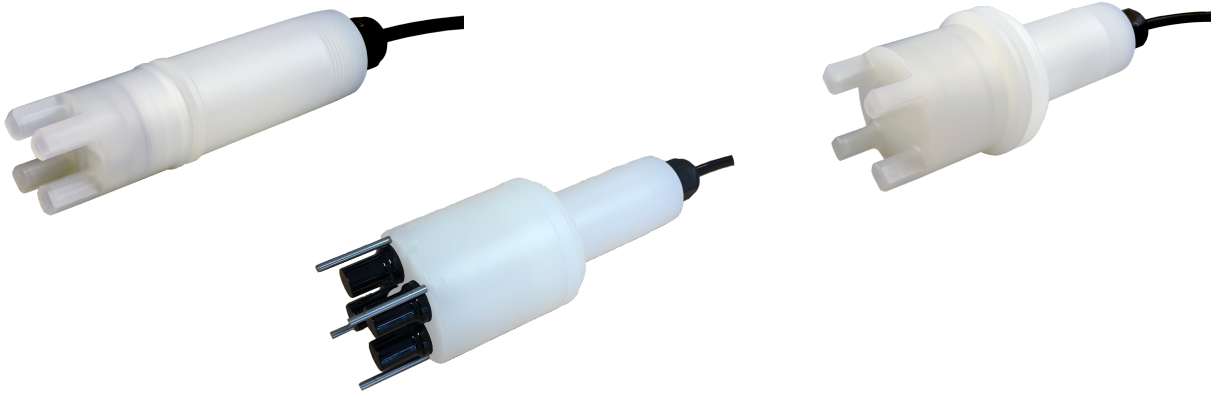
QUADBEAM
TECHNOLOGIES

NEXT LEVEL EFFICIENCY

S20-SWW, S40-SWW and T30-SWW Suspended Solids / Turbidity Sensor



Operating Manual

Modbus + relay output + 4-20mA version

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Intended Use
Responsibility for use of the Quadbeam Technologies sensors with regards suitability for application, intended use, resistance of the sensor components against degradation in the environment used is solely with the operator of the sensor.

The manufacturer is not liable for any damage resulting from the use of the sensor beyond the cost of the sensor.

The intended use of the Quadbeam Technologies S20-SWW, S40-SWW and T30-SWW sensors is the continuous monitoring of Suspended Solids concentration and/or turbidity in a non hygienic industrial, storm water, raw water or waste water installation.

Product Warranty
The S20-SWW and S40-SWW Suspended Solids Sensors have a warranty against defects in materials and workmanship for one year from the date of shipment. During this period Quadbeam Technologies will, at its own discretion, either repair or replace products that prove to be defective.

Limitation of Warranty
No warranty of fitness for a particular purpose is offered. The user assumes the entire risk of using the product. Warranty does not cover damage caused by accidental misuse, abuse, neglect, misapplication or modification. Any liability of Quadbeam Technologies Ltd is limited exclusively to the replacement of defective materials or workmanship.

Disclaimer
Quadbeam Technologies Ltd reserves the right to make changes to this manual or the instrument without notice, as part of our policy of continued developments and improvements.
All care has been taken to ensure accuracy of information contained in this manual. However, we cannot accept responsibility for any errors or damages resulting from errors or inaccuracies of information herein.

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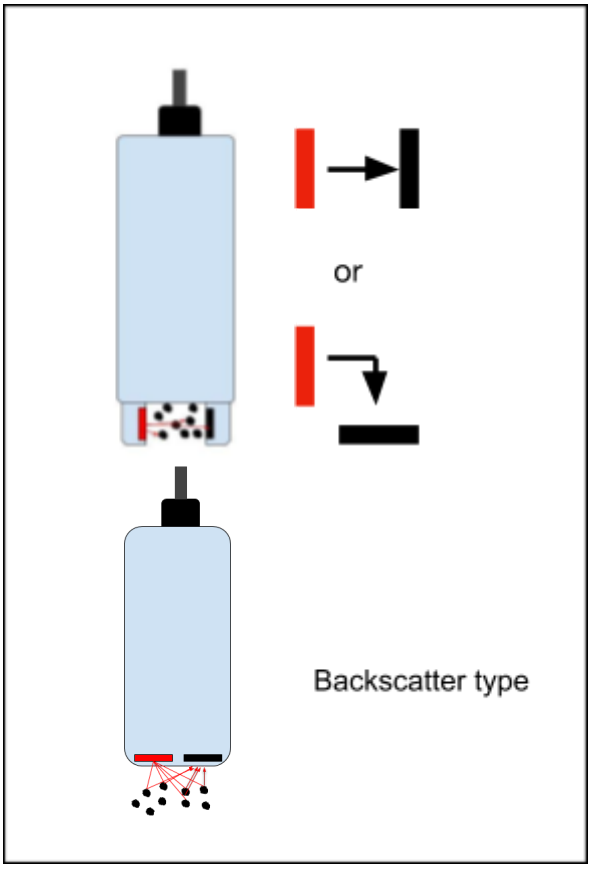
Technologies commonly used in Suspended Solids and Turbidity Sensors

