EVVOS RHTP PROBE USER'S MANUAL
MODBUS OVER RS485 INTERFACE
MODBUS OVER UART INTERFACE

Table of Contents

TABLE OF CONTENTS 2
INDEX OF TABLES 4
HIGHLIGHTS 5
DESCRIPTION 5
MEASURED PARAMETERS AND UNITS 6
SPECIAL FEATURES (ALL MODBUS VERSIONS) 9
ERHTP QUICK START (MODBUS) 10
ERHTP ELECTRICAL AND TIMING SPECIFICATION (MODBUS-RS485 VERSION) 10
ERHTP ELECTRICAL AND TIMING SPECIFICATION (MODBUS-UART VERSION) 11
ERHTP CONFIGURATION (ALL MODBUS VERSIONS) 11
SUMMARY OF SUPPORTED MODBUS FUNCTIONS 11
SUMMARY OF ERHTP REGISTER MAPS 12
WIRING 12
ERHTP Connector (All Modbus Versions) 12
Grounding 12
Patch Cable (optional) 12
Wiring for All Modbus Versions 13
Wiring for Single-Wire Interface (All Modbus Version) 13
DEFINITIONS OF THE PHYSICAL PARAMETERS 14
Air Temperature (Dry-Bulb Temperature) 14
Relative Humidity of Air 14
Barometric Pressure 14
Reduced to Sea Level Atmospheric Pressure 14
Dew Point (Dew Temperature) 14
Absolute Humidity of Air 14
Vapor Pressure in Air 14
Saturated Vapor Pressure in Air 14
Heat Index 14
Speed of Sound in Air 14
Mixing Ratio of Moisture in Air 14
Specific Enthalpy 15
Water Activity in Air 15
Boiling Point of Water 15
Wet-Bulb Temperature 15
Percentage Concentration of CO_2 in Air 15
Height Above Sea Level 15
Vertical Temperature Coefficient 15
MODBUS ORGANIZATION 16
IEEE754 FLOATING POINT FORMAT 16
MODBUS REGISTER MAPS FOR ERHTP 16
Map of Environmental Parameters 16
Map of Statistical Parameters 19
Map of Control Registers 24
Operation Mode *24*
Sampling Rate and Wet-bulb Temperature *24*

Changing the Modbus Communication Settings *24*
Saving User Settings to the On-board EEPROM *24*
Resetting Modbus Communication Settings *29*
MAP OF HEATER PARAMETERS 31
MAP OF DIAGNOSTIC REGISTERS 34
MAP OF FIXED-VALUE TEST REGISTERS 36
MAP OF TRACEABILITY REGISTERS 37
SEA LEVEL PRESSURE CONFIGURATION 38
USER CALIBRATION 39
Description *39*
Application *39*
Calibration Equation *39*
Calculation of Calibration Coefficients *39*
Map of Input Registers for User-Defined Calibration *40*
Map of Test Registers for Evaluation of Calibration *42*
MATLAB Script for Calculating Calibration Coefficients *45*
MAINTENANCE **46**
ENVIRONMENTAL **46**
DIMENSIONS **46**
CONTACT INFORMATION **47**
DOCUMENT REVISION **47**

