OPERATING MANUAL

HD2016

Weighing rain gauge

EN

V1.9

senseca

Contents

1 Introduction

HD2016 is a rain gauge that detects the weight of the rainfall collected by a 400 cm^2 inlet. The sensor is a load cell located at the base of the rainfall collecting reservoir. The signal of the load cell is processed by the internal electronic board of the rain gauge in order to output the information on the rainfall.

A wide range of acquisition systems can be connected to the rain gauge, thanks to the multiplicity of outputs available:

- RS485 with Modbus-RTU or proprietary ASCII protocol
- SDI-12
- Voltage-free pulse contact output

The rain gauge is able to provide the total rainfall, the partial rainfall (from the last reset command or from the last reading command), the average rainfall rate in the last minute and in the last hour.

The measured rainfall is regularly saved into a non-volatile memory, which retains the information even in case of power failure.

The automatic discharge of the rainfall collected allows using a compact and lightweight structure for the installation of the rain gauge.

So as to ensure accurate measurement even with low temperature climatic conditions, a version with heating which is automatically activated below +4 °C has been developed (**HD2016R**) so that snow deposits and ice formations are prevented.

If the discharge of the water collected takes place during a rainfall, a retention valve, located at the top of rain gauge, temporarily holds the current rainfall, so to avoid losing the amount of rainfall that falls while discharging.

The rain gauge is equipped with sophisticated features that allow reducing the effects of wind, ensuring a better accuracy and stability of the measurement. An NTC temperature sensor allows keeping under control the internal temperature of the instrument.

The corrosion resistant materials used and the absence of moving parts guarantee a reduced maintenance and a long operating life. The rainfall collecting parts are treated with a non-adherent product for a better water flow.

The rain gauge is factory calibrated and ready for use. A self-diagnostic system periodically checks the correct operation of the instrument and reports any anomalies.

Models available:

HD2016

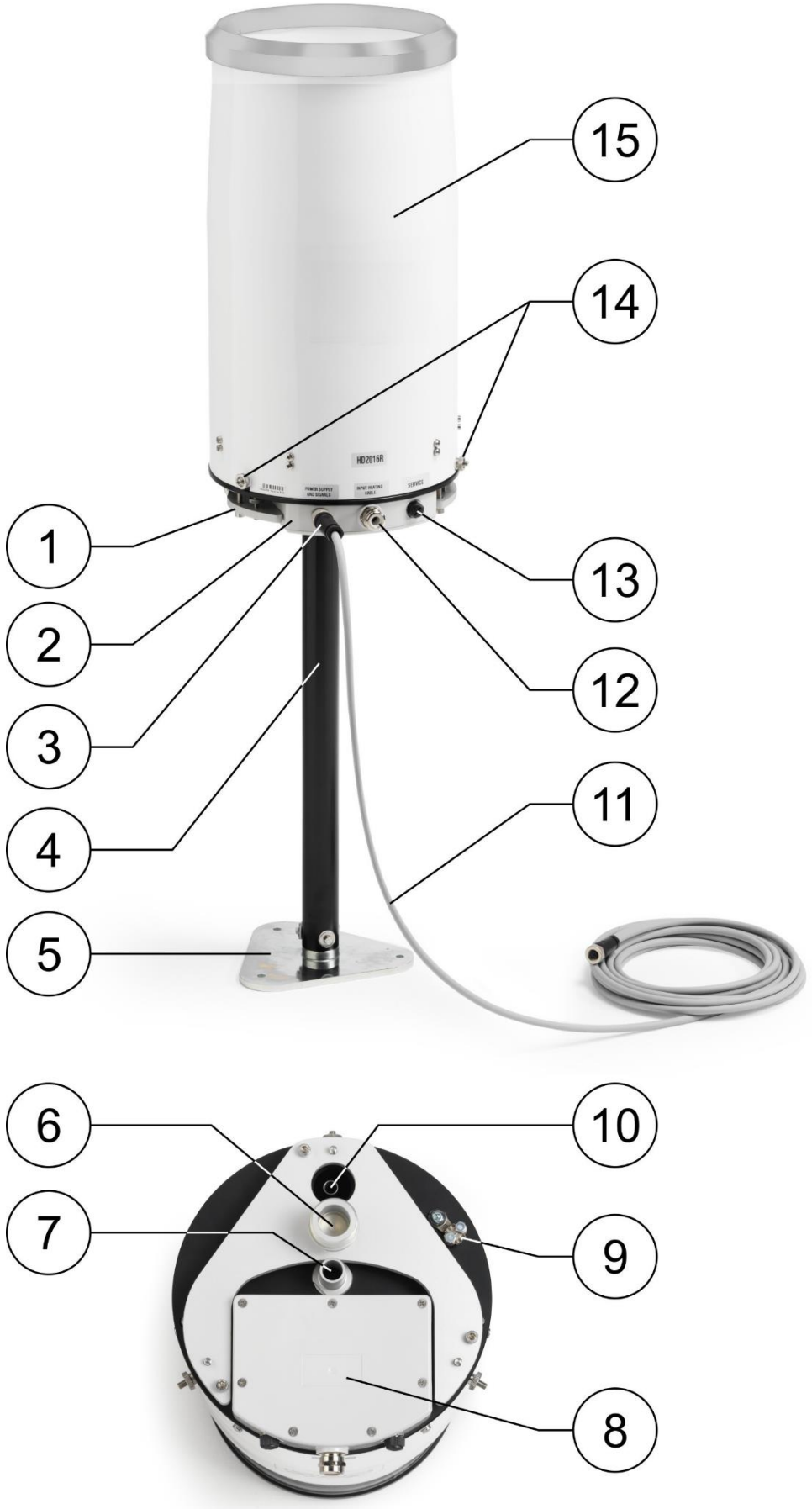
Heating
Blank = not heated
R = heated

2 Technical specifications

Power supply Basic version Heating	 10…15 Vdc 12 Vdc ± 10% (HD2016**R**)
Consumption Basic version Heating	 ≈ 20 mA (1.5 A while discharging, typically for less than 1 minute with 300 cc and maximum 5 minutes with full reservoir) 90 W (HD2016**R**…)
Contact output	Isolated NO (Normally Open) contact (R_{ON} ≈ 1 kΩ, T_{ON} ≈ 60 ms)
Digital outputs	RS485 with Modbus-RTU or ASCII proprietary protocol SDI-12
Resolution	Rainfall: 0.001 mm Weight: 1 mg Rate: 0.001 mm/h or 0.001 mm/min Temperature: 0.1 °C
Accuracy	Rainfall (*): ± 0.2 mm (wind speed < 30 m/s) Temperature: ± 1 °C
Maximum rainfall rate	1000 mm/h
Operating temperature Without heating With heating	 0…+70 °C -20…+70 °C (heating intervention temperature +4 °C) (HD2016**R**)
Capacity	The automatic discharge of the 3000 cc reservoir allows seamless rainfall measurement.
Protection degree	IP 64
Collector area	400 cm^2
Dimensions	∅255 x 457 mm (excluding ground support feet or support for mast)
Minimum section of the connecting cable wires	0.7 mm^2 (AWG 19) for measuring circuit 2.5 mm^2 (AWG 13) for heating

(*) Very light rainfalls (less than about 10 g, corresponding to approx. 0.2 mm) are not detected because the water stagnates in the valves and filters, and does not reach the collecting reservoir.

3 Description



1. **Optional** flange for the installation of the rain gauge raised above ground.
2. Electronic board housing.
3. M12 connector for the connection of the measuring circuit power supply and signals.
4. **Optional** support rod for the installation of the rain gauge raised above ground.
5. **Optional** flat base for fixing the support of the rain gauge raised above ground.
6. Place for the support rod.
7. Discharge of the rainfall collected.
8. Cover of the electronic board housing. To access the electronic board, loosen the 7 screws that secure the cover.
9. Terminal for protective earth connection.
10. Overflow drain.
11. **Optional** cable for the connection of the measuring circuit power supply and signals.
12. Cable gland for the heater power supply.
13. Port reserved for technical service.
14. Screws for fixing the cylindrical cover.
15. Cylindrical cover.

