# WLR 8/15/30

## User Manual

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# I        Disclaimer

The information provided in this manual was deemed accurate as of the publication date. However, updates to this information may have occurred.

This manual does not include all of the details of design, production, or variation of the equipment nor does it cover every possible situation which may arise during installation, operation or maintenance. HyQuest Solutions shall not be liable for any incidental, indirect, special or consequential damages whatsoever arising out of or related to this documentation and the information contained in it, even if HyQuest Solutions has been advised of the possibility of such damages.

Any errors found in any HyQuest Solutions product should be reported to HyQuest Solutions where every effort will be made to quickly resolve the problem.

This document is public.

# II     Glossary + Abbreviations

| Term | Definition |
|---|---|
| $\theta_3$ | See antenna 3 dB beam width |
| Antenna 3 dB Beam Width | also known as the half-power; the angle between the half-power of an antenna pattern or beam over which the relative power is at or above 50% of the peak power |
| bps | bits per second, a measure for data transmission speed |
| CWFM Radar | continuous-wave frequency-modulated radar |
| Dead Zone | Equivalent to blocking distance or dead band, defines the minimum distance between water surface and sensor antenna that is needed to measure precisely (a function of the radio wave frequency) |
| ERP | Effective Radiation Power, IEEE standard definition of directional radiofrequency (RF) power |
| EIRP | Equivalent Isotropically Radiation Power, hypothetical power of an isotropic antenna with equivalent signal strength of the actual source antenna in the direction of the strongest beam |
| GHz | See Hz |
| Hz (GHz) | International Standard System of Units derived unit of frequency, Hertz (symbol: Hz)  GHz: a gigahertz is the multiple of the hertz frequency equivalent to $10^9$ Hz |
| GND | Ground, electrical ground or signal ground |
| Mx, Mxx | ISO standard for metric screw threads w/ M=metric, x or xx = outer diameter in millimeters |
| RF | Radio Frequency |
| RxD | Data reception line |
| TxD | Data transmission line |
| W Band | Frequency band in the microwave range of the electromagnetic spectrum, typically 75..110 GHz |
| WLR 8/15/30 | Water Level Radar w/ measurement range relative to water surface of <ul><li>8 m (26,24 ft)</li><li>15 m (49,2 ft)</li><li>30 m (98,4 ft)</li></ul> |

# III    Safety Instructions

- Read the user manual including all operating instructions prior to installing, connecting and powering up the HyQuest Solutions WLR 8/15/30. The manual provides information on how to operate the product. The manual is intended to be used by qualified personnel, i.e. personnel that have been adequately trained, are sufficiently familiar with installation, mounting, wiring, powering up and operation of the product.
- Keep the user manual on hand for later reference!
- If you encounter problems understanding the information in the manual (or part thereof), please consult the manufacturer or its appointed reseller for further support.
- HyQuest Solutions WLR 8/15/30 is intended to be used in hydrometeorological or environmental monitoring applications.
- Before starting to work, you have to check the functioning and integrity of the system.
  - Check for visible defects on the WLR 8/15/30, this may or may not include any or all of the following mounting facilities, connectors and connections, mechanical parts, internal or external communication devices, power supplies or power supply lines, etc.
  - If defects are found that jeopardize the operational safety, work must be stopped. This is true for defects found before starting to work as well as for defects found while working.
- Do not use the HyQuest Solutions WLR 8/15/30 in areas where there is a danger of explosion.
- The present user manual specifies environmental/climatic operating conditions as well as mechanical and electrical conditions. Installation, wiring, powering up and operating the HyQuest Solutions WLR 8/15/30 must strictly comply with these specifications.
- Perform maintenance only when tools or machinery are not in operation.
- If guards are removed to perform maintenance, replace them immediately after servicing.
- Never make any electrical or mechanical diagnostics, inspections or repairs under any circumstances. Return the product to the manufacturer's named repair centre. You can find information on how to return items for repair in the relevant section of the HyQuest Solutions website.
- Disposal instructions: After taking the HyQuest Solutions WLR 8/15/30 out of service, it must be disposed of in compliance with local waste and environmental regulations. The HyQuest Solutions WLR 8/15/30 is never to be disposed in household waste!
- Inputs and outputs of the device are protected against electric discharges and surges (so-called ESD). Do not touch any part of the electronic components! If you need to touch any part, please discharge yourself, i.e. by touching grounded metal parts.

## Specific Safety Instructions

- The manual provides information on how to operate the sensor system.
- Protect the power supply connection with a fuse (2.5 A fast blow fuse). For cable length exceeding 40 m (131.2 ft), surge protection shall be integrated.
- Please refer to the EIRP power listed in this manual. Note that the main orientation of the sensor is: downward-looking with the core radar beam oriented downwards, installation location must be chosen to avoid the beam is oriented towards living species. The device is designed for use in fixed installation. Mobile applications are not within the scope of the sensor.
- **European Union and European Economic Area**: The national implementation of the framework directive 89/391/EEC and corresponding individual directives, in particular the directive 2009/104/EEC concerning the minimum safety and health requirements for the use of work equipment by workers at work (incl. amendments) must at all times be observed and adhered to.
- **USA-FCC Approval**: The equipment has been tested and found compliant with specifications and limits of Class A digital devices, pursuant to Article 15 of FCC rules. FCC limits ensure electromagnetic compatibility, i.e. a design providing reasonable protection against electromagnetic interference. The HyQuest Solutions WLR 8/15/30 is a device emitting radio frequency. It must be installed and operated in compliance with the User Manual. Non-respect of the stipulations of the manual may result in interference with radio communication devices. When installed in developed areas, a risk of harmful interference exists and it is up to the user to provide necessary measures to limit these interferences at his own expense. **Respect of Local Legislation**: Users must confirm with local legislation. This may or may not include the need to apply and obtain a permission to install a radar sensor. In such a case all provisions of the permission must be observed by the user. Other local/national legislation that must be observed where required concerns any or all of the following topics: safety at work and personnel safety, environmental protection, health issues, electromagnetic compatibility, waste (disposal of products and materials).

# 1    Introduction

Thank you for choosing our product. We hope you will enjoy using the device.

HyQuest Solutions manufactures, sells, installs and operates quality instrumentation, data loggers and communication technology. Products are designed with passion for environmental monitoring and with a deep understanding of the quality, accuracy and robustness needed to fulfil the requirements of measurement practitioners in the field.

The present User Manual will help you understand, install and deploy the device. If, however, you feel that a particular information is missing, incomplete or confusing, please do not hesitate to contact us for further support!

HyQuest Solutions' WLR 8/15/30 is a highly accurate radar level sensor that measures the distance from the sensor to the surface. It uses advanced 80 GHz radar technology to provide accurate and stable measurements. Using contactless technology for measurement of level of fluids and solids provides many advantages over traditional methods due to simple installation, low power consumption and minimal to no maintenance.

# 2    Installation

The level meter must be installed above the water surface, pointing directly towards the water surface. Please read the following carefully and respect these instructions and recommendations as much as possible to obtain the best measurement results.

- Minimum Installation Height above Water Surface: 0.1 m (0.33 ft), recommended > 1 m (3.28 ft)
- Maximum Installation Height above Water Surface: <= max measurement range of the device
- Sensor should be directed at a 90° angle towards the water.

Caution:

- Direct non-obstructed line of sight between sensor antenna and the water surface
- Avoid object in the vicinity of the sensor: may reduce accuracy, introduce offsets
- Reduce vibrations of the mounting structure: affects measurements
- Ensure water surface direct below the sensor is clear of: vegetation, rocks, sand deposition, other obstacles.
  - The sensor applies an algorithmic correction to detect and eliminate obstacles from the distance measurement signal spectrum. However, the correction has limits. Vibrations can further limit the effectiveness of the algorithm.

