Manual

Starflow QSD Model 6527B and 6537A

This equipment has been tested and found to comply with the limits for a Class A digital device, pursuant to Part 15 of the FCC Rules in the USA These limits are designed to provide reasonable protection against harmful interference when the equipment is operated in a commercial environment. This equipment generates, uses, and can radiate radio frequency energy and, if not installed and used in accordance with the instruction manual, may cause harmful interference to radio communications. Operation of this equipment in a residential area is likely to cause harmful interference in which case the user will be required to correct the interference at their own expense.

This equipment has been tested for compliance with European regulations as follows:

Application of Council Directive:
2004/108/EC

Standards to which Conformity is declared:
EN-61000-6-1:2001
EN-61000-4-2:1995
EN-61000-4-3:1995
EN-61000-4-4:1995
EN-61000-4-6:1996
ENV-50204:1995

Any changes or modifications to this equipment not expressly approved by the manufacturer Unidata Pty Ltd could void the user's authority to operate this equipment.

Revision History

File name / Revision	Date	Authors & Change Details	Checked/ Approved
Unidata Manual - 6537A Starflow QSD SDI-12 User Manual 27 05 2019.docx	27 05 2019	IM First Draft	MS
Unidata Manual - 6537A Starflow QSD User Manual 21 06 2019	21 06 2019	RDS, PD	MS
Unidata Manual - 6537A Starflow QSD User Manual 04 07 2019.doc	04 07 2019	CB	KC
Unidata Manual - 6537A Starflow QSD User Manual 12 07 2019.doc	12 07 2019	KC	MS
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Unidata Manual - 6537A Starflow QSD User Manual 28 10 2019.doc	28 10 2019	CB	PD
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Unidata Manual - 6527B and 6537A Starflow QSD User Manual 18 09 2020.docx	18 09 20	CB	IM

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1.0 INTRODUCTION

The 1st generation 6527 Starflow QSD Instrument measures water Velocity, Depth (ultrasonic) and Temperature. The Starflow QSD – 2nd generation has been enhanced to include depth using the Pressure – Hydrostatic method (6527B Starflow QSD) and Electrical Conductivity (6537A Starflow QSD) as well as Tilt. These models come standard with both SDI-12 and RS-485 (Modbus RTU) interfaces.

The capacity of the instrument to measure the water conductivity is unique and allows the instrument to determine not only the water velocity, flow and volume but also an indication of the water quality. The conductivity measurement can also be used where existing techniques for measuring water quality are unsuitable or too expensive.

By using Digital Signal Processing (DSP) techniques, the Starflow QSD is able to perform in a wide range of environments. It is used to measure flows and water conductivity (6537A) in pipes, channels and small streams. It can operate in a range of water qualities from fresh streams to primary sewage channels.

Electrical conductivity feature of 6537A instrument empowers the user to detect unusual waste dumping/agriculture runoff which is not visible using current flow sensors. The pressure depth sensor allows the instrument to be placed in an angled position on the wall of irregularly shaped drainage canals or on the sides of channels in which are difficult or impossible to place it on the channel floor.

The Tilt parameter is measured by an internal accelerometer and represents the pitch and roll of the instrument body as it is installed and its measurement is in degrees angle. This provides the user with useful information of the sensor after mounted underwater or during a post-installation inspection.

Starflow QSD system consists of:

Model 6527B or 6537A Starflow QSD instrument
Model 6527M Stainless Steel Mounting Bracket

6527B

6537A

Hardware Accessories:

The following accessories should be purchased according to your application requirements.

Model 6907B-14	12V, 14Ah Sealed Lead Acid Battery
Model 6904I-10	10W Solar Recharge Panel & Mount
Model 6904I-20	20W Solar Recharge Panel & Mount
Model 6702S	Starflow QSD Weatherproof Enclosure
Model 6705A	Small Expanding Clamp SS expanding turn-buckle and band clips 100mm wide, 100mm long, 50mm expansion Use in pipes up to 600mm (24") in diameter
Model 6705B	Large Expanding Clamp SS expanding turn-buckle and band clips. 100mm wide, 150mm long, 100mm expansion Use in pipes over 600mm (24") in diameter
Model 6705D	1800mm Band Segment 100mm wide, 0.6mm Stainless Steel band With 50mm spaced locating holes at both ends
Model 6705F	Band Joiner Stainless Steel joiner

Instrument Accessories:

Model 6515B	QSD Barometric Reference for pressure depth reading compensation

2.0 SPECIFICATIONS

Velocity (Continuous Beam)

Range	20mm/sec to 0.8 m/sec 20mm/sec to 1.6 m/sec (default) 20mm/sec to 3.2 m/sec 20mm/sec to 13.2 m/sec Bidirectional velocity capability, set using configuration tools
Accuracy	Typical ±1%
Resolution	1 mm/s

Depth (Ultrasonic)

Range	20mm to 5000mm (5m)
Accuracy	± 1% of full scale
Resolution	1 mm

Depth (Pressure)

Range	0mm to 10m
Accuracy	Typical ±0.19% for 0m to 5m range Typical ±0.38% for 0m to 10m range
Resolution	1 mm

Temperature

Range	0°C to 60°C
Accuracy	±0.5°C
Resolution	0.1°C

Electrical Conductivity (EC) – 6537A ONLY

Range	0 to 200,000 µS/cm, typically ±1% of measurement
Resolution	±1 µS/cm

May be recorded as a 16-bit value (0 to 65,535 µS/cm) or
a 32-bit value (0 to 262,143 µS/cm)

Tilt (accelerometer)

Range	±70° in roll and pitch axes.
Accuracy	±1° for angles less than 45°

Power Requirements

Voltage range	12 to 24 V DC
Supply current	50uA standby, 100mA active for 1 second @12V
Power source	12V DC - typically an external batter