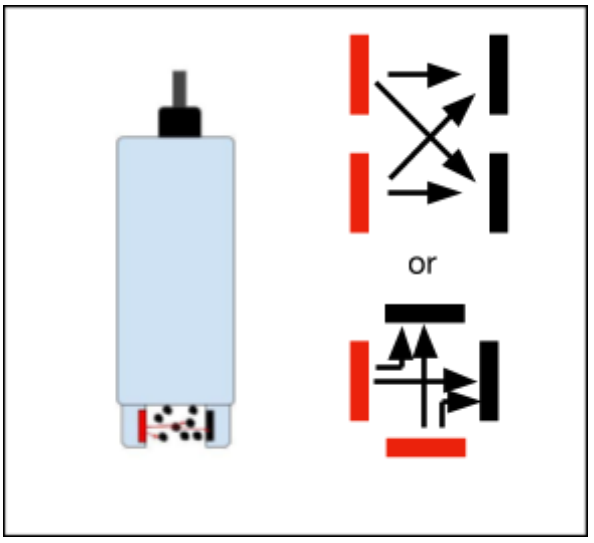
Quadbeam uses the four beam alternating light ratio-metric system of measurement for its sensors.

Suspended Solids Sensors and Turbidity Sensors measure the change in light intensity to produce a relative measure of the solids or turbidity concentration in the liquid being monitored.
Most commonly sold suspended solids sensors and turbidity meters use only a single beam of light. When a single beam of light is used the intensity of the light can be influenced by not only the solids particles suspended in the liquid, but also any solids/contamination that are stuck to the surface of the sensor and variability of the light source and photo diode as they age. Therefore it is critical to keep single beam sensors very clean to get accurate readings.

Multi-beam sensors like the Quadbeam measure across multiple light paths. This allows them to use mathematical algorithms where the change in ratio of intensity of light is measured. This system automatically compensates for contamination stuck to the surface of the sensor and variation of the light components in the sensor. For this reason it is common for multi beam sensors to be used in Process Control installations where a repeatable output is very important.



Common Single Beam Configurations. Signal drifts as sensor ages or gets contaminated



Multi-Beam Configurations. Algorithm compensates for contamination and ageing giving very repeatable signal.

Applications

The Quadbeam SWW sensors can be used in a wide range of Turbidity and Suspended Solids Monitoring and Control Applications, including;

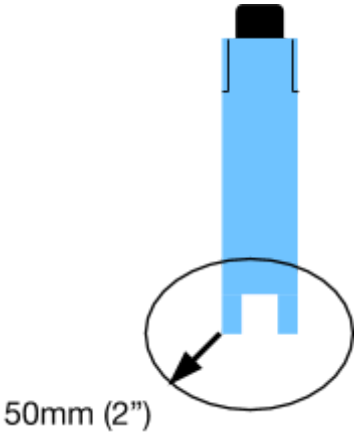
- Stormwater Sediment Monitoring and Control
- Wastewater Suspended Solids Monitoring
- Flocculant Dosing Control
- Environment Turbidity Monitoring
- Raw Water Supply
- Remote Turbidity Monitoring
- Irrigation Water Turbidity Monitoring

Installation

The S20-SWW can be installed inline or immersion
Suspended Solids Sensors and Turbidity Meters work by measuring the change in light intensity. Therefore anything that can reflect, deflect or absorb the light will affect the output of the sensor.

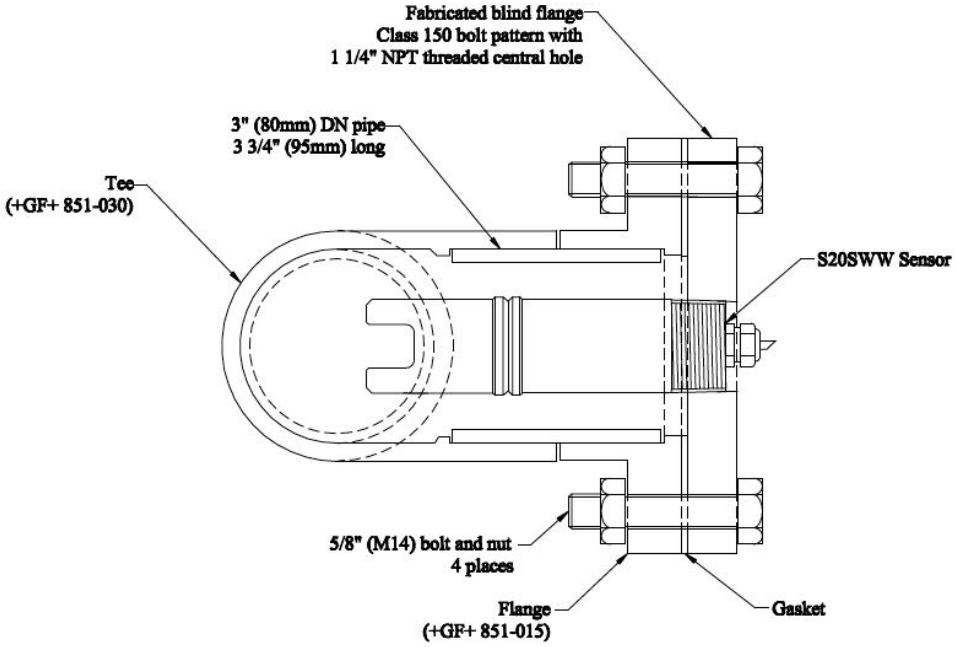
Things that can affect the output of the sensor:
- The suspended solids being measured
- Air bubbles
- Ambient light
- Pipe or vessel walls
- Particle size
- Different materials react differently to 880nm NIR

Keep a Clear Zone
To reduce the chance of reflection of walls of flumes, tanks, channels, sumps etc, it is recommended where possible to have a “Keep Clear” zone from all objects of at least 50mm (2”)



Protect from Sunlight
The spectrum of light from the sun includes 880nm, the wavelength used in these sensors. Therefore they will detect sunlight when exposed directly. Where possible protect from direct sun, a simple cover or “hat” works well.