The figure below shows how the radar should be positioned relative to the water surface.
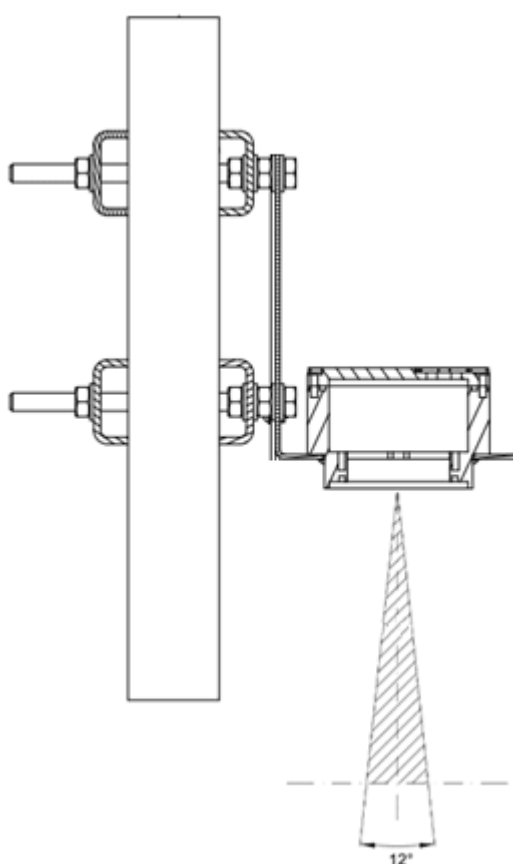


**Figure 1 – Water Level Radar (WLR) Installation**

The height measurement works best when water surface is calm (not too wavy) as flat surfaces better reflect radar beams. In applications with continuous/frequent highly turbulent water, the length of the radar filter can be adjusted to filter out most, if not all the turbulences.

- Slight up to moderate surface waviness will affect reflected signal level (reducing Signal to Noise Ratio SNR), but is unlikely to affect measurement accuracy.
- Strong turbulent flow with high water waviness will reduce accuracy due the unpredictability of the water surface. The averaging effect across the area covered by the radar beam will reduce oscillations.

Instrument radar beam covers a circular area on the water surface. The radar beam has a 3-dB width angle, subsequently the diameter of the pattern on the water surface depends on the distance of the water surface to the instrument. See Table 3 for pre-calculated pattern dimension.

| Height [H] | R | | | Height [H] | R |
|---|---|---|---|---|
| 0.3 m (0.33 ft) | 0.06 m (0.2 ft) | \| | 9 m (29.52 ft) | 1.89 m (6.2 ft) |
| 0.5 m (1.64 ft) | 0.11 m (0.36 ft) | \| | 10 m (32.8 ft) | 2.10 m (6.89 ft) |
| 1 m (3.28 ft) | 0.21 m (0.69 ft) | \| | 11 m (36.08 ft) | 2.31 m (7.58 ft) |
| 2 m (6.56 ft) | 0.42 m (1.38 ft) | \| | 12 m (39.36 ft) | 2.52 m (8.27 ft) |
| 3 m (9.84 ft) | 0.63 m (2.07 ft) | \| | 13 m (42.64 ft) | 2.73 m (8.95 ft) |
| 4 m (13.12 ft) | 0.84 m (2.76 ft) | \| | 14 m (45.92 ft) | 2.94 m (9.64 ft) |
| 5 m (16.4 ft) | 1.05 m (3.44 ft) | \| | 15 m (49.2 ft) | 3.15 m (10.33 ft) |
| 6 m (19.68 ft) | 1.26 m (4.13 ft) | \| | 20 m (65.6 ft) | 4.20 m (13.78 ft) |
| 7 m (22.96 ft) | 1.47 m (4.82 ft) | \| | 25 m (82 ft) | 5.25 m (17.22 ft) |
| 8 m (26.24 ft) | 1.68 m (5.51 ft) | \| | 30 m (98.4 ft) | 6.30 m (20.66 ft) |

**Table 1 – Approximated Height-Dependent Circular Radar Beam Pattern Dimension (Water Surface)**

- Rain and Wind [8]
- Interference and Multiple Radars [8]
- Interference with Fog and Evaporation [9]
- Reflections [9]

## 2.1     Rain and Wind

WLR 8/15/30 instruments has integrated internal software filters to filter out effects of rain, fog or wind for radar distance sensor. These filters however have some limitations. Majority of measurement inaccuracies caused by environmental factors can be solved by proper sensor installation.

For rain and snow suppression, the most effective solution is to mount the radar so that it points directly at water. As rain or snow fall, they affect the water surface, so it isn't as reflective as usually, thus reducing the SNR. However, our devices are tested and calibrated in a way, so they detect the surface even under heavy rainfall.

Influence of the wind on the accuracy is in most cases small and can be neglected. The only exception is strong wind as it will create surface waves and turbulences which can be detected as a shift in level. As mentioned above, length of radar filter can be adjusted to compensate for this.

## 2.2     Interference and Multiple Radars

Distance measurement radar is operating in W-band from 77 GHz to 81 GHz with linear frequency modulation, modulating signal continuously in the mentioned frequency range. To get interference between two or more sensors it will be required to keep central frequencies very precise just like in surface velocity radar and additionally timing synchronization of radar should be kept in range of 25 ns to each other. Such synchronization is very complex to achieve so the interference probability between several radars on the same location is very small.

It is possible that some wideband radiation sources can introduce small and impulse interference for the short period of time, but this should not, or it is very unlikely to affect measurements reported by radar sensor.

## 2.3      Interference with Fog and Evaporation

Generally, radar sensors are not affected by fog or evaporation of water unless very heavy evaporation is present and water density in the air is very high.

The best solution for the distance measurement is in most cases to increase average period to get better average distance value. As evaporation is naturally very turbulent event with significant difference in density over the surface area and in time, averaging of the distance measurement spectrum is solving the problem of accuracy in such conditions.

## 2.4      Reflections

Water is very reflective medium for the radar waves and most of the power transmitted from radar transmitter will be reflected from the water surface. Reflections of the radar transmitted power beam follow the same physical laws as in optics and every time radar beam hits the surface part of the power is reflected away from the radar, part of the power is reflected towards the radar and only a small part of power is absorbed by the water. Depending on the surface roughness and incident angle ratio between power reflected in the direction away from the radar and direction back towards the radar can significantly vary. As incident angle for radars in fixed, only the roughness is determining the ration in our case.

In the case of level meter where incident angle of transmitted radar beam to the water is around 90° most of the power is reflected to the sensor and only small portion of the transmitter power will be dispersed in all directions. Ratio between power reflected to the sensor and power dispersed in all directions is dependent on the surface roughness but in general it is very small amount of the energy that is dispersed, and it is very unlikely that dispersed energy will cause additional multipath problems due to the more reflections from surrounding objects.

# 3        Configuration (formerly Radar Configurator Utility)

HyQuest Solutions provides a user-friendly PC application to configure WLR Water Level Radars. Additionally, the Configurator Utility displays current level readings.

When started, the Configurator Utility displays its main window. Initially, no level data is displayed, as the connection to the level meter device is not established.



