_CRC_calculation(char buffer[], char CRC_SDI[])
//=======================================================
{
    unsigned int16 CRC_digit;

    CRC_digit = SDI_CRC16_algorithm(0, buffer, 0xA001, strlen(buffer));
    SDI_CRC_format(CRC_SDI, CRC_digit);

    return(CRC_digit);
}

//=======================================================
void SDI_CRC_message(char message[])
//=======================================================
{
    sdi_OUT.CRC_INT_VALUE = SDI_CRC_calculation(message, sdi_OUT.CRC_CHAR_VALUE);
    strncat(message, sdi_OUT.CRC_CHAR_VALUE, 3);
}

//=======================================================
void main()
//=======================================================
{
    SDI_CRC_message(sdi_OUT.ANY_out);  // sdi_OUT.ANY_out must point to a SDI-12 string having no CRC attached
}
```

NOTE: use aXT-command to validate the implementation of the CRC algorithm on the master side

3. MODBUS OVER RS485/UART

Table 61.1. Modbus: Special Features of EHTP Supported in the Modbus Version(s)

Secondary Parameters	Sea-level Pressure	Wet-Bulb Temperature	User Calibration	Heater Control	Statistics	Diagnostics	Test values
•	•	•	•	•	•	•	•

3.1. Modbus Organization

Modbus is a standard data transfer protocol for digital systems. It is master-slave communication type where the master is the data logging device, and the slave is the EHTP probe. The master always issues commands first and the slave replies. More information about Modbus here: https://www.modbus.org/

The Modbus protocol can be communicated over a few electrical interfaces: RS232, RS422, RS485, UART, etc.

The industry-standard 2-wire differential RS485 stands out as a preferred noise-proof multipoint physical layer of Modbus. Universal Asynchronous Receiver-Transmitter (UART) is an on-board communication feature in most off-the-shelf microcontrollers, thus, a cost-effective and readily available interfacing solution in many data acquisition systems implementing the Modbus protocol.

3.2. IEEE754 Floating Point Format

Table 62.2. Modbus: IEEE754-Format Floating Point (32-bit)

Byte 1 (MSB)								Byte 2								Byte 3								Byte 4 (LSB)								Example
7	6	5	4	3	2	1	0	7	6	5	4	3	2	1	0	7	6	5	4	3	2	1	0	7	6	5	4	3	2	1	0	-
S	E	E	E	E	E	E	E	E	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	-
0x41								0xA1								0x47								0xAE								20.16°C
0xC1								0xA1								0x47								0xAE								-20.16°C

S – sign (1-bit), E – exponent (8-bit), M – mantissa (23-bit).

IMPORTANT: Modbus master devices based on MCUs by Microchip may require additional conversion between IEEE754 and Microchip-type floating point formats for correct data decoding.

Table 63.3. Modbus: Symbols and Notations

Parameter	Description
Sint16	16-bit signed integer
Unit16	16-bit unsigned integer
Sint32	32-bit signed integer
Unit32	32-bit unsigned integer
Float32	32-bit float in IEEE754 format
$[number]_{dec}$	[number] is in decimal format
$[number]_{hex}$	[number] is in hexadecimal format. Also noted as 0x[number]
S/s	Samples per second – unit for sampling rate
R	Type of a register: readable only
R/W	Type of a register: readable and writable
LSB	Least significant byte in a multibyte number
MSB	Most significant byte in a multibyte number
Hi	High 16-bit word in 32-bit value
Lo	Low 16-bit word in 32-bit value

3.3. Additional Special Features (All Modbus Versions Only)

1. Selectable operation modes: continuous, one-shot mode
2. Sleep mode under user control
3. Map of test registers for evaluation of user-calibration
4. Multipurpose AUX-pin:
   - awakes probe from sleep
   - resets Modbus communication settings to default
   - bidirectional data pin for auxiliary single-wire interface
5. Selectable 3V/5V-electrical interface levels under user control (Modbus-UART version only)

3.4. EHTP Electrical and Timing Specification (Modbus-RS485 Version)

Table 64.4. Modbus: Electrical and Timing Specification (Modbus-RS485 Version)

Parameter	Condition	Min	Typ	Max	Unit
Supply voltage (Vin)	Complying with SDI-12 specifications	7	12	24	Vdc
Current consumption (continuous mode)	Vin = 12Vdc. Heater OFF. **Wired for Modbus or single-wire interface.**	4.9	7.5	9	mA
Idle current consumption (one-shot mode)	Vin = 12Vdc. Heater OFF. **Wired for Modbus or single-wire interface.**	4.9	5	5.6	mA
Measurement current consumption (one-shot mode)	Vin = 12Vdc. Heater OFF. **Wired for Modbus or single-wire interface.**	8	8.5	9.5	mA
Current consumption (sleep mode)	Vin = 12Vdc. Heater OFF. Enabled low-power mode. **Wired for Modbus only.**	180	300	500	uA
RS485 Differential Driver Output	Vin = 12Vdc	1.5	5	5.5	V
RS485 Driver Common-Mode Output Voltage	Vin = 12Vdc	1	-	3	V
RS485 Receiver-Input Resistance	$-7V < V_{CM} < +12V$	95	-	-	kΩ
RS485 Receiver Differential Threshold Voltage	$-7V < V_{CM} < +12V$	-200	-	-50	V
Power-up time	-	1700	2000	2200	ms

3.5. EHTP Electrical and Timing Specification (Modbus-UART Version)

Table 65.5. Modbus: Electrical and Timing Specification (Modbus-UART Version)

Parameter	Condition	Min	Typ	Max	Unit
Supply voltage (Vin)	V_{UART}= 3V (V_{UART} = 5V)	3.3 (5.0)	12.0	24	Vdc
Current consumption (continuous mode)	Vin = 12Vdc. Heater OFF. **Wired for Modbus or single-wire interface.**	0.8	1.6	2	mA
Idle current consumption (one-shot mode)	Vin = 12Vdc. Heater OFF. **Wired for Modbus or single-wire interface.**	0.2	0.7	1	mA
Measurement current consumption (one-shot mode)	Vin = 12Vdc. Heater OFF. **Wired for Modbus or single-wire interface.**	2.8	3	3.5	mA
Current consumption (sleep mode)	Vin = 12Vdc. Heater OFF. Enabled low-power mode. **Wired for Modbus only.**	100	300	500	uA
UART logic high input	V_{UART}= 3V and V_{UART} = 5V	V_{UART} - 1	-	V_{UART} +0.7	V
UART logic high output	V_{UART}= 3V and V_{UART} = 5V	V_{UART} - 0.3	-	V_{UART}	V
UART logic low input	V_{UART} = 5V	-0.7	-	0.8	V
UART logic low output	V_{UART} = 5V	-	-	0.6	V
Power-up time		1700	2000	2200	ms

3.6. EHTP Configuration (All Modbus Versions)

Table 66.6. Modbus: Default Settings and Selectable Options

Parameter	Default Value	Selectable options
Modbus address	238_{dec} ($0xEE_{hex}$)	1_{dec}-247_{dec} ($0x01_{hex}$ – $0xF7_{hex}$)
Baud rate	9600	9600, 19200, 38400, 57600
Data bits	8	8
Parity	E	E
Stop bits	1	1
Flow control	None	None
Size of input buffer	60 bytes	-
Size of output buffer	Dynamic	-
Data transmission	MSB first	-
Modbus mode	RTU	ASCII
Probe operation mode	Continuous	One-Shot, Sleep
Sample rate	0.2 S/s	0.5, 1, 2 S/s
Calibration	Disabled for all parameters	Enable individually for any primary parameter
Logic voltage level	5V (for Modbus-RS485 version) 3V (Modbus-UART version)	5V (fixed for Modbus-RS485 version) 3, 5V (Modbus-UART version)
Heater	OFF	ON (manually), COOLING (automatically)

3.7. EHTP Quick Start (Modbus)

All environmental parameters can be read within a single response using the example below. Returned values are in IEEE754 floating point format. Starting address $44C_{hex}$ (register 1101 in the HTP Map of Environmental Registers).

Table 67.7. Modbus Quick Start: Example of Reading Environmental Data over Modbus

Read Request:
EE 03 04 4C 00 20 92 6A

Field Name	Hex Value
Modbus address	EE
Modbus function	03
Starting address Hi	04
Starting address Lo	4C
Number of registers Hi	00
Number of registers Lo	20
Modbus CRC Hi	92
Modbus CRC Lo	6A

Read Response: EE 03 40 41 8F AE 14 42 8C 38 52 44 73 9D 70 44 73 9D 70 41 46 8F 5C 41 2B BA 5F 41 A4 A3 D7 41 66 B8 52 41 88 00 00 43 AB AC CD 41 15 78 D5 42 26 EB 86 3F 33 5A 85 42 C5 CC CD 41 68 CC CC 42 9C 00 00 41 B9

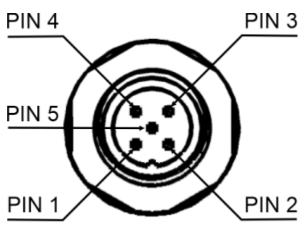
Field Name	Hex Value	Float32 IEEE754 format	Unit
Modbus address (default)	EE	-	-
Modbus function	03	-	-
Byte count	40	-	-
air_ temperature (1101-1102)	41 8F AE 14	17.9599991	°C
relative_humidity (1103-1104)	42 8C 38 52	70.1100006	%
barometric_pressure (1105-1106)	44 73 9D 70	974.459961	hPa
sea_level_pressure (1107-1109)	44 73 9D 70	974.459961	hPa
dew_point (1109-1110)	41 46 8F 5C	12.4099998	°C
absolute_humidity (1111-1112)	41 2B BA 5F	10.7330008	g/m^3
saturated_vapor_pressure (1113-1114)	41 A4 A3 D7	20.5799999	hPa
vapor_pressure (1115-1116)	41 66 B8 52	14.4200001	hPa
heat_index (1117-1118)	41 88 00 00	17.0000000	°C
speed_of_sound (1119-1120)	43 AB AC CD	343.350006	m/s
mixing_ratio (1121-1122)	41 15 78 D5	9.34200001	g/kg
specific_enthalpy (1123-1124)	42 26 EB 86	41.7300034	kJ/kg
water_activity (1125-1126)	3F 33 5A 85	0.70059997	-
water_boiling_point (1127-1128)	42 C5 CC CD	98.9000015	°C
wet_bulb_temperature (1129-1130)	41 68 CC CC	14.5499992	°C
wet_bulb_iterations (1131-1132)	42 9C 00 00	78.0000000	-
Modbus CRC Hi	92	-	-
Modbus CRC Lo	6A	-	-

3.8. Wiring

3.8.1. EHTP Connector (All Modbus Versions)

The Modbus versions of the EHTP probe are equipped with dual interfacing – along with the main Modbus, there is an auxiliary single-wire interface used mainly for compatibility with other Evvos products.

Table 68.8. Modbus: Pinout of the M12-connector on EHTP probe (All Modbus Versions)

Probe's connector (front view)	Pin function	Pin number	Note
	System power supply (Vin)	Pin 1	
	System ground (GND)	Pin 2	Internally connected to casing.
	B- (for RS485) Tx (for UART)	Pin 3	2-wire differential I/O pin B (for RS485) Single-ended transmitter output (for UART)
	A+ (for RS485) Rx (for UART)	Pin 4	2-wire differential I/O pin A (for RS485) Single-ended transmitter output (for UART)
	Auxiliary (AUX)	Pin 5	Single-wire interface bidirectional DATA-pin. **Leave floating when Modbus mode is in use.**

3.8.2. Grounding

The metal casing of the probe is internally connected to GND.

