Instruction and Operation Manual

S 430

Pitot Tube Flow Sensor

SUTO

Dear Customer,

Thank you for choosing our product.

Before starting up the device please read this manual in full and carefully observe instructions stated. The manufacturer cannot be held liable for any damage which occurs as a result of non-observance or non-compliance with this manual.

Should the device be tampered with in any manner other than a procedure which is described and specified in the manual, the warranty is canceled and the manufacturer is exempt from liability.

The device is designed exclusively for the described application.

SUTO offers no guarantee for the suitability for any other purpose. SUTO is also not liable for consequential damage resulting from the delivery, capability or use of this device.

Table of contents

1 Safety instructions

Please check if this instruction manual accords with the product type.

Please observe all notes and instructions indicated in this manual. It contains essential information which must be observed before and during installation, operation and maintenance. Therefore this instruction manual must be read carefully by the technician as well as by the responsible user / qualified personnel.

This instruction manual has to be available at the operation site of the flow sensor at any time. In case of any obscurities or questions, regarding this manual or the product, please contact the manufacturer.
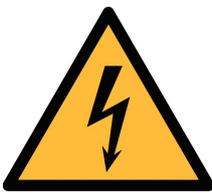
WARNING!

Compressed air!

Any contact with quickly escaping air or bursting parts of the compressed air system can lead to serious injuries or even death!

- Do not exceed the maximum permitted pressure range (see sensors label).

- Only use pressure tight installation material.

- Avoid that persons get hit by escaping air or bursting parts of the instrument.

- The system must be pressureless during maintenance work.
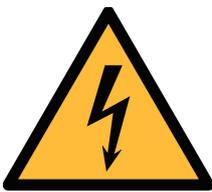
WARNING!

Voltage used for supply!

Any contact with energized parts of the product, may lead to an electrical shock which can lead to serious injuries or even death!

- Consider all regulations for electrical installations.

- The system must be disconnected from any power supply during maintenance work.

- Any electrical work on the system is only allowed by authorized qualified personal.

WARNING!

Permitted operating parameters!

Observe the permitted operating parameters, any operation exceeding this parameters can lead to malfunctions and may lead to damage on the instrument or the system.

- Do not exceed the permitted operating parameters.

- Make sure the product is operated in its permitted limitations.

- Do not exceed or undercut the permitted storage and operation temperature and pressure.

- The product should be maintained and calibrated frequently, at least annually.

General safety instructions

- It is not allowed to use the product in explosive areas.

- Please observe the national regulations before/during installation and operation.

Remarks

- It is not allowed to disassemble the product.

- Always use spanner to mount the product properly.

ATTENTION!

Measurement values can be affected by malfunction!

The product must be installed properly and frequently maintained, otherwise it may lead to wrong measurement values, which can lead to wrong results.

- Always observe the direction of the flow when installing the sensor. The direction is indicated on the housing.

- Do not exceed the maximum operation temperature at the sensors tip.

- Avoid condensation on the sensor element as this will affect the accuracy enormously.

Storage and transportation

- Make sure that the transportation temperature of the sensor without display is between -30 °C ... 70 °C and with display between -10 °C ... 60 °C.

- For transportation it is recommended to use the packaging which comes with the sensor.

- Please make sure that the storage temperature of the sensor is between -10 °C ... 50 °C.

- Avoid direct UV and solar radiation during storage.

- For the storage the humidity has to be <90%, no condensation.

2 Application

The S 430 flow sensor is designed to measure the consumption of compressed air and a variety of other gases in wet air or high mass flow / velocity applications. The sensor can even work in wet and dirty gases such as the outlet of a compressor.

The S 430 can measure the following parameters for compressed air or gases:

Parameter	Factory default unit
Velocity	m/s
Volumetric flow	m^3/h
Pressure	bar
Total consumption	m^3
Temperature	°C
Note: You can change units by means of the service App S4C-FS, the optional local display, or the optional service kit.	

Application notes:

- The S 430 flow sensor is mainly used in compressed air systems in the industrial environment, and is not designed for explosive areas. To use it in explosive areas, please contact the manufacturer.

- If the S 430 sensor is ordered with the option "steam measurement", the 300 mm shaft is equipped. To measure steam, it's required that the fluid temperature is above 130 °C; otherwise the steam is too wet.

   Steam is measured as mass flow (not as volumetric flow) and the available physical units include:

   - Steam flow: kg/h, t/h, lb/h

   - Steam consumption: kg, t, lb

3   Features

- Flow and consumption measurement in wet air or high mass flow/ velocity applications.