4 Installation

The instrument must be installed in an open area (any close objects should be at a distance equal to at least 4 times their height), away from buildings, busy roads, trees, etc., ensuring the space over it is free from all objects which could obstruct rain measurements, and in an easily accessible position for the filter to be cleaned periodically.

Although the rain gauge is equipped with features that allow reducing the effects of wind, for the best measurement accuracy it is recommended to avoid installation in areas exposed to turbulence (for example, do not install the instrument on the top of a hill, but on the side).

As standard, the rain gauge is supplied for ground installation, with three height-adjustable support feet for proper levelling of the instrument, and holes for possible later fixing to the floor (fig. 4.7.2).

The rain gauge can be installed raised above the ground using the optional **ACCR003** support (a mast with M37 internal thread on one side is required). To install the ACCR003 support, it is necessary to unscrew the 3 brackets with feet from the base of the rain gauge, then attach the support for mast as shown in fig. 4.7.3.

For the measurement to be correct, it is important that the rain gauge is placed perfectly levelled; the base of the rain gauge is fitted with a bubble level.

Eight bird spikes can be attached to the rain gauge (optional accessory **ACCR002**), which are screwed into the holes on the top ring of the rain gauge. **Be careful not to get hurt by sharp spikes**.

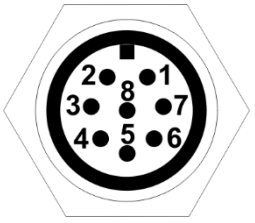
4.1 Electrical connections

The measuring circuit power supply and the outputs (RS485, SDI-12 or contact) are connected via the 8-pole M12 connector. Use a shielded cable over long distances. Upon request, **CP18…** cables are available.

Connector pinout:

Pin	Function	CP18… wire color
1	GND (Negative of measuring circuit power supply and SDI-12 output)	12/Black + 7/Violet + 6/Pink (*)
2	+Vdc (Positive of measuring circuit power supply)	1/Red + 2/Blue + 4/Grey-Pink (*)
3	NC	3/Yellow
4	DATA – (RS485)	9/White
5	DATA + (RS485) or SDI-12 line (depending on the SW1 switch setting)	5/Red-Blue
6	Voltage-free contact	8/Grey
7	NC	10/Brown
8	Voltage-free contact	11/Green

Rain gauge male connector



(*) Wires shorted on the connector pin.

Connect the Protective Earth via the terminal under the base of the rain gauge.

The heater power supply (only HD2016R) is connected directly to the internal terminal block. Unscrew the cover of the electronic board and pass the cable through the cable gland. Use a cable

with 2.5 mm^2 (AWG 13) minimum wires section. The heater power supply is isolated from the measuring circuit.

The following figure shows the electronic board.

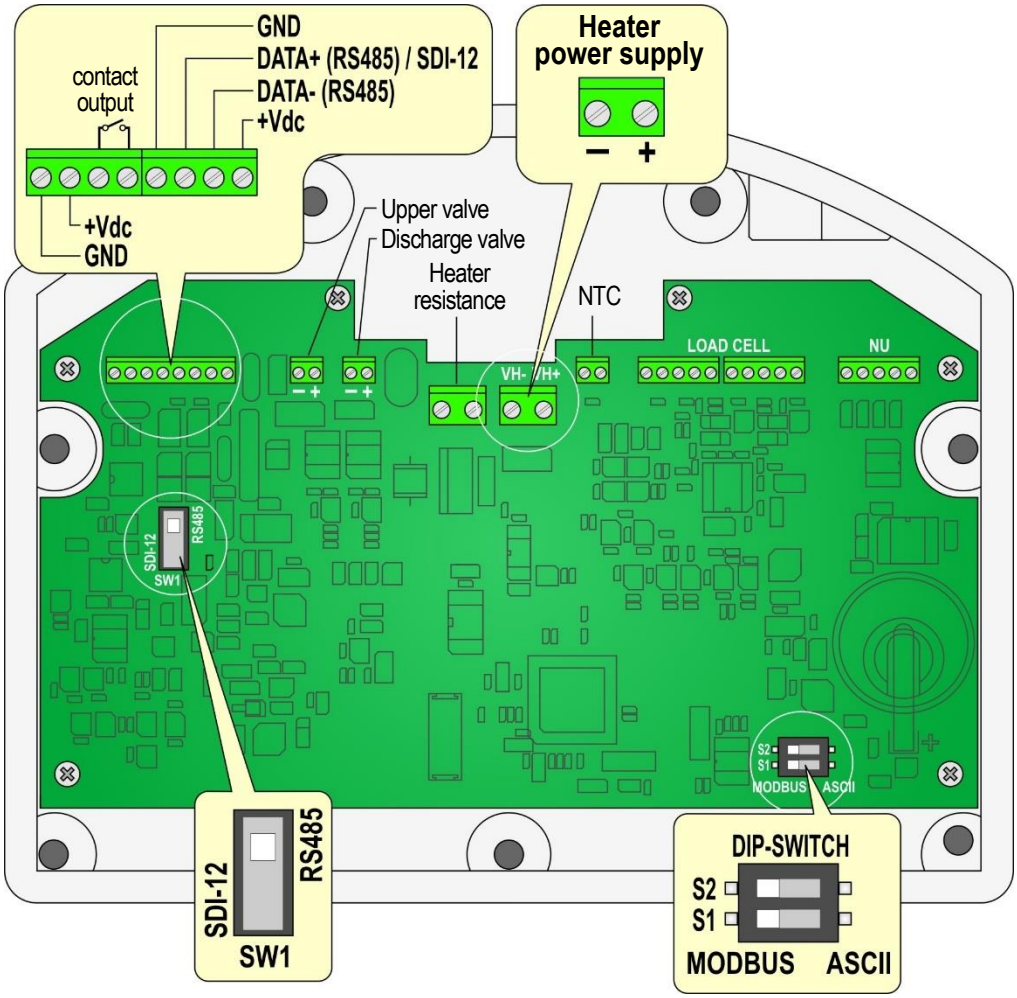


Fig. 4.1.1: electronic board

WARNING FOR VERSION HD2016R:
In order to prevent possible burns by coming into contact with the heater, make sure that the heater is NOT powered when the cylindrical cover of the rain gauge is removed for cleaning or maintenance operations.

4.2 Choosing the digital output and the protocol

The selection of the type of digital output is done by means of the switch **SW1** on the electronic board. Set the switch toward the RS485 or SDI-12 indication depending on the desired output. The switch is set at the factory toward the RS485 indication (unless otherwise requested).

The switch **S1** of the **DIP switch** on the electronic board allows selecting the communication protocol of the digital output at the instrument power-on. Set the switch S1 toward the MODBUS indication to select the standard protocol (Modbus-RTU or SDI-12 depending on the digital output selected with the switch SW1), or set the switch toward the ASCII indication to select the ASCII proprietary protocol. If the standard protocol is selected, it is possible to switch to the ASCII proprietary protocol while the instrument is operating as described in the paragraph " *ASCII proprietary protocol* ". By default, the standard protocol is selected (Modbus-RTU or SDI-12 depending on the digital output selected with the switch SW1).

The setting of the switch SW1 and the DIP switch are read only at instrument power-on, therefore they must be set before powering the instrument. The change of the setting of the switch SW1 and the DIP switch while the instrument is powered has no effect until the instrument is turned off and back on.

Note: the switch S2 of the DIP switch does not perform any function.

To change the other instrument settings, see the paragraph " *ASCII proprietary protocol* ".

