EVVOS RHTP PROBE USER'S MANUAL
SDI-12 INTERFACE

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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
break_duration	-	Duration the SDI-12 break symbol generated by the SDI-12 master and measured by the probe

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. SDI-12 Symbols and Parameters

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

ERHTP Quick Start (SDI-12 version)

Table 7. SDI-12 Quick Start: Example of Reading Environmental Data

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

(1) Default SDI-12 address for ERHTP probes is 0 (zero)
(2) additional values may be returned to 0D0!-command for extended model probes (e.g. ERHTP-CO2)

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

Table 8. SDI-12 Quick Start: Example of Reading Wet-bulb Temperature

Sequence of Commands	Description	Issued by
0M6!	Issue a Start Measurement Command aM6! to start the calculation of *wet_bulb_temperature*	user
00054	Wait for 5 sec. conversion time while the 0M6! command is being executed. Service request will be generated by the probe at the moment data is ready (before the end of the 5-sec interval)	probe
0D0!	Issue Read Data Command aD0! to read *wet_bulb_temperature*	user
0+20.50+26.73+17.57+159	<addr>±<wet_boulb_temperature>±<air_temperature°C>±<dew_point>+<wet_bulb_iterations>	probe

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

ERHTP Electrical and Timing Specification (SDI-12-specific)

Table 9. ERHTP Electrical and Timing Specification (SDI-12-specific)

Parameter	Condition	Min	Typ	Max	Unit
Supply voltage (Vin)	Complying with SDI-12 specifications	5	12	24	Vdc
Current consumption (normal mode)	Vin = 12Vdc. Heater OFF. During measurement. **Wired for SDI-12 or single-wire interface.**	1.6	1.8	2.5	mA
Current consumption (sleep mode)	Vin = 12Vdc. Heater OFF. Disabled Continuous Statistic. **Wired for SDI-12 only.**	170	200	300	uA
SDI-12 logic high input		3.5	5	5.5	V
SDI-12 logic high output	Vin = 12Vdc	4.7	4.8	5.0	V
SDI-12 logic low input		0.3	0.5	0.6	V
SDI-12 logic low output	Vin = 12Vdc	0.05	0.1	0.2	V
Power-up time	-	1700	2000	2200	ms

ERHTP Communication Configuration (SDI-12 Version)

Table 10. SDI-12 Communication Configuration

Parameter	Setting
Baud Rate	1200
Start Bits	1
Data Bits	7 (LSB first)
Parity Bits	1 (even)
Stop Bits	1
Logic type	Inverted (active low)
ERHTP default address	0
ERHTP address range	0-9
SDI-12 break symbol duration generated by the SDI-12 master	9-100 ms (recommended: 12 ms)
Probe response timeout programmed in the SDI-12 master	Recommended value: 200 ms
Power-up time programmed in the SDI-12 master	Recommended value: 2200 ms

Table 11. Absolute Maximal Length of SDI-12 Output String Returned by ERHTP

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

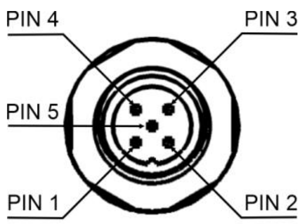
NOTE: the total count of characters includes <addr>, <CRC>, <CR>, <LF>.

Wiring

ERHTP Connector (SDI-12 Version)

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

Table 12. Pinout of the M12-connector on ERHTP probe (SDI-12 Version)

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.
	Auxiliary (AUX)	Pin 3	Single-wire interface bidirectional DATA-pin. **Connect to GND when SDI-12 mode is in use.**
	Unused	Pin 4	Unused wire. Leave floating. Do not connect to any electrical potential.
	SDI-12 DATA	Pin 5	SDI-12 interface bidirectional DATA-port. **Connect to GND when single-wire mode is in use.**

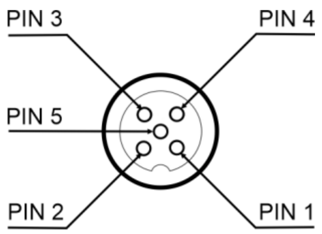
Grounding

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. The cable is equipped with a M12x5-pin, female, A-coded, straight connector on one end and free wires on the other connector.

Table 13. 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 SDI-12 Interface

Table 14. Wiring of ERHTP for SDI-12 Interface

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

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

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

Table 15. 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	Single-wire comm pin
Pin 4	Black	Left floating
Pin 5	Green/yellow	GND

NOTE: it is recommended to connect the unused Pin 5 to GND, else occasional errors in communication may occur.