Communications

SDI-12	SDI-12 v1.3
Connection	Single cable up to 50 metres long (standard fitment is 15m)
Maximum cable	60m defined by SDI12.org
RS-485	Modbus RTU
Connection	Single cable up to 300 metres long (standard fitment is 15m)
Baud rate and parity	Configurable

Environmental

Operating	0°C to 60°C (water temperature)
Storage	-20°C to 60°C
Humidity	up to 100 % RH

Physical

Dimensions	Approximately L 135 mm, W 55 mm, H 22 mm
Material	Epoxy-sealed body, stainless steel mount
Weight	1kg with 15m of Cable
Cable	15 metre
Cable options	User-specified, up to 50 metres

Instrument Wiring Table

Variants for Wiring are detailed below

Brown Wire Variant

Starflow QSD / Wire Colour	Function / Signal Name
White	SDI-12
Brown	Power
Green	Ground
Yellow	A- (Modbus)
Pink	B+ (Modbus)
Grey	One-Wire *

Red Wire Variant

Starflow QSD / Wire Colour	Function / Signal Name
White	SDI-12
Red	Power
Yellow	Ground
Orange	A- (Modbus)
Blue	B+ (Modbus)
Grey	One-Wire *

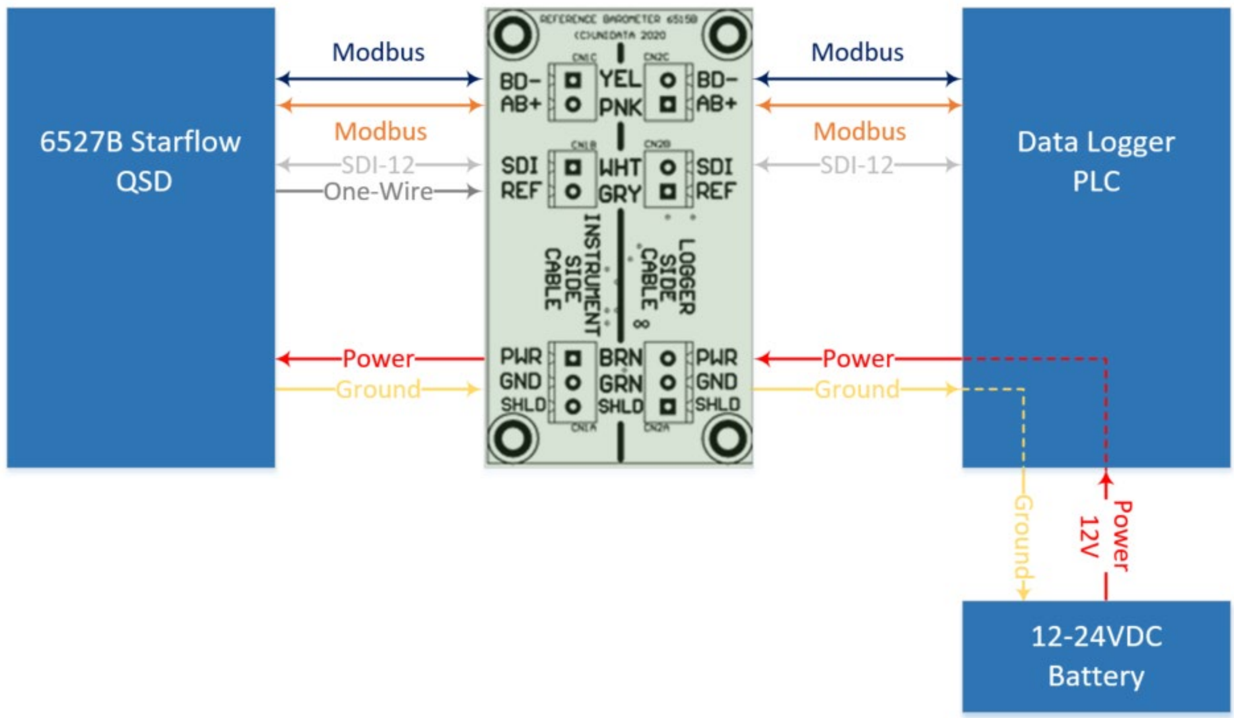
* Use with Unidata 6515B QSD Barometric Reference Module

When Unidata 6515B QSD Barometric Reference module is connected, the instrument will automatically handle the barometric correction and will report actual water level instead of water head plus atmospheric pressure.

If your data logger has a barometric sensor, the data logger program must perform the barometric correction, OR the user can perform a post-processing method to correct for barometric changes by using barometric pressure data from a trusted source such as a weather department or another barometer close by.

The 6515B QSD Barometer Reference module should be:
a) Mounted in an enclosure near to the data logger in a position protected from the elements.
b) The enclosure should be vented to allow the barometer sensor to be exposed to atmospheric pressure variations.

6515B QSD barometric Connection Diagram:



3.0 OPERATING PRINCIPLES & MEASURED PARAMETERS

The 6527B and 6537A Starflow QSD measure:

- Flow velocity
- Depth (ultrasonic)
- Temperature
- Depth (Pressure)
- Electrical Conductivity (EC) – 6537A Only
- Tilt (the angular orientation of the instrument)

The Starflow QSD performs data processing and analysis each time a measurement is made. This can include rolling averaging and outlier/filter functions for Depth (ultrasonic), Velocity, Depth (Pressure) and Conductivity (6537A). The function parameters can be configured via SDI-12 eXtended command or Sonic software.