Index of Tables

TABLE 1. ERHTP ENVIRONMENTAL PARAMETERS 6
TABLE 2. ERHTP DIAGNOSTIC PARAMETERS 6
TABLE 3. ERHTP ON-BOARD HEATER PARAMETERS 6
TABLE 4. ERHTP INPUT PARAMETERS 7
TABLE 5. ERHTP STATISTICAL ENVIRONMENTAL PARAMETERS 7
TABLE 6. SYMBOLS AND NOTATIONS 9
TABLE 7. MODBUS QUICK START: EXAMPLE OF READING ENVIRONMENTAL DATA OVER MODBUS 10
TABLE 8. ERHTP ELECTRICAL AND TIMING SPECIFICATION (MODBUS-RS485-SPECIFIC) 10
TABLE 9. ERHTP ELECTRICAL AND TIMING SPECIFICATION (MODBUS-UART VERSION) 11
TABLE 10. ERHTP MODBUS DEFAULT SETTINGS AND SELECTABLE OPTIONS 11
TABLE 11. MODBUS FUNCTIONS SUPPORTED BY ERHTP 11
TABLE 12. SUMMARY OF MODBUS REGISTER MAPS IN ERHTP 12
TABLE 13. PINOUT OF THE M12-CONNECTOR ON ERHTP PROBE (ALL MODBUS VERSIONS) 12
TABLE 14. PINOUT OF THE OPTIONAL PATCH CABLE 13
TABLE 15. WIRING OF ERHTP FOR ALL MODBUS VERSIONS 13
TABLE 16. WIRING OF ERHTP FOR SINGLE-WIRE INTERFACE 13
TABLE 17. SECONDARY – PRIMARY PARAMETERS FUNCTIONAL DEPENDENCE IN THE CALCULATIONS BY ERHTP 15
TABLE 18. IEEE754-FORMAT FLOATING POINT (32-BIT) 16
TABLE 19. ERHTP MAP OF ENVIRONMENTAL PARAMETERS (INTEGER AND FLOAT FORMATS) 16
TABLE 20. ERHTP MAP OF EXTENDED ENVIRONMENTAL PARAMETERS (INTEGER AND FLOAT FORMATS) FOR RHTP+CO2 17
TABLE 21. EXAMPLE READING: MAP OF ENVIRONMENTAL PARAMETERS (INTEGER FORMAT) 18
TABLE 22. ERHTP MAP OF STATISTICAL ENVIRONMENTAL PARAMETERS (INTEGER AND FLOAT FORMATS) 19
TABLE 23. ERHTP MAP OF EXTENDED STATISTICAL ENVIRONMENTAL PARAMETERS (INTEGER AND FLOAT FORMATS) FOR RHTP+CO2 22
TABLE 24. EXAMPLE READING: MAP OF STATISTICAL ENVIRONMENTAL PARAMETERS (INTEGER FORMAT) 22
TABLE 25. EXAMPLE READING: MAP OF STATISTICAL ENVIRONMENTAL PARAMETERS (FLOAT FORMAT) 23
TABLE 26. ERHTP MAP OF CONTROL REGISTERS 25
TABLE 27. DEC-FORMAT VALUES OF OPERATION_CONFIG REGISTER 29
TABLE 28. DEC-FORMAT VALUES OF CALIBRATION_CONTROL REGISTER 29
TABLE 29. TIMING SEQUENCE TO RESET MODBUS COMMUNICATION SETTINGS USING THE AUX PIN 29
TABLE 30. EXAMPLE WRITE AND READ: MAP OF CONTROL REGISTERS 30
TABLE 31. ERHTP MAP OF HEATER PARAMETERS (INT FORMAT) 31
TABLE 32. EXAMPLE WRITE AND READ: MAP OF HEATER PARAMETERS 32
TABLE 33. ERHTP MAP OF DIAGNOSTIC REGISTERS 34
TABLE 34. ERHTP MAP OF RAW ADC VALUES OF PRIMARY PARAMETERS 34
TABLE 35. ERHTP MAP OF EXTENDED RAW ADC VALUES OF PRIMARY PARAMETERS FOR RHTP+CO2 35
TABLE 36. EXAMPLE WRITE AND READ: MAP OF DIAGNOSTIC REGISTERS 35
TABLE 37. ERHTP MAP OF FIXED-VALUE TEST REGISTERS 36
TABLE 38. EXAMPLE READ: MAP OF FIXED-VALUE TEST REGISTERS 36
TABLE 39. ERHTP MAP OF TRACEABILITY REGISTERS 37
TABLE 40. EXAMPLE READ: MAP OF TRACEABILITY REGISTERS 37
TABLE 41. SEA LEVEL PRESSURE DEFAULT VALUES 38
TABLE 42. ERHTP MAP OF INPUT REGISTERS FOR REDUCED SEA-LEVEL PRESSURE 38
TABLE 43. EXAMPLE WRITE: MAP OF INPUT REGISTERS FOR REDUCED SEA-LEVEL PRESSURE 38
TABLE 44. ERHTP MAP OF INPUT REGISTERS FOR USER-DEFINED CALIBRATION 40
TABLE 45. DEFAULT VALUES OF THE CALIBRATION DATA 41
TABLE 46. EXAMPLE WRITE: MAP OF INPUT REGISTERS FOR USER-DEFINED CALIBRATION 41
TABLE 47. ERHTP MAP OF TEST REGISTERS FOR EVALUATION OF CALIBRATION 42
TABLE 48. ERHTP MAP OF TEST REGISTERS FOR EVALUATION OF CALIBRATION 43
TABLE 49. EXAMPLE WRITE AND READ: MAP OF TEST REGISTERS FOR EVALUATION OF CALIBRATION 44
TABLE 50. MATLAB SCRIPT FOR CALCULATING CALIBRATION COEFFICIENTS 45
TABLE 51. EXAMPLE OF USING THE MATLAB SCRIPT FOR CALIBRATION OF BAROMETRIC PRESSURE 45
TABLE 52. ERHTP GEOMETRY 46
TABLE 53. DOCUMENT REVISIONS AND UPDATES 47