- Measurement at the compressor outlet applicable.

- Steam measurement applicable when a 300 mm shaft is equipped.

- Product for bi-directional measurement available based on the advanced auto-direction-detection technology.

- Insertion-type flow sensor facilitating installation under pressure through a ball valve.

- High temperature application up to 230 °C.

- Applicable to pipes with diameters from 1.25" up to 10". Product for greater-diameter pipes available on request.

- No mechanical wear parts.

- Stainless steel used for all parts that are in contact with the medium.

- Service App S4C-FS available for monitoring and configuring the sensor through mobile devices.

- Optional local display available for monitoring and configuring values directly on the sensor.

4   Technical data

4.1   General data

CE	
Parameters	Flow selectable: Volumetric flow, working condition flow, dry air flow, Free Air Delivery (FAD), mass flow
	Consumption
	Velocity (working condition)
	Medium temperature
	Medium pressure
Selectable units	Volumetric Flow: m^3/h, m^3/min, l/min, l/s, cfm
	Mass flow: kg/h, kg/min, kg/s, t/h, lb/h
	Consumption: m^3, ft^3, t, lb, l, kg
	Velocity: m/s, ft/min
	Temperature: °C, °F
	Pressure: bar, psi, kPa, MPa
Reference conditions	Selectable by users. Default ex-factory settings:
	compressed air: ISO1217 20 °C, 1000 hPa
	other gas: DIN1343 0 °C, 1013.25 hPa
Principle of measurement	Differential pressure with Pitot tube
Sensor	Differential pressure sensor
Measuring medium	Air, gas (non corrosive gas), steam
Operating temperature	-40 °C … 230 °C probe tube -30 °C … 70 °C housing 0 °C … 50 °C local display (optional)
Turn down ratio	1:10 (min/max flow ratio)

Operating pressure	0 … 1.6 MPa
Housing material	PC + ABS
Material of the probe tube, sensor head and the screwing	Stainless steel 1.4404
Protection class	IP65
Dimensions	See dimensional drawing in chapter 5
Display (optional)	2.4" colour graphics display with keypad (optional)
Tube diameter	1.25" to 10" (greater diameters on request)
Screwing thread	G 3/4" (ISO 228/1)
Weight	1.12 kg

4.2 Electrical data

Power supply	24 VDC, 150 mA

4.3 Output signals

Analogue output	Signal: 4 … 20 mA
	Scaling: 0 to maximum volume flow / velocity
	Accuracy: 0.06 mA
Pulse output	1 pulse per consumption unit
	Isolated switch: max. 30 VDC / 200 mA
	Pulse length: 30 … 120 ms depending on the flow rate
Modbus output (default setting)	See section 8.4
M-Bus output (default setting)	See section 8.5

4.4 Accuracy

Accuracy	Flow: ±(1.5% of reading+0.3% full scale) Pressure: 0.5% full scale. Temperature: 0.5 °C
Stated accuracy at	Ambient/process temperature 23 °C ± 3 °C Ambient/process humidity <90% Process pressure at 0.6 MPa