3.1 Flow Velocity Measurement

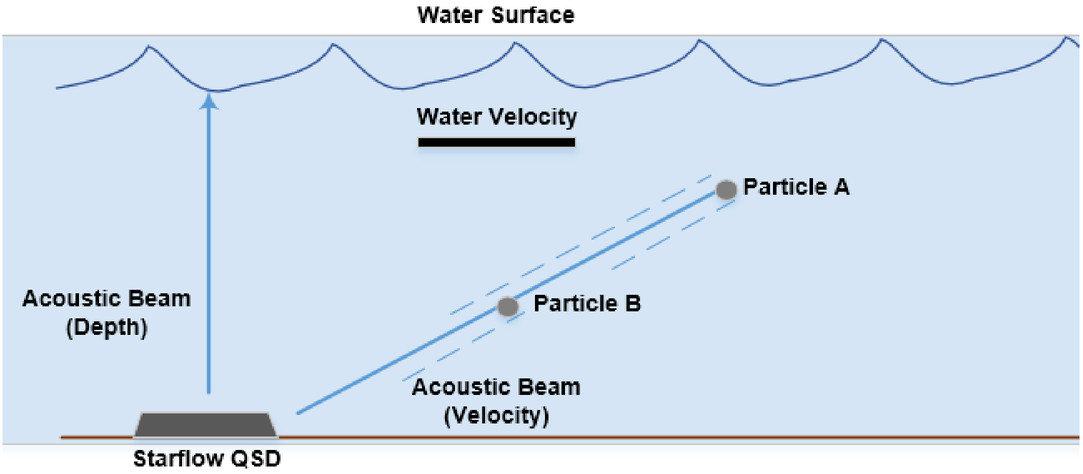
For measuring velocity, the Starflow QSD uses Continuous Mode Doppler. An ultrasonic signal is transmitted into the water flow, echoes (reflections) returned from particles suspended in the water flow are received and analysed to extract the Doppler shift (velocity). The transmission is continuous and simultaneous with the returned signal reception.

During a measurement cycle, the Starflow QSD emits a continuous signal and measures signals returning from scatterers anywhere and everywhere along the beam. These are resolved to a mean velocity that can be related to a channel flow velocity at suitable sites.

The receiver in the instrument detects reflected signals, and those signals are analysed using digital signal processing techniques.

Internally the instrument auto-scales over these ranges if the range is manually set in the settings: A bidirectional velocity capability is a supported option.

20mm / s to 0.8 m sec
20mm / s to 1.6m/s (default)
20mm / s to 3.2 m/s



3.2 Water Depth Measurement – Ultrasonic

For depth measurement, the Starflow QSD uses Time-of-Flight (ToF) Ranging. This involves transmitting a burst of ultrasonic signal upwards, to the surface of the water, and measuring the time taken for the echo from the surface to be received by the instrument. The distance (water depth) is proportional to the transit time and the speed of sound in water (corrected for temperature and density). The maximum ultrasonic depth measurement is limited to 5m.

3.3 Water Depth Measurement - Pressure

Sites where the water contains large amounts of debris or air bubbles may be unsuited for ultrasonic depth measurement. These sites are better suited to using pressure to determine the water depth.

Pressure based depth measurement may also be applicable to sites where the instrument cannot be located on the floor of the flow channel, or it cannot be mounted horizontally.

The Starflow QSD is fitted with a 2 bars absolute pressure sensor. The sensor is located on the bottom face of the instrument and utilises a temperature-compensated digital pressure sensing element.

Where depth pressure sensors are used the atmospheric pressure variation will cause errors in the indicated depth. This is corrected by subtracting the atmospheric pressure from the measured depth pressure. A barometric pressure sensor is required to do this.

If the data logger used to read the Starflow QSD does not incorporate a barometric pressure sensor, then the One Wire Bus 6515B Reference Barometer option should be purchased. 6515B should be mounted near the logger and is read by the Starflow QSD instrument, which will then automatically compensate for the atmospheric pressure variations ensuring an accurate depth measurement is achieved. This enables Starflow QSD to report actual water depth (pressure) instead of barometric pressure plus water head.

3.4 Temperature

A solid-state temperature sensor is used to measure the water temperature. The speed of sound in water and its conductivity is affected by temperature. The instrument uses this measured temperature to compensate for temperature variations automatically.

3.5 Electrical Conductivity EC 6537A Only

The 6537A Starflow QSD is equipped with the capacity to measure the conductivity of the water. A linear four-electrode configuration is used to make the measurement. A small current is passed through the water, and the voltage developed by this current is measured. The instrument uses these values to calculate the raw uncorrected conductivity.

Conductivity is dependent on the temperature of the water. The instrument uses the measured temperature to compensate for the returned conductivity value. Both raw or temperature compensated conductivity values are available.

3.6 Accelerometer

The Starflow QSD has an integral accelerometer sensor to measure the inclination of the instrument. The sensor returns the roll and pitch angle of the sensor (in degrees). This information can be useful in ensuring the installation position of the sensor is correct and for determining if the instrument has moved (bumped or washed away) during the post-installation inspection.

3.7 Power Supply Voltage

The instruments internal power supply voltage is readable as a measurement parameter. The operating range of the power supply is 12 to 24V DC. If the supply voltage falls below defined limits, the instrument stops taking measurements to ensure only quality data is measured.

3.8 Signal Spread

This can be used to determine the amount of “turbulence” affecting the signal quality and used to reject the measurement if the spread (turbulence) is too great. A good flow would return a spread value of around 50, anything above 100 would be considered poor.

Spread	Channel Interpretation
0-50	Excellent SPREAD
60-200	Average SPREAD
200-500	Poor SPREAD
Above 500	Above 500 gives unreliable velocity data.

3.9 Received Signal Strength Indicator (RSSI)

The RSSI channel is the measurement of the received signal power. RSSI values may change significantly for each measurement because of the number of reflectors in the water at any given time.

In turbulent water, the reflectors are more likely to be in suspension and therefore higher signal/RSSI so smoothly flowing water "may" have fewer reflectors but it will depend on the velocity

RSSI	Channel Interpretation
0	No Signal
3-200	Typical signal in water
>1000	Not usable Signal (Too Noisy)

4.0 TAKING MEASUREMENTS FROM THE INSTRUMENT

The Starflow QSD instrument has both SDI-12 and RS485 (Modbus RTU) Interfaces. The following sections describe them in detail. If you are a user of Unidata NRL loggers, you can simply add the Starflow QSD as an instrument within the logging scheme as an SDI-12 instrument.