3.8.3. Wiring for All Modbus Versions

Table 69.9. Modbus: Wiring of EHTP for All Modbus Versions

Probe's Connector (front view)	Patch Cable Wires	Electrical Connection (Modbus-RS485)	Electrical Connection (Modbus-UART)
Pin 1	Brown	Vin	Vin
Pin 2	White	GND	GND
Pin 3	Blue	B-	Tx
Pin 4	Black	A+	Rx
Pin 5	Green/yellow	AUX-comm pin	AUX-comm pin

3.8.4. Wiring for Single-Wire Interface (All Modbus Versions)

Table 70.10. Modbus: Wiring of EHTP (All Modbus Versions) for Single-Wire Interface

Probe's Connector (front view)	Patch Cable Wires	Electrical Connection
Pin 1	Brown	Vin
Pin 2	White	GND
Pin 3	Blue	Left floating / GND
Pin 4	Black	Left floating / GND
Pin 5	Green/yellow	Single-wire comm pin

3.9. Summary of Supported Modbus Functions

Table 71.11. Modbus: Functions Supported by EHTP

Command Code (HEX)	Command Name
0x03	Read Holding Registers
0x06	Write Single Register
0x08	Modbus Diagnostics (sub functions 0x00, 0x01, 0x04, 0x0A, 0x0B, 0x0C, 0x0D, 0x0E)
0x10	Write Multiple Registers
0x17	Read/Write multiple registers

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3.10. Summary of EHTP Register Maps

Table 72.12. Modbus: Summary of Register Maps in EHTP

Start Addr	End Addr	Start Reg	End Reg	Value count	Modbus commands	Description
0x000A	0x0018	0011	0024	7	0x03	Map of Traceability Registers
0x3E8	0x407	1001	1032	16	0x03	Map of Environmental Parameters (INT format)
0x44C	0x46B	1101	1132	16	0x03	Map of Environmental Parameters (FLOAT format)
0xFA0	0x1035	4001	4150	75	0x03	Map of Statistical Parameters (INT format)
0x1194	0x1229	4501	4650	75	0x03	Map of Statistical Parameters (FLOAT format)
0x1388	0x1396	5001	5015	15	0x03, 0x06	Map of Control Registers
0x1B58	0x1B61	7001	7010	10	0x03	Map of Diagnostic Registers
0x1C20	0x1C29	7201	7210	10	0x03	Map of Heater Registers
0x1F40	0x1F53	8001	8020	9	0x03	Map of Fixed-Value Test Registers
0x1FA4	0x1FA6	8101	8103	3	0x03	Map of Raw Value Registers
0x2710	0x2734	10001	10037	16	0x03, 0x10	Map of Input Registers for User-Defined Calibration
0x27D8	0x27DC	10201	10205	3	0x03, 0x10	Map of Input Registers for Reduced Sea-Level Pressure
0x2904	0x293B	10501	10556	28	0x03, 0x10, 0x17	Map of Test Registers for Evaluation of Calibration
-	-	-	-	-	0x08	Map of Modbus Diagnostics

3.11. Map of Environmental Parameters

Table 73.13. Modbus: Map of Environmental Parameters (Integer and Float formats)

Applicable Modbus commands: 0x03

Integer				Float32		Description	
Addr	**Reg**	**Scale**	**Format**	**Addr**	**Reg**	**Parameter**	**Unit**
0x3E8	1001 1002	0.01	Sint32	0x44C	1101 1102	air_ temperature	°C
0x3EA	1003 1004	0.01	Uint32	0x44E	1103 1104	relative_humidity	%
0x3EC	1005 1006	0.01	Uint32	0x450	1105 1106	barometric_pressure	hPa
0x3EE	1007 1008	0.01	Uint32	0x452	1107 1108	sea_level_pressure	hPa
0x3F0	1009 1010	0.01	Sint32	0x454	1109 1110	dew_point	°C
0x3F2	1011 1012	0.001	Uint32	0x456	1111 1112	absolute_humidity	g/m^3
0x3F4	1013 1014	0.01	Uint32	0x458	1113 1114	saturated_vapor_pressure	hPa
0x3F6	1015 1016	0.01	Uint32	0x45A	1115 1116	vapor_pressure	hPa
0x3F8	1017 1018	1	Sint32	0x45C	1117 1118	heat_index	°C
0x3FA	1019 1020	0.01	Uint32	0x45E	1119 1120	speed_of_sound	m/s
0x3FC	1021 1022	0.001	Uint32	0x460	1121 1122	mixing_ratio	g/kg
0x3FE	1023 1024	0.001	Uint32	0x462	1123 1124	specific_enthalpy	kJ/kg

Modbus: Map of Environmental Parameters (Integer and Float formats) (Continued)

Applicable Modbus commands: 0x03							
Integer				Float32		Description	
Addr	Reg	Scale	Format	Addr	Reg	Parameter	Unit
0x400	1025 1026	0.0001	Uint32	0x464	1125 1126	water_activity	-
0x402	1027 1028	0.01	Sint32	0x466	1127 1128	water_boiling_point	°C
0x404	1029 1030	0.01	Sint32	0x468	1129 1130	wet_bulb_temperature	°C
0x406	1031 1032	1	Uint32	0x46A	1131 1132	wet_bulb_iterations	-

Table 74.14. Modbus: Map of Extended Environmental Parameters (Integer and Float formats) for HTP+CO2

Applicable Modbus commands: 0x03							
Integer				Float32		Description	
Addr	Reg	Scale	Format	Addr	Reg	Parameter	Unit
0x408	1033 1034	0.001	Uint32	0x46C	1133 1134	CO2_percentage	%

NOTE: the Map of Extended Environmental Parameters is accessible as an extension of the general Map of Environmental Parameters in some versions of the EHTP probe (e.g. HTP+CO2)

Table 75.15. Modbus: Example Reading (Map of Environmental Parameters) (Integer Format)

Read Request: EE 03 03 E8 00 20 D2 FD

Field Name	Hex Value
Modbus address	EE
Modbus function	03
Starting address Hi	03
Starting address Lo	E8
Number of registers Hi	00
Number of registers Lo	20
Modbus CRC Hi	D2
Modbus CRC Lo	FD

Read Response: EE 03 40 00 00 07 69 00 00 1A D1 00 01 7C 88 00 01 7C 88 00 00 05 19 00 00 2B 93 00 00 08 90 00 00 05 E0 00 00 00 13 00 00 86 5E 00 00 26 19 00 00 AB 1E 00 00 1A CD 00 00 26 A1 00 00 05 FA 00 00 00 55 FA DD

Field Name	Hex Value	Int32	Decoded
Modbus address	EE	-	
Modbus function	03	-	
Byte count	40	-	
Value 1 (1001-1002)	0000 0769	1897	18.97
Value 2 (1003-1004)	0000 1AD1	6865	68.65
Value 3 (1005-1006)	0001 7C88	97416	974.16
Value 4 (1007-1009)	0001 7C88	97416	974.16
Value 5 (1009-1010)	0000 0519	1305	13.05
Value 6 (1011-1012)	0000 2B93	11155	11.155
Value 7 (1013-1014)	0000 0890	2192	21.92
Value 8 (1015-1016)	0000 05E0	1504	15.04
Value 9 (1017-1018)	0000 0013	19	19.0
Value 10 (1019-1020)	0000 865E	34398	343.98
Value 11 (1021-1022)	0000 2619	9753	9.753
Value 12 (1023-1024)	0000 AB1E	43806	43.806
Value 13 (1025-1026)	0000 1ACD	6861	0.6861
Value 14 (1027-1028)	0000 26A1	9889	98.89
Value 15 (1029-1030)	0000 05FA	1530	15.30
Value 16 (1031-1032)	0000 0055	85	85.0
Modbus CRC Hi	FA	-	
Modbus CRC Lo	DD	-	

3.12. Map of Statistical Parameters

Refer to *Statistics*
for detailed description of the feature. Statistical data collection is available during Continuous and One-Shot operation modes. Statistical data collection is always on as an integral part of the internal measurement cycle of EHTP. *STATISTICS_control* in the Map of Control Registers is available for user-triggered reset of statistical data collection. Reset also occurs at power-down.

Table 76.16. Modbus: Map of Statistical Environmental Parameters (Integer and Float formats)

Applicable Modbus command: 0x03

Integer				Float32		Description	
Addr	**Reg**	**Scale**	**Format**	**Addr**	**Reg**	**Parameter**	**Unit**
0xFA0	4001 4002	0.01	Sint32	0x1194	4501 4502	MIN_air_temperature	°C
0xFA2	4003 4004	0.01	Sint32	0x1196	4503 4504	MAX_air_temperature	°C
0xFA4	4005 4006	0.01	Sint32	0x1198	4505 4506	FIRST_air_temperature	°C
0xFA6	4007 4008	0.01	Sint32	0x119A	4507 4508	LAST_air_temperature	°C
0xFA8	4009 4010	1	Uint32	0x119C	4509 4510	COUNT_air_temperature	-
0xFAA	4011 4012	0.01	Uint32	0x119E	4511 4512	MIN_relative_humidity	%
0xFAC	4013 4014	0.01	Uint32	0x11A0	4513 4514	MAX_relative_humidity	%
0xFAE	4015 4016	0.01	Uint32	0x11A2	4515 4516	FIRST_relative_humidity	%
0xFB0	4017 4018	0.01	Uint32	0x11A4	4517 4518	LAST_relative_humidity	%
0xFB2	4019 4020	1	Uint32	0x11A6	4519 4520	COUNT_relative_humidity	-
0xFB4	4021 4022	0.01	Uint32	0x11A8	4521 4522	MIN_barometric_pressure	hPa
0xFB6	4023 4024	0.01	Uint32	0x11AA	4523 4524	MAX_barometric_pressure	hPa
0xFB8	4025 4026	0.01	Uint32	0x11AC	4525 4526	FIRST_barometric_pressure	hPa
0xFBA	4027 4028	0.01	Uint32	0x11AE	4527 4528	LAST_barometric_pressure	hPa
0xFBC	4029 4030	1	Uint32	0x11B0	4529 4530	COUNT_barometric_pressure	-
0xFBE	4031 4032	0.01	Uint32	0x11B2	4531 4532	MIN_sea_level_pressure	hPa
0xFC0	4033 4034	0.01	Uint32	0x11B4	4533 4534	MAX_sea_level_pressure	hPa
0xFC2	4035 4036	0.01	Uint32	0x11B6	4535 4536	FIRST_sea_level_pressure	hPa
0xFC4	4037 4038	0.01	Uint32	0x11B8	4537 4538	LAST_sea_level_pressure	hPa
0xFC6	4039 4040	1	Uint32	0x11BA	4539 4540	COUNT_sea_level_pressure	-

EVVOS

Modbus: Map of Statistical Environmental Parameters (Integer and Float formats) (Continued)

Applicable Modbus command: 0x03

Integer				Float32		Description	
Addr	**Reg**	**Scale**	**Format**	**Addr**	**Reg**	**Parameter**	**Unit**
0xFC8	4041 4042	0.01	Sint32	0x11BC	4541 4542	MIN_dew_point	°C
0xFCA	4043 4044	0.01	Sint32	0x11BE	4543 4544	MAX_dew_point	°C
0xFCC	4045 4046	0.01	Sint32	0x11C0	4545 4546	FIRST_dew_point	°C
0xFCE	4047 4048	0.01	Sint32	0x11C2	4547 4548	LAST_dew_point	°C
0xFD0	4049 4050	1	Uint32	0x11C4	4549 4550	COUNT_dew_point	-
0xFD2	4051 4052	0.001	Uint32	0x11C6	4551 4552	MIN_absolute_humidity	g/m^3
0xFD4	4053 4054	0.001	Uint32	0x11C8	4553 4554	MAX_absolute_humidity	g/m^3
0xFD6	4055 4056	0.001	Uint32	0x11CA	4555 4556	FIRST_absolute_humidity	g/m^3
0xFD8	4057 4058	0.001	Uint32	0x11CC	4557 4558	LAST_absolute_humidity	g/m^3
0xFDA	4059 4060	1	Uint32	0x11CE	4559 4560	COUNT_absolute_humidity	-
0xFDC	4061 4062	0.01	Uint32	0x11D0	4561 4562	MIN_saturated_vapor_pressure	hPa
0xFDE	4063 4064	0.01	Uint32	0x11D2	4563 4564	MAX_saturated_vapor_pressure	hPa
0xFE0	4065 4066	0.01	Uint32	0x11D4	4565 4566	FIRST_saturated_vapor_pressure	hPa
0xFE2	4067 4068	0.01	Uint32	0x11D6	4567 4568	LAST_saturated_vapor_pressure	hPa
0xFE4	4069 4070	1	Uint32	0x11D8	4569 4570	COUNT_saturated_vapor_pressure	-
0xFE6	4071 4072	0.01	Uint32	0x11DA	4571 4572	MIN_vapor_pressure	hPa
0xFE8	4073 4074	0.01	Uint32	0x11DC	4573 4574	MAX_vapor_pressure	hPa
0xFEA	4075 4076	0.01	Uint32	0x11DE	4575 4576	FIRST_vapor_pressure	hPa
0xFEC	4077 4078	0.01	Uint32	0x11E0	4577 4578	LAST_vapor_pressure	hPa
0xFEE	4079 4080	1	Uint32	0x11E2	4579 4580	COUNT_vapor_pressure	-
0xFF0	4081 4082	0.01	Sint32	0x11E4	4581 4582	MIN_heat_index	°C
0xFF2	4083 4084	0.01	Sint32	0x11E6	4583 4584	MAX_heat_index	°C
0xFF4	4085 4086	0.01	Sint32	0x11E8	4585 4586	FIRST_heat_index	°C
0xFF6	4087 4088	0.01	Sint32	0x11EA	4587 4588	LAST_heat_index	°C
0xFF8	4089 4090	1	Uint32	0x11EC	4589 4590	COUNT_heat_index	-

Modbus: Map of Statistical Environmental Parameters (Integer and Float formats) (Continued)

Applicable Modbus command: 0x03

Integer				Float32		Description	
Addr	Reg	Scale	Format	Addr	Reg	Parameter	Unit
0xFFA	4091 4092	0.01	Uint32	0x11EE	4591 4592	MIN_speed_of_sound	m/s
0xFFC	4093 4094	0.01	Uint32	0x11F0	4593 4594	MAX_speed_of_sound	m/s
0xFFE	4095 4096	0.01	Uint32	0x11F2	4595 4596	FIRST_speed_of_sound	m/s
0x1000	4097 4098	0.01	Uint32	0x11F4	4597 4598	LAST_speed_of_sound	m/s
0x1002	4099 4100	1	Uint32	0x11F6	4599 4600	COUNT_speed_of_sound	-
0x1004	4101 4102	0.001	Uint32	0x11F8	4601 4602	MIN_mixing_ratio	g/kg
0x1006	4103 4104	0.001	Uint32	0x11FA	4603 4604	MAX_mixing_ratio	g/kg
0x1008	4105 4106	0.001	Uint32	0x11FC	4605 4606	FIRST_mixing_ratio	g/kg
0x100A	4107 4108	0.001	Uint32	0x11FE	4607 4608	LAST_mixing_ratio	g/kg
0x100C	4109 4110	1	Uint32	0x1200	4609 4610	COUNT_mixing_ratio	-
0x100E	4111 4112	0.001	Uint32	0x1202	4611 4612	MIN_specific_enthalpy	J/kg
0x1010	4113 4114	0.001	Uint32	0x1204	4613 4614	MAX_specific_enthalpy	J/kg
0x1012	4115 4116	0.001	Uint32	0x1206	4615 4616	FIRST_specific_enthalpy	J/kg
0x1014	4117 4118	0.001	Uint32	0x1208	4617 4618	LAST_specific_enthalpy	J/kg
0x1016	4119 4120	1	Uint32	0x120A	4619 4620	COUNT_specific_enthalpy	-
0x1018	4121 4122	0.0001	Uint32	0x120C	4621 4622	MIN_water_activity	-
0x101A	4123 4124	0.0001	Uint32	0x120E	4623 4624	MAX_water_activity	-
0x101C	4125 4126	0.0001	Uint32	0x1210	4625 4626	FIRST_water_activity	-
0x101E	4127 4128	0.0001	Uint32	0x1212	4627 4628	LAST_water_activity	-
0x1020	4129 4130	1	Uint32	0x1214	4629 4630	COUNT_water_activity	-
0x1022	4131 4132	0.01	Sint32	0x1216	4631 4632	MIN_water_boiling_point	°C
0x1024	4133 4134	0.01	Sint32	0x1218	4633 4634	MAX_water_boiling_point	°C
0x1026	4135 4136	0.01	Sint32	0x121A	4635 4636	FIRST_water_boiling_point	°C
0x1028	4137 4138	0.01	Sint32	0x121C	4637 4638	LAST_water_boiling_point	°C
0x102A	4139 4140	1	Uint32	0x121E	4639 4640	COUNT_water_boiling_point	-

Modbus: Map of Statistical Environmental Parameters (Integer and Float formats) (Continued)

Applicable Modbus command: 0x03							
Integer				Float32		Description	
Addr	Reg	Scale	Format	Addr	Reg	Parameter	Unit
0x102C	4141 4142	0.01	Sint32	0x1220	4641 4642	MIN_wet_bulb_temperature	°C
0x102E	4143 4144	0.01	Sint32	0x1222	4643 4644	MAX_wet_bulb_temperature	°C
0x1030	4145 4146	0.01	Sint32	0x1224	4645 4646	FIRST_wet_bulb_temperature	°C
0x1032	4147 4148	0.01	Sint32	0x1226	4647 4648	LAST_wet_bulb_temperature	°C
0x1034	4149 4150	1	Uint32	0x1228	4649 4650	COUNT_wet_bulb_temperature	-

Table 77.17. Modbus: Map of Extended Statistical Environmental Parameters (Integer and Float formats) for HTP+CO2