Pipe Installation
The simplest method for pipe installation is by creating a T with a blank flange and screwing the sensor into the blank flange.



When installing in a pipeline, for best performance position 10 x D downstream and 5 x D upstream from any valve, bend, T, instrument, pump etc.
For horizontal pipe, avoid mounting on top or bottom of the pipe. Bubbles can be present at top and higher solids at bottom.
For vertical, only mount where the flow is in the upwards direction.

Cleaning

Because of the use of the four beam ratiometric technology, the SWW sensor does not have to be perfectly clean to work, only clean enough for light to travel across the light path.

Consider the angle of the sensor relative to the flow. If positioned at an angle away from the flow, the chance of anything getting caught reduces, while maintaining flow over the fingers often induces enough flow to keep clean enough.

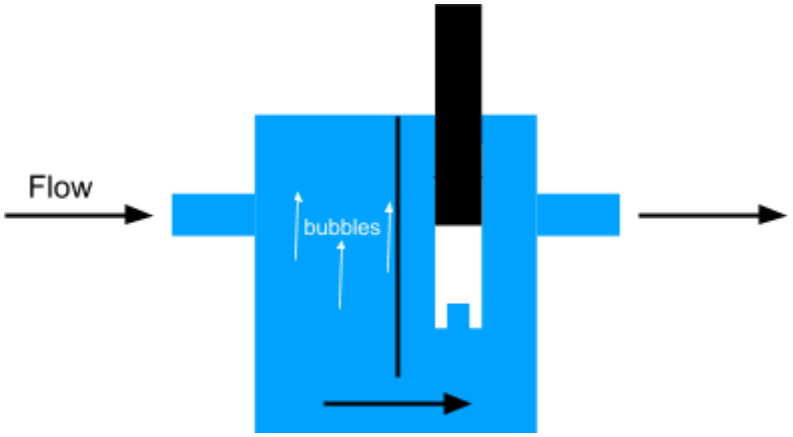
If contamination is too great for simply flow to remove, a cleaner cage is available. This locks onto the head of the sensor.

For remote locations a simple low power submersible pump attached to the cage can create enough flow to keep fingers clean. In locations where air or pressure water is

available, apply this occasionally to the sensor via the cleaner cage. A solid state relay is available in the sensor which can be set up to actuate a switch.

Air Bubbles

Air bubbles can distort the output from Suspended Solids Sensors and Turbidity Meters. It is important to reduce bubbles wherever possible.
Using a simple baffle box can help remove bubbles: flow is decreased allowing the bubbles to rise to the top of the inlet side while liquid flows under the baffle.



Wiring and Programming

For complete information please refer to Appendix B S20SWW Wiring and Programming Manual.

Connection
The SWW series has two power options:

1. 2.7 -5.5V (intended for LiPo battery). This option supports RS485 communications only.

2. 9-32V. This option supports both RS485 and 4-20mA. Refer to Appendix B "Wiring and Programming" for more detail.

Wiring
Determine first which power option is to be used.

	Blue	Gnd ⏚
	Black or Grey	2.7 - 5.5V LiPo
	Brown	9 - 32V
	White	4-20mA out
	Green	RS485 - A
	Yellow	RS485 + B
	Red	SSR1
	Orange or Pink	SSR2

Supply power is either Black or Brown - NOT both

! IMPORTANT !
DO NOT CONNECT BLACK WIRE TO 9-32V

Note 1: *Energising the output solid-state relay (SSR) connects the two SSR pins together.*

Note 2: *The LiPo versions do have reverse-polarity protection. However please guard against the natural tendency to connect Black to Gnd.*

Note 3: *Supply power to either Black or Brown, not both.*

Note 4: *The 4-20mA output is powered from the Brown and does not work when the sensor is powered from the Black.*

Calibration

For more details refer to Appendix A.

Probe Signal Output Value (PS)

Probe Signals is the raw output from the sensor's four beam alternating light algorithm. This signal is very repeatable as the four beam algorithm compensates for contamination on the sensor surface and ageing of the electronics.
If the sensor detects an "impossible" set of measurements and is unable to calculate a PS value, then it flags an error condition. In the presence of an error condition the PS value can be set to its maximum possible value. This is the default behaviour. See "Limp Mode" in the programming chapter if you want to change this.
The aim of calibration is to relate PS to a concentration range to be measured.
The sensor can be configured to provide a meaningful output corresponding to the operator's preference, such as NTU or g/m^3.