Valid working range S 430
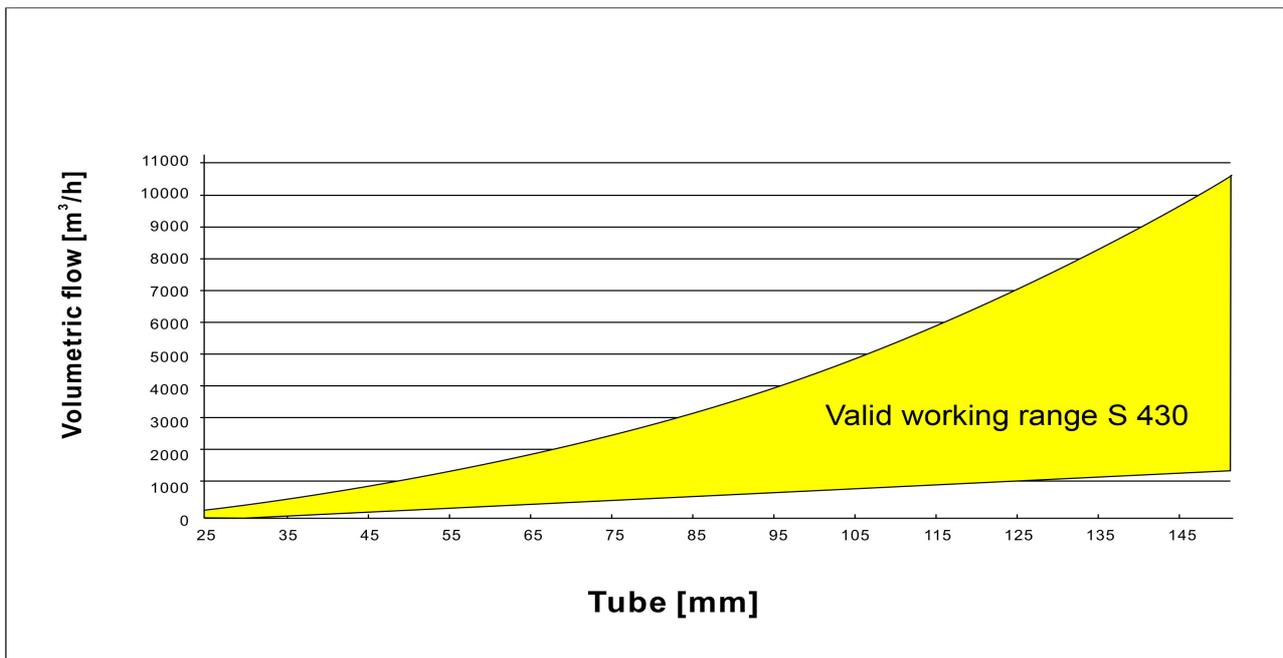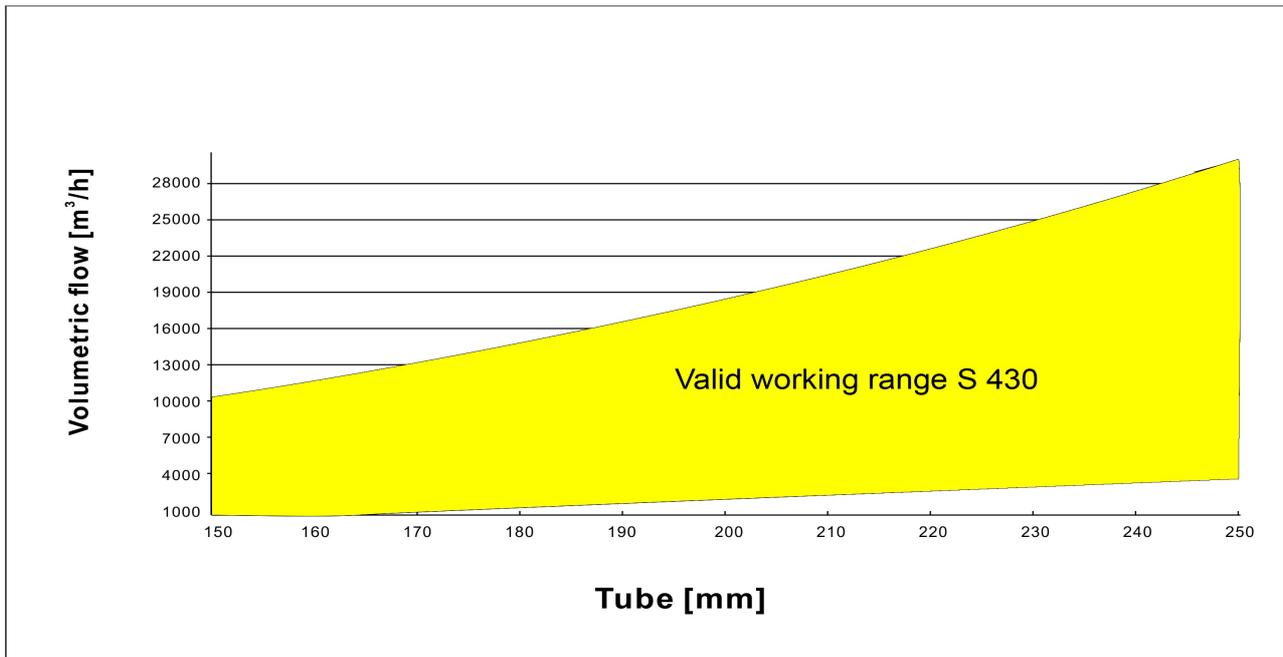
The minimum flow rate depends on the medium pressure and the cut-off setting. Below charts shows the relationship at 20 sm/s cut-off and at 30 sm/s cut-off. The cut-off ex factory is to 20 sm/s.