Applicable Modbus command: 0x03							
Integer				Float32		Description	
Addr	Reg	Scale	Format	Addr	Reg	Parameter	Unit
0x1036	4151 4152	0.01	Sint32	0x122A	4651 4652	MIN_CO2_percentage	°C
0x1038	4153 4154	0.01	Sint32	0x122C	4653 4654	MAX_CO2_percentage	°C
0x103A	4155 4156	0.01	Sint32	0x122E	4655 4656	FIRST_CO2_percentage	°C
0x103C	4157 4158	0.01	Sint32	0x1230	4657 4658	LAST_CO2_percentage	°C
0x103E	4159 4160	1	Uint32	0x1232	4659 4660	COUNT_CO2_percentage	-

NOTE: the Map of Extended Statistical Environmental Parameters is accessible as an extension of the general Map of Statistical Environmental Parameters in some versions of the EHTP probe (e.g. HTP+CO2)

Table 78.18. Modbus: Example Reading (Map of Statistical Environmental Parameters (Integer Format))

Read Request:
EE 03 0F AA 00 0A F0 66

Field Name	Hex Value
Modbus address	EE
Modbus function	03
Starting address Hi	0F
Starting address Lo	AA
Number of registers Hi	00
Number of registers Lo	0A
Modbus CRC Hi	F0
Modbus CRC Lo	66

Read Response: EE 03 14 00 00 1A 15 00 00 23 D8 00 00 1B 8D 00 00 1B DE 00 00 04 8B FF 53

Field Name	Hex Value	Int32	Decoded
Modbus address	EE	-	
Modbus function	03	-	
Byte count	14	-	
Value 1 (4011-4012)	00 00 1A 15	6677	66.77
Value 2 (4013-4014)	00 00 23 D8	9176	91.76
Value 3 (4015-4016)	00 00 1B 8D	7053	70.53
Value 4 (4017-4019)	00 00 1B DE	7134	71.34
Value 5 (4019-4020)	00 00 04 8B	1163	1163
Modbus CRC Hi	FF	-	
Modbus CRC Lo	53	-	

Table 79.19. Modbus: Example Reading (Map of Statistical Environmental Parameters (Float Format))

Read Request:
EE 03 11 BC 00 0A 17 8A

Field Name	Hex Value
Modbus address	EE
Modbus function	03
Starting address Hi	11
Starting address Lo	BC
Number of registers Hi	00
Number of registers Lo	0A
Modbus CRC Hi	17
Modbus CRC Lo	8A

Read Response: EE 03 14 41 3F AE 14 41 99 33 33 41 43 5C 29 41 43 AE 14 44 A2 00 00 23 62

Field Name	Hex Value	Float32
Modbus address	EE	-
Modbus function	03	-
Byte count	14	-
Value 1 (4541-4542)	41 3F AE 14	11.9799995
Value 2 (4543-4544)	41 99 33 33	19.1499996
Value 3 (4545-4546)	41 43 5C 29	12.2100000
Value 4 (4547-4549)	41 43 AE 14	12.2299995
Value 5 (4549-4550)	44 A2 00 00	1296.00000
Modbus CRC Hi	23	
Modbus CRC Lo	62	

3.13. Map of Control Registers

3.13.1. Operation Mode

A Modbus-enabled EHTP supports 3 operation modes: continuous, one-shot, and sleep. The user can select an operation mode based on the required by the application balance between performance and power consumption.

Continuous mode – the conventional, high-performance operation mode available in all Modbus-enabled probes. After power-up, a probe repeats continuously its internal measurement cycle with constant, user-selected sample rate. Between measurements the onboard MCU idles with RS485 driver always ON (Modbus over RS485 version). A timeout of 2 sec is recommended for the Master to wait for the response.

One-shot mode – a reduced-power mode that performs a single measurement cycle on demand. This mode is valuable in setups requiring synchronization between measurements and other activities controlled by a master device. The user can engage a measurement by writing a trigger code to *OPERATION_trigger* register. After receiving a valid trigger code a probe starts a measurement of all environmental parameters (including wet-bulb temperature) and automatically changes its current *OPERATION_mode* setting to One-Shot. When all calculations are over the probe returns a standard Modbus response to function 0x06. Refer to ***Error! Reference source not found.*** for a response timeout.
Between measurements the onboard MCU idles with RS485 driver always ON (Modbus over RS485). Reading the *OPERATION_trigger* register returns a status code that indicates whether a new set of measured values is available. Status code is automatically cleared upon the first valid reading of any of the values in the new set.

Sleep mode – a low-power mode that enables an EHTP probe to remain operational for prolonged periods with minimal impact on the power source. This mode is geared towards battery-powered applications. Writing a valid sleep code into the *OPERATION_trigger* register forces the on-board MCU into deep sleep and turns the RS485 driver OFF (Modbus over RS485 version). Modbus commands are no longer recognized by a probe. No measurements are performed by EHTP in sleep mode. Exiting sleep mode is performed by 2 methods:

1) Complete power-down/power-up cycle: a probe is re-initialized with its most recent settings saved to EEPROM.
2) Generating a falling edge on the AUX pin: a probe always wakes up with *OPERATION_mode* = Continuous and SAMPLE_RATE = 2 S/s. All other settings remain unchanged even if not stored in EEPROM (data in EEPROM also not affected).

3.13.2. Response Timeout

An EHTP probe is designed to always respond to a Master's command within a specified period. If, for any reason, the probe is momentarily unable to respond on time, an internal timeout event is generated, and a response is not issued at all. This guarantees that a master may safely attempt to repeat command transmission without risk of collisions on the data bus. Probe's internal timeout timer is started at the end of reception of a valid command.

Table 80.20. Modbus: EHTP Response Timeout (All Modbus Versions)

Operation mode	*Timeout*	*Unit*
Continuous mode: SAMPLE_RATE = 0.2 S/s (default)	1600	ms
Continuous mode: SAMPLE_RATE = 0.5 S/s	800	ms
Continuous mode: SAMPLE_RATE = 1 S/s	400	ms
Continuous mode: SAMPLE_RATE = 2 S/s	200	ms
One-Shot mode	6000	ms
Sleep mode	-	-

3.13.3. Sampling Rate and Wet-bulb Temperature

The map of environmental parameters and the map of statistical parameters are updated within each measurement cycle. Calculation of wet-bulb temperature is available only with 0.2 S/s sample rate. This measurement is not available in higher sample rates (when *OPERATION_mode* = Continuous). Higher sample rates come at the expense of higher power consumption. Refer to *Calculating the Wet-Bulb Temperature* for detailed description.

3.13.4. Changing the Modbus Communication Settings

Valid change of any Modbus communication setting is followed by a standard Modbus response message using the old setting before engaging the new one. Changes of settings are performed on the run by HTP and do not lead to full probe's re-initialization and loss of measurement data. Example in ***Error! Reference source not found.***.

3.13.5. Saving User Settings to the On-board EEPROM

On power-up all operational and communication settings are initialized with their corresponding values stored in the on-board EEPROM. As an added fail-save feature all user-defined changes to the configuration registers introduced during probe run time remain active only up to the next powered down. To make the changes permanent by storing them in the on-board EEPROM the user must write a valid save-code in the *MODBUS_save_settings* register. A single write to *MODBUS_save_settings* after reconfiguring multiple operational and communication parameters is enough to store all of them to EEPROM. Writing valid reset code to registers *MODBUS_RESET_comm* and *MODBUS_RESET_addr* will automatically save the default settings to EEPROM.

Table 81.21. Modbus: Map of Control Registers

Applicable Modbus commands: 0x03, 0x06

Addr	Reg	Parameter	Type	Mode	Description
0x1388	5001	OPERATION_config	Uint16	R/W	Refer to Table 27 for all numerical combinations of OPERATION_mode and SAMPLE_RATE OPERATION_mode (write MSB in the register): 0x00•• – no action 0xFF•• – continuous mode 0x10•• – one-shot mode SAMPLE_RATE for continuous mode (write LSB in the register): 0x••00 – no action 0x••20 – 2 S/s 0x••10 – 1 S/s 0x••05 – 0.5 S/s 0x••02 – 0.2 S/s (supports wet-bulb temperature) NOTE: register values shown in HEX-format only

Modbus: Map of Control Registers (Continued)

Applicable Modbus commands: 0x03, 0x06

Addr	Reg	Parameter	Type	Mode	Description
0x1389	5002	OPERATION_trigger	Uint16	R/W	OPERATION_trigger (write): 0x0000 (0_{dec}) – no action 0xAAAA (43690_{dec}) – trigger sleep mode. 0xFFFF (65535_{dec}) – starts a measurement. Automatically changes OPERATION_mode to one-shot OPERATION_trigger (read): 0x0000 (0_{dec}) – no new data available 0x00FF (255_{dec}) – data ready
0x138A	5003	STATISTICS_control	Uint16	W	Clear-and-reset statistical data collection. STATISTICS_control (write): 0x0000 (0_{dec}) – no action 0xFFFF (65535_{dec}) – reset all parameters simultaneously 0x01FF (511_{dec}) – reset only real_TEMPERATURE 0x02FF (767_{dec}) – reset only real_REL_HUMIDITY 0x03FF (1023_{dec}) – reset only real_ATM_PRESSURE 0x04FF (1279_{dec}) – reset only sea_level_PRESSURE 0x05FF (1535_{dec}) – reset only DEW_POINT 0x06FF (1791_{dec}) – reset only ABS_HUMIDITY 0x07FF (2047_{dec}) – reset only SAT_VAP_PRESSURE 0x08FF (2303_{dec}) – reset only VAP_PRESSURE 0x09FF (2559_{dec}) – reset only HEAT_INDEX 0x0AFF (2815_{dec}) – reset only SPEED_OF_SOUND 0x0BFF (3071_{dec}) – reset only MIXING_RATIO 0x0CFF (3327_{dec}) – reset only SPECIFIC_ENTHALPY 0x0DFF (3583_{dec}) – reset only WATER_ACTIVITY 0x0EFF (3839_{dec}) – reset only WATER_BOILING_POINT 0x0FFF (4095_{dec}) – reset only WET_BULB_TEMPERATURE STATISTICS_control (read): 0x0000 (0_{dec}) – always
0x138B	5004	CALIBRATION_control	Uint16	R/W	Use the MODBUS_save_settings to save to EEPROM. Refer to Table 28 for all numerical settings of CALIBRATION_control CALIBRATION_control (write): 0x0000 (0_{dec}) – no action 0x •b•d•f••FF$_{hex}$ – enable calibration per values of b, d, f 0x ••••••••0F$_{hex}$ – reset all calibration coefficients to default Where: Bit 14 [b]: 1 = enable user calibration over real_TEMPERATURE 0 = Disable user calibration over real_TEMPERATURE bit 12 [d]: 1 = Enable user calibration over real_REL_HUMIDITY 0 = Disable user calibration over real_REL_HUMIDITY bit 10 [f]: 1 = Enable user calibration over real_ATM_PRESSURE 0 = Disable user calibration over real_ATM_PRESSURE CALIBRATION_control (read): 0x00[0b0d0f00] Where: Bit 6 [b]: 1 = calibration over real_TEMPERATURE enabled 0 = calibration over real_TEMPERATURE disabled bit 4 [d]: 1 = calibration over real_REL_HUMIDITY enabled 0 = calibration over real_REL_HUMIDITY disabled bit 2 [f]: 1 = calibration over real_ATM_PRESSURE enabled 0 = calibration over real_ATM_PRESSURE disabled

Modbus: Map of Control Registers (Continued)

Applicable Modbus commands: 0x03, 0x06

Addr	Reg	Parameter	Type	Mode	Description
0x138C	5005	DIAGNOSTICS_control	Uint16	R/W	Performs probe diagnostics: RAM test, reading of on-board voltages, update of error diagnostic registers. DIAGNOSTICS_control (write): 0x0000 (0_{dec}) – no action 0xFFFF (65535_{dec}) – start diagnostics DIAGNOSTICS_control (read): 0x0000 (0_{dec}) – no new data 0x00FF (255_{dec}) – new data ready. Automatically cleared after reading
0x138D	5006	HEAT_set_time/ HEATER_status	Uint16	R/W	Starts HEATING state for a selected HEAT_set_time. When time up the heater is automatically turns off and COOLING state is activated. The cycle ends with OFF state. Temperature and humidity values will be affected during HEATING and COOLING state. HEAT_set_time (write): 0x0000 (0_{dec}) – no action 0x00FF (255_{dec}) – disable HEATER (interrupt operation) 0x01FF (511_{dec}) – enable HEATER for 10 s 0x02FF (767_{dec}) – enable HEATER for 20 s 0x03FF (1023_{dec}) – enable HEATER for 30 s 0x04FF (1279_{dec}) – enable HEATER for 40 s 0x05FF (1535_{dec}) – enable HEATER for 50 s 0x06FF (1791_{dec}) – enable HEATER for 60 s 0x07FF (2047_{dec}) – enable HEATER for 70 s 0x08FF (2303_{dec}) – enable HEATER for 80 s 0x09FF (2559_{dec}) – enable HEATER for 90 s HEATER_status (read): 0x0000 (0_{dec}) – Heater in OFF state 0x0001 (1_{dec}) – Heater in HEATING state 0x0002 (2_{dec}) – Heater in COOLING stat
0x138E	5007	MODBUS_voltage_level	Uint16	R/W	**Only available with Modbus over UART.** User-selectable voltage levels of COMM port digital data. Use the MODBUS_save_settings to save to EEPROM. MODBUS_voltage_level (write): 0x0000 (0_{dec}) – no action 0x03FF (1023_{dec}) - 3V UART voltage level 0x05FF (1535_{dec}) - 5V UART voltage level MODBUS_voltage_level (read): 0x0003 (3_{dec}) - 3V UART voltage level 0x0005 (3_{dec}) - 5V UART voltage level NOTE: 5V-input levels are accepted when in 3V-configuration.