Setup using Modbus RS485

Ex-factory, the Modbus device address is 1. If there will be other devices on the bus, change the device address by first setting the "debug" flag (bit 9 of register 8), and then setting the desired new address in register 16. (See Appendix B for details.)
Place the sensor in the lowest solids concentration fluid in the range to be measured take note of the PS value, register address 3.
Place the sensor in the highest solids concentration in the range to be measured, take note of the PS value, register address 3.
This is now the minimum and maximum points of the expected measurement range and can be related to the "engineering values" used to measure the concentration of the samples, for example mg/l or g/m^3.
Span the 4-20mA over this range by inserting the PS value for the lowest concentration into register 5 and the PS value for the highest in register 6.

4-20mA and Relay Setup

For full details refer to SWW Wiring and Programming Manual and Appendix A and Appendix B of this document.

No Modbus? Then setup using PC software "SWW Configurator"

1. Connect Sensor to power supply
2. Connect Sensor to USB-RS485 dongle then plug into computer running the configuration software (supplied on USB memory card with sensor)
3. Confirm communications are running ("Running" in status bar)
4. Place the sensor in the lowest solids concentration fluid in the range to be measured, and take note of the sensor output value
5. Place the sensor in the highest solids concentration fluid in the range to be measured, and take note of the sensor output value
6. Span the 4-20mA by inserting the sensor output value for the lowest concentration into the 4mA box and the PS value for the highest in the 20mA box.

Calibration Tips

Use identical test vessels for each test.

Keep the sensor in the centre of the test vessel

Keep ambient light as constant as possible

Keep temperature as constant as possible

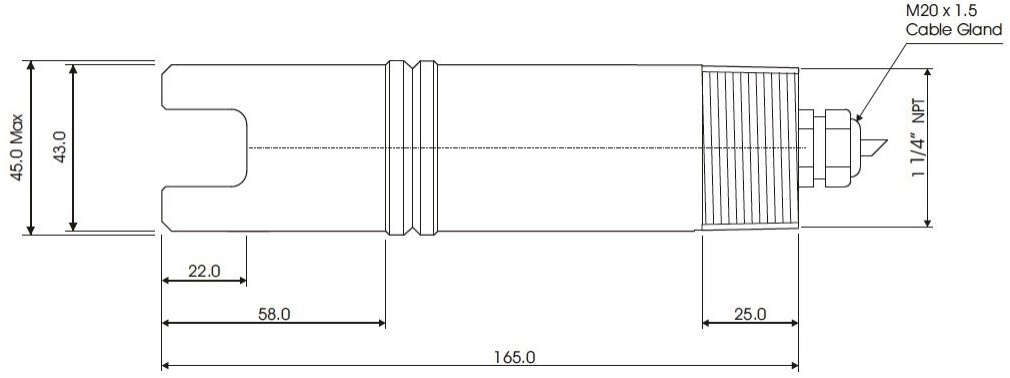
Ensure suspended solids being measured do not quickly drop out or float to top. Use stirrer if necessary

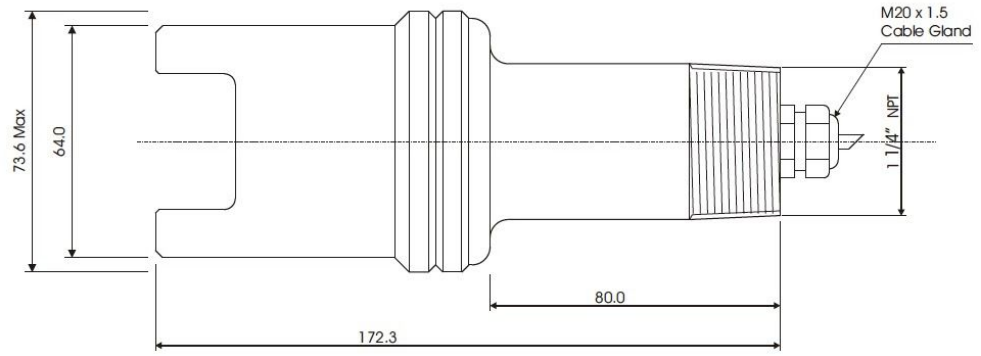
Where possible use the actual liquid and solids that are to be monitored. Different materials absorb NIR at different rates so for more repeatable results use the materials that are in fact going to be measured.