Summary of Command Set

Table 16. Standard SDI-12 Commands

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

Table 17. ERHTP-specific SDI-12 Commands

Command	Description	Note
aXR!	**Master Reset Command** User-triggered software master reset of the ERHTP probe. All unsaved to EEPROM data is lost as well as accumulated statistical data. Correct reception of XR-command is indicated by ERHTP with issuing Service Request before the actual reset takes place. Probe returns to normal operation after a power-up sequence.	aXR!
aXH! aXH? aXHx!	**Heater Control Command Set** XH-command set is used to manage the on-board heater. Heater is used at very high humidity levels for removing condensed water drops on the humidity sensor. Special algorithm smooths the errors in the measured temperature values for the duration of the heating/cooling cycle.	x=0÷9
aXSx! aXSCx! aXSN! aXSN? aXSF! aXSF? aXSR!	**Statistics Control Command Set** XS-command set is used to manage 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. Two types of statistical data collection are available: Continuous Statistics and Triggered Statistics (default). With Continuous Statistics enabled the monitored parameters are measured at a minimum of 1S/s sample rate and R-commands are accessible. The probe does not enter a sleep cycle and its power consumption remains constantly high. Triggered Statistics is the default mode of operation enabling data collection triggered by issuing M- or C-command. This mode does not affect the sleep cycle of the probe.	x=0÷14 for standard ERHTP version. Extended versions may have greater count
aXT! aXT?	**Test Data Command** XT-commands provide means to test and verify SDI-12 communication between master and a probe. They are useful test tool during development of SDI-12 communication routines or for periodic communication test during run time. Depending on the selected command-mode a probe returns: • a fixed test string formatted as per SDI-12 protocol (address + fixed data + CRC) • currently signed SDI-12 address, and the duration of the Break symbol (start of data transfer) as measured by the probe.	
aXPH:<value>! aXPV:<value>! aXPH? aXPV? aXPS! aXPR!	**Sea-Level-Pressure Configuration Command Set** XP-command set enables the conversion of local barometric pressure to standard mean sea level atmospheric pressure as a means of migrating to worldwide standard atmospheric pressure value. Such a conversion is valid in stationary installations only.	
aXLTA:<value>! aXLTB:<value>! aXLTC:<value>! aXLXT:<value>! aXLT? aXLD0:<value>! aXLN0! aXLF0! aXLHA:<value>! aXLHB:<value>! aXLHC:<value>! aXLXH:<value>! aXLH? aXLD1:<value>! aXLN1! aXLF1! aXLPA:<value>! aXLPB:<value>! aXLPC:<value>! aXLXP:<value>! aXLH? aXLD2:<value>! aXLN2! aXLF2! aXLD? aXLN! aXLN? aXLF! aXLF? aXLS! aXLR!	**User Calibration Command Set** The XL-command set provide the means to manage individual multipoint calibrations for each of the primary parameters (air temperature, relative humidity, barometric pressure) measured by an ERHTP probe. Increased accuracy of all parameters is achieved through the second-order polynomial calibrating formulas applied over the values of the primary parameters before calculating the secondary parameters. For calculation of the calibration coefficients a set of no less than 3 referent measurements is required. Additional referent measurements will enhance the calibration accuracy. Fine error analysis for demanding applications is enabled with the aXLXy!-commands. Any datalogger that supports Transparent SDI-12 Mode (manual mode) can be used for writing/reading the calibration data to an ERHTP probe.	<value> is user-inputted value

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 18. 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

SDI-12 Organization

SDI-12 is a standard electrical interface and data protocol for digital environmental probes. 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 SDI-12 here: https://sdi-12.org/

Minor Deviations in ERHTP from the Standard SDI-12 Protocol

1. Some ERHTP-specific command sets may return stings longer than 35 characters.
2. Some ERHTP-specific commands may delay their output for up to 150 ms.
3. Aborting the execution of a command is not supported by ERHTP.

SDI-12 Command Set for ERHTP

Service Request

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

Address Query Command (?!)