Modbus: Map of Control Registers (Continued)

Applicable Modbus commands: 0x03, 0x06

Addr	Reg	Parameter	Type	Mode	Description
0x138F	5008	MODBUS_baud_rate	Uint16	R/W	User-selectable baud rate of COMM port digital data input/output stream. Use the MODBUS_save_settings to save to EEPROM. MODBUS_baud_rate (write/read): 0x0000 (0_{dec}) – no action 0x0096 (150_{dec}) – 9600 baud 0x0192 (402_{dec}) – 19200 baud 0x0384 (900_{dec}) – 38400 baud 0x0576 (1398_{dec}) – 57600 baud
0x1390	5009	MODBUS_bits_parity	Uint16	R/W	Modbus communication settings: parity/data_bits/stop_bits MODBUS_bits_parity (write/read): 0x0081 (129_{dec}) – none, 8, 1 0xEE81 (61057_{dec}) – even, 8, 1 0xDD81 (56705_{dec}) – odd, 8, 1
0x1391	5010	MODBUS_slave_id	Uint16	R/W	User-selectable Modbus slave address for HTP. Address in range 1-247_{dec}. Use the MODBUS_save_settings to save to EEPROM. MODBUS_slave_id (write): 0x••00 – no action 0x••FF – change address MODBUS_slave_id (read): 0x00•• Where: •• = 0x01-0xF7 (1-247) NOTE: register values shown in HEX-format only
0x1392	5011	MODBUS_RTU_ASCII	Uint16	R/W	User-selectable mode of Modbus communication. Use the MODBUS_save_settings to save to EEPROM. MODBUS_RTU_ASCII (write): 0x0000 (0_{dec}) – no action 0xAAFF (43775_{dec}) – RTU 0xBBFF (48127_{dec}) – ASCII MODBUS_RTU_ASCII (read): 0x00AA (170_{dec}) – RTU 0x00BB (187_{dec}) – ASCII
0x1393	5012	MODBUS_save_settings	Uint16	W/R	Save all user settings to EEPROM MODBUS_save_settings (write): 0x0000 (0_{dec}) – no action 0xFFFF (65535_{dec}) – save Read: 0x0000 (0_{dec}) – saved 0x0001 (1_{dec}) – error saving
0x1394	5013	MODBUS_RESET_addr	Uint16	W	Reset to default of the Modbus slave address and saves to EEPROM MODBUS_RESET_addr (write): 0x0000 (0_{dec}) – no action 0xFFFF (65535_{dec}) – reset MODBUS_RESET_addr (read): 0x0000 (0_{dec}) – always

Modbus: Map of Control Registers (Continued)

Applicable Modbus commands: 0x03, 0x06					
Addr	**Reg**	**Parameter**	**Type**	**Mode**	**Description**
0x1395	5014	MODBUS_RESET_comm	Uint16	W	Reset to defaults of the Modbus communication settings, saves to EEPROM and restarts the on-board MCU. MODBUS_RESET_comm (write): 0x0000 (0_{dec}) – no action 0xFFFF (65535_{dec}) – reset to defaults MODBUS_RESET_comm (read): 0x0000 (0_{dec}) – always
0x1396	5015	RESET_PROBE	Uint16	W	Triggers software restart the on-board MCU. All data/settings not in EEROM re-initialized to power-up configurations. RESET_PROBE (write): 0x0000 (0_{dec}) – no action 0xFFFF (65535_{dec}) – reset RESET_PROBE (read): 0x0000 (0_{dec}) – always

Table 82.22. Modbus: DEC-format values of OPERATION_config register

		OPERATION_mode		
		0x00••	**0xFF••**	**0x10••**
SAMPLE_RATE	**0x••00**	0x0000 (0_{dec})	0xFF00 (65280_{dec})	0x1000 (4096_{dec})
	0x••20	0x0020 (32_{dec})	0xFF20 (65312_{dec})	N/A
	0x••10	0x0010 (16_{dec})	0xFF10 (65296_{dec})	N/A
	0x••05	0x0005 (5_{dec})	0xFF05 (65285_{dec})	N/A
	0x••02	0x0002 (2_{dec})	0xFF02 (65282_{dec})	N/A

Table 83.23. Modbus: DEC-format values of CALIBRATION_control register

		CALIBRATION_control	
		0x•b•d•f••0F	**0x•b•d•f••FF**
Enabling bits	**b=0, d=0, f=0**	0x000F (15_{dec})	0x00FF (255_{dec})
	b=1, d=1, f=1	0x540F (21519_{dec})	0x54FF (21759_{dec})
	b=0, d=0, f=1	0x040F (1039_{dec})	0x04FF (1279_{dec})
	b=0, d=1, f=0	0x100F (4111_{dec})	0x10FF (4351_{dec})
	b=1, d=0, f=0	0x400F (16399_{dec})	0x40FF (16639_{dec})
	b=0, d=1, f=1	0x140F (5135_{dec})	0x14FF (5375_{dec})
	b=1, d=1, f=0	0x500F (20495_{dec})	0x50FF (20735_{dec})
	b=1, d=0, f=1	0x440F (17423_{dec})	0x44FF (17663_{dec})

Table 84.24. Modbus: Example Modbus Communication Setting Change (Map of Control Registers)

Current Modbus parity: E (EVEN),
New Modbus parity: N (NONE),
Current Modbus address: 0x02

Write Request: 02 06 13 90 00 81 4D 30

Field Name	Hex Value
Modbus address	02
Modbus function	06
Register Address Hi	13
Register Address Lo	90
Value Hi	00
Value Lo	81
Modbus CRC Hi	4D
Modbus CRC Lo	30

NOTE1: Write Response contains the same message as Write Request but is transmitted using the new NONE parity. The Modbus Master may indicate error because it is still configured for EVEN parity. **At this point the Modbus Master must be re-configured to run with the new communication setting (in the example: parity set to NONE) to continue communicating with the HTP probe.** The same note is valid for changes in the baud rate, too.

NOTE2: to make the changes permanent a separate command for saving changes to probe's EEPROM by writing 0xFFFF to register 5012 must be issued by the master using the new communication setting (in the example: parity set to NONE)

Table 85.25. Modbus: Example Write and Read (Map of Control Registers)

OPERATION_mode: continuous
SAMPLE_RATE: 1S/s

Write Request: EE 06 13 88 FF 10 5B C7
Write Response: same as request

Field Name	Hex Value
Modbus address	EE
Modbus function	06
Starting address Hi	13
Starting address Lo	88
Number of registers Hi	FF
Number of registers Lo	10
Modbus CRC Hi	5B
Modbus CRC Lo	C7

Read Request:
EE 03 13 88 00 0B 96 3C

Field Name	Hex Value
Modbus address	EE
Modbus function	03
Starting address Hi	13
Starting address Lo	88
Number of registers Hi	00
Number of registers Lo	0B
Modbus CRC Hi	96
Modbus CRC Lo	3C

Read Response: EE 03 16 FF 10 00 00 00 00 00 00 00 00 00 00 00 05 00 96 EE 81 00 EE 00 AA A2 CB

Field Name	Hex Value	Decoded
Modbus address	EE	-
Modbus function	03	-
Byte count	16	-
Value 1 (5001)	FF 10	OPERATION_mode: continuous SAMPLE_RATE: 1 S/s
Value 2 (5002)	00 00	OPERATION_trigger: -
Value 3 (5003)	00 00	STATISTICS_control: -
Value 4 (5004)	00 00	CALIBRATION_control: disabled
Value 5 (5005)	00 00	DIAGNOSTICS_control: no new
Value 6 (5006)	00 00	HEATER_status: OFF
Value 7 (5007)	00 05	MODBUS_voltage_level: 5V
Value 8 (5008)	00 96	MODBUS_baud_rate: 9600dec
Value 9 (5009)	EE 81	MODBUS_bits_parity: even, 8, 1
Value 10 (5010)	00 EE	MODBUS_slave_id: 248dec
Value 11 (5011)	00 AA	MODBUS_RTU_ASCII: RTU
Modbus CRC Hi	A2	-
Modbus CRC Lo	CB	-

3.13.6. Changing the Modbus Address

Address change is performed in two steps. Step 1 is the actual change. If Step 2 is not performed, the new address is stored in probe's RAM and is only valid until the power-down. This is a useful feature during tests and integration. It is highly recommended to perform Step 2 for field installations. A description of the steps with a practical example is provided below.

Step 1 – the master requests to change probe's Modbus address from 0xEE (default) to 0x02 by writing 0x02FF to register 5010 (reg address 0x1391) using the 0x06 Modbus command:

EE 06 13 91 02 FF 8B 1C

The probe responds with:

02 06 13 91 02 FF 9D B0 (new address changed to 0x02).

At this point the Modbus Master must be re-configured to address the probe with 0x02 from now on.

Step 2 – the master requests the new address to be saved to probe's EEPROM by writing 0xFFFF to register 5012 (reg address 0x1393) using the 0x06 Modbus command:

02 06 13 93 FF FF 7C E0 (please, note that the new Modbus address 0x02 must be used to get a valid response)

The probe responds with:

02 06 13 93 FF FF 7C E0 (data saved successfully to EEPROM).

Table 86.26. Modbus: Example Address Reset (Map of Control Registers)

Current Modbus address: 0x02
Default Modbus address: 0xEE (automatically saved in EEROM before write response)

Write Request: 02 06 13 94 FF FF CD 21

Field Name	Hex Value
Modbus address	***02*** (current address)
Modbus function	06
Register Address Hi	13
Register Address Lo	94
Value Hi	FF
Value Lo	FF
Modbus CRC Hi	CD
Modbus CRC Lo	21

Write Response: EE 06 13 94 FF FF DB 8D

Field Name	Hex Value
Modbus address	***EE*** (default address)
Modbus function	06
Register Address Hi	13
Register Address Lo	94
Value Hi	FF
Value Lo	FF
Modbus CRC Hi	A2
Modbus CRC Lo	CB

3.13.7. Resetting Modbus Communication Settings

Settings not saved in EEPROM – all change not explicitly saved in EEPROM using the *MODBUS_save_settings* register can be discarded by 2 methods:

1) Writing valid reset code to register *RESET_PROBE* using Modbus protocol itself
2) Complete power-down of a probe

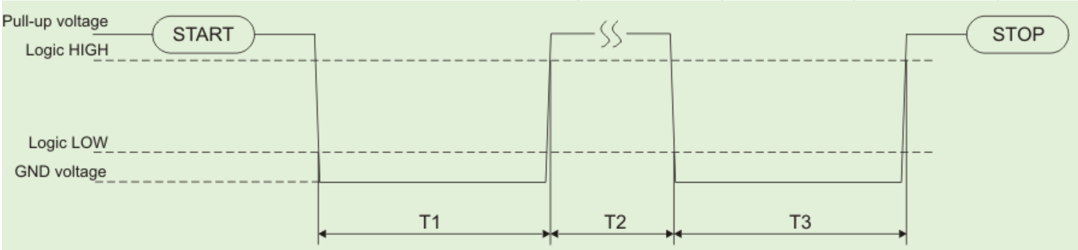
Both methods lead to loss of all available measurement data. HTP is re-initialized with the (user-defined) settings stored in EEPROM.