5   Dimensional drawing

90.0

100.6

423.0 (220 version)
503.0 (300 version)

220.0 (standard)
Option: 300

SW22

SW32

14.0

Ø15.0
Ø17.0

G3/4" (ISO 228/1)
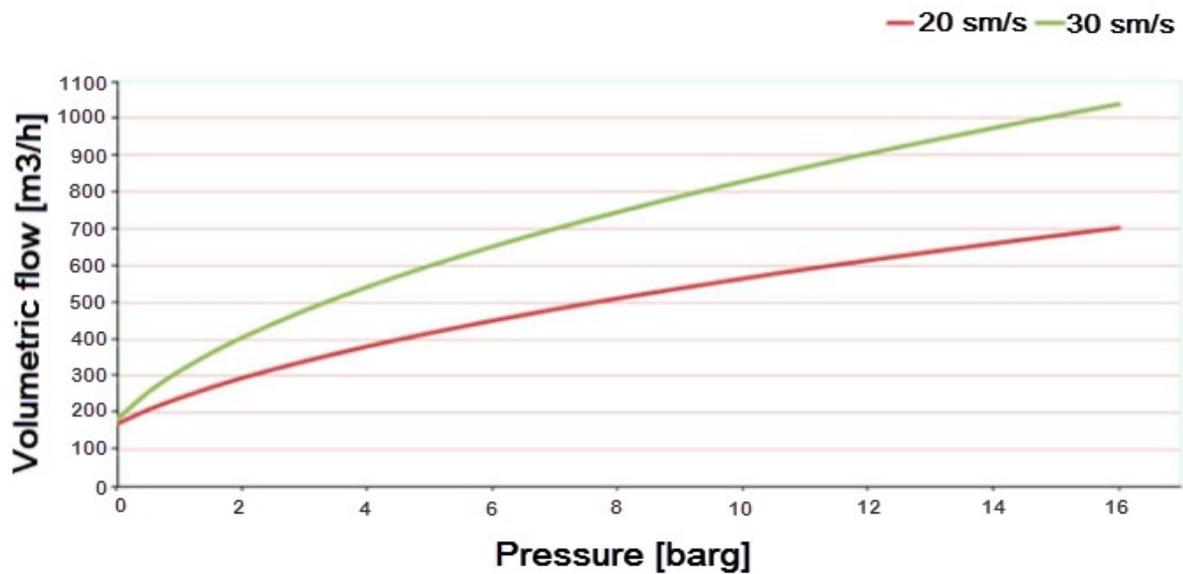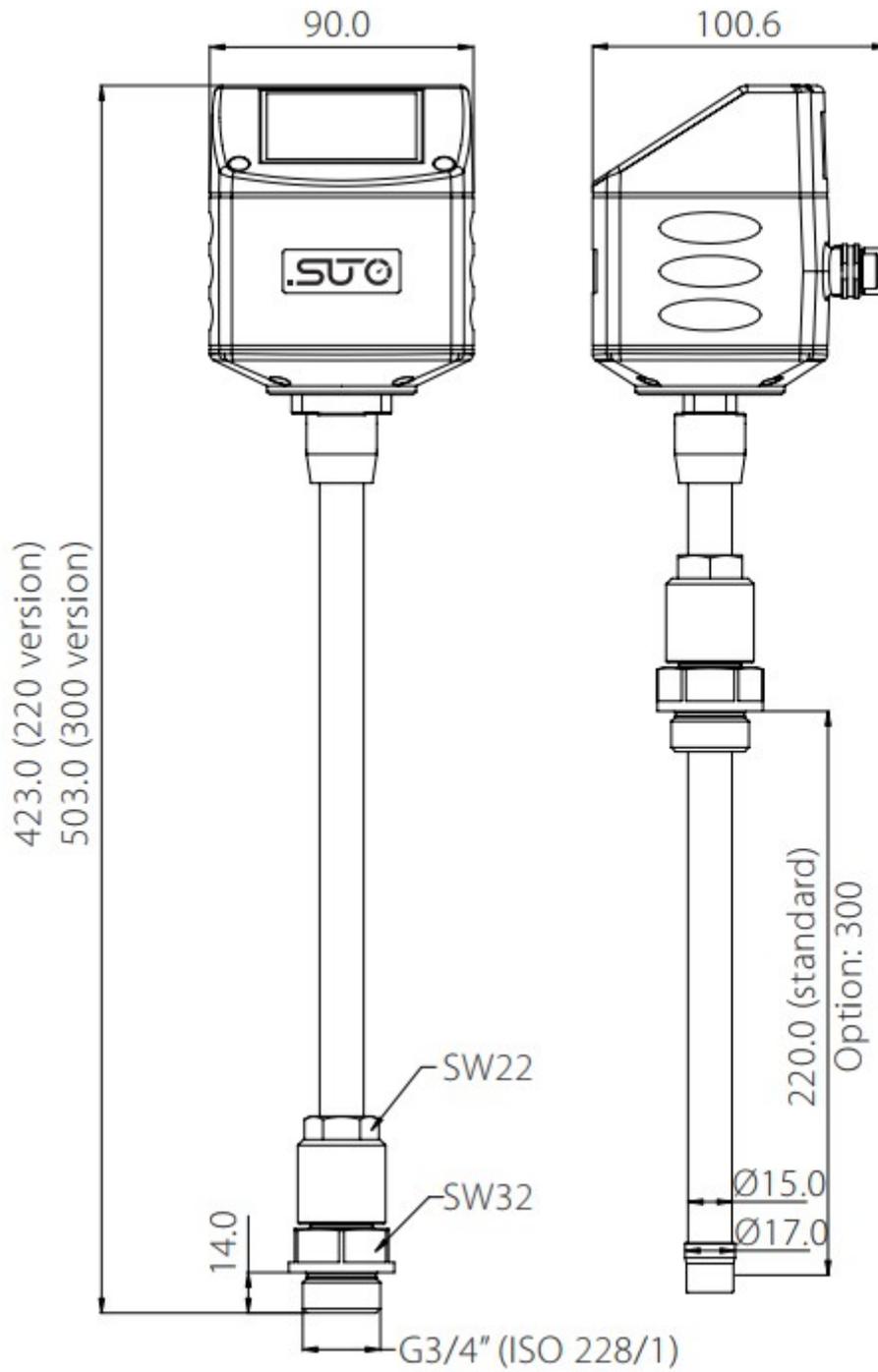
6   Installation