Table 19. Implementation of Address Query Command

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

Table 20. Example of Address Query Command

?!
0

Identification Command (aI)

Table 21. Implementation of Identification Command

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

Table 22. Example of Identification Command

0I!
013EVVOS   RHTP-S011010/032001

Change Address Command (aAb)

Table 23. Implementation of Change Address Command

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

Table 24. Example of Change Address Command

?!
0
0A1!
1
?!
1

Verification Command (aV)

Table 25. Implementation of Verification Command

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

Table 26. Example of Verification Command

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

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

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

Table 27. Differences between aM-, aC-, aR, aH-Command Sets

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

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

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

Table 28. Implementation of Start Measurement (aM!, aC!) Command Sets + Reading output (aD!)

aM! aMC! (aCC! aC!)	Start measurements of all environmental parameters except wet bulb temperature. Values are returned in standard SDI-12 format. Additionally, the formatted outputs of commands aM1 to aM9 (excluding aM6!) are also made available for reading with optional issuing of aD1! to aD9!. NOTE: *model_specific_parameter* is present only with the extended models e.g. ERHTP+CO2. <atttn><CR><LF> (or <atttnn><CR><LF>)
aD0!	<addr>±<air_temperature°C>+<relative_humidity>+<barometric_pressure><±model_specific_parameter><CRC><CR><LF>
aM1! aMC1! (aC1! aCC1!)	Starts measurements of relative humidity, air temperature and atmospheric pressure. Values are converted to integers for compatibility reasons. NOTE: *model_specific_parameter* is present only with the extended models e.g. ERHTP+CO2. <atttn><CR><LF> (or <atttnn><CR><LF>)
aD0!	<addr>±<air_temperature°C>+<relative_humidity>+<barometric_pressure><±model_specific_parameter><CRC><CR><LF>
aM2! aMC2! (aC2! aCC2!)	Starts measurements of relative air temperature, dew point, heat index, air temperature (Fahrenheit). Values are returned in standard SDI-12 format. <atttn><CR><LF> (or <atttnn><CR><LF>)
aD0!	<addr>±<air_temperature°C>±<dew_point>±<heat_index>±<air_temperature°F><CRC><CR><LF>

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

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

Table 29. Examples aM- and aCC-Commands

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

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

Reading Wet-Bulb Temperature

Wet-bulb temperature is calculated through iterative solution of the wet-bulb thermodynamic equation, adjusted for the momentary values of the primary parameters air temperature, relative humidity, and barometric pressure.

Step 1: Issue an aM6!-command (alternatively aMC6!, aC6!, or aCC6!) to measure the momentary values of the primary parameters and, based on them, calculate the value of wet-bulb temperature.

Step 2: Issue aD0!-command to read the calculated value of *wet_bulb_temperature*.

Table 30. Example of Wet-bulb Temperature Measurement with aM- and aCC-Commands

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

Read Continuous Measurement Command Set (aR)

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

Table 31. Implementation of aR-/aRC-commands

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

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

Table 32. Example of aR-commands

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

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

Table 33. Implementation of Identify Measurement Command Set (aIM!, aIMC!, aIC!, aICC!, aIHA!, aIV!)

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

Table 34. Example of Identify Measurement Command Set (aIM!, aIMC!, aIC!, aICC!, aIHA!, aIV!)

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

High Volume Command Set (aHA, aHB)

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

Table 35. High Volume Command Set + Reading output (aD!) Implementation

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

Table 36. Examples aHA-Command

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

Heater Control Command Set (aXH)

XH-command set is used to manage the on-board heater. The 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.

Table 37. Implementation of Heater Control Command Set

aXH?	Reads status of the heater. <addr>+<HEAT_status>+<HEAT_mode>+<remaining_time>+<set_time>±<delta_temperature>±<initial_temperature>+<HEAT_duty_cycle>+<VIN_voltage><CR><LF> Where: HEAT_status = 0 (OFF default state): remaining_time = 0 set_time = 0 delta_temperature = 0 initial_temperature = air_temperature HEAT_status = 1 (HEATING): remaining_time = HEAT_remaining_time set_time = HEAT_set_time delta_temperature = HEAT_delta_temperature initial_temperature = HEAT_initial_temperature HEAT_status = 2 (COOLING): remaining_time = COOL_remaining_time set_time = COOL_set_time delta_temperature = COOL_delta_temperature initial_temperature = COOL_initial_temperature HEAT_mode = 0 (MANUAL): heater under manual control by the user HEAT_mode = 1 (AUTOMATIC): heater operation is controller automatically by the probe (firmware version dependent)
aXH0!	Turns heater OFF. Overrides remaining time by previously issued aXH(1-9) command. Stops COOLING state if active. <addr><CR><LF>
aXH1!	Heater is ON for 10 sec → Automatic OFF → Cooling time 30 sec. <addr><CR><LF>
aXH2!	Heater is ON for 20 sec → Automatic OFF → Cooling time 60 sec. <addr><CR><LF>
aXH3!	Heater is ON for 30 sec → Automatic OFF → Cooling time 90 sec. <addr><CR><LF>
aXH4!	Heater is ON for 40 sec → Automatic OFF → Cooling time 120 sec. <addr><CR><LF>
aXH5!	Heater is ON for 50 sec → Automatic OFF → Cooling time 150 sec. <addr><CR><LF>
aXH6!	Heater is ON for 60 sec → Automatic OFF → Cooling time 180 sec. <addr><CR><LF>