RELATIVE HUMIDITY, TEMPERATURE, AND BAROMETRIC PRESSURE PROBE

Evvos RHTP 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. An additional measurement of CO_2-percentage (in air) compensated for relative humidity and air temperature is available in the RHTP+CO2 version of the probe.

Applications

- Environmental monitoring
- Weather forecasting solutions
- Industrial data acquisition
- Precision agriculture/farming
- Cold chain and HVAC applications
- Internet of things (IoT)
- CO_2-monitoring in industry/agriculture/farming (RHTP+CO2 version)

Primary parameters

- Relative humidity
- Air temperature
- Barometric pressure
- CO_2-percentage in air (RHTP+CO2 version)

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

Highlights

- Stainless steel enclosure and filter cap engineered to shield sensing elements in harsh environments
- Waterproof protection, and internal electronics sealed in resin, coated electrical parts
- Multiple electrical interfacing options - SDI-12 (v.1.4), RS-485 (Modbus), UART (Modbus), 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 oil-resistant flexible cable (optional)

Description

RHTP is a high-accuracy, digital probe. It measures 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 circuitries, and durable cable, ensure 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 it is recommended to install a RHTP probe in a solar shield.

Measured Parameters and Units

Table 1. ERHTP 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 humid air
saturated_vapor_pressure	hPa	Saturated vapor pressure in humid air
heat_index	°C	Physiological heat index in humid air
speed_of_sound	m/s	Speed of sound in humid air
mixing_ratio	g/kg	Mixing ratio of moisture in air
specific_enthalpy	kJ/kg	Thermodynamic specific enthalpy of humid air
water_activity	-	Water activity in humid air
water_boiling_point	°C	Boiling point of water
wet_bulb_temperature	°C	Thermodynamic wet-bulb temperature
CO2_percentage	%	**RHTP-CO2 version only:** concentration (percentage) of CO_2 in air

Table 2. ERHTP Diagnostic Parameters

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

NOTE: MCU_errors, power_errors, sensor_errors, errors_count reset to 0 at power-up.

Table 3. ERHTP On-board Heater Parameters

Parameter	Unit	Description
HEAT_mode	-	Indicator of the operational mode of the on-board heater: MANUAL, AUTO
HEAT_status	-	Indicator of the state of the heater cycle: ON, COOLING, OFF
HEAT_duty_cycle	-	Automatically set parameter for PWM control of the on-board heater
HEAT_set_time	s	User-defined ON time for the on-board heater
HEAT_remaining_time	s	Self-updating remaining ON time for the on-board heater when enabled
HEAT_initial_temperature	°C	Temperature of the RH-sensor at the beginning of heater's ON state
HEAT_delta_temperature	°C	Increase of temperature of the RH-sensor during heating
COOL_remaining_time	s	Self-updating remaining COOLING time for the RH-sensor after heater automatically shuts OFF
COOL_initial_temperature	°C	The temperature of the RH-sensor at the end of heater's ON state
COOL_delata_temperature	°C	Decrease of temperature of the RH-sensor during cooling

Table 4. ERHTP Input Parameters

Parameter	Unit	Description
height_above_sea_level	m	Height of installation point above sea level (for fixed installations only)
vertical_temp_coeff	°C/100m	Vertical temperature gradient in the atmosphere
CAL_temperature_A	-	Calibration coefficient A for air temperature
CAL_temperature_B	-	Calibration coefficient B for air temperature
CAL_temperature_C	-	Calibration coefficient C for air temperature
CAL_temperature_date	-	User-defined date of the most recent air temperature calibration
TEST_temperature_value	°C/°F	User-defined temperature value for manual test and evaluation of the air temperature calibration
CAL_humidity_A	-	Calibration coefficient A for relative humidity
CAL_humidity_B	-	Calibration coefficient B for relative humidity
CAL_humidity_C	-	Calibration coefficient C for relative humidity
CAL_humidity_date	-	User-defined date of the most recent relative humidity calibration
TEST_humidity_value	%	User-defined temperature value for manual test and evaluation of the relative humidity calibration
CAL_pressure_A	-	Calibration coefficient A for barometric pressure
CAL_pressure_B	-	Calibration coefficient B for barometric pressure
CAL_pressure_C	-	Calibration coefficient C for barometric pressure
CAL_pressure_date	-	User-defined date of the most recent barometric pressure calibration
TEST_pressure_value	hPa	User-defined temperature value for manual test and evaluation of the barometric pressure calibration