Settings saved in EEPROM - once user-defined changes are saved to on-board EEPROM, EHTP offers 2 methods for resetting the Modbus communication settings to defaults:

1) Writing a valid reset code to register *MODBUS_RESET_comm* using Modbus protocol itself – the preferred method when the user-defined communication settings are known and supported by the Modbus master device.
2) Generating a reset sequence to the AUX pin – general Modbus-independent method for reset in case no previous knowledge for the user-defined communication settings is available. The AUX pin has an internal pull-up resistor. Using an open drain circuit the master device must execute the timing sequence T1-T2-T3 on the AUX pin (see ***Error! Reference source not found.***). Prior to resetting Modbus communication settings, a probe must be awoken f rom sleep mode if such is enabled.

Table 87.27. Modbus: Timing Sequence to Reset Communication Settings Using the AUX Pin

Parameter	Min	Typ	Max	Unit
T1 (Master pulls down the AUX pin)	180	185	190	ms
T2 (Master releases the AUX pin)	150	185	240	ms
T3 (Master pulls down the AUX pin again)	180	185	190	ms



NOTE: there is no strict timing requirement about T2.

3.14. Map of Heater Parameters

Refer to *On-board Heater*
for detailed description of the heater operation. Use *HEATER_control* register in the Map of Control Registers to enable the on-board heater. Its operational status parameters can be read from the Map of Heater Parameters.

Table 88.28. Modbus: Map of Heater Parameters (INT format)

Applicable Modbus commands: 0x03

Addr	Reg	Parameter	Unit	Scale	Format	Description
0x1C20	7201	HEATER_mode	-	1	Uint16	Indicator of the operational mode of the on-board heater: MANUAL, AUTO
0x1C21	7202	HEATER_status	-	1	Uint16	Indication of the current state of the on-board heater. The heater can be activated by the master system when potential moisture built-up on the humidity sensor is detected. Transition between states is automatic in the order OFF→ HEATING→COOLING→OFF. Temperature and humidity values will be affected during HEATING and COOLING modes. HEATER_status (read): 0x0000 (0_{dec}) – Heater in OFF state (default) 0x0001 (1_{dec}) – Heater in HEATING state 0x0002 (2_{dec}) – Heater in COOLING state
0x1C22	7203	HEAT_remaining_time/ COOL_remaining_time	s	1	Uint16	Countdown value of the remaining time until the heater transits from OFF→HEATING state or COOLING→OFF state. The value is updated every second.
0x1C23	7204	HEAT_set_time/ COOL_set_time	s	1	Uint16	User-selected interval for the HEATING (automatic for COOLING) state of the on-board heater. Actual configuration is performed over HEATER_control register. Value remains at user's disposal until a new valid command for heater activation is processed.
0x1C24	7205 7206	HEAT_delta_temperature/ COOL_delta_temperature	°C	0.01	Sint32	Temperature increase during the HEATING/COOLING state of the on-board heater. Value is updated every second for the interval of HEATING/COOLING. Value remains at user's disposal until a new valid command for heater activation is processed.
0x1C26	7207 7208	HEAT_initial_temperature/ COOL_initial_temperature	°C	0.01	Sint32	The real_TEMPERATURE value in the moment a valid command for switching the on-board heater OFF → HEATING (or HEATING→COOLING) state is processed. Value remains at user's disposal until a new valid command for heater activation is processed.
0x1C28	7209	HEAT_duty_cycle	%	-	Uint16	Automatically set parameter for PWM control of the on-board heater.
0x1C29	7210	VIN_voltage	mV	1	Uint16	Unregulated input DC supply voltage for the probe used in the calculation of HEAT_duty_cycle.

Table 89.29. Modbus: Example Write and Read (Map of Heater Parameters)

HEAT_set_time (5006): turn ON for 20 s

Write Request: EE 06 13 8D 02 FF 4A DA
Write Response: same as request

Field Name	Hex Value
Modbus address	EE
Modbus function	06
Starting address Hi	13
Starting address Lo	8D
Number of registers Hi	02
Number of registers Lo	FF
Modbus CRC Hi	4A
Modbus CRC Lo	DA

Read Request:
EE 03 1C 20 00 0A D5 08 (Heater status)

Field Name	Hex Value
Modbus address	EE
Modbus function	03
Starting address Hi	1C
Starting address Lo	20
Number of registers Hi	00
Number of registers Lo	0A
Modbus CRC Hi	D5
Modbus CRC Lo	08

Read Response: EE 03 14 00 00 00 01 00 13 00 14 00 00 00 1F 00 00 07 85 00 1D 25 0A 1C DA (HEATING mode)

Field Name	Hex Value	Integer
Modbus address	EE	-
Modbus function	03	-
Byte count	14	-
Value 1 (7201)	00 00	0
Value 2 (7202)	00 01	1
Value 3 (7203)	00 13	19
Value 4 (7204)	00 14	20
Value 5 (7205-7206)	00 00 00 1F	31
Value 6 (7207-7208)	00 00 07 85	1925
Value 7 (7209)	00 1D	29
Value 8 (7210)	25 0A	9482
Modbus CRC Hi	1C	-
Modbus CRC Lo	DA	-

Read Request:
EE 03 1C 20 00 0A D5 08 (Heater status)

Field Name	Hex Value
Modbus address	EE
Modbus function	03
Starting address Hi	1C
Starting address Lo	20
Number of registers Hi	00
Number of registers Lo	0A
Modbus CRC Hi	D5
Modbus CRC Lo	08

Read Response: EE 03 14 00 00 00 02 00 2A 00 3C FF FF FE 75 00 00 0B 2D 00 00 24 F4 D2 84 (COOLING mode)

Field Name	Hex Value	Integer
Modbus address	EE	-
Modbus function	03	-
Byte count	14	-
Value 1 (7201)	00 00	0
Value 2 (7202)	00 02	2
Value 3 (7203)	00 2A	42
Value 4 (7204)	00 3C	60
Value 5 (7205-7206)	FF FF FE 75	-395
Value 6 (7207-7208)	00 00 0B 2D	2861
Value 7 (7209)	00 00	0
Value 8 (7210)	24 F4	9460
Modbus CRC Hi	D2	-
Modbus CRC Lo	84	-

Modbus: Example Write and Read (Map of Heater Parameters)(Continued)

Read Request:
EE 03 1C 20 00 0A D5 08 (Heater status)

Field Name	Hex Value
Modbus address	EE
Modbus function	03
Starting address Hi	1C
Starting address Lo	20
Number of registers Hi	00
Number of registers Lo	0A
Modbus CRC Hi	D5
Modbus CRC Lo	08

Read Response: EE 03 14 00 00 00 00 00 00 00 00 00 00 00 00 00 00 07 EF 00 00 24 F4 AA 7C (OFF mode)

Field Name	Hex Value	Integer
Modbus address	EE	-
Modbus function	03	-
Byte count	14	-
Value 1 (7201)	00 00	0
Value 2 (7202)	00 00	0
Value 3 (7203)	00 00	0
Value 4 (7204)	00 00	0
Value 5 (7205-7206)	00 00 00 00	0
Value 6 (7207-7208)	00 00 07 EF	2031
Value 7 (7209)	00 00	0
Value 8 (7210)	24 F4	9460
Modbus CRC Hi	AA	-
Modbus CRC Lo	7C	-

3.15. Map of Diagnostic Registers

Refer to *Diagnostics*
for a detailed description of the feature. The Map contains values of technical parameters for validation of probe's health during run time. Values are updated automatically on power-up and manually after writing valid code to *DIAGNOSTICS_control* register located in the Map of Control Register.

Table 90.30. Modbus: Map of Diagnostic Registers

Applicable Modbus commands: 0x03

Addr	Reg	Parameter	Unit	Scale	Format	Description
0x1B58	7001	MCU_voltage	mV	1	Unit16	Regulated DC supply voltage for the on-board MCU
0x1B59	7002	SEN_voltage	mV	1	Unit16	Regulated DC supply voltage for the sensing circuits
0x1B5A	7003	VIN_voltage	mV	1	Unit16	Unregulated input DC supply voltage for the probe
0x1B5B	7004	MCU_temperature	°C	0.1	Snit16	Temperature of the MCU
0x1B5C	7005	TEMPERATURE_MCU_... ..._OFFSET	°C	0.1	Snit16	Automatic calibration offset for MCU temperature
0x1B5D	7006	RESET_cause	-	1	Unit16	Most recent reset cause of the on-board MCU: RESET_cause (read): 0x0000 (0_{dec}) – unknown 0x0001 (1_{dec}) – normal power-up 0x0002 (2_{dec}) – brownout restart 0x0003 (3_{dec}) – MCLR wake-up from sleep mode 0x0004 (4_{dec}) – WDT timeout 0x0005 (5_{dec}) – WDT wake-up from sleep 0x0006 (6_{dec}) – Interrupt wake-up form sleep 0x0007 (7_{dec}) – MCLR during normal operation 0x0008 (8_{dec}) – soft reset instruction 0x0009 (9_{dec}) – stack overflow 0x000A (10_{dec}) – stack underflow 0x000B (11_{dec}) – WDT window violation

Modbus: Map of Diagnostic Registers (Continued)						
Applicable Modbus commands: 0x03						
0x1B5E	7007	POWER_errors	-	1	Unit16	Out-of-range event in on-board supply voltages: Bit 0 (LSb) – detected in VIN_voltage Bit 1 – detected in MCU_voltage Bit 2 – detected in SEN_voltage Bit 4 – error in master voltage regulator
0x1B5F	7008	MCU_errors	-	1	Unit16	Error within the on-board MCU detected: Bit 0 (LSb) – write-to-EEPROM error detected Bit 1 – RAM error detected during self-test Bit 2 – on-board MCU's oscillator error detected
0x1B60	7009	SENSOR_errors	-	1	Unit16	Out-of-range in values of primary parameters: Bit 0 (LSb) – detected in air temperature Bit 1 – detected in relative humidity Bit 2 – detected in barometric pressure
0x1B61	7010	ERRORS_count	-	1	Unit16	Total number of errors in ***XXX_errors*** registers

NOTE: bits in POWER_errors, MCU_errors, SENSOR_errors set (event detected), cleared (no error).

Table 91.31. Modbus: Map of Raw ADC Values of Primary Parameters

Applicable Modbus commands: 0x03				
Addr	**Reg**	**Parameter**	**Format**	**Description**
0x1FA4	8101	ADC_raw_temperature	Unit16	Temperature raw value
0x1FA5	8102	ADC_raw_humidity	Unit16	Humidity raw value
0x1FA6	8103	ADC_raw_pressure	Unit16	Pressure raw value

Table 92.32. Modbus: Map of Extended Raw ADC Values of Primary Parameters for HTP+CO2

Applicable Modbus commands: 0x03				
Addr	**Reg**	**Parameter**	**Format**	**Description**
0x1FA7	8104	ADC_raw_CO2_percentage	Unit16	CO2 percentage raw value

Table 93.33. Modbus: Example Write and Read (Map of Diagnostic Registers)

Start Diagnostics

Write Request: EE 06 13 8C FF FF 5B 8A
Write Response: same as request

Field Name	Hex Value
Modbus address	EE
Modbus function	06
Starting address Hi	13
Starting address Lo	8C
Number of registers Hi	FF
Number of registers Lo	FF
Modbus CRC Hi	5B
Modbus CRC Lo	8A

Read Diagnostic Data

Read Request: EE 03 1B 58 00 0A 54 65
Read Response: EE 03 14 0B 85 0A F3 24 BA 00 BE 02 17 00 01 00 00 00 00 00 00 00 00 80 DE

Field Name	Hex Value	Integer
Modbus address	EE	-
Modbus function	03	-
Byte count	14	-
Value 1 (7201)	0B 85	2949
Value 2 (7202)	0A F3	2803
Value 3 (7203)	24 BA	9402
Value 4 (7204)	00 BE	190
Value 5 (7205)	02 17	535
Value 6 (7206)	00 01	1
Value 7 (7207)	00 00	0
Value 8 (7208)	00 00	0
Value 9 (7209)	00 00	0
Value 10 (7210)	00 00	0
Modbus CRC Hi	80	-
Modbus CRC Lo	DE	-

3.16. Map of Fixed-Value Test Registers

Refer to *Test Aid*
for a detailed description of the feature.