4.3 RS485 connection

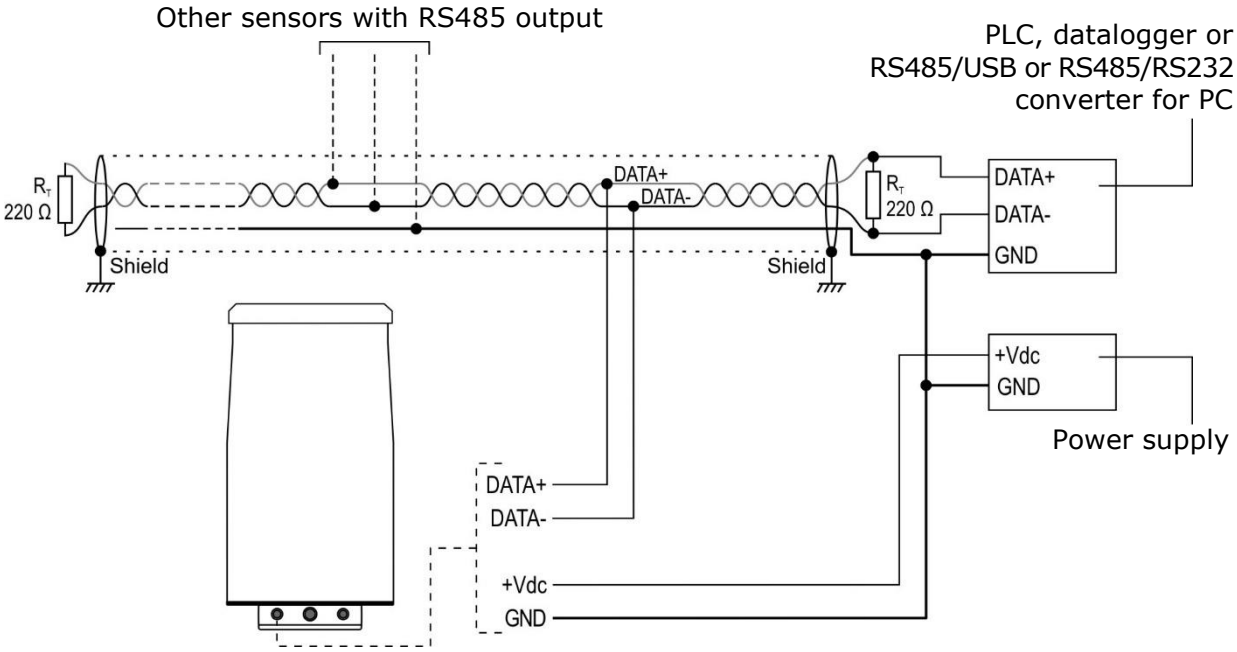


Fig. 4.3.1: RS485 connection

Multiple sensors can be connected in sequence through a twisted-pair shielded cable for signals and a third wire for ground.

The maximum RS485 bus length depends on baud rate and cable characteristics. Typically, using a specific RS485 cable, the maximum length is 1200 m.

Before connecting the rain gauge to the network, set the address and the communication parameters, if different from the factory preset.

The rain gauge has a built-in termination resistor, but it is not connected by default; if the rain gauge is at one end of the network, you can connect the built-in termination resistor by using the command **COt** of the ASCII proprietary protocol.

The RS485 output of the rain gauge is not isolated from the power supply.

4.4 RS485 connection

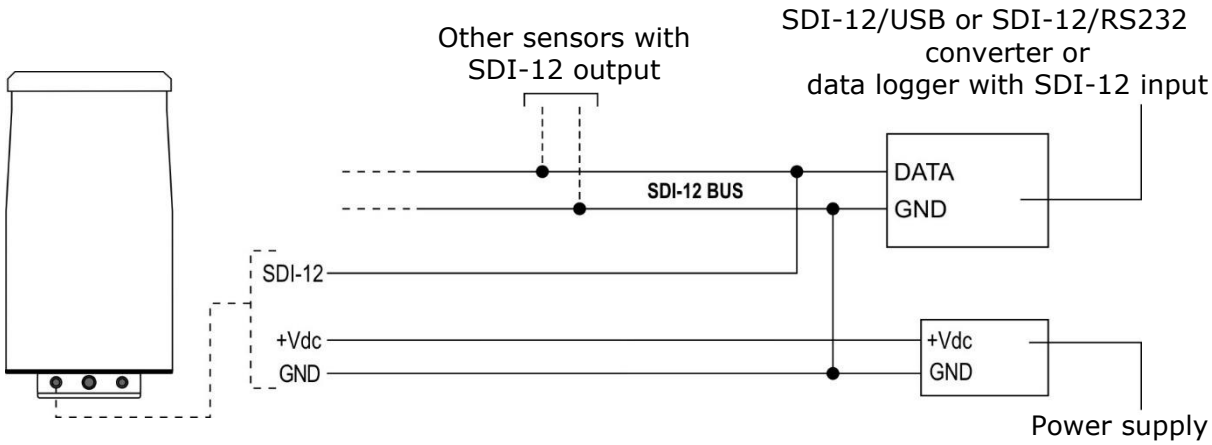


Fig. 4.4.1: SDI-12 connection

More sensors can be connected in parallel. The baud rate is 1200. The SDI-12 bus maximum length is 60 m.

Set the address before connecting the instrument to the network, if different from the factory preset.

4.5 Contact output

The voltage-free contact output simulates the pulse output of a tipping bucket rain gauge. The contact is isolated and is normally open. At 1 minute intervals, the output generates a pulse train (T_{ON} ≈ 60 ms, T_{OFF} ≈ 60 ms) as a function of the rainfall measured in the previous minute. Each pulse corresponds to an amount of rainfall configurable from 0.001 to 1 mm/pulse (default=0.2) by using the command **CP0** of the ASCII proprietary protocol.

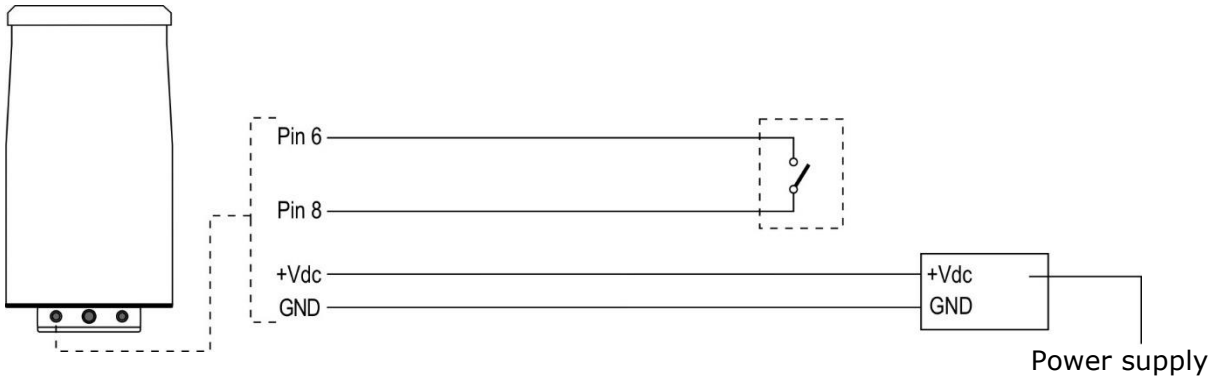


Fig. 4.5.1 – contact output connection

4.6 Unlocking the load cell

The load cell is locked for the transport of the rain gauge. Loosen the three nuts at the base of the cylindrical cover and remove the cylindrical cover by pulling it upwards. Unlock the load cell located at the base of the rain gauge by loosening the two screws on the sides of the cell and translating the locking support outward. Replace the cylindrical cover and tighten the 3 fixing nuts.