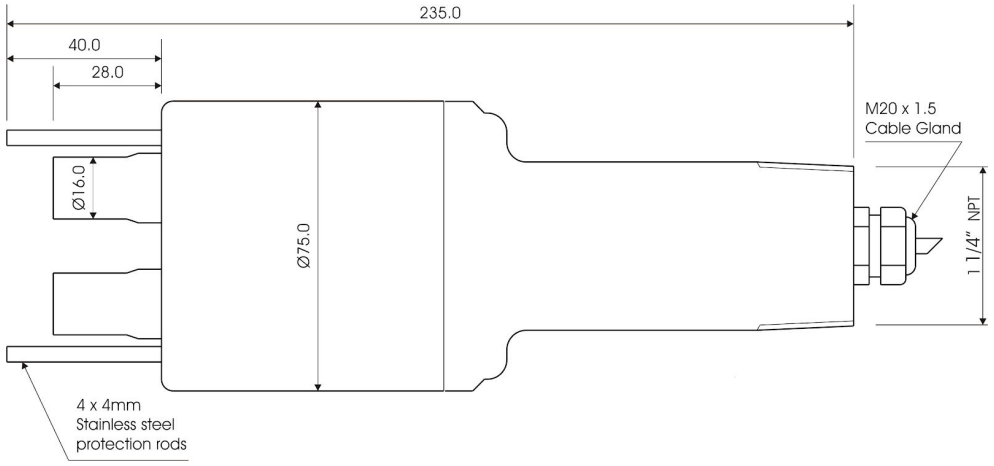
Specifications

Measuring Range will vary depending on media and particle characteristics

S20-SWW	0 to 10g/l normal activated sludge
S40-SWW	0 to 2.5g/l normal activated sludge
T30-SWW	0 to 1000 NTU
Accuracy	+/- 2% of reading
Repeatability	+/- 1% of reading
Temperature	0 to 50 C
Body Material	Polypropylene
Max Pressure	5 bar
Cable Material	Polyurethane
Cable Length	10m
Wavelength	880nm
Outputs	RS485, 4-20mA, 1x SS relay
Power Requirements	0.15W at 5V for Modbus only or 9 to 32V for 4-20mA and Modbus
Optional Extra	Cleaner cage assembly

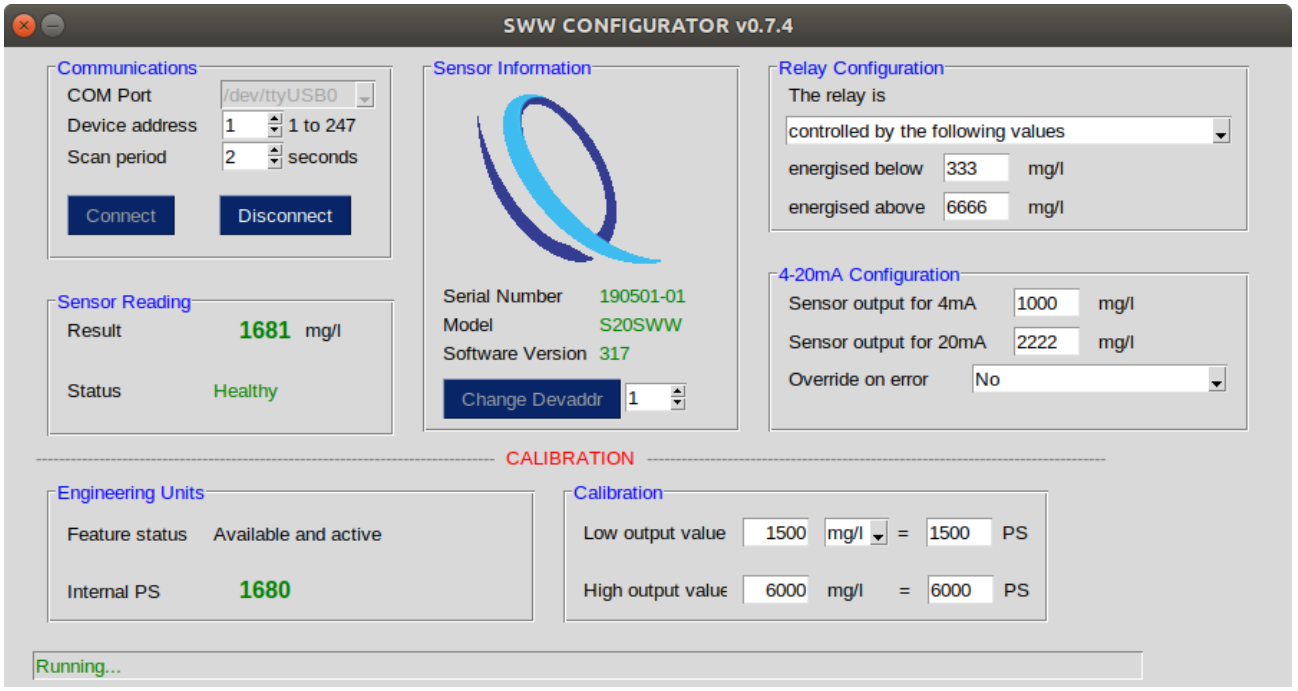



M20 x 1.5
Cable Gland
73.6 Max
64.0
1 1/4" NPT
80.0
172.3


235.0
40.0
28.0
M20 x 1.5
Cable Gland
Ø16.0
Ø75.0
1 1/4" NPT
4 x 4mm
Stainless steel
protection rods

Appendix A - Configuration using PC Software Provided

All readings can be made by using Modbus commands. Also, all settings can be changed using Modbus commands: see Appendix B. This software is intended for the convenience of customers who do not have Modbus, but need to change some of the settings from the factory defaults.



The sensor leaves the factory with the most common settings[1]. These are:

- Modbus device address 1, Baud rate 19200,E,8,1
- Relay output de-energised up to, and energised above, PS=2500
- Analogue output follows the PS value
- The PS value goes to maximum while a measurement error condition is present

The Modbus device address must be unique on the bus. If this sensor will be used on a Modbus network with other devices, the address value of this unit must be changed. Connect to the sensor at its current address, then set the new chosen value next to the “Change Devaddr” button and press it. Permissible values are 1 to 247. You will lose communication with it, so if you want to continue, you have to put the new address in the “Device address” box.