Table 94.34. Modbus: Map of Fixed-Value Test Registers

Applicable Modbus commands: 0x03

Addr	Reg	Parameter	Format	Description
0x1F40	8001 8002	Fixed test value 1	Uint32	0xAAAAAAAA (2 863 311 530$_{dec}$)
0x1F42	8003 8004	Fixed test value 2	Uint32	0x55555555 (1 431 655 765$_{dec}$)
0x1F44	8005 8006	Fixed test value 3	Uint32	0x0F0F0F0F (252 645 135$_{dec}$)
0x1F46	8007 8008	Fixed test value 4	Uint32	0xFF00FF00 (4 278 255 360$_{dec}$)
0x1F48	8009 8010	Fixed test value 5	Sint32	1234567$_{dec}$
0x1F4A	8011 8012	Fixed test value 6	Sint32	-1234567$_{dec}$
0x1F4C	8013 8014	Fixed test value 7	Float32	12345.6789$_{dec}$
0x1F4E	8015 8016	Fixed test value 8	Float32	-9876.54321$_{dec}$
0x1F50	8017 8018 8019 8020	Fixed test message (Char 1-2) Fixed test message (Char 3-4) Fixed test message (Char 5-6) Fixed test message (Char 7-8)	Str8	"-987.654"

Table 95.35. Modbus: Example Read (Map of Fixed-Value Test Registers)

Request: EE 03 1F 50 00 04 55 53

Field Name	Hex Value
Modbus address	EE
Modbus function	03
Starting address Hi	1F
Starting address Lo	50
Number of registers Hi	00
Number of registers Lo	04
Modbus CRC Hi	55
Modbus CRC Lo	53

Response: EE 03 08 2D 39 38 37 2E 36 35 34 96 5F

Field Name	Hex Value	ASCII
Modbus address	EE	-
Modbus function	03	-
Byte count	08	
Fixed test message (8017)	2D 39	'-' + '9'
Fixed test message (8018)	38 37	'8' + '7'
Fixed test message (8019)	2E 36	'.' + '6'
Fixed test message (8020)	35 34	'5' + '4'
Modbus CRC Hi	96	-
Modbus CRC Lo	5F	-

3.17. Map of Traceability Registers

Table 96.36. Modbus: Map of Traceability Registers

Applicable Modbus commands: 0x03

Addr	Reg	Parameter	Format	Description
0x000A	0011 0012	HW_revision	Float32	Hardware revision of the probe
0x000C	0013 0014	FW_revision	Float32	Firmware revision of the probe
0x000E	0015 0016	modbus_FW_revision	Float32	Revision of Modbus firmware routines in the probe
0x0010	0017	DAQ_version	Uint16	Manufacturer's code for internal traceability and compatibility
0x0011	0018	evvos_device_code	Uint16	Manufacturer's code for internal traceability and compatibility
0x0012	0019 0020 0021	probe_name	Str6	Name of probe (including interfacing code)
0x0018	0022 0023 0024	manufacturer_name	Str6	Name of manufacturer

Table 97.37. Modbus: Example Read (Map of Traceability Registers)

Read Request:
EE 03 00 0A 00 0E F2 93

Field Name	Hex Value
Modbus address	EE
Modbus function	03
Starting address Hi	00
Starting address Lo	0A
Number of registers Hi	00
Number of registers Lo	0E
Modbus CRC Hi	F2
Modbus CRC Lo	93

Read Response: EE 03 1C 3F 8C CC CD 3F 80 00 00 3F 80 00 00 00 1E 00 01 52 48 54 50 2D 52 45 56 56 4F 53 20 C2 4A

Field Name	Hex Value	Decoded
Modbus address	EE	-
Modbus function	03	-
Byte count	1C	28
HW_revision (0011-0012)	3F 8C CC CD	1.1
FW_revision (0013-0014)	3F 80 00 00	1.0
modbus_FW_revision (0015-0016)	3F 80 00 00	1.0
DAQ_version (0017)	00 1E	30
evvos_device_code (0018)	00 01	1
probe_name (0019 - 0021)	52 48 54 50	HTP-R
manufacturer_name (0022-0024)	45 56 56 4F	EVVOS
Modbus CRC Hi	C2	-
Modbus CRC Lo	4A	-

3.18. Sea Level Pressure Configuration

Refer to Test Aid
for a detailed description of the feature. To make the input data permanent by storing it in the on-board EEPROM the user must write a valid "save" code in the *MODBUS_save_settings* register. A single write to *MODBUS_save_settings* after reconfiguring multiple operational and/or communication parameters is enough to store all of them to EEPROM.

Table 98.38. Modbus: Map of Input Registers for Reduced Sea-Level Pressure

Applicable Modbus commands: 0x03, 0x10					
Addr	**Reg**	**Parameter**	**Format**	**Type**	**Description**
0x27D8	10201	user_sea_level_data_flag	Uint16	R	Indicator for availability of user-defined data 0x01 (1_{dec}) – user-defined values are available and in use 0xFF (255_{dec}) – default values are in use
0x27D9	10202 10203	height_above_sea_level	Float32	R/W	Height (in meters) of installation point above sea level (for fixed installations only)
0x27DB	10204 10205	vertical_temp_coeff	Float32	R/W	Vertical temperature gradient (°C/100 meter) in the atmosphere

Table 99.39. Modbus: Example Write (Map of Input Registers for Reduced Sea-Level Pressure)

Value to be written:
height_above_sea_level = 344.6 m

Write Request:
EE 10 27 D9 00 02 04 43 AC 4C CD C6 4F

Field Name	**Hex Value**
Modbus address	EE
Modbus function	10
Starting address Hi	27
Starting address Lo	D9
Quantity of registers Hi	00
Quantity of registers Lo	02
Byte count	04
Register value Hi	43 AC
Register value Lo	4C CD
Modbus CRC Hi	C6
Modbus CRC Lo	4F

Write Response:
EE 10 27 D9 00 02 8C 18

Field Name	**Hex Value**
Modbus address	EE
Modbus function	10
Starting address Hi	27
Starting address Lo	D9
Quantity of registers Hi	00
Quantity of registers Lo	02
Modbus CRC Hi	8C
Modbus CRC Lo	18

3.19. User Calibration

3.19.1. Description

Refer to *Test Aid*
for a detailed description of the feature. Any Modbus PC software that supports functions 0x03, 0x10 (alternatively 0x17 for the Map of Test Registers for Evaluation of Calibration) can be used for writing/reading the calibration data to an EHTP probe. Writing any calibration coefficients automatically sets *CAL_temperature_status*, *CAL_humidity_status*, and *CAL_pressure_status*. Manual change of the flags is accessible in *CALIBRATION_control* register in the Map of Control Registers. Fine manual error analysis for demanding applications is enabled with the Map of Test Registers for Evaluation of Calibration.

3.19.2. Calculation of Calibration Coefficients

The word "parameter" below refers to any of the primary parameters, measured by an EHTP probe: air temperature, relative humidity, and barometric pressure. The steps are valid for the general form of the calibration equation (A≠0). See ***Error! Reference source not found.*** for practical example.

1. For a selected parameter, perform multiple measurements of at least 3 reference values to gather a table of multipoint reference data.
2. Enter the reference data into the least square algorithm (e.g. the provided MATLAB script) to calculate calibration coefficients A, B, C for the selected parameter
3. Enter the calibration coefficients in the EHTP probe in respective address(es) in the Map
4. Optional: write calibration date(s) in the EHTP probe using the respective address(es) in the Map
5. In HTP Modbus versions the *CAL_..._status* flags for all primary parameters are automatically set after entering any calibration data
6. Optional: perform a manual test/verification in the EHTP with a known value using the Map of Test Registers for Evaluation of Calibration
7. Save all calibration data in the EHTP to EEPROM by writing valid code in *MODBUS_save_settings*.

3.19.3. Map of Input Registers for User-Defined Calibration

Table 100.40. Modbus: Map of Input Registers for User-Defined Calibration

Applicable Modbus commands: 0x03, 0x10

Addr	Reg	Parameter	Format	Type	Description
0x2710	10001	user_cal_status_flag	Uint16	R	0x01 (1_{dec}) – user-defined values are available and in use 0xFF (255_{dec}) – default values are in use
0x2711	10002	CAL_temperature_status	Uint16	R	0x00 (0_{dec}) – calibration disabled for air temperature 0x01 (1_{dec}) – calibration enabled for air temperature
0x2712	10003	CAL_humidity_status	Uint16	R	0x00 (0_{dec}) – calibration disabled for relative humidity 0x01 (1_{dec}) – calibration is enabled for relative humidity
0x2713	10004	CAL_pressure_status	Uint16	R	0x00 (0_{dec}) – calibration disabled for barometric pressure 0x01 (1_{dec}) – calibration is enabled for barometric pressure
0x2714	10005 10006	T_coef_A	Float32	R/W	Calibration coefficient A for air temperature
0x2716	10007 10008	T_coef_B	Float32	R/W	Calibration coefficient B for air temperature
0x2718	10009 10010	T_coef_C	Float32	R/W	Calibration coefficient C for air temperature
0x271A	10011 10012	RH_coef_A	Float32	R/W	Calibration coefficient A for relative humidity
0x271C	10013 10014	RH_coef_B	Float32	R/W	Calibration coefficient B for relative humidity
0x271E	10015 10016	RH_coef_C	Float32	R/W	Calibration coefficient C for relative humidity

Modbus: Map of Input Registers for User-Defined Calibration (Continued)

Applicable Modbus commands: 0x03, 0x10

Addr	Reg	Parameter	Format	Type	Description
0x2720	10017 10018	P_coef_A	Float32	R/W	Calibration coefficient A for barometric pressure
0x2722	10019 10020	P_coef_B	Float32	R/W	Calibration coefficient B for barometric pressure
0x2724	10021 10022	P_coef_C	Float32	R/W	Calibration coefficient C for barometric pressure
0x2726	10023 10024 10025 10026 10027	CAL_temperature_date	Str10	R/W	User-defined date of the most recent air temperature calibration
0x272B	10028 10029 10030 10031 10032	CAL_humidity_date	Str10	R/W	User-defined date of the most recent relative humidity calibration
0x2730	10033 10034 10035 10036 10037	CAL_pressure_date	Str10	R/W	User-defined date of the most recent barometric pressure calibration

Table 101.41. Modbus: Example Write (Map of Input Registers for User-Defined Calibration)

Calibration data to be written (example values only):
T_coef_A = 0.000001,
T_coef_B = 1.0002,
T_coef_C = 0.15

Wirte Request: EE 10 27 14 00 06 0C 35 86 37 BD 3F 80 06 8E 3E 19 99 9A F5 65

Field Name	Hex Value
Modbus address	EE
Modbus function	10
Starting address Hi	27
Starting address Lo	14
Quantity of registers Hi	00
Quantity of registers Lo	06
Byte count	0C
Register value 1 Hi	35 86
Register value 1 Lo	37 BD
Register value 2 Hi	3F 80
Register value 2 Lo	06 8E
Register value 3 Hi	3E 19
Register value 4 Lo	99 9A
Modbus CRC Hi	F5
Modbus CRC Lo	65

Write Response: EE 10 27 14 00 06 1C 24

Field Name	Hex Value
Modbus address	EE
Modbus function	10
Starting address Hi	27
Starting address Lo	14
Quantity of registers Hi	00
Quantity of registers Lo	06
Modbus CRC Hi	1C
Modbus CRC Lo	24

NOTE: to store the changes permanently, a separate command for saving changes to probe's EEPROM by writing 0xFFFF to register 5012 must be issued by the master

3.19.4. Map of Test Registers for Evaluation of Calibration

The map provides a means of built-in manual test and assessment of a user calibration. The values of the secondary parameters are calculated correctly only if all 3 "*TEST_..._value*" are written (*TEST_temperature_value*, *TEST_humidity_value*, *TEST_pressure_value*). Out-of-range test values are accepted but their use may result in erroneous values of secondary parameters. For a test the value of a primary parameter, its corresponding calibrated value is always calculated.