**Figure 2 – Level Meter Configurator main window**

To connect the Configurator utility with the level meter, connect your PC to the radar using an RS-232 serial cable connection. Then, select the Radar à Connect menu option in the Configurator Utility, and choose the appropriate COM port number. The Configurator will try to establish a data link between your PC and the level meter device. After the data link is established, active device parameters will be displayed, and the level measurements will be displayed:
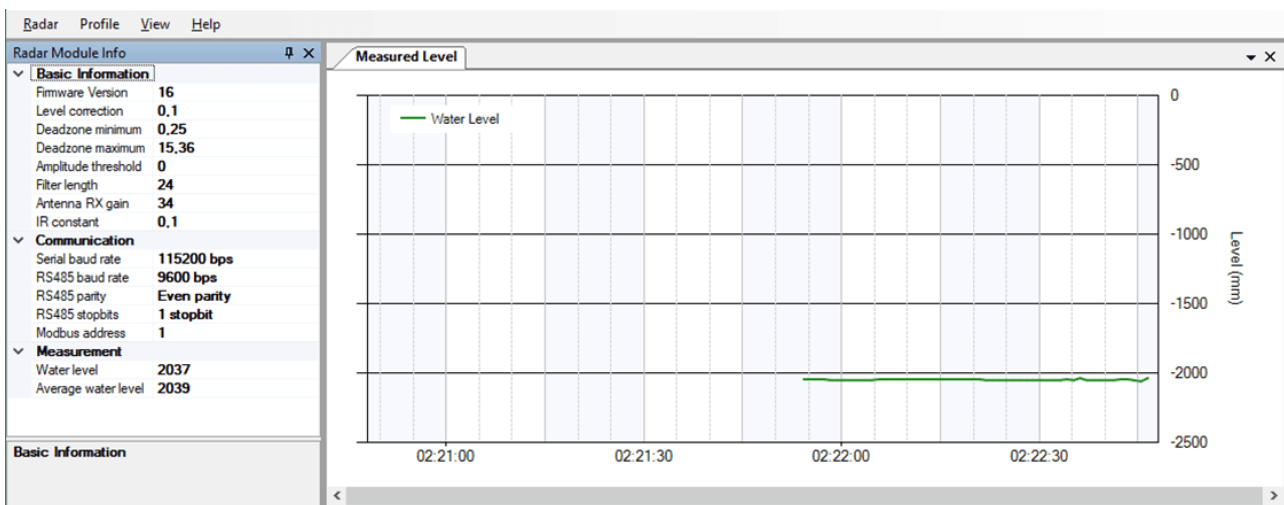


**Figure 3 – Configurator main window with device connected**

The utility window is divided into two panes, that can be manually re-arranged. The first panel (at the left part of the screen) is the Radar Module Info pane that displays the radar level meter information and operating parameters. Some of these parameters can be changed by editing the values directly inside the Radar Module Info pane. The following information is displayed:

| Firmware version | the version of the firmware running in the radar sensor device |
|---|---|
| Level correction | correction in meters to be added to the detected level |
| Dead zone minimum | minimum detected distance |

| | |
|---|---|
| Dead zone maximum | maximum detected distance |
| Filter length | if moving average filter is used, select the averaging window length |
| Amplitude threshold | minimum spectrum amplitude necessary for peak detection |
| RX gain | the current gain value of the radar signal amplifier |
| IR constant | if IR is used, this value is used for the IR filter |
| Serial baud rate | the communication baud rate used for serial communication |
| RS485 baud rate | the communication baud rate used for RS485 communication |
| RS485 parity | parity used on the RS485 bus |
| RS485 stop bits | stop bits used on the RS485 bus |
| Modbus address | device address on the RS485 bus |
| Water level | water level in meters |
| Average water level | average water level in meters, using filter length |

The second pane (in the right part of the window) displays the history graph showing the measured level in the last 30 minutes.

# 4      Repair

HyQuest Solutions precision instruments and data loggers are produced in quality-controlled processes. All HyQuest Solutions production and assembly sites in Australia, New Zealand and Europe are ISO 90001 certified. All equipment is factory tested and/or factory calibrated before it is shipped to the client. This ensures that HyQuest Solutions products perform to their fullest capacity when delivered.

Despite HyQuest Solutions most rigorous quality assurance (QA), malfunction may occur within or outside of the warranty period. In rare cases, a product may not be delivered in accordance with your order.

In such cases HyQuest Solutions' return and repair policy applies. For you as a customer, this means the following:

1.  Contact HyQuest Solutions using the Repair Request Form made available online:

    https://cdn.hyquestsolutions.eu/fileadmin/Services/Downloads/HS-RepairRequestForm_EU.pdf
    In response you will receive a reference number that must be referenced on all further correspondence and on the freight documents accompanying your return shipment.

2.  Please provide as much information and/or clear instructions within the return paperwork. This will assist our test engineers with their diagnosis.

3.  Please do not ship the goods prior to obtaining the reference number. HyQuest Solutions will not reject any equipment that arrives without reference number; however, it may take us longer to process.

Custom requirements for items sent to HyQuest Solutions for warranty or non-warranty repairs: Check with your national customs/tax authorities for details, processes and paperwork regarding tax exempt return of products. Typically, special custom tariff codes are available (such as HS Code = 9802.00) that verify the item is being returned for repair and has no commercial value. Please note that the customs invoice / dispatch documents should also clearly state: "Goods being returned to manufacturer for repair – No Commercial value". It is mandatory to have any returned goods accompanied by a commercial invoice on headed paper. HyQuest Solutions reserves the right to charge the customer for time spent rectifying incorrect customs documents.

**Note**: Please ensure that your goods are packed carefully and securely. Damage that occurs during transit is not covered by our warranty and may be chargeable.

# 5 Technical Data (formerly Electrical Characteristics)

|  | WLR 8 | WLR 15 | WLR 30 |
|---|---|---|---|
| Detection Distance | 8 m | 15 m | 30 m |
| Radar Type | W-band 77-81 GHz FMCW radar | | |
| Beam Angle | 12° both axes | | |
| Blind Zone | 0.2 m | | |
| Resolution | 0.2 m | | |
| Accuracy | ± 3 mm | | |
| IP Rating | IP68 | | |
| Interfaces | ▪ SDI-12<br>▪ Analog: 4 - 20 mA<br>▪ Serial Interface:<br>  ▪ 1 × serial RS-485 half-duplex, 1 × serial RS-232 (two-wire interface)<br>  ▪ Serial Baud Rate: 1200 bps to 115200 bps<br>  ▪ Serial Protocols: Modbus | | |
| Connector | M12 circular 12-pin | | |
| Power Supply | Power Input: 9 to 27 V DC<br><br>Power Consumption: <2.2 W (typical 1.8 W) | | |
| Temperature Range | Operational temperature: -40 °C to +85 °C (without heating or coolers) | | |
| Enclosure Dimensions | Ø 65 mm × H 55 mm | | |
| Compliance | FCC, CE | | |

# 6 Obligations of the Operator and Disposal

This chapter contains the following subsections:

## 6.1 Obligations of the Operator

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*European Union*

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In the Single European Market it is the responsibility of the operator to ensure that the following legal regulations are observed and complied with: national implementation of the framework directive (89/391/EEC) and the associated individual directives, in particular 2009/104/EC, on minimum safety and health requirements for the use of work equipment by employees at work.

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*Worldwide*

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Regulations: If and where required, operating licences must be obtained by the operator. In addition, national or regional environmental protection requirements must be complied with, regardless of local legal provisions regarding the following topics:

- Occupational safety
- Product disposal

Connections: Local regulations for electrical installation and connections must be observed.

## 6.2 Dismantling / Disposal

When disposing of the units and their accessories, the applicable local regulations regarding environment, disposal and occupational safety must be observed.

**Before dismantling**

- Electrical Devices:
  - Switch off the units.
  - Disconnect electrical appliances from the power supply, regardless of whether the appliances are connected to the mains or to another power source.
- Mechanical devices:
  - Fix all loose components. Prevent the device from moving independently or unintentionally.
  - Loosen mechanical fastenings: Please note that appliances can be heavy and that loosening the fastenings may cause them to become mechanically unstable.

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*Disposal*

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Operators of old appliances must recycle them separately from unsorted municipal waste. This applies in particular to electrical waste and old electronic equipment.

Electrical waste and electronic equipment must not be disposed of as household waste!

Instead, these old appliances must be collected separately and disposed of via the local collection and return systems.

Integrated or provided batteries and accumulators must be separated from the appliances and disposed of at the

designated collection point. At the end of its service life, the lithium-ion battery must be disposed of according to legal provisions.

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*EU WEEE Directive*

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As players in the environmental market, KISTERS AG and HyQuest Solutions are committed to supporting efforts to avoid and recycle waste. Please consider:

- Avoidance before recycling!

- Recycling before disposal!

This symbol indicates that the scrapping of the unit must be carried out in accordance with Directive 2012/19/EU. Please observe the local implementation of the directive and any accompanying or supplementary laws and regulations.