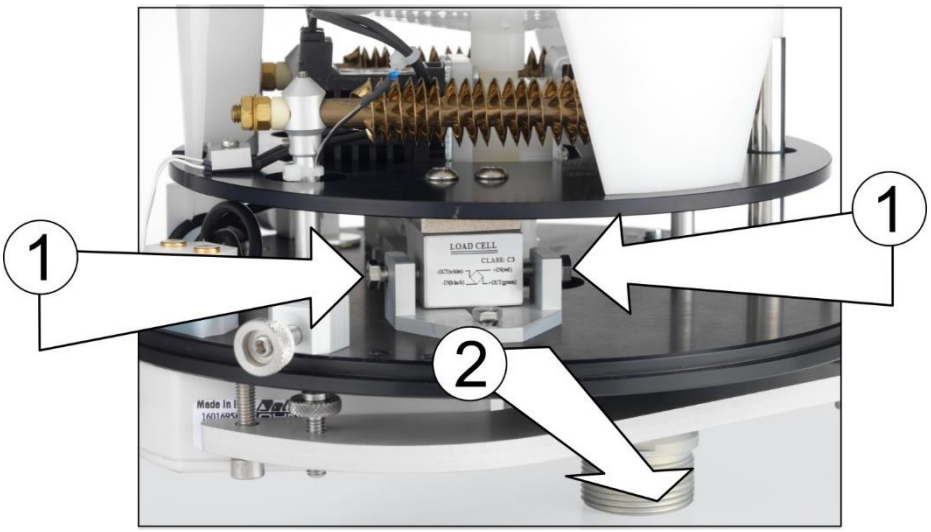


Fig. 4.6.1: unlocking the load cell

4.7 Fixing the rain gauge

For ground installation, adjust the height of the feet so that the instrument is perfectly levelled. The instrument can be fixed to the floor by using the holes provided in the feet, close to the adjustment screws.

Fig. 4.7.1: location of the bubble level

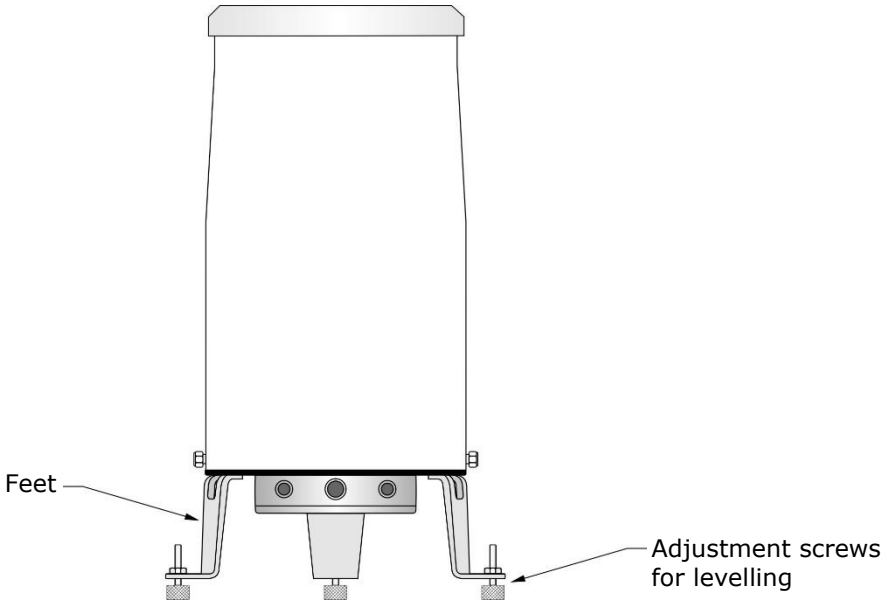


Fig. 4.7.2: ground installation

For raised installation, unscrew the 3 brackets with feet from the base of the rain gauge, then attach the **ACCR003** support for mast to the rain gauge base.

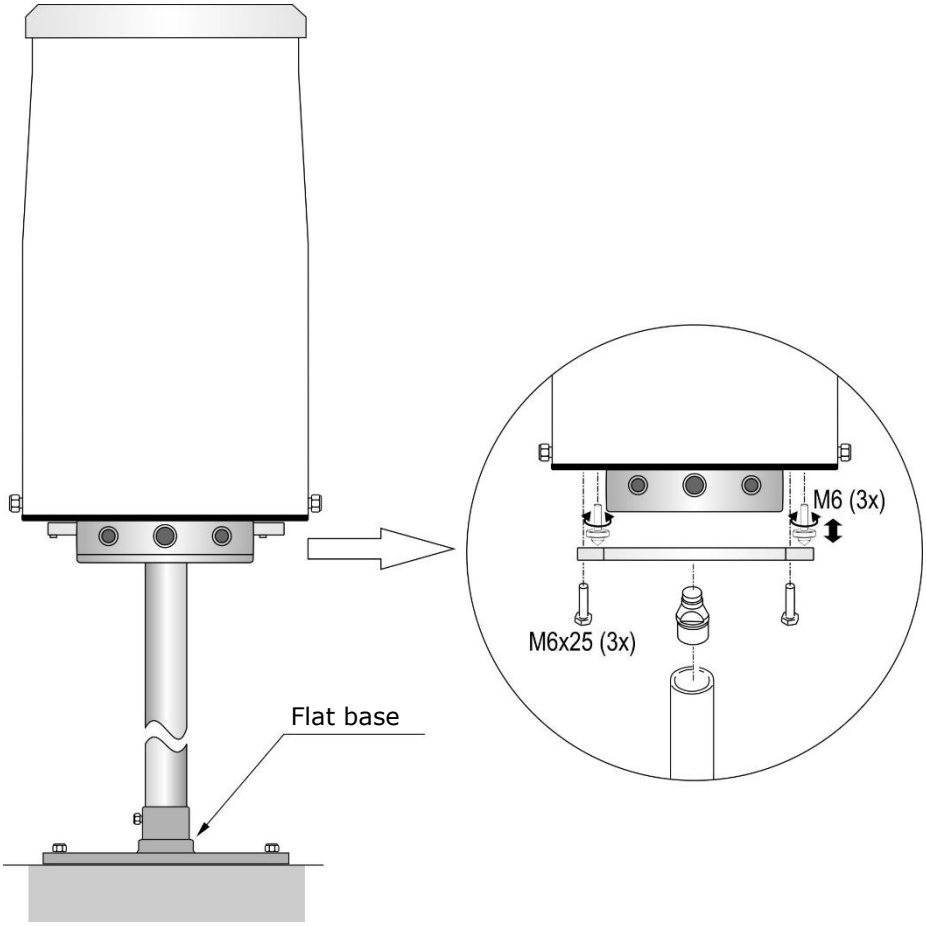


Fig. 4.7.3: installation raised above ground

5 ASCII proprietary protocol

The ASCII proprietary protocol is mainly used to set the operating parameters of the instrument by sending serial commands from a PC. The protocol can be used both with RS485 and SDI-12 physical interface.

The rain gauge should be connected to the PC by using a converter from RS485 or SDI-12 (depending on the rain gauge output used) to USB or RS232C (depending on the PC port used). The use of the **RS48** cable incorporating an RS485/USB converter is recommended. If a USB converter is used, it is necessary to install the relevant USB drivers in the PC.

The ASCII proprietary protocol can be activated both at instrument power-on and while the instrument is operating with the Modbus-RTU or SDI-12 protocols.

In order to activate the ASCII proprietary protocol at the rain gauge power-on, the DIP switch S1 on the electronic board must be set to OFF (toward the ASCII indication, see the fig. on page 8) before turning the instrument on. If activated at power-on, the protocol operates with the following communication parameters:

- Baud Rate = 57600
- Data bits = 8
- Parity = None (N)
- Stop bits = 1
- Flow control = None

If the rain gauge is powered with the DIP switch S1 set to ON (toward the MODBUS indication on the electronic board), the Modbus-RTU or SDI-12 protocol, depending on the physical interface used, is activated by default. In this case, the ASCII proprietary protocol can be activated without turning the rain gauge off and without changing the setting of the DIP switch S1 by the following procedure:

1. In the PC, start a standard serial communication program, then set the COM port number to which the instrument is connecting and the communication parameters with which the instrument is operating (19200 8E1 by default for RS485 Modbus-RTU, 1200 7E1 for SDI-12).
2. Send the command **|||** (sequence of three 124 decimal code ASCII characters followed by the Enter key). The instrument replies with **@**.
3. Within 10 seconds from the reply of the instrument, send the command **@** (64 decimal code ASCII character followed by the Enter key). The instrument replies with ***address*: &**, where nnn is the address of the instrument (if the instrument does not receive the command @ within 10 seconds, the ASCII proprietary protocol is not activated; in this case, repeat from point 2). The ASCII proprietary protocol is now active keeping the communication parameters of the previous protocol (therefore, it is not necessary to change the settings of the serial communication program).