Table 5. ERHTP 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_dew_point	°C	
MAX_dew_point	°C	
FIRST_dew_point	°C	
LAST_dew_point	°C	
COUNT_dew_point	-	

ERHTP Statistical Environmental Parameters (continued)

Parameter	Unit	Description
MIN_absolute_humidity	g/m^3	Minimal value of parameter within a statistical sample
MAX_absolute_humidity	g/m^3	Maximal value of parameter within a statistical sample
FIRST_absolute_humidity	g/m^3	First value of parameter within a statistical sample
LAST_absolute_humidity	g/m^3	Last value of parameter within a statistical sample
COUNT_absolute_humidity	-	Count of values a statistical sample is based upon
MIN_vapor_pressure	hPa	
MAX_vapor_pressure	hPa	
FIRST_vapor_pressure	hPa	
LAST_vapor_pressure	hPa	
COUNT_vapor_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	-	
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	-	

ERHTP Statistical Environmental Parameters (continued)

Parameter	Unit	Description
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 ERHTP-CO2 version of the probe
MAX_CO2_percentage	%	Available only in ERHTP-CO2 version of the probe
FIRST_CO2_percentage	%	Available only in ERHTP-CO2 version of the probe
LAST_CO2_percentage	%	Available only in ERHTP-CO2 version of the probe
COUNT_CO2_percentage	-	Available only in ERHTP-CO2 version of the probe

Table 6. 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

Special features (All Modbus Versions)

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)

ERHTP Quick Start (Modbus)

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

Table 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	-	-

ERHTP Electrical and Timing Specification (Modbus-RS485 Version)

Table 8. ERHTP Electrical and Timing Specification (Modbus-RS485-specific)

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

ERHTP Electrical and Timing Specification (Modbus-UART Version)

Table 9. ERHTP 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

ERHTP Configuration (All Modbus Versions)

Table 10. ERHTP 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)

Summary of Supported Modbus Functions

Table 11. Modbus Functions Supported by ERHTP

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

Summary of ERHTP Register Maps

Table 12. Summary of Modbus Register Maps in ERHTP

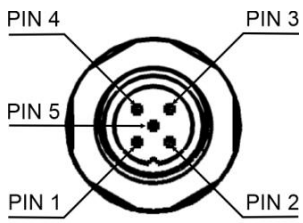
Start Addr	End Addr	Start Reg	End Reg	Value count	Modbus commands	Description
0x000A	0x0018	0011	0024	7	0x03	Map of Traceability Registers
0x3E8	0x407	1001	1032	16	0x03	Map of Environmental Parameters (INT format)
0x44C	0x46B	1101	1132	16	0x03	Map of Environmental Parameters (FLOAT format)
0xFA0	0x1035	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

Wiring

ERHTP Connector (All Modbus Versions)

The Modbus versions of the ERHTP 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 13. Pinout of the M12-connector on ERHTP 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.**

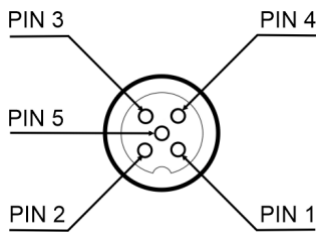
Grounding

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

Patch Cable (optional)

The optional cable is suitable for ERHTP 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 ERHTP Modbus versions enabling the user to take advantage of the AUX pin. The cable is equipped with an M12x5-pin, female, A-coded, straight connector on one end and free wires on the other connector.

Table 14. 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

Wiring for All Modbus Versions

Table 15. Wiring of ERHTP 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

Wiring for Single-Wire Interface (All Modbus Version)

Table 16. Wiring of ERHTP 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

Definitions of the Physical Parameters

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.

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.

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".

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.

Dew Point (Dew Temperature)

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

Absolute Humidity of Air

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

Vapor Pressure in Air

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

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.

Heat Index

An equivalent raised value of air temperature, perceived by a human body due to the presence of relative humidity in air. 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.