# 7 Appendices

This chapter contains the following subsections:

## 7.1        Connector Pin-Out

The level meter uses robust IP66 circular M12 connector with 12 positions and the mating cable is also delivered with the level meter. See the figure below for connector and cable details.
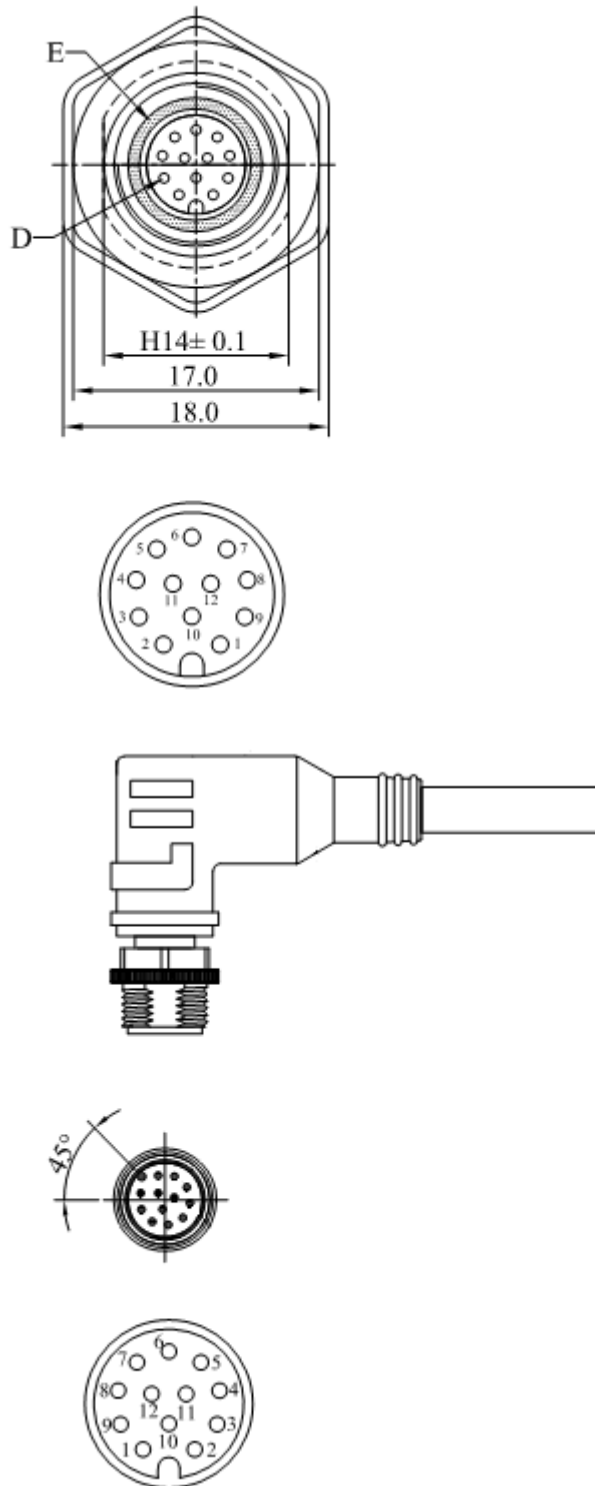


**Figure 4 – Level meter connectors**

The table below shows pin assignments for each single pin of the connector illustrated in the figure above.

| Pin No. | Wire Color | | Pin Name | Pin Description |
|---|---|---|---|---|
| 1 | White | | GND | This pin should be connected to the ground (negative) pole of the power supply. SDI-12 Ground |
| 2 | Brown | | +Vin | WLR supply power Voltage range 9..27 VDC, power supply >= 2.2 W SDI-12 Power |
| 3 | Green | | RS232 – TxD | RS-232 data transmit signal |
| 4 | Yellow | | RS232 – RxD | RS-232 data receive signal |
| 5 | Grey | | --- | ----- |
| 6 | Pink | | --- | ----- |
| 7 | Blue | | --- | ----- |
| 8 | Red | | Vout+ | Output power supply (=Vin) for supply of external optional equipment and for use with analogue 4-20mA output |
| 9 | Orange | | RS485 – D- | RS-485 data transmitter/receiver low signal |
| 10 | Dark Red | | RS485 – D+ | RS-485 data transmitter/receiver high signal |
| 11 | Black | | SDI-12 Data | SDI-12 Data Line |
| 12 | Purple | | 4-20 mA Output | Analogue 4-20 mA output |

**Table 2 – Connector and cable pin-out**

- SDI-12 Interface [19]
- Serial RS-485 Interface [19]
- Serial RS-232 Interface [19]
- Analogue 4-20 mA Output [19]

### 7.1.1    SDI-12 Interface

SDI-12 interface is widely used communication interface in hydrology applications. Such interface is characterized with only one communication wire, slow speed communication and possibility for very long communication cables.

The implemented command set is compliant with SDI-12, Version 1.3 (even though not all commands are fully implemented).

Caution: Differences with SDI-12 sensors

- The Water Level Radar (WLR) is a high-frequency device. The slowest scan rate is 1 sample/sec (1 Hz). A faster version is available with a scan rate of 10 samples/sec (Hz).
- The supply voltage is higher than the standard 5V requirement of the standard.
- The power consumption is higher.

### 7.1.2    Serial RS-485 Interface

Serial RS-485 interface is implemented as standard industrial half-duplex communication interface. Communication interface is short-circuited and overvoltage internally protected. Depending on the receiving device interface can be used with only two wires (D+ dark red wire & D- orange wire) or in some cases ground connection (signal GND grey wire) is also required. For more details please consult receiver specifications.

Most common communication protocol used with RS-485 interface is Modbus-RTU, but other protocols are also available. Details of communication protocols are described later in this manual.

### 7.1.3    Serial RS-232 Interface

Serial RS-232 interface is implemented as standard PC full-duplex serial interface with voltage levels adequate for direct connection to PC computer or other embedded device used for serial RS-232 communication.

In case RS-232 interface is connected to standard DB-9 PC connector, TxD line (green wire) is connected to pin 2 and RxD (yellow wire) is connected to pin 3. For proper operation of serial interface additional connection of signal GND (grey wire) is required on pin 5 of the DB-9 connector.

The serial RS-232 interface is used as a service port. For more details see Servicing protocol (RS-232) 27.

Option – on order: HyQuest Solutions can supply cable with DB-9 connector connected to the cable.

### 7.1.4    Analogue 4-20 mA Output

Analogue current 4-20 mA output is provided for easier compatibility with older logging and control systems. Output is implemented as current sink architecture with common ground. Maximal voltage applied to the sink can go up to 30 VDC providing greater flexibility in connection of the sensor to PLCs, loggers, or data concentrators.