4.1 SDI-12 Operation

The Starflow QSD can be operated as a standard SDI-12 (V1.3) sensor.

Measurement commands (M! & C!) returns atttn(n) response with ttt indicating the delay until measurements are ready and n(n) indicates the number of parameters returned.

A Service Request is sent.

- The R! command returns an acknowledge response a<CR><LF>
- The D! command returns the measured data values.

SDI-12 Command Notes:

1. Change Address aAb! is supported
2. Start Verification aV! returns an acknowledge response
3. Extended Command aX is supported (refer to QSD SDI-12 supplement document)
4. D/R1…9! Commands operate the same as a D/R0! command
5. M/C1...9! Commands operate the same as an M/C! command
6. MC, CC & RC commands requesting CRC are supported

Note: CRC is always recommended

4.1.1 Channels Table

The Starflow QSD has a list of data registers within the instrument that are re-mapped to SDI-12 channels. These SDI-12 parameters are assigned to the Channels, and their order of return can be configured using SDI-12 eXtended commands. The channel allocation is shown in the below table:

Channel	Description	Units	Example	Meaning
0	Water Temperature	1/10 ºC	+152	15.2ºC
1	Battery Voltage	1/100 Volts	+1302	13.02Volts
2	Ultrasonic Depth	mm	+123	123mm
3	CW Water Velocity	+/- mm/s	-234	234mm/s -ve flow
4	RSSI (signal level)	no units	+66	66 (no units)
5	Signal Spread	no units	+45	45 (no units)
10	X-Axis Tilt	+/- deg	-9	9 deg left tilt
11	Y-Axis Tilt	+/- deg	7	7 deg forward tilt
12	Pressure Depth	+/- mm	+123	123mm
13	Barometric Reference	+ mm	+10120	10120mm
70	Conductivity (UC)	µS/cm	+2350	2350µS/cm
72	Conductivity (TC)	µS/cm	+2350	2350µS/cm

4.1.2 Measurement Command (aM!)

6527B/6537A Starflow QSD measures several parameters, and these are available for collection by a data logger. The default configuration returns nine parameters using the **aM!** command. Other sets of parameters are also available using the **aMx!** commands.

Example 1: aM!

Parameter	Description	Units	Example	Meaning
1	Water Temperature	1/10 ºC	+152	15.2ºC
2	Battery Voltage	1/100 Volts	+1302	13.02Volts
3	Ultrasonic Depth	mm	+123	123mm
4	CW Water Velocity	+/- mm/s	-234	234mm/s -ve flow
5	RSSI (signal level)	no units	+66	66 (no units)
6	Signal Spread	no units	+45	45 (no units)
7	Conductivity (TC)	µS/cm	+2350	2350µS/cm
8	Pressure Depth	+/- mm	+123	123mm
9	Barometric Reference	+ mm	+10120	10120mm

Start Measurement Command (aM!) example:

0M! 00059 <CR><LF> (Measurement ready in 5 seconds and nine parameters available)

0D0! 0+152+1302+123+234+66+45+2340+123+10120 <CR><LF>

Example 2: aM1! (Firmware 20 and above)

Parameter	Description	Units	Example	Meaning
1	Water Temperature	1/10 ºC	+152	15.2ºC
2	Battery Voltage	1/100 Volts	+1302	13.02Volts
3	Ultrasonic Depth	mm	+123	123mm
4	CW Water Velocity	+/- mm/s	-234	234mm/s -ve flow

Start Measurement Command (aM1!) example:

0M1! 00054 <CR><LF> (Measurement ready in 5 seconds and 4 parameters available)

0D0! 0+213+1343+123+234<CR><LF>

Example 3: aM2! (Firmware 20 and above)

Parameter	Description	Units	Example	Meaning
1	Pressure Depth	+/- mm	+123	123mm
2	Barometric Reference	+ mm	+10120	10120mm

Start Measurement Command (aM2!) example:

0M2! 00052 <CR><LF> (Measurement ready in 5 seconds and 2 parameters available)

0D0! 0+123+10120 <CR><LF>

Example 4: aM3! (Firmware 20 and above)

Parameter	Description	Units	Example	Meaning
1	Conductivity (UC)	µS/cm	+2350	2350µS/cm
2	Conductivity (TC)	µS/cm	+2350	2350µS/cm

Start Measurement Command (aM3!) example:

0M3! 00052 <CR><LF> (Measurement ready in 5 seconds and 2 parameters available)

0D0! 0+2350+2350 <CR><LF>

Example 5: aM4! (Firmware 20 and above)

Parameter	Description	Units	Example	Meaning
1	X-axis Tilt	+/- deg	-9	9 deg left tilt
2	Y-axis Tilt	+/- deg	7	7 deg forward tilt

Start Measurement Command (aM4!) example:

0M4! 00052 <CR><LF> (Measurement ready in 5 seconds and 2 parameters available)

0D0! 0-9+7 <CR><LF>

Example 6: aM5! (Firmware 20 and above)

Parameter	Description	Units	Example	Meaning
1	RSSI (signal level)	no units	+66	66 (no units)
2	Signal Spread	no units	+45	45 (no units)

Start Measurement Command (aM5!) example:

0M5! 00052 <CR><LF> (Measurement ready in 5 seconds and 2 parameters available)

0D0! 0+66+45 <CR><LF>

Note: More information on C! And R! Commands can be found in QSD SDI-12 supplement document.

4.2 Modbus RS485 Operation

The Starflow QSD can be operated as a Modbus RTU Slave sensor. The Baud rate and parity selected must be configured prior to using the instrument. The instrument supports configurable Baud rates for the RS-485 Communication Port (the SDI-12 Port is fixed to 1200/9600 as per the SDI-12 standard). There are two configuration parameters (baud rate & parity), and these may be changed via Modbus commands.