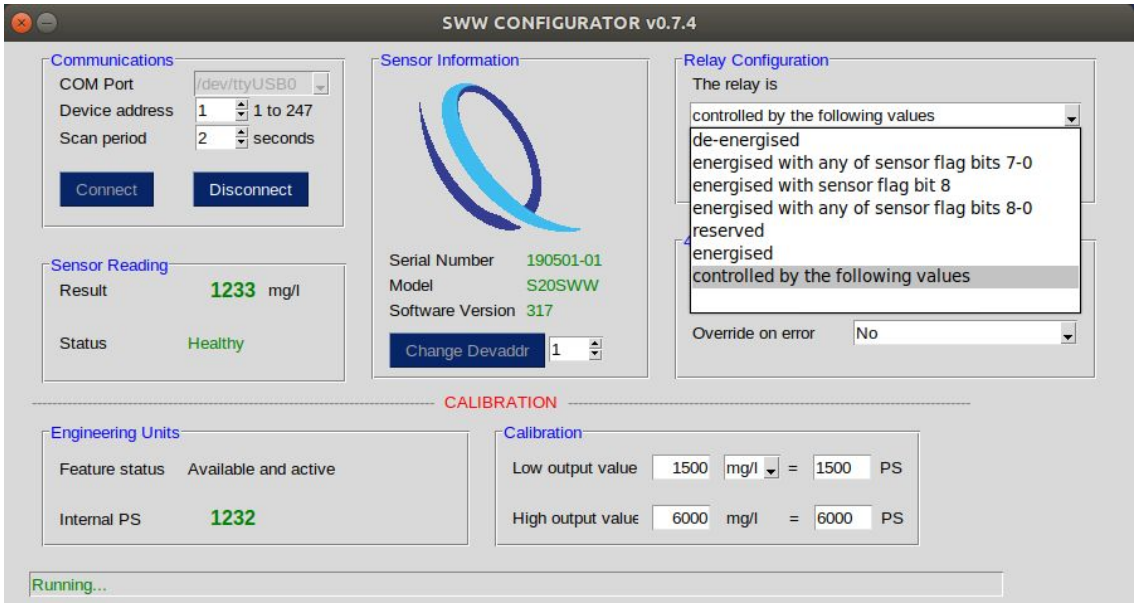
To change the behaviour of the relay output, there are several possible choices. Choose the setting from the dropdown list.

In the "Depends on sensor output value" mode, there are two possibilities:

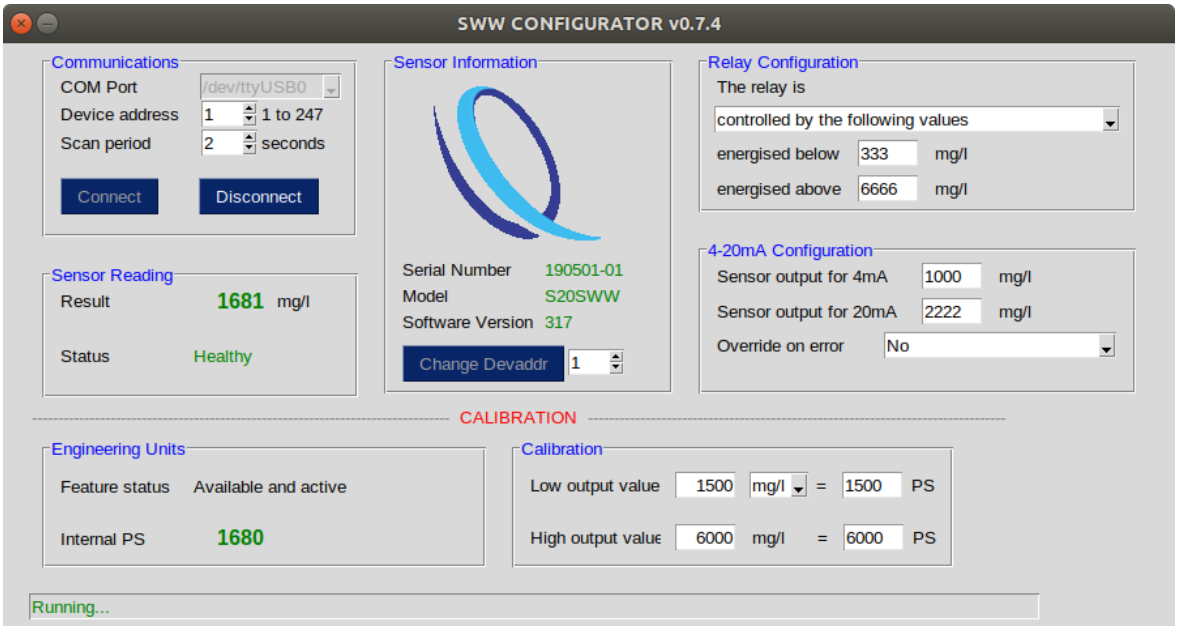
- the relay is energised between two PS values: put the lower value in the first box and the higher value in the second box, or

[1]While correct at time of initial publication, these may change without notice.

- the relay is de-energised between two PS values: put the higher value in the first box and the lower value in the second box.