Before you install the sensor, make sure that all components listed below are included in your package.

Qty	Description	Item No.
1	S 430 sensor	S695 4300 or S695 4302
1	Sealing ring	No P/N
1	Alignment key	No P/N
2	M12 plug	C219 0059
1	Instruction manual	No P/N
1	Calibration certificate	No P/N

6.1 Installation requirements

To install the sensor, a ball valve or a nozzle with the following specifications is needed:

- The inner thread must be G 3/4".

- The diameter of the hole must be ≥ 18 mm, otherwise the shaft can not be inserted in.
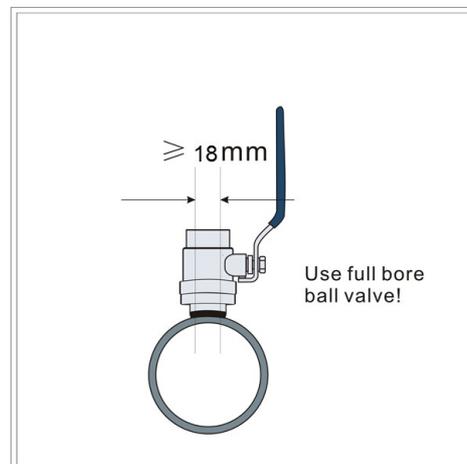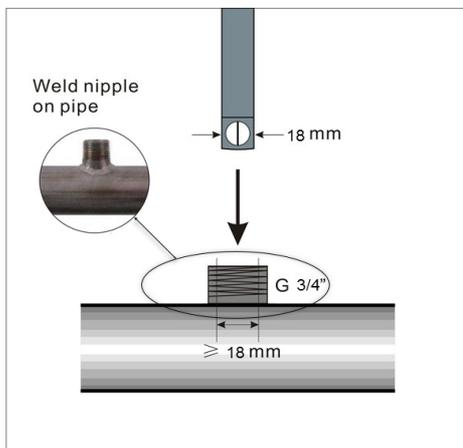
6.2 Determining the installation point

To achieve and maintain the accuracy stated in the technical data, the sensor must be inserted in a straight pipe section with unhindered flow characteristics.

6.2.1 Inlet and outlet sections

Unhindered flow characteristics are achieved if the section in front of the sensor (inlet) and behind the sensor (outlet) are sufficiently long, absolutely straight and free of obstructions such as edges, seams, curves, and so on.

Make sure that enough space exists at your site for an adequate installation as described in this manual.

ATTENTION!

Wrong measurement may occur if the sensor is not installed correctly.

- Pay careful attention to the design of the inlet and outlet sections. Obstructions can cause counter-flow turbulence as well as turbulence in the direction of the flow.

- The sensor is for indoor use only! At an outdoor installation, the sensor must be protected from solar radiation and rain.

Note: If there is any combination of the below, the longest straight inlet section must be maintained.