Signal range and function for 4-20 mA analogue output can be configured in setup application so the sensor will be able to signal best suitable value range with available current range. Current step in the sensor is 0.3 µA limiting resolution possible for the value signalling and care has to be taken in the setup of minimal value to be represented by 4 mA and maximal value to be represented by 20 mA, so the resolution is sufficient for the system requirements.
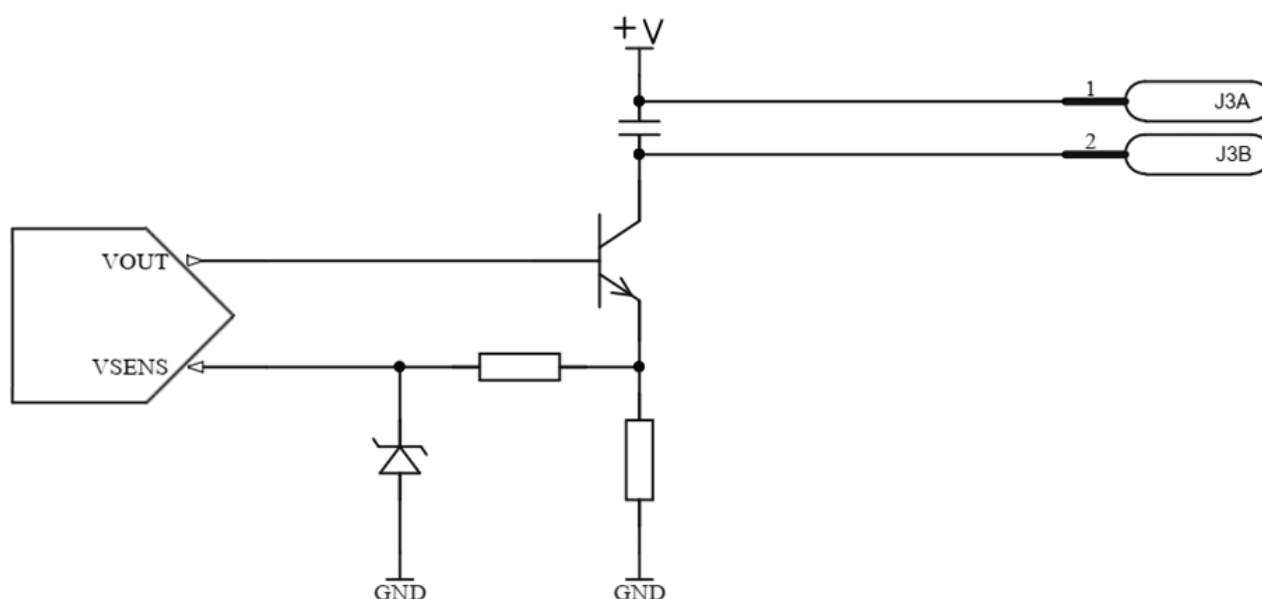
**Figure 5 – Schematics 4-20 mA Output**

## 7.2 Data Interface

WLR 8/15/30 Water Level Radars are equipped with serial data interfaces.

Interfaces available on WLR Water Level Radars are compatible with HyQuest Solutions iRIS Data Loggers, and many third-party data loggers.

- SDI-12 [20]
- Serial RS-485 Interface [21]

### 7.2.1 SDI-12

Serial SDI-12 is the preferred interface in many hydrometeorological applications. Multiple Water Level Radars can be connected via SDI-12 to a single data logger. Level measurements are not reported automatically, but are reported only after being requested by the master device (data logger unit). WLR 8/15/30 implements a sub-set of the SDI-12 Version 1.3 command set. Detailed description of the protocol is given in the Chapter 6 of this User manual.

Default communication parameters are:

| Bitrate: | 1200 bps |
|---|---|
| Start bits: | 1 |
| Data bits: | 7 |
| Stop bits: | 1 |
| Parity: | Even |

## 7.2.2    Serial RS-485 Interface

Serial RS-485 interface is used for connecting multiple level meters to a single data logger. RS-485 allows to connect multiple level meters on a single bus. Level measurements are not reported automatically, but are reported only after being requested by the master device (data logger unit). WLR 8/15/30 supports Modbus RTU over RS-485 bus. Detailed description of the protocol is given in the Chapter 6 of this User manual.

Default communication parameters are:

| Bitrate: | 9600 bps |
|---|---|
| Data bits: | 8 |
| Stop bits: | 1 |
| Parity: | Even |
| Parity: | Even |

## 7.3    Data Protocols

WLR 8/15/30 level meters supports the following data protocols:

- SDI-12 Version 1.3 (sub-set), multiple devices on a single SDI-12 bus
- Servicing protocol on RS-232 interface for configuring the unit, one device per connection
- Modbus RTU on RS-485 interface, multiple devices on a single RS-485 bus

Support for additional protocols is available upon customer request.

- SDI-12 protocol 21
- Servicing protocol (RS-232) 27
- Modbus RTU protocol (RS-485) 29

## 7.3.1    SDI-12 protocol

WLR Water Level Radars will respond to all SDI-12 v1.3 commands. However, the core functionality is assured by means of using the commands referenced in Table 3.

**Note**:

- 'a' represents the device address.
- Active commands to set/change parameters are highlighted in Table 3.

| Name | Command | Response | Details |
|---|---|---|---|
| Address query | ?! | a\<CR>\<LF> | Device will identify using its SDI-12 address, default address is 0 |
| Ping sensor | a! | a\<CR>\<LF> | Device will respond if its address is 'a' |
| Address change | aAb! | b\<CR>\<LF> | Device will respond if its address is 'a' with its new address 'b' |
| Send identification | aI! | a13KISTERS LX-80 fffssssss\<CR>\<LF> | a – address SDI-12 version – 1.3 |

| Name | Command | Response | Details |
|---|---|---|---|
|  |  |  | vendor identification – KISTERS |
|  |  |  | sensor model – LX-80 |
|  |  |  | sensor version – fff, where fff is firmware version |
|  |  |  | sssss - device serial number |
| Start verification | aV! | a00001<CR><LF> | One value is ready imminently |
| Send data | aD0! | a+d<CR><LF> | d – verification:<br>0 -> not ready, 1 -> ready |
| Additional data | aD1! .. aD9! | a0<CR><LF> | No values are returned for additional data |
| Start measurement | aM!/aMC! | ammm8<CR><LF> | 8 values are ready within mmm seconds |
| Send data - aM | aD0! | a+f+f+d+d+d+d+f+f<CR><LF><br><br>a+f+f+d+d+d+d+f+f<CRC><CR><LF> | +f – measured relative level depending on sensor height<br>+f – measured distance from sensor to water<br>+d – measured temperature inside device<br>+d – measured water temperature (on request only)<br>+d – measured tilt angle of device in x direction (on request only)<br>+d – measured tilt angle of device in y direction (on request only)<br>+f – SNR of latest measurement<br>+f - standard deviation of the data in mm |
| Additional data | aD1! .. aD9! | a0<CR><LF><br>a0<CRC><CR><LF> | No values are returned for additional data |
| Concurrent measurement | aC!/aCC! | ammm8<CR><LF> | 8 values are ready within mmm seconds |
| Start measurement | aM1!/aMC1! | ammm9<CR><LF> | 9 values are ready within mmm seconds |
| Concurrent measurement | aC1!/aCC1! | ammm9<CR><LF> | 9 values are ready within mmm seconds |
| Send data - aM1 | aD0! | a+f+f+f+f+f<CR><LF> | +f – significant wave height $H_{1/3}$ |

| Name | Command | Response | Details |
|---|---|---|---|
| | | a+f+f+f+f<CRC><CR><LF> | +f – significant wave height $H_S$ |
| | | | +f – zero cross-up period $T_{ZUC}$ |
| | | | +f – crest period $T_{CREST}$ |
| | | | +f – peak wave period $T_{PEAK}$ |
| Send data - aM1 | aD1! | a+f+f+f+f<CR><LF> | +f – minimum water level $L_{MIN}$ |
| | | a+f+f+f+f<CRC><CR><LF> | +f – maximum water level $L_{MAX}$ |
| | | | +f – average water level $L_{MEAN}$ |
| | | | +f – median water level $L_{MED}$ |
| Aditional data | aD2! .. aD9! | a0<CR><LF> | No values are returned for additional data |
| | | a0<CRC><CR><LF> | |
| Start measurement | aM2!/aMC2! | ammm3<CR><LF> | 3 values are ready within mmm seconds |
| Concurrent measurement | aC2!/aCC2! | ammm3<CR><LF> | 3 values are ready within mmm seconds |
| Send data - aM2 | aD0! | a+f+f+f<CR><LF> | +f – significant wave height $H_{S\_M0}$ |
| | | a+f+f+f<CRC><CR><LF> | +f – zero up-crossing period $T_{ZUC\_SPEC}$ |
| | | | +f – crest period $T_{CREST\_SPEC}$ |
| Additional data | aD1! .. aD9! | a0<CR><LF> | No values are returned for additional data |
| | | a0<CRC><CR><LF> | |
| Continuous measurement | aR0! .. aR9! | a<CR><LF> | The continuous mode is not supported |
| | | a<CRC><CR><LF> | |
| Get measurement unit for level | aXGLUN! | a+d<CR><LF> | +d – measurement unit for level |
| | | | 0 – mm |
| | | | 1 – cm |
| | | | 2 – m |
| | | | 3 – in |
| | | | 4 – ft |
| Set measurement unit for level | aXGLUN+d! | a+d<CR><LF> | +d – measurement unit for level |
| | | | 0 – mm |
| | | | 1 – cm |
| | | | 2 – m |