   To disable the ASCII proprietary protocol after use and return to the previous protocol, send the command **#** (or power cycle the instrument).

After activation of the ASCII proprietary protocol, the serial commands given below can be sent.

To change the rain gauge parameters, the serial command **CAL USER ON** must be sent first (the instrument replies with *address*: USER ENABLED!). In order to cancel the command CAL USER ON, send the command **CAL END** (the instrument replies with *address*: LOCKED). The command CAL USER ON is automatically disabled after 5 minutes of inactivity. If the settings should be only read, the command CAL USER ON is not required.

Instrument general information

Command	Reply	Description
P0	*address*: &	Ping
G0	HD2016	Model
G2	SN=*number*	Serial number
G3	Firm. Ver.=*version*	Firmware version
G4	Firm. Date=yyyy/mm/dd	Firmware date
GD	F cal:yyyy/mm/dd hh:mm:ss	Factory calibration date

Reservoir discharge

Command	Reply	Description
CD	*address*: &	Runs the reservoir discharge cycle
CVL	*address*: *state*&	Changes the state of the reservoir discharge valve: *state*=**Opened** ⇒ valve has been opened *state*=**Closed** ⇒ valve has been closed
COa	*address*: &	Activates the discharge after 20 minutes from the end of the rainfall if the reservoir filling percentage is greater than or equal to 80% (2400 cc)
COb	*address*: &	Activates the discharge after 20 minutes from the end of the rainfall if the reservoir filling percentage is greater than or equal to 10% (300 cc)
RDE	*address*: *delay*	Reads the delay time before running the discharge at the end of a rainfall (default = 20 minutes)
CDE *nnn*	*address*: &	Activates the discharge after *nnn* minutes ($20 \leq nnn \leq 480$) from the end of the rainfall if the reservoir filling percentage is greater than the set threshold
RTE	*address*: *percentage*	Reads the reservoir filling percentage that enables the discharge (default = 10% ⇒ 300 cc)
CTE *nn*	*address*: &	Activates the discharge (after the delay time set) if the reservoir filling percentage is greater than *nn* % ($1 \leq nn \leq 99$)

Note: the discharge takes place normally at the end of a rainfall after the delay time set; if the reservoir should overfill during a rainfall, the discharge will take place during the rainfall and the upper retention valve will close to maintain the current rainfall in the upper part of the rain gauge; at the end of the discharge phase, the rainfall collected in the upper part of the rain gauge will be discharged in the main reservoir and weighted.

Upper retention valve

Command	Reply	Description
ROv	*address*: *state*	Reads the enabling state of the upper retention valve: *state*=**0** ⇒ valve is not enabled *state*=**1** ⇒ valve is enabled
COv *n*	*address*: &	Enables/disables the use of the upper retention valve: *n*=**0** ⇒ disable ; *n*=**1** ⇒ enable
CVH	*address*: *state*&	Change the state of the upper retention valve: *state*=**Opened** ⇒ valve has been opened *state*=**Closed** ⇒ valve has been closed

Heater

The HD2016R rain gauge has a temperature sensor that detects the internal temperature of the instrument (**not the air temperature**). The heater is activated when the internal temperature falls below the value set with the command CTL (default 4 °C) and is switched off when the internal temperature rises above the value set with the command CTH (default 10 °C).

Command	Reply	Description
RTH	*address*: *temperature*	Reads the heater deactivation temperature (default = 10.0 °C)
CTH *nn.d*	*address*: &	Sets the heater deactivation temperature to the value *nn.d* (activation temperature ≤ *nn.d* ≤ 10.0 °C)
RTL	*address*: *temperature*	Reads the heater activation temperature (default = 4.0 °C)
CTL *nn.d*	*address*: &	Sets the heater activation temperature to the value *nn.d* (4.0 °C ≤ *nn.d* ≤ deactivation temperature)
RTD	*address*: *state*	Reads the heater enabling state: *state*=**Enabled** ⇒ heater is used *state*=**Disabled** ⇒ heater is not used
CTD *n*	*address*: &	Enables/disables the use of the heater: *n*=**0** ⇒ disable ; *n*=**1** ⇒ enable
CHS	*address*: *state*&	Changes the activation state of the heater: *state*=**On** ⇒ heater has been switched on *state*=**Off** ⇒ heater has been switched off

Resolution of contact output

Command	Reply	Description
RP0	*address*: *resolution*	Reads the resolution, in mm/pulse, of the contact output (default = 0.200 mm/pulse)
CP0 *n.ddd*	*address*: &	Sets the resolution of the contact output to the value *n.ddd* mm/pulse (max. 1 mm/pulse)

Counters reset

Command	Reply	Description
CS	*address*: &	Resets the partial rainfall value
CLR	*address*: &	Resets all the counters It must be run before the total weight counter reaches the maximum value 999,999,999 mg

RS485 settings

Command	Reply	Description
ROt	*address*: *state*	Reads the connection state of the termination resistor of the RS485 output: *state*=**0** ⇒ termination resistor not connected *state*=**1** ⇒ termination resistor connected
COt *n*	*address*: &	Connect/disconnect the termination resistor of the RS485 output: *n*=**0** ⇒ disconnect ; *n*=**1** ⇒ connect
RMA	*address*: *address* address	Reads the Modbus address (default = 1)
CMA *nnn*	*address*: &	Sets the Modbus address to *nnn* (1…247)
RMB	*address*: *baud rate index* MB baud	Reads the Modbus Baud Rate: *Baud rate index*=**0** ⇒ 1200 *Baud rate index*=**1** ⇒ 2400 *Baud rate index*=**2** ⇒ 4800 *Baud rate index*=**3** ⇒ 9600 *Baud rate index*=**4** ⇒ 19200 (default)
CMB *n*	*address*: &	Sets the Modbus Baud Rate of index *n*: *n*=**0** ⇒ 1200 ; *n*=**1** ⇒ 2400 ; *n*=**2** ⇒ 4800 *n*=**3** ⇒ 9600 ; *n*=**4** ⇒ 19200
RMP	*address*: *mode index* MB mode	Reads the Modbus transmission mode: *mode index*=**0** ⇒ 8N1 *mode index*=**1** ⇒ 8N2 *mode index*=**2** ⇒ 8E1 (default) *mode index*=**3** ⇒ 8E2 *mode index*=**4** ⇒ 8O1 *mode index*=**5** ⇒ 8O2 (N=no parity, E=even parity, O=odd parity)
CMP *n*	*address*: &	Sets the Modbus transmission mode: *n*=**0** ⇒ 8N1 ; *n*=**1** ⇒ 8N2 ; *n*=**2** ⇒ 8E1 *n*=**3** ⇒ 8E2 ; *n*=**4** ⇒ 8O1 ; *n*=**5** ⇒ 8O2 (N=no parity, E=even parity, O=odd parity)
RMW	*address*: *delay index* MB Tx delay	Reads the receiving mode after the Modbus transmission: *delay index*=**0** ⇒ Violate protocol and go in receiving mode right after Tx *delay index*=**1** ⇒ Respect protocol and wait for 3.5 characters after Tx (default)
CMW *n*	*address*: &	Sets the receiving mode after the Modbus transmission: *n*=**0** ⇒ Violate protocol and go in receiving mode right after Tx *n*=**1** ⇒ Respect protocol and wait for 3.5 characters after Tx