- Expansion
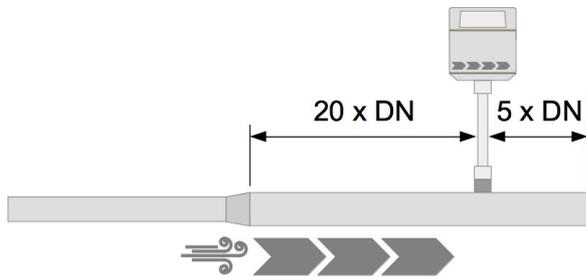
- Reduction
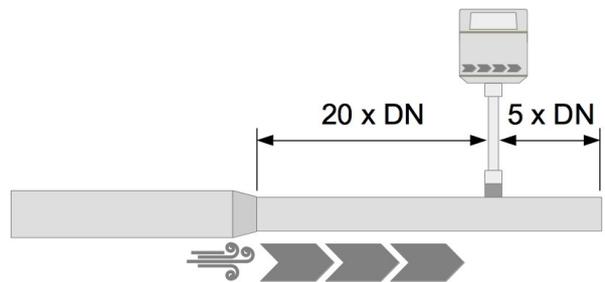
- 90° Bend
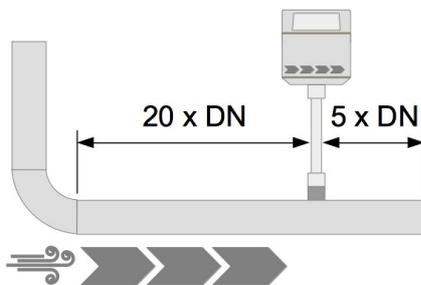
- 2×90° Bend
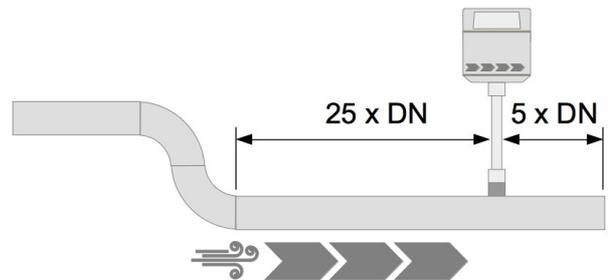
- 3 dimensional Bend
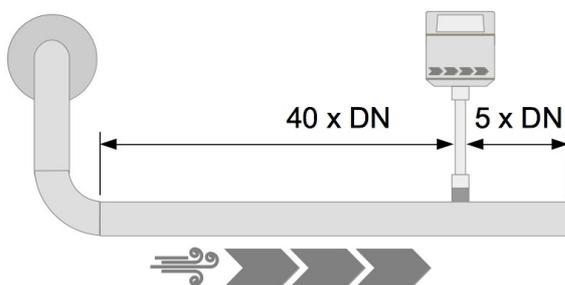
- T-piece
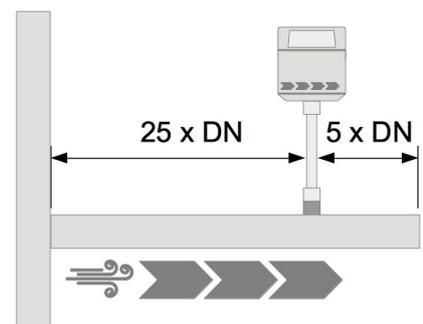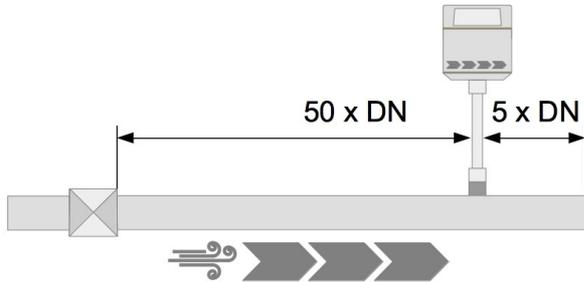
- Shut-off valve
- Filter or similar (unknown objects)
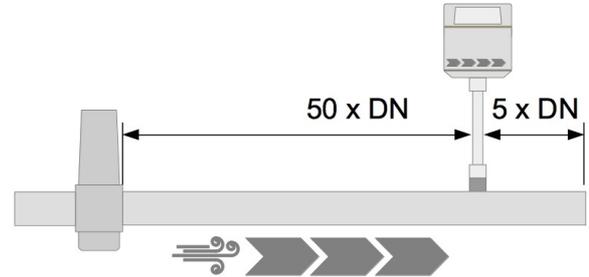
6.2.2 Insertion angles