| Name | Command | Response | Details |
|---|---|---|---|
| | | | 3 – in<br>4 – ft |
| Get minimum active zone value | aXGDZ0! | a+f<CR><LF> | +f – active zone minimum value, sensor will not report measurement lower than this |
| Set minimum active zone value | aXGDZ0+f! | a+f<CR><LF> | +f – active zone minimum value, sensor will not report measurement lower than this |
| Get maximum active zone value | aXGDZ1! | a+f<CR><LF> | +f – active zone maximum value, sensor will not report measurement higher than this |
| Set maximum active zone value | aXGDZ1+f! | a+f<CR><LF> | +f – active zone maximum value, sensor will not report measurement higher than this |
| Get sensor height value | aXGSHR! | a+f<CR><LF> | +f – sensor height above riverbed |
| Set sensor height value | aXGSHR+f! | a+f<CR><LF> | +f – sensor height above riverbed |
| Set current staff gauge reading | aXGSGR+f! | a+f<CR><LF> | +f – current staff gauge reading, device will calculate sensor height above riverbed as: staff gauge reading + distance from sensor to water |
| Get average time in second for level | aXGLAV! | a+f<CR><LF> | +f – averaging time in seconds |
| Set average time in second for level | aXGLAV+f! | a+f<CR><LF> | +f – averaging time in seconds |
| Get filter type for data filtering | aXGLFT! | a+t<CR><LF> | +t – filter type, any of the following:<br>0 – no filter<br>1 – IIR filter<br>2 – Moving average<br>3 – Median<br>4 – Standard deviation |
| Set filter type for data filtering | aXGLFT+t! | a+t<CR><LF> | +t – filter type, any of the following:<br>0 – no filter<br>1 – IIR filter<br>2 – Moving average |

| Name | Command | Response | Details |
|---|---|---|---|
| | | | 3 – Median |
| | | | 4 – Standard deviation |
| Get IIR filter constant | aXGLIR! | a+c<CR><LF> | +c – IIR filter constant used in IIR filter |
| Set IIR filter constant | aXGLIR+c! | a+c<CR><LF> | +c – IIR filter constant used in IIR filter, recommended range is from +0.0 to +1.0 |
| Get peak detector type | aXGPDT! | a+t<CR><LF> | +t – identifies the peak detector type, can be any of the following: <br><br> 0 – report the distance to the maximum peak which corresponds to the maximum radar signal reflection <br><br> 1 - report the last peak which corresponds to the furthest reflection from the radar; this may include multipath reflections in typical cases and should be avoided |
| Set peak detector type | aXGPDT+t! | a+t<CR><LF> | +t – identifies the peak detector type, can be any of the following: <br><br> 0 – report the distance to the maximum peak which corresponds to the maximum radar signal reflection <br><br> 1 - report the last peak which corresponds to the furthest reflection from the radar; this may include multipath reflections in typical cases and should be avoided |
| Get wave analysis length | aXGWAL! | a+f<CR><LF> | +f – the wave analysis length, in range between 0 and 3600 |
| Set wave analysis length | aXGWAL+f! | a+f<CR><LF> | +f – the wave analysis length, in range between 0 and 3600 |

| Name | Command | Response | Details |
|---|---|---|---|
| Get NMEA protocol flags value | aXGNPF! | a+d<CR><LF> | +d – NMEA protocol flag value <br><br> 0 – all sentences are sent <br><br> 1 – $WAV is not sent <br><br> 2 – $ANG is not sent <br><br> 3 – $WAV and $ANG are not sent |
| Set NMEA protocol flags value | aXGNPF+d! | a+d<CR><LF> | +d – NMEA protocol flag value <br><br> 0 – all sentences are sent <br><br> 1 – $WAV is not sent |

| Get NMEA protocol flags value | aXGNPF! | a+d<CR><LF> | +d – NMEA protocol flag value<br><br>0 – all sentences are sent<br><br>1 – $WAV is not sent<br><br>2 – $ANG is not sent<br><br>3 – $WAV and $ANG are not sent |
|---|---|---|---|
|  |  |  | 2 – $ANG is not sent<br><br>3 – $WAV and $ANG are not sent |
| Save background signal level | aXGBKG+d! | a+d<CR><LF> | Stores the radar echo curve signature from zero distance up to defined distance d. The stored echo curve is used as a reference signal background level, and only reflections stronger than the saved level will be used when searching for the water level. To clear this setting, send this command with a parameter d set to 0 (zero).<br><br>+d – distance in currently used units |
| Wake up from sleep mode | aXGLWU! | a+0<CR><LF> | When the instrument is configured to operate in SDI-12 mode, it goes to sleep until SDI-12 measure command (xM!) is issued. Connection to the instrument through RS-232 and RS-485 interfaces is not possible while the instrument is in the sleep mode. To facilitate connecting to the instrument from the PC application, after issuing this command, the instrument will wake up and remain in active state for 60 seconds. During that time, a connection over serial cable can be established using KISTERS Instrument Configurator PC application. If the connection is established within this 60-second period, the instrument will remain in the active state as long as the PC application is connected to the instrument. |
| Clear the stored radar calibration, perform self-calibration, and store new calibration parameters. | aXGCLR! | a+1<CR><LF> | Forces the instrument to clear the stored radar calibration, and to perform the self-calibration again. In majority of cases the factory calibration will be valid through the whole lifetime of the instrument, and there will be no need to redo the self-calibration. |
| Perform factory reset | aXGFAC! | a+1<CR><LF> | Revert the device to default factory settings. To fully revert the device to factory settings, the device must be power-cycled after the factory reset command is executed. |

| Get NMEA protocol flags value | aXGNPF! | a+d<CR><LF> | +d – NMEA protocol flag value<br><br>0 – all sentences are sent<br><br>1 – $WAV is not sent<br><br>2 – $ANG is not sent<br><br>3 – $WAV and $ANG are not sent |
|---|---|---|---|
| Get force continuous calibration value | aXGFCL! | a+d<CR><LF> | +d – force continuous calibration value<br><br>0 – turned off<br><br>1 – turned on |
| Set force continuous calibration value | aXGFCL+d! | a+d<CR><LF> | +d – force continuous calibration value<br><br>0 – turned off<br><br>1 – turned on |

**Table 3 – SDI-12 commands**

## 7.3.2    Servicing protocol (RS-232)

The servicing protocol is used to retrieve and modify device operating parameters. Various device settings, such as unit system and filtering parameters are configured using this protocol. The servicing protocol is always active.

To make radar configuration easy, HyQuest Solutions provides a Configurator utility application. Regular users do not need to be concerned about the servicing protocol used between the Configurator utility and the level meter device. The Configurator utility is described in the Chapter 8 of this manual.

The servicing protocol listens on RS-232 serial port for incoming requests, and on each received request, it will answer back.