Printing the measures

Command	Reply	Description
SR *n*	*address*: *measured value*	Single print of the measure of index n: *n*=0 ⇒ Status register content in hexadecimal *n*=2 ⇒ Partial rainfall, in µm, from the last reading command *n*=4 ⇒ Total rainfall in µm *n*=6 ⇒ Partial rainfall, in µm, from the last reset command *n*=8 ⇒ Average rainfall rate, in µm/min, calculated in the last minute *n*=10 ⇒ Average rainfall rate, in µm/h, calculated in the last hour *n*=12 ⇒ Rain gauge internal temperature in °C *n*=14 ⇒ Rainfall total weight (Pmg) in mg (*) *n*=16 ⇒ Rainfall total weight, in mg, considering the evaporation (Wmg) (*) *n*=18 ⇒ Weight, in mg, of the current reservoir content (Tmg) (*) *n*=20 ⇒ Partial rainfall, in mils, from the last reading command *n*=22 ⇒ Total rainfall in mils *n*=24 ⇒ Partial rainfall, in mils, from the last reset command *n*=26 ⇒ Average rainfall rate, in mils/min, calculated in the last minute *n*=28 ⇒ Average rainfall rate, in mils/h, calculated in the last hour *n*=30 ⇒ Rain gauge internal temperature in °F (*) For details on weight measurements, please see the paragraph "Notes on weight measurements".
RR *n*	*address*: *measured value*	Continuous print (once per second) of the measure of index n (see the command SR for the indexes)
S0	String with 16 fields	Single print of all the measures: *campo 1* ⇒ & followed by a control code *campo 2* ⇒ Filling percentage of the rain gauge reservoir *campo 3* ⇒ Weight, in mg, of the current reservoir content (Tmg) (*) *campo 4* ⇒ Rainfall total weight, in mg, considering the evaporation (Wmg) (*) *campo 5* ⇒ Rainfall total weight (Pmg) in mg (*) *campo 6* ⇒ Partial rainfall, in µm, from the last reset command *campo 7* ⇒ Average rainfall rate, in µm/min, calculated in the last minute *campo 8* ⇒ Average rainfall rate, in µm/h, calculated in the last hour *campo 9* ⇒ Reservoir status (*Evap* if in evaporation, *Rain* if in precipitation) followed by * (valid data) or ! (invalid data) *campo 10* ⇒ Indicates how long the status reported in the previous field has been active *campi 11…15* ⇒ Confidential information *campo 16* ⇒ Internal temperature in °C (*) For details on weight measurements, please see the paragraph "Notes on weight measurements".
R0	String with 16 fields	Continuous print (once per second) of all the measures (see the command S0 for the fields)
ST	*address*: & *voltage status_register*	Prints the supply voltage in Volt and the content of the status register in hexadecimal

Command	Reply	Description
SS	*address*: *status_register*	Prints the content of the status register in hexadecimal

6 MODBUS-RTU protocol

For enabling the Modbus-RTU protocol, set on the electronic board, before powering the instrument, the DIP switch S1 to ON, toward the MODBUS indication, and the switch SW1 toward the RS485 indication (see the figure on page 8).

In Modbus-RTU mode, the instrument sends the detected measurements only if specifically requested by the PC, PLC or data logger.

The default communication parameters are:

- Baud Rate = 19200
- Data bits = 8
- Parity = Even (E)
- Stop bits = 1
- Flow control = None

The communication parameters can be changed by using the appropriate serial commands of the ASCII proprietary protocol or, alternatively, directly with Modbus commands by changing the value of the Holding Registers described later.

The function code 04h (Read Input Registers) allows reading the values measured by the instrument. The following table lists the Input Registers available.

Modbus Input Registers

Register address	Datum	Format
0	Content of the status register	16-bit integer
1	Not used	16-bit integer
2,3	Partial rainfall, in µm, from the last reading command	16-bit integer
4,5	Total rainfall in µm	16-bit integer
6,7	Partial rainfall, in µm, from the last reset command	16-bit integer
8,9	Average rainfall rate, in µm/min, calculated in the last minute	16-bit integer
10,11	Average rainfall rate, in µm/h, calculated in the last hour	16-bit integer
12,13	Rain gauge internal temperature in °C	16-bit integer
14,15	Rainfall total weight (Pmg) in mg (*)	16-bit integer
16,17	Rainfall total weight, in mg, considering the evaporation (Wmg) (*)	16-bit integer
18,19	Weight, in mg, of the current reservoir content (Tmg) (*)	16-bit integer
20,21	Partial rainfall, in mils, from the last reading command	16-bit integer
22,23	Total rainfall in mils	16-bit integer
24,25	Partial rainfall, in mils, from the last reset command	16-bit integer
26,27	Average rainfall rate, in mils/min, calculated in the last minute	16-bit integer
28,29	Average rainfall rate, in mils/h, calculated in the last hour	16-bit integer
30,31	Rain gauge internal temperature in °F	16-bit integer

(*) For details on weight measurements, please see the paragraph “Notes on weight measurements”.

The measures are signed 32-bit integer values. Two consecutive 16-bit registers must be accessed to read a measure. The register with lower address (for example the register with address 12 for the temperature in °C) contains the most significant bits.

Some operating parameters of the instrument can be changed directly with Modbus commands by setting the value of the Holding Registers with the function code 06h (Write Single Register) or 10h (Write Multiple Registers). The following table lists the Holding Registers available.

Modbus Holding Registers

Register address	Datum	Format
0	Indicator of the correct execution of the last writing command. If **0**, the command has been executed correctly. If **1**, command execution errors occurred.	16-bit integer
1	Indicator of the correct permanent storage of the parameters. If **0**, the parameters have stored correctly. If **1**, storage errors occurred.	16-bit integer
2	Content of the status register	16-bit integer
8	Heater enabling/disabling. Write **A500**h to enable the use of the heater. Write **A501**h to disable the use of the heater.	16-bit integer
9	Reset of all the counters. Write **A55A**h to reset the counters.	16-bit integer
10	Reset of the partial rainfall value. Write **A55B**h to reset the value.	16-bit integer
11	Reservoir discharge cycle. Write **A55A**h to run the discharge cycle.	16-bit integer
100	Modbus address (from 1 to 247, default=1).	16-bit integer
101	Modbus Baud Rate. If **0**, the Baud Rate is 9600. If **1**, the Baud Rate is 19200 (default).	16-bit integer
102	Modbus transmission mode. **0** ⇒ 8N1, **1** ⇒ 8N2, **2** ⇒ 8E1 (default), **3** ⇒ 8E2, **4** ⇒ 8O1, n=**5** ⇒ 8O2 (N=no parity, E=even parity, O=odd parity)	16-bit integer
103	Receiving mode after the Modbus transmission (Tx). **0** ⇒ Violates the protocol and goes immediately in reception mode after Tx **1** ⇒ Respects the protocol and waits for 3.5 characters after Tx (default)	16-bit integer

In order to check whether the last writing operation has been completed successfully, verify that the Holding Register with address 0 contains 0 by using the function 03h (Read Holding Registers).

The 06h and 10h writing functions change only the value of the parameters in the RAM memory, the change is therefore cancelled in case of power supply failure in the instrument. **For making the change permanent, write the hexadecimal value FF00 in the Coil with address 2 by using the 05h function code (Write Single Coil). The command 05h must be sent within 10 seconds from the last 06h or 10h command.**

Modbus Coils

Register address	Datum
2	Permanent storage of the parameters.

In order to check whether the permanent storage has been completed successfully, verify that the Holding Register with address 1 contains 0, by using the function 03h (Read Holding Registers).

7 SDI-12 protocol

For enabling the SDI-12 protocol, before powering the instrument set on the electronic board the DIP switch S1 to ON, toward the MODBUS indication, and the switch SW1 toward the SDI-12 indication (see the figure on page 8).