When changing these, the new settings come into effect AFTER the response has been sent to the Modbus PC utility. To continue communicating via RS-485, the PC utility’s baud rate settings MUST then be changed to match that of the Starflow QSD.

RS485 Baud rate and Parity setting options can be configured using Modbus commands (refer to QSD Modbus supplement document).

4.2.1 Reading the measured parameters via Modbus

Physical links requirement: RS485 - low power, 2V, three-wire (A/B signals & ground), differential, half-duplex; at 9600bps (support up to 1000m cable, at 19200bps up to 500m cable, at 115Kkps up to 100m cable) and it supports PP, MD & MP protocols.

Protocol requirement: MODBUS (Modicon) - variable speed (9600 & 19200), MD over RS485. For PC configuration, an USB to RS485 converter is required. The instrument has to be powered via 12V and ground; A- and B+ signals will need to be connected as per wiring table in specifications section 2.0.

The instrument supports the **Modbus RTU communication protocol**; this is the format of choice for serial communications such as RS485/RS232 as it is the most efficient.
The general message structure will consist of the device address, function code, data payload and the checksum.

4.2.2 Master Format

Device Address	Function Code	Data Payload	CRC

Device address – 1 byte field ranging from 1 to 247. Broadcast address 0

Function code – 1 byte field with a value range 1-127 representing the standard or extended function code

Data payload – 0-N bytes with response data from the device. Error response will be a 1 byte value 1-255.

CRC – 2 bytes computed mathematically

4.2.3 Slave Response Format

Device Address	Function Code	Data Payload	CRC

Device Address – Echo of device address sent in the master message to the device

Function code – Echo of function code sent in the master message to the device

Data payload – 0-N bytes with the response from the device.

CRC- 2 bytes with a value computed mathematically

4.2.4 Standard Message Format

Read Holding Registers is used to retrieve measurements

Message		
Address	1 byte	1-247
Function Code	1 byte	0x03
Data Address	2 bytes	0 to 0xFFFF
Register Count	2 bytes	
CRC	2 bytes	

**Byte count = 2*Register Count*

Response		
Address	1 byte	1-247
Function Code	1 byte	0x03
Byte Count	1 byte	
Data Payload	N bytes	
CRC	2 bytes	

Write Single Register is used to configure instrument settings

To set a single register in a device:

Message		
Address	1 byte	1-247
Function Code	1 byte	0x06
Data Address	2 bytes	0 to 0xFFFF
Register Count	2 bytes	0 to 0xFFFF
CRC	2 bytes	

Response		
Address	1 byte	1-247
Function Code	1 byte	0x06
Byte Count	1 byte	0 to 0xFFFF
Data Payload	N bytes	0 to 0xFFFF
CRC	2 bytes	

RS485 Settings

Baud rates – Support Baud rates from 9600 to 115200

Data Bits – 8 data bits (7 data bits is not valid setting for Modbus RTU)

Parity Bits – Even, Odd and None

Stop Bits – 1 or 2

***Default settings will be 9600,8,N,1**.

4.2.5 Modbus Registers

The below list of parameters will all be located in the holding registers.

Sensor Common Registers: Registers Numbered 0001 to nnnn have Data Addresses 0000 to **nnnn-1**

Register XXXX	Size (Reg)	Mode/Access	Data Type	Description
0001	1	Read only	ushort	Water Temperature * 0.1 DegC
0002	1	Read only	ushort	Battery Voltage * 0.01 Volts
0003	1	Read only	ushort	Water Depth (Ultrasonic) mm
0004	1	Read only	sshort	CW Water Velocity mm/s
0005	1	Read only	ushort	RSSI
0006	1	Read only	ushort	Signal Spread
0007	1	Read only	ushort	EC Conductivity Un-Corrected
0008	1	Read only	ushort	EC Hi-Resolution Un-Corrected
0009	1	Read only	ushort	EC Conductivity Temperature Corrected
0010	1	Read only	ushort	EC Hi-Resolution Temperature Corrected
0011	1	Read only	sshort	Accelerometer X +/- 90 deg
0012	1	Read only	sshort	Accelerometer Y +/- 90 deg
0013	1	Read only	sshort	Water Depth (Pressure) mm
0014	1	Read only	ushort	OWB Barometric Reference mm
0015	1	Read only	sshort	PW Velocity in +/- mm/s

Example 1: Water Temperature

Send - 01 03 00 00 00 01 84 0A

Receive - 01 03 02 00 DC B9 DD

00 DC = 220

Temperature = 220 x 0.1 = 22.0 ˚C

Example 2: Water Temperature, Battery Voltage, Water Depth, Velocity, RSSI, Signal Spread

Send - 01 03 00 00 00 06 C5 C8

Receive - 01 03 0C 00 DF 05 3F 00 8D 00 55 00 10 00 18 5E 8D

00 DF = 223

Temperature = 223 x 0.1 = 22.3 ˚C

05 3F = 1343

Battery = 1343 x 0.01 = 13.43 V

00 8D = 141

Water depth (Ultrasonic) = 141 mm

00 55 = 85

CW water Velocity = 85 mm/s

00 10 = 16

RSSI =16

00 18 = 24

Signal Spread = 24

Note: Refer to Starflow QSD Modbus supplement document for additional information

5.0 INSTALLATION

5.1 Site Considerations

The Doppler signal received, and the accuracy of the computed velocity is related to the flow and cross-section characteristics of the site. A suitable site has the following features:

Feature	Description
Flows are laminar, and the velocity measured by the transducer can be related to the mean velocity of the channel.	Velocity is measured from a limited path in front of and above the acoustic sensors. This area varies with the amount of suspended material in the water and the channel characteristics. The user has to determine the relationship between the measured and mean velocity.
The channel cross-section is stable.	The relationship between water level and the cross-sectional area is used as part of the flow computation.
Velocities are greater than 20 mm/second.	The transducer does not process velocities slower than this. The maximum velocity is 5 metres/second. The transducer will measure velocities in both directions.
Reflectors are present in the water.	Generally, the more material in the water, the better. Starflow QSD generally works well in clean natural streams, but problems may be encountered in extremely clean water.
No excessive aeration.	Bubbles are good scatterers, and occasional small bubbles will enhance the signal. However, the speed of sound can be affected if there are excessive amounts of air entrapped in the flow.
The bed is stable and Starflow QSD will not be buried by deposits.	Some coating and partial burying have little effect on the measured velocity, but it should be avoided. Any burying or sediment covering the depth transducer will affect the depth reading results.
Starflow QSD Pointing Upstream or Downstream?	Pointing the sensor end downstream will stop it accumulating debris; however, in some channels, the sensor body may disturb the velocity distribution unacceptably. The velocity reading will be positive when pointing upstream and negative when pointing downstream. The Starflow QSD may be configured to only read positive velocities regardless of water flow direction.
Starflow QSD Depth sensor not situated parallel to the surface?	If Depth sensor is not parallel to the surface (~ ±10 °) the readings could be compromised
Corrugated Pipes	In general, the Starflow QSD is not suited to installation in corrugated pipes.

5.2 Instrument Mounting – Pipes & Culverts

A typical installation is in a pipe or culvert with diameters between 150mm and 2000 mm. The Starflow QSD should be located near the downstream end of a straight and clean culvert, where non-turbulent flow conditions are maximised. The mounting should ensure the unit sits right on the bottom to avoid debris catching beneath it.

It is recommended that in open pipe situations that the instrument is situated five times the diameter from the opening or discharge. This will allow the instrument to measure the best possible laminar flow. Keep the instrument away from pipe joints. Corrugated culverts are not suitable for Starflow QSD instruments.

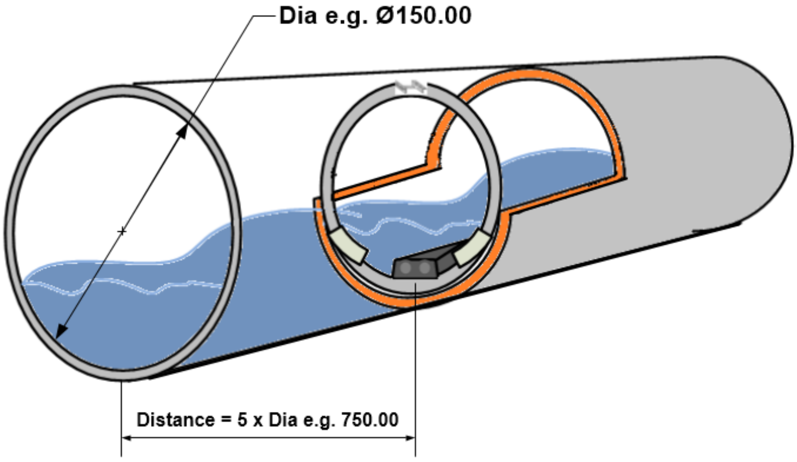


Diagram showing instrument five diameters in from pipe opening

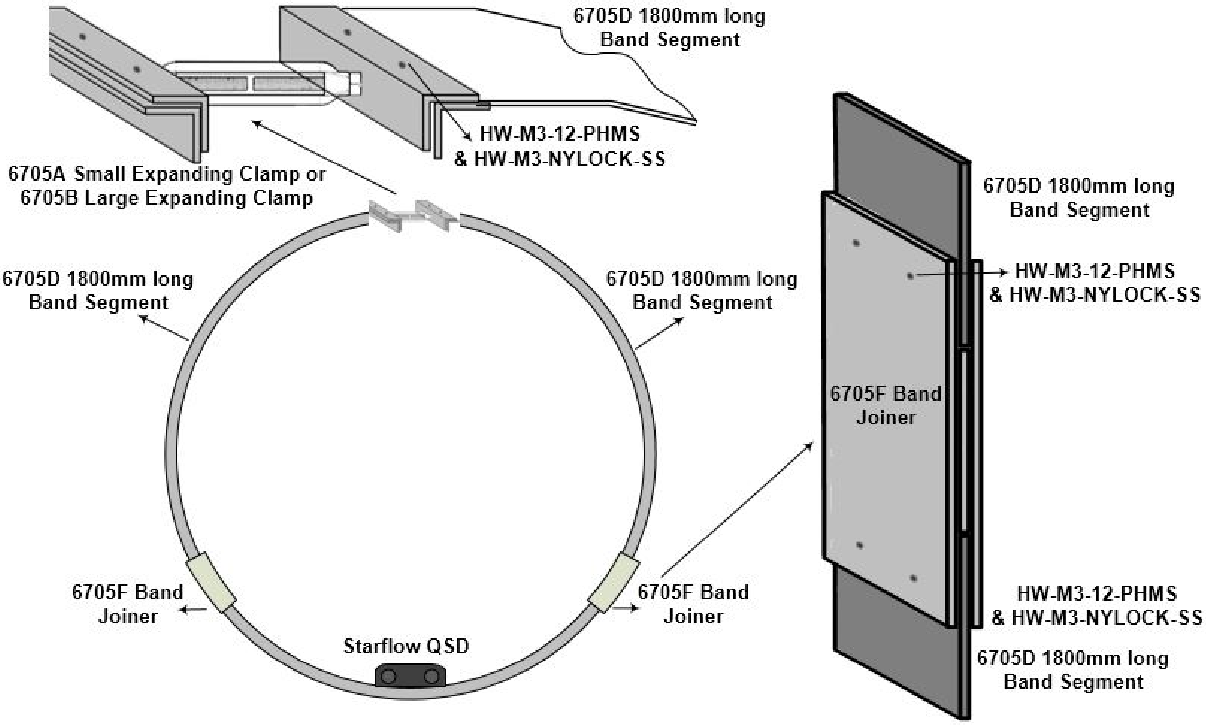
In culverts, the sensor can be mounted on a stainless steel band that is slipped inside the pipe and expanded to lock it in position. In open channels, special mounting brackets may be required.
The Model 6705 Expanding Band kit allows you to install a Starflow QSD instrument into a pipe.
Kit design is modular, allowing it to fit into any size pipe. The band is flexible enough to fit irregular shapes, such as ovoid (egg-shaped) sections. All components are made from stainless steel, and the band fittings are 100mm wide to fit the standard Starflow QSD mount.