The following requests are recognized by the servicing protocol:

**Change serial baud rate**

> Changes the device serial baud rate.
> #set_baud_rate=9600
> #set_baud_rate=38400
> #set_baud_rate=57600
> #set_baud_rate=115200

**Change Modbus ID**

> Changes the Modbus ID of the device. Accepts integer values.
> #set_Modbus_id=<1-255>

**Change SDI-12 ID**

> Changes the SDI-12 ID of the device. Accepts integer values.
> #set_sdi_id=<1-255>

**Change Modbus baud rate**

> Changes the baud rate for Modbus RTU communication with the device.
> #set_Modbus_baud_rate=9600
> #set_Modbus_baud_rate=19200
> #set_Modbus_baud_rate=38400
> #set_Modbus_baud_rate=57600
> #set_Modbus_baud_rate=115200

**Change Modbus parity**

> Changes Modbus RTU parity setting. 0=no parity, 1=odd parity, 2=even parity.
> #set_Modbus_parity=0
> #set_Modbus_parity=1

#set_Modbus_parity=2

## Change Modbus stop bits

Changes the number of stop bits for Modbus RTU communication with the device.
#set_Modbus_stop bits=1
#set_Modbus_stop bits=2

## Change moving average filter

Changes the window length (i.e. the number of samples samples) that are taken into account by their moving average filter. Accepts integer values.
#set_frame_number=<1-1000>

## Change IR filter

XXX Changes the constant used by IR filter. Accepted values are floating point using decimal point between 0 and 1.
#set_IR_constant=<0-1>

## Change measurement offset

Changes level offset. Accepted values are floating point using decimal point in meters. The pre-set value results from factory calibration and should not be changed unless necessary.
#set_level_offset=<0->

## Change amplitude threshold

Changes the minimum spectrum amplitude threshold for peak detection. Peaks below the threshold will not be detected. Accepts integer values.
#set_amplitude_threshold=<0->

## Change Dead zone settings

Changes the dead zone of the radar sensor. Objects below 'Dead zone min' and beyond 'Dead zone max' will not be recorded. Accepted values are floating point using decimal point in millimetres.
#set_Dead zone_min=<0->
#set_Dead zone_max=<0->

## Change 4-20mA settings

Sets the range for the 4-20mA output. 'analogue min' is reported as 4 mA. 'analogue max' is reported as 20 mA. Both values are accepted as floating point, in millimetres.
#set_analogue_min=<0->
#set_analogue_max=<0->

## Change sensor height

Sets the sensor height relative to the bottom of the riverbed. The sensor will output relative measurement of the actual water level based on its height above the riverbed.
#set_sensor_height=<0->

## Retrieve current device status

#get_info

Requests the current device status. Here is an example status output:

# device_type:999

# firmware:16

# serial_number:000000

# Modbus_id:2

# baud_rate:115200

# rs485_baud_rate:9600

# rs485_parity:2

# rs485_stop bits:1

# level_range:15360.000000

# level_resolution:7.500000

# level_offset:0.100000

# Dead zone min:0.200000

# Dead zone max:15.360000

# averaging_frame_number:24

# spectrum_amplitude_threshold:15

# IR_constant:0.250000

# FFT_size:4096

# chirp_slope_rate:40

# ramp_duration:100

# sampling_rate:8191

# number_of_samples:777

# RX_gain:34

# active_TX_antenna:1

### 7.3.3    Modbus RTU protocol (RS-485)

The unit responds to Modbus requests over RS-485 dana line. The baud rate is configured through the PC application, and 1 stop bit, even parity, 8 data bits configuration is used.

Modbus registers that are accessed by Modbus protocol are 16-bit (2-byte) registers. Any number of registers can be read or written over Modbus.

Modbus is a request-response protocol where a master (such as datalogger) sends out requests, and slave devices (such as WLR 8/15/30 sensors) responds. The request and response format, with example is given in tables 3-6.

In each request, the master can either ask the slave to retrieve value of one or more registers, or the master can set the value of one or more registers. Each register holds one 16-bit value.

| Name | Addr | Fun | Data start Addr | | Data#of regs | | CRC16 | |
|------|------|-----|-----------------|---|--------------|---|-------|---|
| Length | 1 byte | 1 byte | 2 bytes (H,L) | | 2 bytes (H,L) | | 2 bytes (L,H) | |
| Example | 0X01 | 0X03 | 0X00 | 0X00 | 0X00 | 0X01 | 0X84 | 0X0A |

**Table 4 – Master request format**

| Name | Content | Detail |
|---|---|---|
| Address | 0X01 | Slave address (Sensor id) |
| Function | 0X03 | Read slave info |
| Data start Addr | 0X00 | The address of the first register to read (HIGH) |
| | 0X00 | The address of the first register to read (LOW) – Sensor ID reg |
| Data of regs | 0X00 | High |
| | 0X01 | Low (read only 1 register) |
| CRC16 | 0X84 | CRC Low |
| | 0X0A | CRC High |

**Table 5 – Request example**

| Name | Addr | Fun | Byte count | Data | | CRC16 | |
|---|---|---|---|---|---|---|---|
| Length | 1 byte | 1 byte | 1 byte | 2 bytes (H,L) | | 2 bytes (L,H) | |
| Example | 0X01 | 0X03 | 0X02 | 0X00 | 0X01 | 0X79 | 0X84 |
| | | | | | | | |

**Table 6 – Slave (sensor) response format**

| Name | Content | Detail |
|---|---|---|
| Address | 0X01 | Slave address (Sensor id) |
| Function | 0X03 | Read slave info |
| Data length | 0X02 | Data length is 2 bytes |
| Data | 0X00 | Data high byte |
| | 0X01 | Data low byte, means ID is 1 |
| CRC16 | 0X79 | CRC Low |
| | 0X84 | CRC High |

**Table 7 – Response example**

Table 7 defines the data returned by the unit when the master requests register read. Table 8 defines how to write device configuration. Rows highlighted in blue denote the important values measured by the sensor. Rows highlighted in green denote operating parameters that could be changed in the field.

| Fun | Data Addr | Data Length | Data Range | Details |
|---|---|---|---|---|
| 0X03 | 0x0001 | 2 bytes | 0 – device range[mm] | Current level measurement |
| | 0x0002 | 2 bytes | 0 – device range[mm] | Average level measurement |
| | 0x0003 | 2 bytes | 0 → 9600<br>1 → 38400<br>2 → 57600<br>3 → 115200<br>0xFF → other/error | RS-232 baud rate |
| | 0x0004 | 2 bytes | 1 - 255 | Modbus ID |
| | 0x0005 | 2 bytes | 0 → 9600<br>1 → 19200<br>2 → 38400<br>3 → 57600<br>4 → 115200<br>0xFF → other/error | RS-485 baud rate (Modbus) |

**Table 8 – Retrieving data from the sensor**

| Fun | Data Addr | Data Length | Data Range | Details |
|---|---|---|---|---|
| 0X03 | 0x0006 | 2 bytes | 0 → no parity<br>    1 stopbit<br>1 → no parity<br>    2 stop bits<br>2 → odd parity<br>    1 stopbit<br>3 → odd parity<br>    2 stop bits<br>4 → even parity<br>    1 stopbit<br>5 → even parity<br>    2 stop bits | RS-485 parity and stop bits |

| Fun | Data Addr | Data Length | Data Range | Details |
|-----|-----------|-------------|------------|---------|
| | | | default → even parity<br><br>1 stopbit | |
| | 0x0007 | 2 bytes | 1-65535 | SDI-12 ID |
| | 0x000A | 2 bytes | 900 - 65535 | Device type;<br>WLR X → 999, 998 |
| | 0x000B | 2 bytes | 1 – 32<br>default: 24 | Number of frames for average measurement |
| | 0x000C | 2 bytes | 1 – 65535<br>default: 0 | Minimum spectrum amplitude threshold, used for detecting peaks |
| | 0x000D | 2 bytes | 0 – device range [mm]<br><br>default → 0 | Dead zone minimum in mm |
| | 0x000E | 2 bytes | 0 – device range[mm]<br><br>default → device range [mm] | Dead zone maximum in mm |
| | 0x000F | 2 bytes | 0 – device range[mm]<br><br>default → device range [mm] | 4-20mA minimum value in mm |
| | 0x0010 | 2 bytes | 0 – device range[mm]<br><br>default → device range [mm] | 4-20mA maximum value in mm |
| | 0x0011 | 2 bytes | 0 – device range [mm] | Level measurement offset |
| | 0x0012 | 2 bytes | 0 – 1000 | IR filter constant<br><br>$$IR_{const} = \frac{value_{int}}{1000}$$ |
| | 0x0013 | 2 bytes | 0 – 34 | RX gain |
| | 0x0014 | 2 bytes | 1 – 3 | Active TX antenna |
| | 0x0015 | 2 bytes | 2 printable characters | Serial number[0-1] |