The instrument is in compliance with the version 1.3 of the protocol. The communication parameters of the protocol are:

- Baud Rate = 1200
- Data bits = 7
- Parity = Even (E)
- Stop bits = 1

Communication with the instrument is performed by sending a command in the following format:

<Address><Command>!

With <Address> = address of the instrument the command is sent to
<Command> = type of operation requested to the instrument

The instrument reply is as follows:

<Address><Data><CR><LF>

With <Address> = address of the replying instrument
<Data> = information sent by the instrument
<CR> = ASCII character *Carriage Return*
<LF> = ASCII character *Line Feed*

The table below shows the available SDI-12 commands. For consistency with the documentation of the SDI-12 standard, the instrument address is indicated in the table with the letter **a**. The rain gauge leaves the factory with address preset to 0. The address can be changed by using the proper SDI-12 command reported in the table.

SDI-12 commands

Command	Instrument reply	Description
a!	a<CR><LF>	Verifies the presence of the instrument.
aI!	allccccccccmmmmmmvvvssssssss<CR><LF> with: a = address of the instrument (1 character) ll = SDI-12 compliant version (2 characters) cccccccc = manufacturer (8 characters) mmmmmm = instrument model (6 characters) vvv = firmware version (3 characters) ssssssss = serial number (8 characters)	Requests for information from the instrument.
aAb! Where: b = new address	b<CR><LF> Note: if the b character is not an acceptable address, the instrument replies with a instead of b.	Modification of the instrument address.
?!	a<CR><LF>	Request of the address of the instrument. If more than one sensor is connected to the bus, a conflict occurs.

Type M (start measurement) and C (start concurrent measurement) commands

Command	Instrument reply	Description
Total rainfall (mm) and rainfall rate		
aM! **aC!**	atttn<CR><LF> with: ttt = number of seconds necessary for the instrument to make the measure available (3 characters) n = number of detected variables (1 character for aM!, 2 characters for aC!) Note: ttt = 000 means that datum is immediately available.	Request to detect: - total rainfall (mm) - rainfall rate
aD0!	a+S_R+I_M+I_H+R_T <CR><LF> with: S_R = content of the status register in hexadecimal I_M = average rainfall rate, in mm/min, calculated in the last minute I_H = average rainfall rate, in mm/h, calculated in the last hour R_T = total rainfall in mm	Reads: - total rainfall (mm) - rainfall rate
Rainfall (mm), rainfall rate and temperature (°C)		
aM1! **aC1!**	atttn<CR><LF> with: ttt = number of seconds necessary for the instrument to make the measure available (3 characters) n = number of detected variables (1 character for aM1!, 2 characters for aC1!) Note: ttt = 000 means that datum is immediately available.	Request to detect: - rainfall (mm) - rainfall rate - temperature (°C)
aD0!	a+S_R+I_H+R_T <CR><LF> with: S_R = content of the status register in hexadecimal I_H = average rainfall rate, in mm/h, calculated in the last hour R_T = total rainfall in mm	Reads: - total rainfall (mm) - rainfall rate
aD1!	a+R_P+I_M+T <CR><LF> with: R_P = partial rainfall, in mm, from the last reset command I_M = average rainfall rate, in mm/min, calculated in the last minute T = rain gauge internal temperature in °C	Reads: - partial rainfall (mm) - rainfall rate - temperature (°C)

Command	Instrument reply	Description
Rainfall (inches), rainfall rate and temperature (°F)		
aM2! **aC2!**	atttn<CR><LF> with: ttt = number of seconds necessary for the instrument to make the measure available (3 characters) n = number of detected variables (1 character for aM2!, 2 characters for aC2!) Note: ttt = 000 means that datum is immediately available.	Request to detect: - rainfall (inches) - rainfall rate - temperature (°F)
aD0!	$a+S_R+I_H+R_T$ <CR><LF> with: S_R = content of the status register in hexadecimal I_H = average rainfall rate, in inches/h, calculated in the last hour R_T = total rainfall in inches	Reads: - total rainfall (inches) - rainfall rate
aD1!	$a+R_P+I_M+T$ <CR><LF> with: R_P = partial rainfall, in inches, from the last reset command I_M = average rainfall rate, in inches/min, calculated in the last minute T = rain gauge internal temperature in °F	Reads: - partial rainfall (inches) - rainfall rate - temperature (°F)
Rainfall weight		
aM3! **aC3!**	atttn<CR><LF> with: ttt = number of seconds necessary for the instrument to make the measure available (3 characters) n = number of detected variables (1 character for aM3!, 2 characters for aC3!) Note: ttt = 000 means that datum is immediately available.	Request to detect the rainfall weight.
aD0!	$a+S_R$+Pmg+Wmg+Tmg <CR><LF> with: S_R = content of the status register in hexadecimal Pmg = rainfall total weight in mg (*) Wmg = rainfall total weight, in mg, considering the evaporation (*) Tmg = weight, in mg, of the current reservoir content (*)	Reads the rainfall weight.

(*) For details on weight measurements, please see the paragraph "Notes on weight measurements".

Type R (continuous measurements) commands

Command	Instrument reply	Description
aR0!	a+S_R+I_M+I_H+R_T <CR><LF> with: S_R = content of the status register in hexadecimal I_M = average rainfall rate, in mm/min, calculated in the last minute I_H = average rainfall rate, in mm/h, calculated in the last hour R_T = total rainfall in mm	Reads: - total rainfall (mm) - rainfall rate
aR1!	a+S_R+I_H+R_T+R_P+I_M+T <CR><LF> with: S_R = content of the status register in hexadecimal I_H = average rainfall rate, in mm/h, calculated in the last hour R_T = total rainfall in mm R_P = partial rainfall, in mm, from the last reset command I_M = average rainfall rate, in mm/min, calculated in the last minute T = rain gauge internal temperature in °C	Reads: - total rainfall (mm) - partial rainfall (mm) - rainfall rate - temperature (°C)
aR2!	a+S_R+I_H+R_T+R_P+I_M+T <CR><LF> with: S_R = content of the status register in hexadecimal I_H = average rainfall rate, in inches/h, calculated in the last hour R_T = total rainfall in inches R_P = partial rainfall, in inches, from the last reset command I_M = average rainfall rate, in inches/min, calculated in the last minute T = rain gauge internal temperature in °F	Reads: - total rainfall (inches) - partial rainfall (inches) - rainfall rate - temperature (°F)
aR3!	a+S_R+Pmg+Wmg+Tmg <CR><LF> with: S_R = content of the status register in hexadecimal Pmg = rainfall total weight in mg (*) Wmg = rainfall total weight, in mg, considering the evaporation (*) Tmg = weight, in mg, of the current reservoir content (*)	Reads the rainfall weight.

In addition to the above-mentioned commands, the sensor also implements the corresponding commands with CRC, that require to add a 3-character CRC code at the end of the reply before <CR><LF>. The format of these commands is obtained from the previous by adding the letter C: aMC!, aMC1!, aMC2!, aMC3!, aCC!, aCC1!, aCC2!, aCC3!, aRC0!, aRC1!, aRC2!, aRC3!.

Extended SDI-12 Commands

The commands described in the ASCII proprietary protocol can be sent as extended SDI-12 commands by prefixing the command with **aXS**, where **a** is the instrument address, and terminating the command with the exclamation mark (for example, 0XSCS! to send the command CS to the instrument with address 0).

To change the rain gauge parameters, the command **aXSCAL USER ON!** must be sent first (the instrument replies USER ENABLED). To cancel the command CAL USER ON, send the command **aXSCAL END!** (the instrument replies LOCKED).

For more information about the SDI-12 protocol, visit the website "www.sdi-12.org".

8 Notes on weight measurements

The rain gauge gives three weight measures in mg:

- **Tmg**: weight of the current content of the rainfall reservoir.
- **Pmg**: total weight of all the rainfall collected from when the rain gauge is in operation.