Implementation of Heater Control Command Set (continued)

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

Table 38. Example of Heater Control

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

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

Statistics Control Command Set (aXS)

XS-command set is used to manage 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 (corresponding to more than 5 days of continuous operation). Two types of statistical data collection are available: Continuous Statistics and Triggered Statistics (default). With Continuous Statistics ON, monitored parameters are measured at 1S/s sample rate and R-commands are accessible. The probe does not enter a sleep cycle and its power consumption remains constantly high.
Triggered Statistics is the default mode of operation enabling data collection triggered by issuing M- or C-command. This mode does not affect the sleep cycle of the probe.

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

Table 39. Statistics Data Output Commands

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

Statistics Data Output Commands (continued)

aXS10! aXSC10!	Reads statistical data for sea level pressure (+CRC). At least parameter *height_above_sea_level* must be configured by the user (see aXP-commands). Else *sea_level_pressure = barometric_pressure.* <addr>+<MIN_sea_level_pressure>+<MAX_sea_level_pressure>+<FIRST_sea_level_pressure>+ <LAST_sea_level_pressure>+ <COUNT_sea_level_pressure><CRC><CR><LF>
aXS11! aXSC11!	Reads statistical data for mixing ratio (+CRC) <addr>+<MIN_mixing_ratio>+<MAX_mixing_ratio>+<FIRST_mixing_ratio>+<LAST_mixing_ratio>+ <COUNT_mixing_ratio><CRC><CR><LF>
aXS12! aXSC12!	Reads statistical data for specific enthalpy (+CRC) <addr>+<MIN_specific_enthalpy>+<MAX_specific_enthalpy>+<FIRST_specific_enthalpy>+ <LAST_specific_enthalpy>+<COUNT_specific_enthalpy><CRC><CR><LF>
aXS13! aXSC13!	Reads statistical data for water activity (+CRC) <addr>+<MIN_water_activity>+<MAX_water_activity>+<FIRST_water_activity>+<LAST_water_activity>+ <COUNT_water_activity><CRC><CR><LF>
aXS14! aXSC14!	Reads statistical data for boiling point of water (+CRC) <addr>+<MIN_water_boiling_point>+<MAX_water_boiling_point>+<FIRST_water_boiling_point>+ <LAST_water_boiling_point>+<COUNT_water_boiling_point><CRC><CR><LF>
aXS15! aXSC15!	Reads statistical data for CO2-percentage in air (+CRC) NOTE: command valid only in RHTP-CO2 version of the probe. <addr>+<MIN_CO2_percentage>+<MAX_CO2_percentage>+<FIRST_CO2_percentage>+<LAST__CO2_percentage>+ <COUNT_CO2_percentage><CRC><CR><LF>

Table 40. Statistics Control Commands

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

Table 41. Statistics Reset Commands

aXSR!	Resets accumulated statistics for all monitored parameters. <addr><CR><LF>
aXSR0!	Resets accumulated statistics for air temperature. <addr><CR><LF>
aXSR1!	Resets accumulated statistics for relative humidity. <addr><CR><LF>
aXSR2!	Resets accumulated statistics for barometric pressure. <addr><CR><LF>
aXSR3!	Resets accumulated statistics for dew point. <addr><CR><LF>
aXSR4!	Resets accumulated statistics for heat index. <addr><CR><LF>
aXSR5!	Resets accumulated statistics for absolute humidity. <addr><CR><LF>
aXSR6!	Resets accumulated statistics for vapour pressure. <addr><CR><LF>
aXSR7!	Resets accumulated statistics for saturated vapour pressure <addr><CR><LF>
aXSR8!	Resets accumulated statistics for speed of sound. <addr><CR><LF>
aXSR9!	Resets accumulated statistics for wet-bulb temperature. <addr><CR><LF>
aXSR10!	Resets accumulated statistics for sea level pressure. <addr><CR><LF>
aXSR11!	Resets accumulated statistics for mixing ratio. <addr><CR><LF>
aXSR12!	Resets accumulated statistics for specific enthalpy. <addr><CR><LF>
aXSR13!	Resets accumulated statistics for water activity. <addr><CR><LF>
aXSR14!	Resets accumulated statistics for CO2-percentage in air. NOTE: command valid only in RHTP-CO2 version of the probe. <addr><CR><LF>