There is no hysteresis feature. If this is required then it must be implemented in software by the recipient of the process signal (the analogue or digital representation of the sensor output value). The reading is normally updated approximately 3 times per second, so the worst case situation is that the relay could change state every time, i.e. at 1.5Hz.



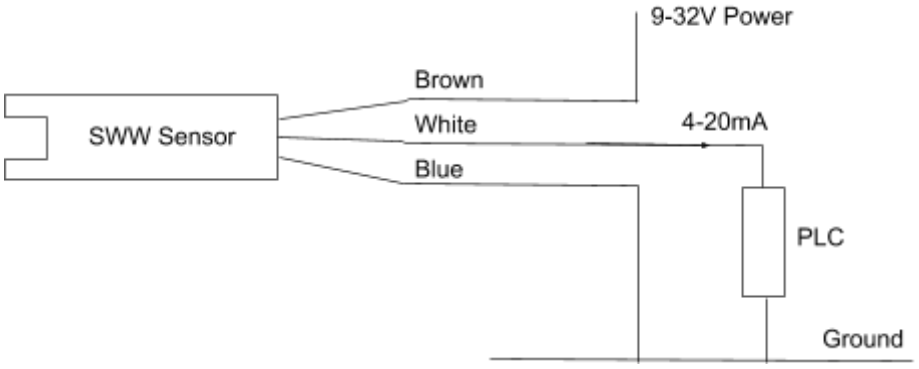
In normal operation the value of the 4-20mA output signal is controlled by the PS value, linearly scaled in the span between the two values. For example, if the application needs extra resolution in the PS value range 1600 to 2200, the 4-20mA signal can be zoomed in to only this region. The drawback is that values outside this range are offscale.

To control what happens in the event of a sensor or measurement error, choose from the dropdown list.

Appendix B - Wiring and Programming

Introduction

This is a family of sensors with different features. They can be powered from 3.3-5.5V (intended for a LiPo battery) or alternatively from 9-32V (intended for plant 12V or 24V supply).
When powered from 9-32V, there is a 4-20mA analogue output available. There is no supply voltage booster, so if the supply is only 9V then the analogue output will be unable to drive the full 20mA into a 500 ohm burden (which would need at least 10V output). A lower value of burden resistor must be chosen in this situation.



All variants have a solid-state relay output as well, with a maximum current when on of 100mA, and a maximum voltage when off of 400V.
The sensor uses a total power consumption of about 150mW plus whatever is required to drive 3V comms into 120R terminators if connected, plus the power necessary to drive 4-20mA into its burden, if connected.

All settings are changed by serial data.

- MB, using RS485 multidrop hardware
  using the Modbus RTU protocol, following Modicon document PI-MBUS-300 Rev.J (June 1996). The sensor implements the minimum requirements of Modbus RTU. The comms parameters are 19200,8,E,1. It only responds to functions 03, 06 and 16, read and write holding registers. Ex-factory the device address is set to 1.

There are no single-bit “coils” or “inputs” that can be set or read. There are only “holding registers” which hold 16-bit unsigned numbers. The raw result of the measurement by the Quadbeam system is a number called a “Probe Signal Value”. There is a feature enabling conversion to engineering units (this is the only one which can go negative). Each sensor should ideally be individually calibrated in the process conditions which prevail during operation of that sensor.

Table of Holding Registers (Modbus)

Register number	Reg. address	Name	RO	WP	NV	Brief Description
40001	0	MANUFACTURER		X	X	0x5142 (“QB” in ASCII)
40002	1	MODEL_NUMBER		X	X	0x0020 (32_D) = SSD20W 0x0014 (20_D) = S20SWW 0x0028 (40_D) = S40SWW 0x001e (30_D) = T30SWW
40003	2	SOFTWARE_VER	X		X	Build number
40004	3	PS_VALUE	X			Sensor reading
40005	4	FLAGS_VALUE	X			Sensor status flags byte
40006	5	PS_FOR_4MA			X	Output value for analogue zero output
40007	6	PS_FOR_20MA			X	Output value for analogue full-scale output
40008	7	RANGE_&_UNITS				0='mg/l', 1='g/l', 2='ppm', 3='%', 4='NTU', 5='FNU', >5=<blank> [NUBS]
40009	8	ACTION_FLAGS			X	Output signal control (see below)
40010	9	RELAY_ON_ABOVE			X	Relay output “ON” above this PS value
40011	10	RELAY_ON_BELOW			X	Relay output “ON” below this PS value
40012	11	FORCE_CURRENT		X		Force a known 4-22mA output. Cleared on powerup. Overrides output when within 4000-22000 range.
40013	12	DAC_FOR_4MA		X	X	Adjust accuracy of 4mA output
40014	13	DAC_FOR_20MA		X	X	Adjust accuracy of 20mA output
40015	14	DAC_NOW	X			Value being converted to current now
40016	15	COMMS_ERROR_COUNT	X			Running total of comms errors since last power-up
40017	16	MODBUS_DEVADDR		X	X	Modbus device address, 1 - 247
40018	17	DATA_MAPVERSION	X		X	Version number of this table
40019	18	SENSOR_SERNUMLO	X	X	X	Serial number part 2 [NUBS]
40020	19	SENSOR_SERNUMHI BUS_ERR_COUNT	X	X	X	Serial number part 1 [NUBS]

RO (read only) means that writing these locations has no effect.
WP (write protected) means that the *Debug* flag must be set to allow changes.
NV (non-volatile) means that the setting survives power-cycling.
[NUBS] means this value is not used by the sensor

Sensor software 316 added a “scale and offset” feature, which is implemented as a two-entry lookup table as follows.