  The Pmg value is not decreased when the rainfall reservoir is discharged or when the reservoir content evaporates.

  The value can be reset by using the command CLR of the ASCII proprietary protocol or through the holding register with address 9 of the Modbus-RTU protocol.

  The maximum achievable value is 999,999,999 mg (1 mg resolution) corresponding to about 25,000 mm of rainfall.
- **Wmg**: value used to evaluate the weight changes in the reservoir due to rainfall or evaporation (changes due to water discharge are excluded).

  At the rain gauge power-on, Wmg is set equal to Pmg (total weight); subsequently, the value is increased during a rainfall and decreased when the reservoir content evaporates. The Wmg value is not decreased when the rainfall reservoir is discharged. In practice, the change of Wmg follows the change of Tmg (weight of the current content of the reservoir) but without taking into account that the water is discharged when the reservoir is full. The Wmg value is equal to the value of Pmg minus the weight of all the water evaporated from when the rain gauge is in operation.

  The value is reset when Pmg is reset.

9 Status register

The 16-bit status register gives the following information:

Bit	Description
0	Indicates the presence of an error condition (OR function of the bits 1, 2, 3, 4, 6, 7, 8, 9, 10)
1,2	Error in the values of the configuration parameters in memory
3	Error in the program memory
4	The power supply of the instrument is outside the allowed limits
5	Communication error
6	Error in the pulses counting (contact output)
7	The device has executed a reset
8	Rainfall reservoir not completely emptied (content > 10%)
9	Emptying of rainfall reservoir not activated (content > 80%)
10	Total rainfall overflow
11	The heater is forced in the OFF state
12	Heater state (0=OFF, 1=ON)
13	Rainfall state (0=no raining, 1=currently raining)
14	Emptying rainfall reservoir
15	Invalid data

To ensure the reliability of the measured values, it is recommended to periodically check the content of the status register (especially the bits 0 and 15)

10 Maintenance

WARNING FOR VERSION HD2016R:
In order to prevent possible burns by coming into contact with the heater, make sure that the heater is NOT powered when the cylindrical cover of the rain gauge is removed for cleaning or maintenance operations.

Verify the upper filter cleanliness periodically; check that there is no debris, leaves, dirt or anything else that might obstruct the flowing of water. To accurately clean the filter, remove it from the rain gauge and wash it with the help of a brush.

Fig.10.1: upper filter

To clean the inside of the rain gauge, loosen the three nuts at the base of the cylindrical cover and remove the cylindrical cover by pulling it upwards.

Fig. 10.2: removing the cylindrical cover

Remove the cover of the rainfall collecting reservoir and check that there are no deposits of soil, sand or any other obstructing things. To clean the water drain, open the discharge valve by using the serial command **CVL** of the ASCII proprietary protocol (see chapter 5).

Fig. 10.3: rainfall collecting reservoir

If necessary, the surfaces can be cleaned with non-aggressive detergent.

Checking the operation of the discharge valve:

1. Connect the rain gauge to the PC.
2. Enable the ASCII proprietary protocol (see chapter 5).
3. Disable the upper retention valve by sending the serial command **COv 0**.
4. Pour some water in the rain gauge so as to fill the rainfall collecting reservoir partially.
5. Open the discharge valve by using the serial command **CVL** and check that the water flows out from the discharge pipe of the rain gauge.
6. To close the discharge valve, send the serial command **CVL** again.

Checking the operation of the upper retention valve:

1. Connect the rain gauge to the PC.
2. Enable the ASCII proprietary protocol (see chapter 5).
3. Close the upper retention valve by using the serial command **CVH**.
4. Open the discharge valve by using the serial command **CVL**.
5. Pour some water in the rain gauge and check that water does not flow out from the discharge pipe of the rain gauge.
6. Open the upper retention valve by using the serial command **CVH** and check that the water flows out from the discharge pipe of the rain gauge.

Checking the overflow drain:

1. Connect the rain gauge to the PC.
2. Enable the ASCII proprietary protocol (see chapter 5).
3. Disable the upper retention valve by sending the serial command **COv 0**.
4. Close the discharge valve by using the serial command **CVL**.
5. Pour water in the rain gauge continuously until the water begins to flow out from the overflow drain.
6. To empty the rainfall collecting reservoir, open the discharge valve by using the serial command **CVL**.

Periodic counters reset:

The total weight counter (Pmg) can reach the maximum value 999,999,999 mg. The counter is not automatically reset when it reaches the maximum value. Before the counter reaches the maximum value, reset it in one of the following ways:

1. By sending the command **CLR** of the ASCII proprietary protocol.
2. By writing **A55A**h in the **Holding Register with address *9*** of the Modbus-RTU protocol.
3. By sending the extended command **aXSCLR!** (**a** is the instrument address) of the SDI-12 protocol.

11 Safety instructions

The instrument proper operation and operating safety can be ensured only in the climatic conditions specified in this manual and if all standard safety measures as well as the specific measures described in this manual are followed.

Do not use the instrument in places where there are:

- Corrosive or flammable gases.
- Direct vibrations or shocks to the instrument.
- High-intensity electromagnetic fields, static electricity.

Do not remove the cylindrical cover of the instrument before unplugging the power cable of the heater.

Ensure that there is the system ground (Protective Earth) and the connecting cable is in good condition.

User obligations

The instrument operator shall follow the directives and regulations below that refer to the treatment of dangerous materials:

- EU directives on workplace safety.
- National law regulations on workplace safety.
- Accident prevention regulations.

12 Accessories ordering codes

The rain gauge is supplied as standard for ground installation with feet.

Bird spikes, bracket for mast installation and mast have to be ordered separately.

ACCR002	Bird spikes (8 spikes).
ACCR003	Support for installation on a mast (not included); a mast with M37 internal thread on one side is required.
POLT005	Mast ∅40 mm, internally threaded M37 on one side; length 500 mm.
POLT010	Mast ∅40 mm, internally threaded M37 on one side; length 1 m.
CP18…	Cable with 8-pole M12 connector on one end, open wires on the other end. Length 5 m (CP18.5) or 10 m (CP18.10).
HD2003.78	Flat base for fixing the mast to a floor.

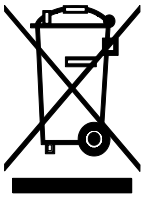
WARRANTY

The manufacturer is required to respond to the "factory warranty" only in those cases provided by Legislative Decree 6 September 2005 - n. 206. Each instrument is sold after rigorous inspections; if any manufacturing defect is found, it is necessary to contact the distributor where the instrument was purchased from. During the warranty period (24 months from the date of invoice) any manufacturing defects found will be repaired free of charge. Misuse, wear, neglect, lack or inefficient maintenance as well as theft and damage during transport are excluded. Warranty does not apply if changes, tampering or unauthorized repairs are made on the product. Solutions, probes, electrodes and microphones are not guaranteed as the improper use, even for a few minutes, may cause irreparable damages.
The manufacturer repairs the products that show defects of construction in accordance with the terms and conditions of warranty included in the manual of the product. For any dispute, the competent court is the Court of Padua. The Italian law and the "Convention on Contracts for the International Sales of Goods" apply.

TECHNICAL INFORMATION

The quality level of our instruments is the result of the continuous product development. This may lead to differences between the information reported in the manual and the instrument you have purchased.
We reserve the right to change technical specifications and dimensions to fit the product requirements without prior notice.

DISPOSAL INFORMATION



Electrical and electronic equipment marked with specific symbol in compliance with 2012/19/EU Directive must be disposed of separately from household waste. European users can hand them over to the dealer or to the manufacturer when purchasing a new electrical and electronic equipment, or to a WEEE collection point designated by local authorities. Illegal disposal is punished by law.

Disposing of electrical and electronic equipment separately from normal waste helps to preserve natural resources and allows materials to be recycled in an environmentally friendly way without risks to human health.

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