Table 42 Example of Resetting Statistics

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

Test Data Command (aXT)

XT-commands provide means to test and verify SDI-12 communication between master and a probe. They are useful test tool during development of SDI-12 communication routines or for periodic communication test during run time.

Table 43. Implementation of Test Data Command

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

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

Table 44. List of All Test Data Command Outputs

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

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

Table 45. Example of Test Data Command

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

Sea Level Pressure Configuration Command Set (aXP)

XP-command set enables the conversion of local barometric pressure to standard mean sea level atmospheric pressure as a means of migrating to worldwide standard atmospheric pressure value. Such 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).

Table 46. 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 47. Implementation of Sea Level Pressure Command Set

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

Table 48. Example of Sea Level Pressure Configuration

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

Master Reset Command (aXR)

Table 49. Implementation of Master Reset Command

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

Table 50. Example of Master Rest Command

0XR!
0
(reset takes place)

User Calibration

Description

The XL-command set 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 error analysis for demanding applications is enabled with the aXLXy!-commands. Any datalogger that supports Transparent SDI-12 Mode (manual mode) can be used for writing/reading the calibration data to an ERHTP probe.

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 using the XL-command set
4. Optional: write calibration date(s) in the ERHTP probe using the XL-command set
5. Enable calibration routine for a primary parameter in the ERHTP using the XL-command set
6. Optional: perform a manual test/verification in the ERHTP with a known value using the XL-command set
7. Save all calibration data in the ERHTP to EEPROM using the XL-command set

Table 51. Default Values of the Calibration Data

Parameter	Description	Default
CAL_temperature_A	Calibration coefficient A for air temperature	0.000000
CAL_temperature_B	Calibration coefficient B for air temperature	1.000000
CAL_temperature_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	-
CAL_humidity_A	Calibration coefficient A for relative humidity	0.000000
CAL_humidity_B	Calibration coefficient B for relative humidity	1.000000
CAL_humidity_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	-
CAL_pressure_A	Calibration coefficient A for barometric pressure	0.000000
CAL_pressure_B	Calibration coefficient B for barometric pressure	1.000000
CAL_pressure_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	-

User Calibration Command Set (aXL)

Table 52. Implementation of Air Temperature Calibration Commands

aXLTA:<value>!	Writes value for temperature calibration coefficient A Input: <addr>XLTA: <CAL_temperature_A>! Reply: <addr><CR><LF>
aXLTB:<value>!	Writes value for temperature calibration coefficient B Input: <addr>XLTB: <CAL_temperature_B>! Reply: <addr><CR><LF>
aXLTC:<value>!	Writes value for temperature calibration coefficient C Input: <addr>XLTC: <CAL_temperature_C>! Reply: <addr><CR><LF>
aXLT?	Reads values for temperature calibration coefficients A, B, C <addr>±<CAL_temperature_A>±<CAL_temperature_B>±<CAL_temperature_C>
aXLD0:<value>!	Writes string for the most recent temperature calibration date (max 10 characters) Input: <addr>XLD0:<CAL_temperature_date>! Reply: <addr><CR><LF>
aXLN0!	Enables calibration routine over the temperature measurements <addr><CR><LF>

Implementation of Air Temperature Calibration Commands (continued)

aXLF0!	Disables calibration routine over the temperature measurements <addr><CR><LF>
aXLXT:<value>!	Manual Test&Evaluation command for temperature calibration. Input value independent on measurement unit Input: <addr>XLXH: ±<TEST_temperature_value>! Reply: <addr>±<TEST_temperature_value>±<CAL_temperature_value>+<CAL_temperature_status><CR><LF>