Table 102.42. Modbus: Map of Test Registers for Evaluation of Calibration

Applicable Modbus commands: 0x03, 0x10, 0x17

Addr	Reg	Parameter	Unit	Type	Format	Description
0x2904	10501 10502	TEST_temperature_value	°C	W/R	Float32	Air temperature (input value)
0x2906	10503 10504	TEST_humidity_value	%	W/R	Float32	Relative humidity of air (input value)
0x2908	10505 10506	TEST_pressure_value	hPa	W/R	Float32	Barometric pressure (input value)
0x290A	10507 10508	CAL_air_temperature	°C	R	Float32	Air temperature (calibrated value)
0x290C	10509 10510	CAL_relative_humidity	%	R	Float32	Relative humidity of air (calibrated value)
0x290E	10511 10512	CAL_barometric_pressure	hPa	R	Float32	Barometric pressure (calibrated value)
0x2910	10513 10514	UN_sea_level_pressure	hPa	R	Float32	Reduced to sea level atmospheric pressure (uncalibrated value)
0x2912	10515 10516	CAL_sea_level_pressure	hPa	R	Float32	Reduced to sea level atmospheric pressure (calibrated value)
0x2914	10517 10518	UN_dew_point	°C	R	Float32	Dew point (uncalibrated value)
0x2916	10519 10520	CAL_dew_point	°C	R	Float32	Dew point (calibrated value)
0x2918	10521 10522	UN_absolute_humidity	g/m^3	R	Float32	Absolute humidity of air (uncalibrated value)
0x291A	10523 10524	CAL_absolute_humidity	g/m^3	R	Float32	Absolute humidity of air (calibrated value)
0x291C	10525 10526	UN_saturated_vapor_pressure	hPa	R	Float32	Vapor pressure in humid air (uncalibrated value)
0x291E	10527 10528	CAL_saturated_vapor_pressure	hPa	R	Float32	Vapor pressure in humid air (calibrated value)
0x2920	10529 10530	UN_vapor_pressure	hPa	R	Float32	Saturated vapor pressure in humid air (uncalibrated value)
0x2922	10531 10532	CAL_vapor_pressure	hPa	R	Float32	Saturated vapor pressure in humid air (calibrated value)
0x2924	10533 10534	UN_heat_index	°C	R	Float32	Physiological heat index in humid air (uncalibrated value)
0x2926	10535 10536	CAL_heat_index	°C	R	Float32	Physiological heat index in humid air (calibrated value)
0x2928	10537 10538	UN_speed_of_sound	m/s	R	Float32	Speed of sound in humid air (uncalibrated value)
0x292A	10539 10540	CAL_speed_of_sound	m/s	R	Float32	Speed of sound in humid air (calibrated value)
0x292C	10541 10542	UN_mixing_ratio	g/kg	R	Float32	Mixing ratio of moisture in air (uncalibrated value)
0x292E	10543 10544	CAL_mixing_ratio	g/kg	R	Float32	Mixing ratio of moisture in air (calibrated value)

Modbus: Map of Test Registers for Evaluation of Calibration (Continued)

Applicable Modbus commands: 0x03, 0x10, 0x17

Addr	Reg	Parameter	Unit	Type	Format	Description
0x2930	10545 10546	UN_specific_enthalpy	kJ/kg	R	Float32	Thermodynamic specific enthalpy of humid air (uncalibrated value)
0x2932	10547 10548	CAL_specific_enthalpy	kJ/kg	R	Float32	Thermodynamic specific enthalpy of humid air (calibrated value)
0x2934	10549 10550	UN_water_activity	-	R	Float32	Water activity in humid air (uncalibrated value)
0x2936	10551 10552	CAL_water_activity	-	R	Float32	Water activity in humid air (calibrated value)
0x2938	10553 10554	UN_water_boiling_point	°C	R	Float32	Boiling point of water (uncalibrated value)
0x293A	10555 10556	CAL_water_boiling_point	°C	R	Float32	Boiling point of water (calibrated value)

Table 103.43. Modbus: Example Write and Read (Map of Test Registers for Evaluation of Calibration)

Calibration Values Used in the Example

Values for temperature calibration coefficients	Values for temperature calibration coefficients	Values for temperature calibration coefficients	Installation height above sea level
T_coef_A = 0.000001	RH_coef_A = 0.0 (default)	P_coef_A = 0.0 (default)	height_above_sea_level = 344.6 m
T_coef_B = 1.0002	RH_coef_B = 1.0 (default)	P_coef_B = 1.0 (default)	
T_coef_C = 0.15	RH_coef_C = 0.0 (default)	P_coef_C = 0.0 (default)	

Test values to be written:
TEST_temperature_value = -21.58°C,
TEST_humidity_value = 30.46%,
TEST_pressure_value = 999.99 hPa

Write Request: EE 10 29 04 00 06 0C C1 AC A3 D7 41 F3 AE 14 44 79 FF 5C 02 79

Field Name	Hex Value
Modbus address	EE
Modbus function	10
Starting address Hi	29
Starting address Lo	04
Quantity of registers Hi	00
Quantity of registers Lo	06
Byte count	0C
Register value 1 Hi	C1 AC
Register value 1 Lo	A3 D7
Register value 2 Hi	41 F3
Register value 2 Lo	AE 14
Register value 3 Hi	44 79
Register value 4 Lo	FF 5C
Modbus CRC Hi	02
Modbus CRC Lo	79

Write Response: EE 10 29 04 00 06 1F 09

Field Name	Hex Value
Modbus address	EE
Modbus function	10
Starting address Hi	29
Starting address Lo	04
Quantity of registers Hi	00
Quantity of registers Lo	06
Modbus CRC Hi	1F
Modbus CRC Lo	09

Read Request:
EE 03 29 04 00 14 1A C7

Field Name	Hex Value
Modbus address	EE
Modbus function	03
Starting address Hi	29
Starting address Lo	04
Number of registers Hi	00
Number of registers Lo	14
Modbus CRC Hi	1A
Modbus CRC Lo	C7

Read Response:
EE 03 28 C1 AC A3 D7 41 F3 AE 14 44 79 FF 5C C1 AB 5C 29 41 F3 AE 14 44 79 FF 5C 44 83 00 00 44 83 00 00 C2 09 8F 5C C2 09 00 00 C0 AD

Field Name	Hex Value	Decoded
Modbus address	EE	-
Modbus function	03	-
Byte count	28	-
Value 1 (10501-10502)	C1 AC A3 D7	-21.5799999
Value 2 (10503-10504)	41 F3 AE 14	30.4599991
Value 3 (10505-10506)	44 79 FF 5C	999.989990
Value 4 (10507-10509)	C1 AB 5C 29	-21.4200001
Value 5 (10509-10510)	41 F3 AE 14	30.4599991
Value 6 (10511-10512)	44 79 FF 5C	999.989990
Value 7 (10513-10514)	44 83 00 00	1048.00000
Value 8 (10515-10516)	44 83 00 00	1048.00000
Value 9 (10517-10518)	C2 09 8F 5C	-34.3899994
Value 10 (10519-10520)	C2 09 00 00	-34.2500000
Modbus CRC Hi	C0	-
Modbus CRC Lo	AD	-

4. NMEA-0183 OVER RS422/UART

Table 104.1. NMEA: Special Features of EHTP Supported in the NMEA-Talker Version(s)

Secondary Parameters	Sea-level Pressure	Wet-Bulb Temperature	User Calibration	Heater Control	Statistics	Diagnostics	Test Aid
•		•				•	

4.1. NMEA Association

NMEA-0183 is a standard data transfer protocol for digital systems. It is a Talker-Listener communication type where the Listener is the data logging device, and the Talker is the EHTP probe. The Talker continually issues measurement data without the need of explicit read-requests by the Listener. More information about NMEA-0183 here: https://www.nmea.org/

The Standard NMEA protocol can be communicated over a few electrical interfaces: RS422, UART, etc.

The 4-wire differential RS422 is the standard Talker/Listener physical layer of NMEA-0183. Universal Asynchronous Receiver-Transmitter (UART) is an on-board communication feature in most off-the-shelf microcontrollers, thus, a cost-effective and readily available interfacing solution in many data acquisition systems implementing the NMEA-0183 protocol.

4.2. EHTP Quick Start (NMEA-0183)

1. Wire an HTP-NMEA probe to an NMEA LISTENER device (see EHTP Connector). The LISTENER device must be configured for the same communication settings as the HTP probe (see EHTP Configuration).
2. Power the HTP-NMEA probe (see EHTP Electrical and Timing Specification for supply voltage range). Upon successful power-up the HTP probe automatically starts transmission of NMEA-0183-formatted sentences in TALKER mode (see NMEA-0183 Sentences Supported by EHTP for sentence content).

4.3. EHTP Electrical and Timing Specification (NMEA-0183 over RS422 Version)

Table 105.2. NMEA: Electrical and Timing Specification (NMEA-0183 over RS422 Version)

Parameter	Condition(1)	Min	Typ	Max	Unit
Supply voltage (Vin)	Single-wire (NMEA-0183)	3.3 (7.0)(2)	12	24	Vdc
Current consumption (continuous mode)	Vin = 12Vdc. Heater OFF. **Wired for NMEA-0183 or single-wire interface.**	6.5	7.6	7.9	mA
RS422 Differential Driver Output	Vin = 12Vdc	1.5	5	5.5	V
RS422 Driver Common-Mode Output Voltage	Vin = 12Vdc	1	-	3	V
RS422 Receiver-Input Resistance	-7V < V_{CM} < +12V	95	-	-	kΩ
RS422 Receiver Differential Threshold Voltage	-7V < V_{CM} < +12V	-200	-	-50	V
Power-up time	-	1700	2000	2200	ms

(1) NOTE: No termination resistor on the RS422 line

(2) NOTE: power supply below 7.0 Vdc on start-up automatically disables the NMEA TALKER functions. Only single-wire interface remains accessible.

4.4. EHTP Electrical and Timing Specification (NMEA-0183 over UART Version)

Table 106.3. NMEA: EHTP Electrical and Timing Specification (Specific for NMEA-0183 over UART Version)

Parameter	Condition	Min	Typ	Max	Unit
Supply voltage (Vin)	V_{UART}= 3V (V_{UART} = 5V)	3.3 (5.0)	12.0	24	Vdc
Current consumption (continuous mode)	Vin = 12Vdc. Heater OFF. **Wired for NMEA or single-wire interface.**	3	3.5	5	mA
UART logic high input	V_{UART}= 3V and V_{UART} = 5V	V_{UART} - 1	-	V_{UART} +0.7	V
UART logic high output	V_{UART}= 3V and V_{UART} = 5V	V_{UART} - 0.3	-	V_{UART}	V
UART logic low input	V_{UART} = 5V	-0.7	-	0.8	V
UART logic low output	V_{UART} = 5V	-	-	0.6	V
Power-up time		1700	2000	2200	ms

4.5. EHTP Configuration (All NMEA-0183 Versions)

Table 107.4. NMEA: EHTP NMEA-0183 TALKER Default Settings

Parameter	Default Value
Baud rate	4800
Data bits	8
Parity	N
Stop bits	1
Flow control	None
Size of input buffer	80 bytes
Size of output buffer	Dynamic (applicable for LISTENER mode only)
Data transmission	MSB first
NMEA-0183 mode(1)	Standard (configuration 4800/8/N)
Probe operation mode	Continuous
Sample rate	0.5 S/s
Calibration	Disabled for all parameters
Logic voltage level	5V (NMEA-0183 over RS422) 3V (NMEA-0183 over UART)
Heater	OFF

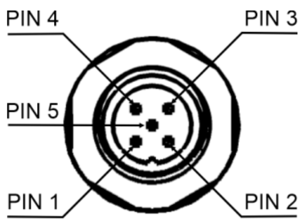
NOTE: to lower the overall power consumption the RS422 driver in EHTP is switched ON only during NMEA transmission. When in OFF state both communication pins of the RS422 driver are kept at the same constant voltage of app. 2.5 Vdc.

4.6. Wiring

4.6.1. EHTP Connector (All NMEA-0183 Versions)

The NMEA-0183 versions of the EHTP probe are equipped with dual interfacing – along with the main NMEA-0183 protocol, there is an auxiliary single-wire interface used mainly for compatibility with other Evvos products.

Table 108.5. NMEA: Pinout of the M12-connector on EHTP probe (All NMEA Versions)

Probe's connector (front view)	Pin function	Pin number	Note
	System power supply (Vin)	Pin 1	
	System ground (GND)	Pin 2	Internally connected to casing.
	B- (for RS422) Tx (for UART)	Pin 3	2-wire differential NMEA-Talker (for RS422) Single-ended transmitter output (for UART)
	A+ (for RS422) Rx (for UART)	Pin 4	2-wire differential NMEA-Talker (for RS422) Single-ended receiver output (for UART)
	Auxiliary (AUX)	Pin 5	Single-wire interface bidirectional DATA-pin. **Leave floating when NMEA mode is in use.**

4.6.2. Grounding

The metal casing of the probe is internally connected to GND.