Insertion into a horizontal pipe
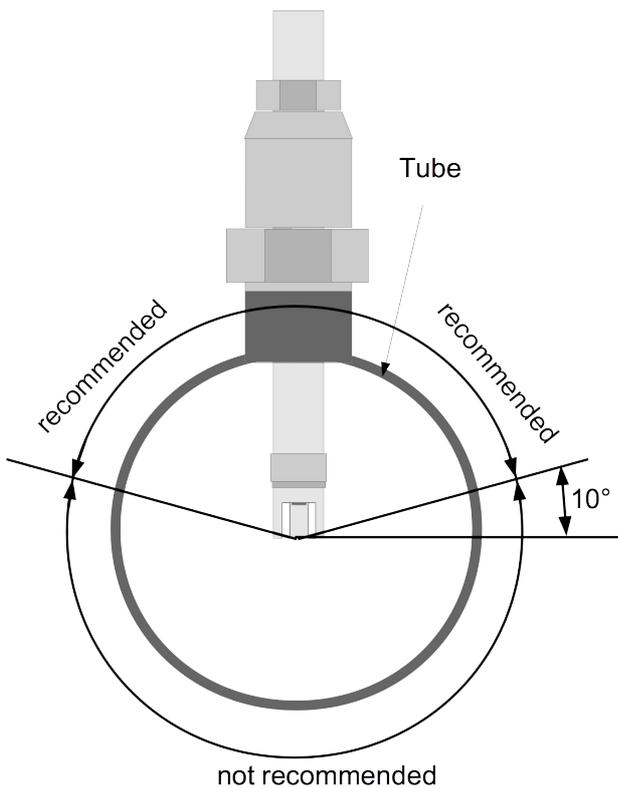
As shown in the left figure, the angle to the horizontal level must be >10°. A horizontal installation is NOT permitted.

Please install the sensor only in the recommended area.

Insertion into a vertical pipe
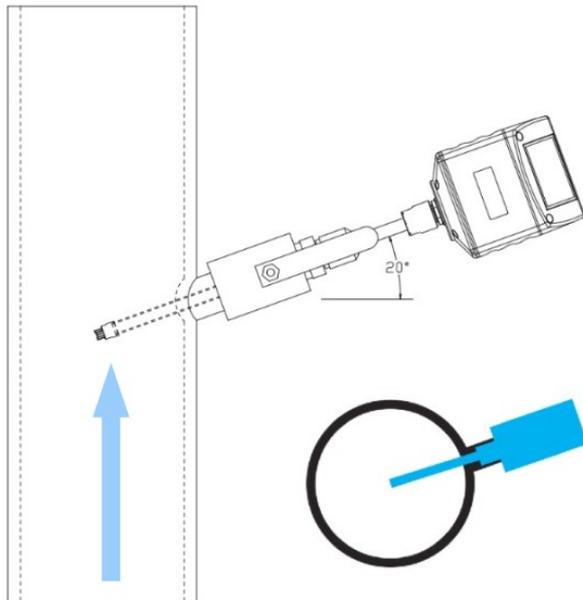
As shown in the left figure, S 430 can be used in a vertical pipe only when:
- The flow is from bottom up, and;
- The sensor is installed with an at least 10-degree angle. (Recommended angel is 20 degrees).

ATTENTION: Do not install the sensor in vertical pipes where the flow is from top down.

6.3 Calculating the insertion depth

Generally, the sensor tip must be placed in the centre of the pipe. To facilitate this, the sensor is designed with a scale engraved on its shaft. To determine the right position, calculate the insertion depth as described below.

Note: If the pipe diameter is greater than the shaft length, it is feasible to install the sensor out of centre of the pipe. For more information, please contact the manufacturer.