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.

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.

Specific Enthalpy

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

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.

Boiling Point of Water

The temperature at which the water vapour pressure equals barometric pressure.

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.

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. Percentage of CO_2 in air is often monitored in safety applications.

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 RHTP 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 RHTP probe).

Vertical Temperature Coefficient

The rate of temperature drop per every 100 meters of vertical elevation above sea level.

Table 17. Secondary – Primary Parameters Functional Dependence in the Calculations by ERHTP

Secondary parameters	**Primary parameters**		
Parameter	***Air Temperature***	***Relative Humidity***	***Barometric Pressure***
Reduced to Sea Level Atmospheric Pressure[1]	•		•
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

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 ERHTP 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.

IEEE754 Floating Point Format

Table 18. 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.

Modbus Register Maps for ERHTP

Map of Environmental Parameters

Table 19. ERHTP 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

ERHTP Map of Environmental Parameters (Integer and Float formats) (Continued)

Applicable Modbus commands: 0x03							
Integer				**Float32**		**Description**	
Addr	**Reg**	**Scale**	**Format**	**Addr**	**Reg**	**Parameter**	**Unit**
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
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 20. ERHTP Map of Extended Environmental Parameters (Integer and Float formats) for RHTP+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 ERHTP probe (e.g. RHTP+CO2)

Table 21. 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	-	

Map of Statistical Parameters

This map contains the added capability of accumulating statistical data for all environmental parameters. On-demand reporting of the minimum (MIN_...), maximum (MAX_...), first (FIRST_...) and last (LAST_...) collected values for each parameter is made available to the master. For any parameter, the maximal count of values (COUNT_...) within a statistical sample is 999999. 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 ERHTP. STATISTICS_control in the Map of Control Registers is available for user-induced reset of statistical data collection. Reset also occurs at power-down.

Table 22. ERHTP 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	-

ERHTP 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	-

ERHTP 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	-

ERHTP 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 23. ERHTP Map of Extended Statistical Environmental Parameters (Integer and Float formats) for RHTP+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 ERHTP probe (e.g. RHTP+CO2)

Table 24. 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 25. 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	

Map of Control Registers

Operation Mode

ERHTP 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. A timeout of 6 sec must be programmed in the Master to wait for the response.
Between measurements the onboard MCU idles with RS485 driver always ON (Modbus over RS485 version). 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 ERHTP 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 ERHTP 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).

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.

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 RHTP and do not lead to full probe's re-initialization and loss of measurement data.

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 26. ERHTP 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
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

ERHTP Map of Control Registers (Continued)

Applicable Modbus commands: 0x03, 0x06

Addr	Reg	Parameter	Type	Mode	Description
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
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

ERHTP Map of Control Registers (Continued)

Applicable Modbus commands: 0x03, 0x06

Addr	Reg	Parameter	Type	Mode	Description
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.
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

ERHTP Map of Control Registers (Continued)

Applicable Modbus commands: 0x03, 0x06

Addr	Reg	Parameter	Type	Mode	Description
0x1391	5010	MODBUS_slave_id	Uint16	R/W	User-selectable Modbus slave address for RHTP. 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
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 27. 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 28. 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})

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

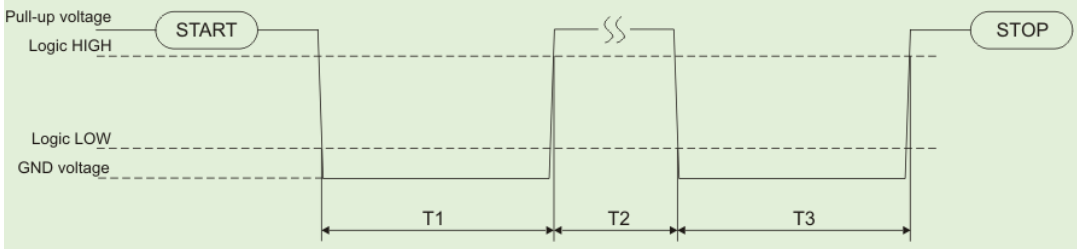
Both methods lead to loss of all available measurement data. RHTP is re-initialized with the (user-defined) settings stored in EEPROM.

Settings saved in EEPROM - once user-defined changes are saved to on-board EEPROM, ERHTP 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 internal pull-up resistor. Using an open drain circuit the master device must execute the timing sequence T1-T2-T3 on the AUX pin. Prior to resetting Modbus communication settings a probe must be awoken from sleep mode if such is enabled.