4.6.3. Wiring for All NMEA-0183 Versions

Table 109.6. NMEA: Wiring of EHTP for All NMEA Versions

Probe's Connector (front view)	Patch Cable Wires	Electrical Connection (NMEA-RS422)	Electrical Connection (NMEA-UART)
Pin 1	Brown	Vin	Vin
Pin 2	White	GND	GND
Pin 3	Blue	B-	Tx
Pin 4	Black	A+	Rx
Pin 5	Green/yellow	AUX-comm pin (floating)	AUX-comm pin (floating)

4.6.4. Wiring for Single-Wire Interface (All NMEA-0183 Versions)

Table 110.7. NMEA: Wiring of EHTP for Single-Wire Interface

Probe's Connector (front view)	Patch Cable Wires	Electrical Connection
Pin 1	Brown	Vin
Pin 2	White	GND
Pin 3	Blue	Left floating
Pin 4	Black	Left floating
Pin 5	Green/yellow	Single-wire comm pin

4.7. NMEA-0183 Sentences Supported by EHTP

4.7.1. Summary of Supported NMEA-0183 Sentences

Table 111.8. NMEA: NMEA-0183 TALKER Sentences Supported by EHTP

Sentence mnemonics	Description
$WIXDR	Transducer measurements by a weather instrument (HTP Sentences 1- 8)
HTP Sentences 1 - 5	Environmental data set: outputted in accordance with the sample rate setting
HTP Sentence 6	Outputted once per 5 environmental data sets
HTP Sentences 7 - 8	Outputted once per 20 environmental data sets
$WIUID	Identification of a weather instrument (on power-up and once per 100 environmental data sets)

NOTE: for detailed description of the parameters refer to Measured Parameters and Units

4.7.2. NMEA Sentence 1

Table 112.9. NMEA EHTP Sentence 1: Air Temperature, Relative Humidity, Barometric Pressure

Sentence	**$WIXDR,C,<Value_1>,C,ATC,H,<Value_2>,P,RH,P,<Value_3>,P,BP*<CRC>CR><LF>**	
Example	**$WIXDR,C,28.7,C,ATC,H,43.5,P,RH,P,97671.0,P,BP*39**	
Mnemonic	***Description***	***Decoded example***
$	NMEA delimiter: start of sentence	
WI	NMEA TALKER identifier mnemonics: WEATHER INSTRUMENTS	
XDR	NMEA general purpose formatter: TRANSDUCER MEASUREMENTS	
C	NMEA transducer type: TEMPERATURE	
<Value_1>	Value of *air_temperature*	28.7 °C
C	NMEA unit of measure: degrees Celsius (°C)	
ATC	NMEA transducer ID: *air_temperature*	
H	NMEA transducer type: HUMIDITY	
<Value_2>	Value of *relative_humidity*	43.5 %
P	NMEA unit of measure: Percent (%)	
RH	NMEA transducer ID: *relative_humidity*	
P	NMEA transducer type: PRESSURE	
<Value_3>	Value of *barometric_pressure*	97671 Pa
P	NMEA unit of measure: Pascal (Pa)	
BP	NMEA transducer ID: *barometric_pressure*	
*	NMEA delimiter: checksum	
<CRC>	Checksum value	

4.7.3. NMEA Sentence 2

Table 113.10. NMEA EHTP Sentence 2: Dew Point, Heat Index

Sentence	**$WIXDR,C,<Value_4>,C,DP,C,<Value_5>,C,HI*<CRC><CR><LF>**	
Example	**$WIXDR,C,15.1,C,DP,C,29.0,C,HI*4B**	
Mnemonic	***Description***	***Decoded example***
$	NMEA delimiter: start of sentence	
WI	NMEA TALKER identifier mnemonics: WEATHER INSTRUMENTS	
XDR	NMEA general purpose formatter: TRANSDUCER MEASUREMENTS	
C	NMEA transducer type: TEMPERATURE	
<Value_4>	Value of *dew_point*	15.1 °C
C	NMEA unit of measure: degrees Celsius (°C)	
DP	NMEA transducer ID: *dew_point*	
C	NMEA transducer type: TEMPERATURE	
<Value_5>	Value of *heat_index*	29.0 °C
C	NMEA unit of measure: degrees Celsius (°C)	
HI	NMEA transducer ID: *heat_index*	
*	NMEA delimiter: checksum	
<CRC>	Checksum value	

4.7.4. NMEA Sentence 3

Table 114.11. NMEA EHTP Sentence 3: Absolute Humidity, Mixing Ratio

Sentence	`$WIXDR,B,<Value_6>,K,AH,G,<Value_7>,G,MR*<CRC><CR><LF>`	
Example	`$WIXDR,B,0.012357,K,AH,G,11.162,G,MR*6C`	
Mnemonic	***Description***	***Decoded example***
$	NMEA delimiter: start of sentence	
WI	NMEA TALKER identifier mnemonics: WEATHER INSTRUMENTS	
XDR	NMEA general purpose formatter: TRANSDUCER MEASUREMENTS	
B	NMEA transducer type: ABSOLUTE HUMIDITY	
<Value_6>	Value of *absolute_humidity*	0.012357 kg/m^3
K	NMEA unit of measure: kilogram per cubic meter of air (kg/m^3)	
AH	NMEA transducer ID: *absolute_humidity*	
G	NMEA transducer type: GENERIC (here: MIXING RATIO)	
<Value_7>	Value of *mixing_ratio*	11.162
G	NMEA unit of measure: none	
MR	NMEA transducer ID: *mixing_ratio*	
*	NMEA delimiter: checksum	
<CRC>	Checksum value	

4.7.5. NMEA Sentence 4

Table 115.12. NMEA EHTP Sentence 4: Vapour Pressure, Saturated Vapour Pressure, Boiling Point of Water

Sentence	`$WIXDR,P,<Value_8>,P,VP,P,<Value_9>,P,SVP,C,<Value_10>,C,BPW*<CRC><CR><LF>`	
Example	`$WIXDR,P,1722.0,P,VP,P,3957.0,P,SVP,C,98.9,C,BPW*5E`	
Mnemonic	***Description***	***Decoded example***
$	NMEA delimiter: start of sentence	
WI	NMEA TALKER identifier mnemonics: WEATHER INSTRUMENTS	
XDR	NMEA general purpose formatter: TRANSDUCER MEASUREMENTS	
P	NMEA transducer type: PRESSURE	
<Value_8>	Value of *vapour_pressure*	1722.0 Pa
P	NMEA unit of measure: Pascal (Pa)	
VP	NMEA transducer ID: *vapour_pressure*	
P	NMEA transducer type: PRESSURE	
<Value_9>	Value of *saturated_vapour_pressure*	3957.0 Pa
P	NMEA unit of measure: Pascal (Pa)	
SVP	NMEA transducer ID: *saturated_vapour_pressure*	
C	NMEA transducer type: TEMPERATURE	
<Value_10>	Value of *water_boiling_point*	98.9 °C
C	NMEA unit of measure: degrees Celsius (°C)	
BPW	NMEA transducer ID: *water_boiling_point*	
*	NMEA delimiter: checksum	
<CRC>	Checksum value	

4.7.6. NMEA Sentence 5

Table 116.13. NMEA EHTP Sentence 5: Speed of Sound, Specific Enthalpy, Water Activity

Sentence	`$WIXDR,G,<Value_11>,M,SOS,G,<Value_12>,K,SE,G,<Value_13>,N,WA*<CRC><CR><LF>`	
Example	`$WIXDR,G,349.9,M,SOS,G,57.4,K,SE,G,0.4351,N,WA*3C`	
Mnemonic	***Description***	***Decoded example***
$	NMEA delimiter: start of sentence	
WI	NMEA TALKER identifier mnemonics: WEATHER INSTRUMENTS	
XDR	NMEA general purpose formatter: TRANSDUCER MEASUREMENTS	
G	NMEA transducer type: GENERIC (here: SPEED OF SOUND)	
<Value_11>	Value of *speed_of_sound*	349.9 m/s
M	NMEA unit of measure: meter per second (m/s)	
SOS	NMEA transducer type: *speed_of_sound*	
G	NMEA transducer type: GENERIC (here: SPECIFIC ENTHALPY)	
<Value_12>	Value of *specific_enthalpy*	57.4 kJ/kg
K	NMEA unit of measure: kilojoules per kilogram (kJ/kg)	
SE	NMEA transducer ID: *specific_enthalpy*	
G	NMEA transducer type: GENERIC (here: WATER ACTIVITY)	
<Value_13>	Value of *water_activity*	0.4351
N	NMEA unit of measure: none	
WA	NMEA transducer ID: *water_activity*	
*	NMEA delimiter: checksum	
<CRC>	Checksum value	

4.7.7. NMEA Sentence 6

Table 117.14. NMEA EHTP Sentence 6: Wet-Bulb Temperature

Sentence	`$WIXDR,C,<Value_14>,C,WB*<CRC><CR><LF>`	
Example	`$WIXDR,C,18.7,C,WB*55`	
Mnemonic	***Description***	***Decoded example***
$	NMEA delimiter: start of sentence	
WI	NMEA TALKER identifier mnemonics: WEATHER INSTRUMENTS	
XDR	NMEA general purpose formatter: TRANSDUCER MEASUREMENTS	
C	NMEA transducer type: TEMPERATURE	
<Value_14>	Value of *wet_bulb_temperature*	18.7 °C
C	NMEA unit of measure: degrees Celsius (°C)	
WB	NMEA transducer ID: *wet_bulb_temperature*	
*	NMEA delimiter: checksum	
<CRC>	Checksum value	

NOTE: see Measured Parameters and Units

4.7.8. NMEA Sentence 7

Table 118.15. NMEA EHTP Sentence 7: MCU Voltage, Sensor Voltage, Supply Voltage

Sentence	`$WIXDR,U,<Value_15>,V,MCU,U,<Value_16>,V,SEN,U,<Value_17>,V,VIN*<CRC><CR><LF>`	
Example	`$WIXDR,U,4.670,V,MCU,U,2.816,V,SEN,U,9.490,V,VIN*23`	
Mnemonic	***Description***	***Decoded example***
$	NMEA delimiter: start of sentence	
WI	NMEA TALKER identifier mnemonics: WEATHER INSTRUMENTS	
XDR	NMEA general purpose formatter: TRANSDUCER MEASUREMENTS	
U	NMEA transducer type: VOLTAGE	
<Value_15>	Value of *MCU_voltage*	4.670 V
V	NMEA unit of measure: volt (V)	
MCU	NMEA transducer type: *MCU_voltage*	
U	NMEA transducer type: VOLTAGE	
<Value_16>	Value of *SEN_voltage*	2.816 V
V	NMEA unit of measure: volt (V)	
SEN	NMEA transducer ID: sensor's supply voltage	
U	NMEA transducer type: VOLTAGE	
<Value_17>	Value of *VIN_voltage*	9.490 V
V	NMEA unit of measure: volt (V)	
VIN	NMEA transducer ID: HTP supply voltage	
*	NMEA delimiter: checksum	
<CRC>	Checksum value	

NOTE: see Description of Diagnostic Registers

4.7.9. NMEA Sentence 8

Table 119.16. NMEA EHTP Sentence 8: Reset Cause, MCU Errors, Power Errors, Sensor Errors, Total Error Count

Sentence	`$WIXDR,G,<Value_18>,D,RC,G,<Value_19>,C,MCUE,G,<Value_20>,C,PE,G,<Value_21>, C,SE,G,<Value_22>,C,EC*<CRC><CR><LF>`	
Example	`$WIXDR,G,1,D,RC,G,0,C,MCUE,G,0,C,PE,G,0,C,SE,G,0,C,EC*68`	
Mnemonic	***Description***	***Decoded example***
$	NMEA delimiter: start of sentence	
WI	NMEA TALKER identifier mnemonics: WEATHER INSTRUMENTS	
XDR	NMEA general purpose formatter: TRANSDUCER MEASUREMENTS	
Mnemonic	***Description***	***Decoded example***
G	NMEA transducer type: GENERIC (here: DIAGNOSTICS)	
<Value_18>	Value of *RESET_cause*	1
D	NMEA unit of measure: none	
RC	NMEA transducer ID: *RESET_cause*	
G	NMEA transducer type: GENERIC (here: DIAGNOSTICS)	
<Value_19>	Value of *MCU_errors*	0
C	NMEA unit of measure: none	

MCUE	NMEA transducer ID: *MCU_errors*	
NMEA EHTP Sentence 8: Reset Cause, MCU Errors, Power Errors, Sensor Errors, Total Error Count (Continued)		
G	NMEA transducer type: GENERIC (here: DIAGNOSTICS)	
<Value_20>	Value of *POWER_errors*	0
C	NMEA unit of measure: none	
PE	NMEA transducer ID: *POWER_errors*	
G	NMEA transducer type: GENERIC (here: DIAGNOSTICS)	
<Value_21>	Value of *SENSOR_errors*	0
C	NMEA unit of measure: none	
SE	NMEA transducer ID: *SENSOR_errors*	
G	NMEA transducer type: GENERIC (here: DIAGNOSTICS)	
<Value_22>	Value of *ERRORS_count*	0
C	NMEA unit of measure: none	
EC	NMEA transducer ID: *ERROR_count*	
*	NMEA delimiter: checksum	
<CRC>	Checksum value	

NOTE: see *Description of Diagnostic Registers*

4.7.10. NMEA ID Sentence

Table 120.17. NMEA EHTP ID Sentence: Traceability and Identification

Sentence	`$WIUID,EVVOSHTPNMEA0183,<Value_1> <Value_2> <Value_3> <Value_4> <Value_5> *<CRC><CR><LF>`	
Example	`$WIUID,EVVOSHTPNMEA0183,001 1.1 1.0 028 1.0*29`	
Mnemonic	***Description***	***Decoded example***
$	NMEA delimiter: start of sentence	
WI	NMEA TALKER identifier mnemonics: WEATHER INSTRUMENTS	
UID	NMEA general purpose formatter: USER IDENTIFICATION CODE TRANSMISSION	
EVVOS	Content of traceability register *manufacturer_name*	
HTP NMEA0183	Content of traceability register *probe_name*	
<Value_1>	Content of traceability register *evvos_device_code*	001
<Value_2>	Content of traceability register *HW_revision*	1.1
<Value_3>	Content of traceability register *FW_revision*	1.0
<Value_4>	Content of traceability register *DAQ_version*	028
<Value_5>	Content of traceability register *NMEA_FW_revision*	1.0
*	NMEA delimiter: checksum	
<CRC>	Checksum value	

NOTE: see *Description of Traceability Registers*

4.8. Description of Diagnostic Registers

Table 121.18. NMEA: Description of Diagnostic Registers in NMEA ID Sentence

Parameter	Unit	Format	Description
MCU_voltage	V	Integer	Regulated DC supply voltage for the on-board MCU

SEN_voltage	V	Integer	Regulated DC supply voltage for the sensing circuits

NMEA: Description of Diagnostic Registers in NMEA ID Sentence (Continued)

Parameter	Unit	Format	Description
VIN_voltage	V	Integer	Unregulated input DC supply voltage for the probe
RESET_cause	-	Integer	Most recent reset cause of the on-board MCU: RESET_cause (read): 0x0000 (0_{dec}) – unknown 0x0001 (1_{dec}) – normal power-up 0x0002 (2_{dec}) – brownout restart 0x0003 (3_{dec}) – MCLR wake-up from sleep mode 0x0004 (4_{dec}) – WDT timeout 0x0005 (5_{dec}) – WDT wake-up from sleep 0x0006 (6_{dec}) – Interrupt wake-up form sleep 0x0007 (7_{dec}) – MCLR during normal operation 0x0008 (8_{dec}) – soft reset instruction 0x0009 (9_{dec}) – stack overflow 0x000A (10_{dec}) – stack underflow 0x000B (11_{dec}) – WDT window violation
POWER_errors	-	Integer	Out-of-range event in on-board supply voltages: Bit 0 (LSb) – detected in *VIN_voltage* Bit 1 – detected in *MCU_voltage* Bit 2 – detected in *SEN_voltage* Bit 4 – error in master voltage regulator
MCU_errors	-	Integer	Error within the on-board MCU detected: Bit 0 (LSb) – write-to-EEPROM error detected Bit 1 – RAM error detected during self-test Bit 2 – on-board MCU's oscillator error detected
SENSOR_errors	-	Integer	Out-of-range in values of primary parameters: Bit 0 (LSb) – detected in air temperature Bit 1 – detected in relative humidity Bit 2 – detected in barometric pressure
ERRORS_count	-	Integer	Total number of errors in ***XXX_errors*** registers

NOTE: for detailed description of the feature refer to *Measured Parameters and Units*

4.9. Description of Traceability Registers

Table 122.19. NMEA: Description of Traceability Registers

Parameter	Format	Description
HW_revision	Float	Hardware revision of the probe
FW_revision	Float	Firmware revision of the probe
NMEA_FW_revision	Float	Revision of NMEA-0183 stack routines in the probe
DAQ_version	Integer	Manufacturer's code for internal traceability and compatibility
evvos_device_code	Integer	Manufacturer's code for internal traceability and compatibility
probe_name	String	Name of probe (including interfacing code)
manufacturer_name	String	Name of manufacturer