Table 53. Implementation of Relative Humidity Calibration Commands

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

Table 54. Implementation of Barometric Pressure Calibration Commands

aXLPA:<value>!	Writes value for pressure calibration coefficient A Input: <addr>XLPA:<CAL_pressure_A>! Reply: <addr><CR><LF>
aXLPB:<value>!	Writes value for pressure calibration coefficient B Input: <addr>XLPB:<CAL_pressure_B>! Reply: <addr><CR><LF>

Implementation of Barometric Pressure Calibration Commands (continued)

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

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

Table 55. Implementation of Auxiliary Calibration Commands

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

Example for Inputting Calibration Data in the Probe

Table 56. Example of Inputting Calibration Data in ERHTP

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

MATLAB Script for Calculating Calibration Coefficients

Table 57. 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 58. Example of Using the MATLAB Script for Calibration of Barometric Pressure

USER-PERFORMED INPUT of reference data	
MATLAB Script	**Description**
`USER_DATA = [ 950, 949.3; 1000, 1000.2; 1010, 1010.3; 1015, 1015.9; ];`	4-point reference data set manually inputted in the script by the user: reference_value_1 = 950 hPa, corresponding_measured_value_1 = 949.3 hPa reference_value_2 = 1000 hPa, corresponding_measured_value_2 = 1000.2 hPa reference_value_3 = 1010 hPa, corresponding_measured_value_3 = 1010.3 hPa reference_value_4 = 1015 hPa, corresponding_measured_value_4 = 1015.9 hPa
`order = 2;`	Calculating calibration coefficients for 2-order equation: $x_{cal} = Ax^2 + Bx + C$
Displaying of calibration coefficients	
MATLAB Command Window	**Description**
`CAL_A = 4.2018e-04`	CAL_pressure_A = 0.0004218 to be inputted to ERHTP
`CAL_B = 0.1968`	CAL_pressure_B = 0.1968 to be inputted to ERHTP
`CAL_C = 383.1403`	CAL_pressure_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

CRC Algorithm

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

Table 59. CRC Algorithm Implemented in ERHTP

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

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

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

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

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

    return(CRC_digit);
}

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

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

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

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

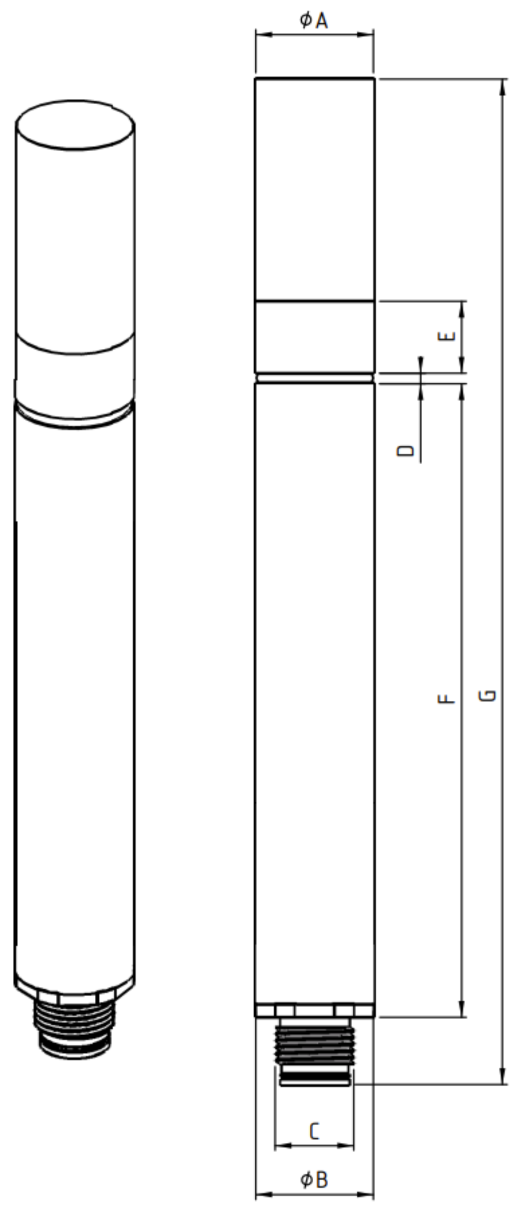


Table 60. ERHTP Geometry

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 61. Document Revisions and Updates

Revision	Description	Date
1.0	Initial Release	21-Sep-2022
1.1	Updated compliance with SDI-12 v1.4	9-Mar-2023
1.2	Document re-formatted	17-Apr-2023