Table 29. Timing Sequence to Reset Modbus 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.

Table 30. 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	-

Map of Heater Parameters

Heater is used at very high humidity levels for removing condensed water drops on the humidity sensor. A special algorithm smooths the errors in measured temperature values for the duration of the heating/cooling cycle. Values of relative humidity, and barometric pressure remain constant for the duration of the heating/cooling cycle. The *HEATER_control* register is available in the Map of Control Registers for enabling the heater.

Table 31. ERHTP 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. 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 32. 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

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

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

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

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	-

Read Request:
EE 03 1C 20 00 0A D5 08

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 07 EF 00 00 24 F4 AA 7C

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	-

Map of Diagnostic Registers

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 33. ERHTP 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
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 34. ERHTP 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 35. ERHTP Map of Extended Raw ADC Values of Primary Parameters for RHTP+CO2

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

Table 36. 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	-

Map of Fixed-Value Test Registers

The Map provides means to test and verify Modbus communication between master and a probe. It is useful test tool during development of Modbus communication routines or for periodic communication test during run time.

Table 37. ERHTP 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 38. 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	-

Map of Traceability Registers

Table 39. ERHTP 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 40. 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	RHTP-R
manufacturer_name (0022-0024)	45 56 56 4F	EVVOS
Modbus CRC Hi	C2	-
Modbus CRC Lo	4A	-

Sea Level Pressure Configuration

This map 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 conversion is valid in stationary installations only. Two user-input parameters are expected by the probe: exact altitude of the probe's installation point (mandatory) and local vertical temperature coefficient (optional). If no user-defined data is available, the environmental parameter *sea_level_pressure* remains equal to *barometric_pressure*. 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 41. Sea Level Pressure Default Values

Configurable Parameters	Default Values	Units
height_above_sea_level	0 (recommended range: 0 ÷ 5000)	m
vertical_temp_coeff	0.6 (recommended range: 0.5 ÷ 0.65)	°C/100 m

Table 42. ERHTP 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	altitude_value	Float32	R/W	Height (in meters) of installation point above sea level (for fixed installations only)
0x27DB	10204 10205	VTC_value	Float32	R/W	Vertical temperature gradient (°C/100 meter) in the atmosphere

Table 43. 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

User Calibration

Description

The Map of Input Registers for User-Defined Calibration provides the means to manage individual, multipoint calibrations for each of the primary parameters (air temperature, relative humidity, and barometric pressure) measured by an ERHTP probe. Increased accuracy of all parameters is achieved through 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 reference measurements is required. Additional reference measurements will enhance the calibration accuracy. Fine manual error analysis for demanding applications is enabled with the Map of Test Registers for Evaluation of Calibration. 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 ERHTP probe. Writing any calibration coefficients automatically sets *T_cal_status_flag*, *RH_cal_status_flag* and *P_cal_status_flag*. Manual change of the flags is accessible in *CALIBRATION_control* register in the Map of Control Registers.

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

Calibration Equation

The general form of the calibration equation programmed in ERHTP 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:

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

This simplified (1-order) equation is applied to reduce offset and gain errors.

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

Calculation of Calibration Coefficients

The word "parameter" refers to any of the primary parameters, measured by an ERHTP 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 ERHTP probe in respective address(es) in the Map
4. Optional: write calibration date(s) in the ERHTP probe using the respective address(es) in the Map

5. In RHTP 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 ERHTP with a known value using the Map of Test Registers for Evaluation of Calibration
7. Save all calibration data in the ERHTP to EEPROM by writing valid code in *MODBUS_save_settings*.

Map of Input Registers for User-Defined Calibration

Table 44. ERHTP 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
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 45. Default Values of the Calibration Data