Although pipes come in standard diameters, their dimensions are not always accurate. This means that an expanding band system must allow the installer to make adjustments on site. To achieve this, the Model 6705 system is made so that general assembly can be done in the workshop, whilst adjustments can be made in the field with hand tools. An expanding turn-buckle locks the band into the pipe. To determine what installation hardware is needed for pipe installation, the pipe diameter needs to be known.

Pipe Diameter	Clamp	Bands	Joiners
Up to 600mm	6705A	6705D	-
600 - 1200mm	6705B	2 x 6705D	1
1200 - 1800mm	6705B	3 x 6705D	2

Note: Pipes less than 150mm diameter are NOT RECOMMENDED for Starflow QSD installation due to the instrument's size. Do the following:

1. If the inside circumference of the pipe is ACCURATELY known, then cut the band assembly to this length LESS 25mm for fitting clearance. Circumference (length) = Diameter x 3.14
2. Arrange the clamp, band(s) and joiner(s) so that Starflow QSD unit will be positioned at the bottom (invert) of the pipe and an Expanding Clamp at the top (obvert) of pipe (see diagram).



3. Drill 4 x 5mm holes, 85mm spaced in the centre of the band to locate the instrument. Use the Starflow QSD mounting clamp 6527M as a guide.

   Use a small pilot drill bit (about 2mm) then finish with the 5mm bit. When drilling stainless steel use a slow speed and high pressure. Avoid stopping as the material will work harden, making it more difficult to drill.
4. Use M3 x 12mm stainless steel machine screws and M3 nylock nuts (supplied) to connect all parts. (If pop rivets and the pop rivet gun are available they can be used as the replacement for the screws and nuts sets)
   Note: the band length must be measured to include the Expanding Clamp (fully closed), bands and joiners all together as shown.
5. Position and tighten Starflow QSD and band, the bolt the Starflow QSD mount to the band
6. Fold the band into a circle to easily fit inside the pipe and position into place inside the pipe

7. Slip the loose end of the band into the expanding clamp

8. Adjust clamp until the band is tight inside the pipe (use spanner if necessary)

5.3 Instrument Mounting – Open Channels

Open channel installations share many of the considerations required for pipes and culvert installations.

The mounting of the instrument may be determined by the type of channel and its construction. The instrument mounting bracket should be securely affixed to the floor of the channel either directly or via an intermediary platform such as a suitable concrete slab or a stainless steel plate.

Where possible the cable to the instrument should be run back behind the instrument for several meters to minimise the effect of debris caught in the cable on the measurement. Appropriate shielding or conduit should be installed to protect the cable from damage.

Care should be taken when selecting the site. Chose a location where the water flow is uninterrupted, and there are no obstructions. The photo on the above right is perhaps the most ideal site with the Starflow QSD looking into the direction of flow.

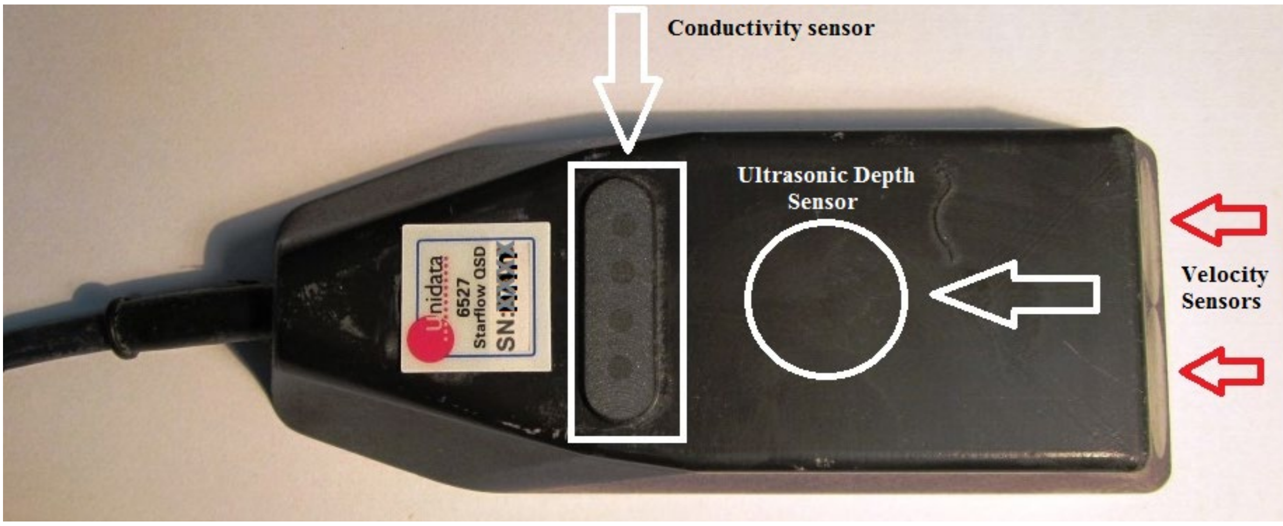
It is not always possible to prepare the site, such as shown in the above photo examples. If mounting in a stream bed, look for a site free from rocks, fallen tree branches and sharp bends in the channel. Also, beware areas where the water is turbulent and chose a site that is free from standing waves and whirlpools. These will reduce the effectiveness of the Starflow and may return poor data.

If the stream bed is continually moving, there is a chance of the Instrument being covered by silt. The Starflow will not work if it is covered by silt or sand. If this is a problem, then the Starflow QSD must be raised above the stream bed and a depth offset introduced.