Register number	Reg. address	Name	RO	WP	NV	Brief Description
40043	42	UNITS_KEY			X	Flags indicating options, see below
40044	43	UNITS_PS1			X	
40045	44	UNITS_ENG1			X	
40046	45	UNITS_PS2			X	
40047	46	UNITS_ENG2			X	
40048	47	UNITS_ENGLO			X	Result when below table, and not extrapolating
40049	48	UNITS_ENGHI			X	Result when above table, and not extrapolating
40050	49	UNITS_RESULT	X			

Options flags UNITS_KEY register contents

					Extra-polate above table	Extra-polate below table	Swap RESULT with PS_VALUE	Enable	Even Parity
Bit 9	Bit 8	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0

1. Table entries must be in ascending order of sensor reading.
2. Default for all sensors is to extrapolate above and below the table, not to swap the result into the sensor output “probe signal” PS_VALUE register, and Enabled. The parity bit is therefore set to 1 to make an even number of 1’s.
3. If any of these values is/are changed, there is a write to non-volatile memory. The comms reply to the message will occur, but after that the sensor may “go deaf” for 100ms or so.

Sensor software 330 added a “smoothing” feature, whereby the output of the sensor is the average of the previous 4 - 64 instantaneous valid readings. The ex-factory setting is 8. Each reading takes approximately 400ms, so the largest amount of smoothing implies a delay of at least 25 seconds. If there are any invalid readings in the sequence (and Limp Mode is turned off, see below) it will take longer.
Sensor software 330 adds a "smoothing" feature to the output value.

Register number	Reg. address	Name	RO	WP	NV	Brief Description
40043	50	AVERAGING_WINDOW_SIZE				Output value is the average of the previous 4 - 64 values. Ex-factory this is set to 8.
40044	51	AVERAGING_METHOD				Reserved for future. The method used is a simple arithmetic mean.
40045	52	SMOOTHING_SIZE				Reserved for future. Memory set aside for previous reading is fixed at 64.

Sensor software 332 adds register 53 which contains 15-bits "Microamps" which is the calculated analogue output, and the top bit is the relay state. This allows simple user software to indicate these values on the screen.

Register number	Reg. address	Name	RO	WP	NV	Brief Description
40051	53	R_OUTPUT	X			15 bits analogue output in uA, top bit = relay output

Table of FLAGS_VALUE: sensor status bits, measurement errors

		Custom	Not used	Partial Impedance	Gain error	Full depletion	Partial depletion	Signal overload	No signal
Bit 9	Bit 8	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0

Table of ACTION_FLAGS: what happens to outputs in various situations

Unpublished	Debug	Res-erved	LIMP	Relay output	4-20mA output
Bits 15-10	Bit 9	Bit 8	Bit 7	Bits 6-4	Bits 3-0

To allow the Modbus address to be changed, **Bit 9** must be set.

Bit 7 can be set to disable the normal behaviour that PS=full-scale if an error is present. This defeats the measurement validity checks, and allows potentially invalid output results to be calculated and output. If you set this bit, you should always check status (FLAGS_VALUE) to confirm confidence in the PS value.

Bits 6-4: relay output control
The SSR Form A (see datasheet for International Rectifier PVT412 “Connection A” for more details) connects the Red and Orange cable cores together when energised.
0 = de-energised
1 = energised if any of sensor flag bits 7-0 is/are set
2 = energised if sensor flag bit 8 is set
3 = energised if any of sensor flag bits 8-0 is/are set
4 = reserved
5 = energised
6,7 = controlled by values of PS, RELAY_ON_ABOVE and RELAY_ON_BELOW as follows.
If RELAY_ON_ABOVE is lower than RELAY_ON_BELOW, then the relay is energised when the PS value is between the two, and de-energised otherwise. If RELAY_ON_BELOW is lower than RELAY_ON_ABOVE, then the relay is de-energised when the PS value is between the two, and energised otherwise. If RELAY_ON_BELOW and RELAY_ON_ABOVE are the same, the relay is de-energised.

Bits 3-0 (bottom nybble): 4-20mA output control
In normal operation, the output signal is a linear interpolation of the PS value, in the range specified by the contents of registers 5 and 6. Optionally, this can be overridden and forced to a special value in the event of an error by setting these bits.
0 = any of FLAGS_VALUE bits 7-0 is/are set causes 22mA to be output
1 = any of bits 7-0 is/are set causes 20mA to be output
2 = any of bits 7-0 is/are set causes 4mA to be output
3 = any of bits 7-0 is/are set causes the output to freeze (i.e. hold its last “good” value)
4..15 = output signal is not affected by error conditions.
Note that some sensor errors can cause the PS calculation to produce a zero or full-scale value (16000 for S Series) and this “erroneous” PS value will be converted to mA.
If the *Debug* flag is set, the output signal can be forced to any arbitrary value by setting the “FORCE_CURRENT” register to a value from 4000-22000. This register is cleared to 0 at power-up.