Parameter	Description	Default
T_coef_A	Calibration coefficient A for air temperature	0.000000
T_coef_B	Calibration coefficient B for air temperature	1.000000
T_coef_C	Calibration coefficient C for air temperature	0.000000
CAL_temperature_status	Calibration state (ON=1/OFF=0) for air temperature	0
CAL_temperature_date	User-defined date of the most recent air temperature calibration	0
TEST_temperature_value	User-defined temperature value for manual test and evaluation of the air temperature calibration	0
RH_coef_A	Calibration coefficient A for relative humidity	0.000000
RH_coef_B	Calibration coefficient B for relative humidity	1.000000
RH_coef_C	Calibration coefficient C for relative humidity	0.000000
CAL_humidity_status	Calibration state (ON=1/OFF=0) for relative humidity	0
CAL_humidity_date	User-defined date of the most recent relative humidity calibration	0
TEST_humidity_value	User-defined temperature value for manual test and evaluation of the relative humidity calibration	0
P_coef_A	Calibration coefficient A for barometric pressure	0.000000
P_coef_B	Calibration coefficient B for barometric pressure	1.000000
P_coef_C	Calibration coefficient C for barometric pressure	0.000000
CAL_pressure_status	Calibration state (ON=1/OFF=0) for barometric pressure	0
CAL_pressure_date	User-defined date of the most recent barometric pressure calibration	0
TEST_pressure_value	User-defined temperature value for manual test and evaluation of the barometric pressure calibration	0

Table 46. 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

Map of Test Registers for Evaluation of Calibration

The values of the secondary parameters in this map are calculated correctly only if all 3 "TEST_..._values" are written. Out-of-range test values are accepted but their use may result in erroneous values of secondary parameters. For a test value of a primary parameter its corresponding calibrated value is always calculated.

Table 47. ERHTP 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)

Table 48. ERHTP Map of Test Registers for Evaluation of Calibration

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 49. 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	-

MATLAB Script for Calculating Calibration Coefficients

Table 50. 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 51. 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`
	P_coef_A = 0.0004218 to be inputted to ERHTP

`CAL_B =`
 	
`  0.1968`
	P_coef_B = 0.1968 to be inputted to ERHTP

`CAL_C =`
 	
`  383.1403`
	P_coef_C = 383.1403 to be inputted to ERHTP

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

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 of 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.

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.

Dimensions

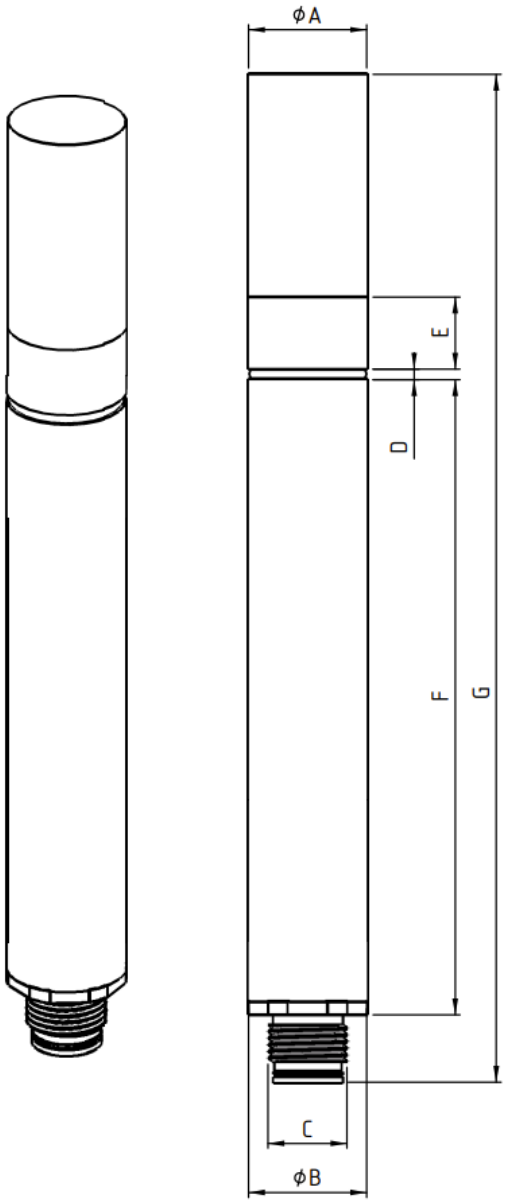


Table 52. ERHTP Geometry

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	1.1	1.3	1.7	mm
	0.043	0.051	0.067	in
E	9.9	10	10.1	mm
	3.898	3.934	3.976	in
F	102.8	103	103.2	mm
	4.047	4.055	4.063	in
G	153	155	157	mm
	6.024	6.102	6.181	in

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Document Revision

Table 53. Document Revisions and Updates

Revision	Description	Date
1.0	Initial release	11-Nov-2022
1.1	Added description of Modbus over UART, added description of extended parameters	9-Mar-2023
1.2	Document re-formatted	17-Apr-2023