The use of the Doppler Spectrum utility is useful when selecting a suitable site. This Doppler Spectrum utility can assist during the installation of the Starflow QSD to determine the suitability of a potential site. It can show the operator the quality of the data being returned by the instrument in Real-Time. By changing the location of the instrument, real-time information is fed back to the operator to assist in locating the instrument in the best possible location.

6.0 INSTRUMENT MAINTENANCE

The Starflow QSD requires very little maintenance. During routine site visits, the following checks can be performed:



Piezo element faces	Clean the instrument surfaces where the Piezo elements are located by wiping with a cloth. If needed, a plastic scraper can be used to remove any bio-fouling. Take care not to scrape the surface of the instrument. Refer to the above diagram for the areas where the ultrasonic eyes and conductivity sensors reside. These areas must be kept clean. The front face of the instrument and the area above the depth Piezo should be clear.
Pressure depth sensor	Check that the opening to the depth pressure sensor is clear of any fouling. Use a brush to clear any material.
Conductivity Electrodes	With a cloth wipe the electrode faces. Do not use abrasive materials to clean them as this will affect the calibration of the conductivity measurement.
Cable	Inspect the cable to ensure that it has not been damaged.
General inspection	Visually check the instrument to see that it has not been damaged by heavy debris in the measured stream.

APPENDIX A - FACTORS AFFECTING FLOW MEASUREMENT ACCURACY

Starflow QSD measures velocity to an accuracy of ±2% and depth to ±1% of range. This is logged to a resolution of 1 mm/sec and 1mm respectively.

The purpose of the Starflow QSD system is to produce velocity data. There are many opportunities for errors to accrue in the process and degrade the result. These can be reduced or eliminated by using the instrument properly. Some of the more significant potential error sources follow.

Alignment with Flow and Depth

For the calibration to be valid, the transducer needs to be horizontally and vertically aligned with the flow. While Starflow QSD instruments are calibrated pointing into the flow, they can be pointed downstream with little loss of calibration accuracy. You may want to do this when fouling of the sensor face is a problem. Any angled flow in the horizontal plane will reduce the recorded velocity.

The Starflow QSD instrument must be mounted in the water parallel to the surface for depth readings to measure accurately (~ +/- 10˚), if not the depth may read inaccurately and therefore the recorded depth can be recorded incorrectly.

Instantaneous Versus "Averaged" Velocity

When you observe Starflow QSD velocities, they will be seen to vary by 10% or more from scan to scan at some sites. Because Starflow QSD is very sensitive to variations in velocities, you are able to see the natural velocity changes in the channel.

Although the discharge in a channel may be reasonably constant for a period of time, the velocity distribution is always changing. Different velocity streams wander from side to side and bed to surface as they progress down the channel. Turbulent swirls and eddies are carried downstream for long distances while they slowly decay. Hydrographers are used to having this action partly removed by the mechanical inertia of a current meter and the period over which a typical measurement is timed. However, all will have noticed that the rate of revolutions of the current meter varies during the timing period.

Continual velocity logging at one location with a Starflow QSD will show these cyclic velocity pulsations. The characteristics will be different for different sites and will vary with discharge. Cycles will typically include short period fluctuations (a few seconds) overlaid on longer cyclic fluctuations (up to many minutes). Longer-term pulsations may also be seen particularly in larger streams when in flood.

When comparing Starflow QSD velocity and mechanical current meter readings, the display should be observed long enough to estimate the mean of the readings. The Starflow QSD will do most of this processing internally but if an external logger is being used to record the readings averaging could also be done here this will help attenuate short frequency variations.

Conversion of Logged to Mean Velocity

The measured velocity data may have to be adjusted during post-processing to reflect a mean velocity for the channel. The factors used will be site-specific and have to be determined by the operator. This is done by obtaining a mean channel velocity by conventional techniques and comparing it with the average logged velocity. If necessary, this process should be repeated at various discharges. Where the relationship is complex or unstable, the accuracy of this method is compromised.

In laminar flow conditions the channel mean velocity could be expected to be between 90% and 110% of the logged velocity.

In small channels (say a 500mm diameter pipe) the factor may be close to 100% as a representative area of flow will have been “seen” by Starflow QSD and contributed to the logged velocity.

In larger channels only the area adjacent to Starflow QSD will be “seen”, and the relationship will depend on how this portion relates to the vertical and horizontal velocity distribution in the channel. An instrument located in the centre of the stream would normally be in a higher velocity area. However, in a deep channel, Starflow QSD may only see the slower portion of the velocity profile.

The Speed of Sound in Water

Velocity measurements are directly related to the speed of sound in water. The factor used to scale the velocity measurement is based on the speed of sound in freshwater at 20°C (see table below). This velocity of sound gives a calibration factor of 0.550mm/sec per Hz of Doppler shift.

This calibration factor may be adjusted for other conditions; for example, the calibration factor for seawater is 0.5618mm/sec/Hz.

The speed of sound varies significantly with water density. Water density is dependent on pressure, water temperature, salinity and sediment content. Of these, the temperature has the most significant effect, and it is measured by the Starflow QSD and applied in the correction of velocity measurements.

The Starflow QSD corrects for the variation of the speed of sound in water due to temperature using a factor of 0.00138mm/s/Hz/°C. This correction is the best fit for water temperatures between 0°C to 30°C.

The following table shows how the speed of sound varies with temperature and between fresh and seawater.

Temperature (ºC)	"Fresh Water"	"Sea Water"
0	1402	1449
5	1426	1471
10	1447	1490
15	1466	1507
20	1482	1521
25	1497	1534
30	1509	1545
35	1520	1555

The velocity of Sound in Water (m/s) at atmospheric pressure

Bubbles in the water are desirable as scatterers, but too many can affect the speed of sound. In the air, the speed of sound is about 350 m/s.