| Fun | Data Addr | Data Length | Data Range | Details |
|---|---|---|---|---|
|  | 0x0016 | 2 bytes | 2 printable characters | Serial number[2-3] |
|  | 0x0017 | 2 bytes | 2 printable characters | Serial number[4-5] |
|  | 0x0018 | 2 bytes |  | FW version |
|  | 0x0019 | 2 bytes | 4096,8192 | Number of FFT samples |

| Fun | Data Addr | Data Length | Data Range | Details |
|---|---|---|---|---|
| 0X03 | 0x001A | 2 bytes | 0-255 | Temperature of electronics inside the case |
|  | 0x001B | 2 bytes | 0+ | SNR of the current measurement |
|  | 0x0020 | 2 bytes | Current relative level | Current level measured depending on the sensor height; Calculated as sensor height – current level measurement |
|  | 0x0021 | 2 bytes | Average relative | Average level measured depending on the sensor height; Calculated as sensor height – average level measurement |
|  | 0x0022 | 2 bytes | Sensor height | Sensor height in mm above the riverbed |

| Fun | Data Addr | Data Length | Data Range | Details |
|---|---|---|---|---|
| 0x06 | 0x0003 | 2 bytes | 0 → 9600<br>1 → 38400<br>2 → 57600<br>3 → 115200<br>0xFF → other/error | RS-232 baud rate |
|  | 0x0004 | 2 bytes | 1 - 255 | Modbus ID |
|  | 0x0005 | 2 bytes | 0 → 9600<br>1 → 19200 | RS-485 baud rate (Modbus) |

| Fun | Data Addr | Data Length | Data Range | Details |
|---|---|---|---|---|
| | | | 2 → 38400<br>3 → 57600<br>4 → 115200<br>0xFF → other/error | |
| | 0x0006 | 2 bytes | 0 → no parity<br>    1 stopbit<br>1 → no parity<br>    2 stop bits<br>2 → odd parity<br>    1 stopbit<br>3 → odd parity<br>    2 stop bits<br>4 → even parity<br>    1 stopbit<br>5 → even parity<br>    2 stop bits<br>default → even parity<br>    1 stopbit | RS-485 parity and stop bits |

**Table 9 – Writing data to the sensor**

| Fun | Data Addr | Data Length | Data Range | Details |
|---|---|---|---|---|
| 0x06 | 0x0007 | 2 bytes | 1 – 65535 | SDI-12 ID |
| | 0x000B | 2 bytes | 1 – 1000<br>default: 100 | Number of frames for average measurement |
| | 0x000C | 2 bytes | 1 – 65535<br>default: 0 | Minimum spectrum amplitude threshold, used for detecting peaks |
| | 0x000D | 2 bytes | 0 – device range [mm]<br>default → 0 | Dead zone minimum in mm |
| | 0x000E | 2 bytes | 0 – device range[mm]<br>default → device range [mm] | Dead zone maximum in mm |
| | 0x000F | 2 bytes | 0 – device range[mm]<br>default → device range [mm] | 4-20mA minimum value in mm |
| | 0x0010 | 2 bytes | 0 – device range[mm]<br>default → device range [mm] | 4-20mA maximum value in mm |
| | 0x0011 | 2 bytes | 0 – device range [mm] | Level measurement offset |
| | 0x0012 | 2 bytes | 0 – 1 | IR filter constant<br><br>$$IR_{const} = \frac{value_{int}}{1000}$$ |
| | 0x0015 | 2 bytes | 2 printable characters | Serial number[0-1] |
| | 0x0016 | 2 bytes | 2 printable characters | Serial number[2-3] |
| | 0x0017 | 2 bytes | 2 printable characters | Serial number[4-5] |
| | 0x0022 | 2 bytes | Sensor height | Sensor height in mm above the riverbed |

**Table 10 – SDI-12**

## 7.4 Mechanical Drawing

For mechanical dimensions of the Water Level Radar (WLR), please refer to the figure below.
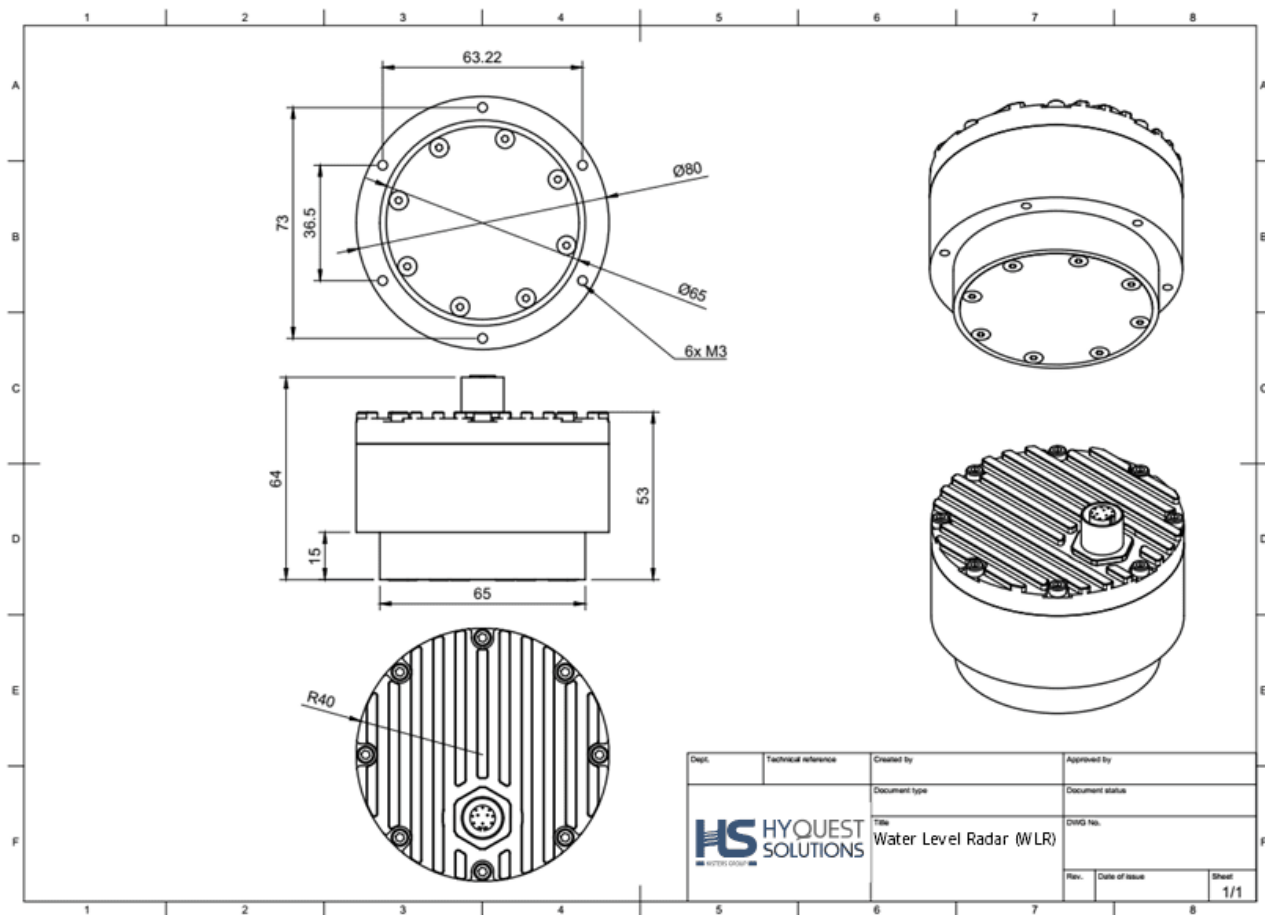


**Figure 6 – HS Water Level Radar (WLR): Mechanical Drawing, all dimensions in mm (1 mm = 0.00328 ft or 0,0393701 inch)**

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