6.3.1 Centre installation

Centre installation is the default and recommended installation type.
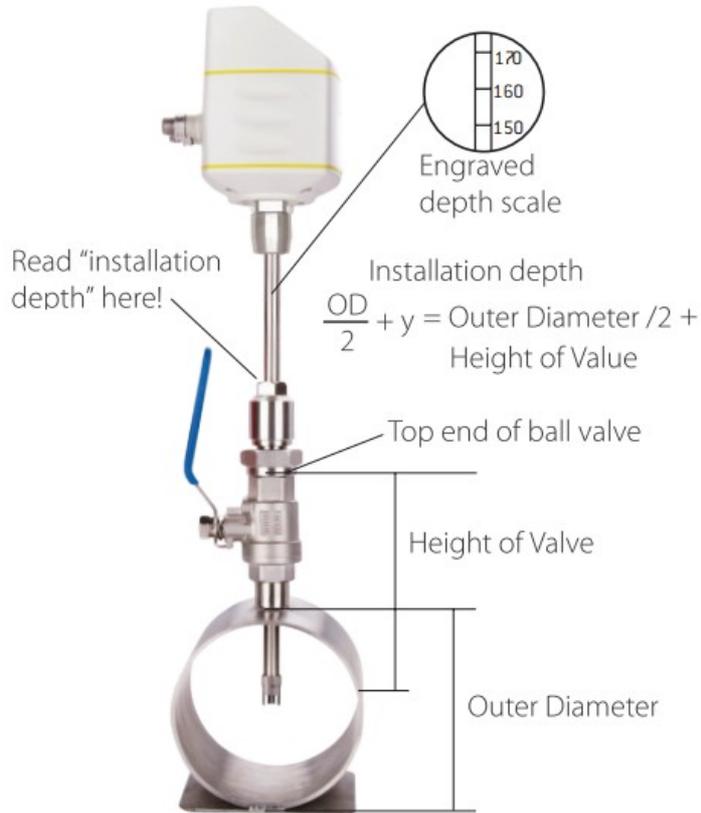
Calculation example:

A 2"-diameter pipe and an 87 mm-height ball valve:

$$OD = 60.3\,\text{mm}$$
$$\frac{OD}{2} = \frac{60.3\,\text{mm}}{2} = 30.15\,\text{mm}$$

Height of Valve $= 87\,\text{mm}$;
Insertion depth
$= 30.15\,\text{mm} + 87\,\text{mm} = 117.15\,\text{mm}$

6.3.2 Non-centre installation

In bigger pipe diameter (> DN150) situations, the non-centre installation is applicable. In the non-centre installation, the sensor is inserted to exact 100 mm-depth of pipes.
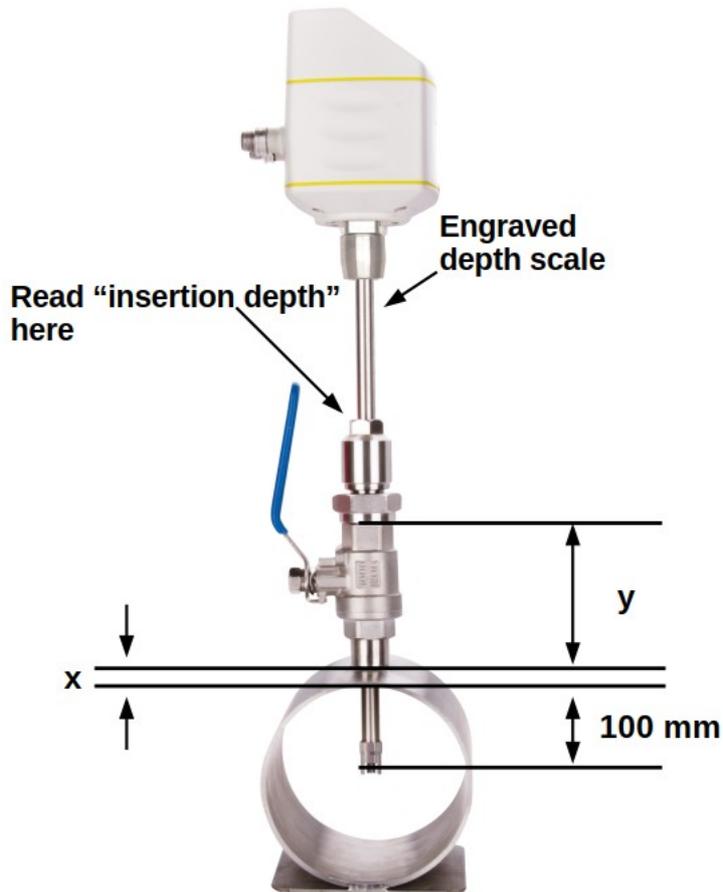
Insertion depth $= x + y + 100$
x is the wall thickness of pipe
y = Height of the ball valve

Calculation example:

A 12"-diameter pipe with the wall thickness of 9 mm and a 87 mm-height ball valve.

$x = 9\,mm\,;\,y = 87\,mm$
Insertion depth
$= 9\,mm + 87\,mm + 100\,mm = 196\,mm$

6.4 Installing the sensor

This section describes how to install S 430.

First please observe the flow direction sign indicated on the sensor head or on the shaft. It must match the flow direction of the compressed air or gas.

Sensor head

Clamp sleeve
Connection head
Sensor tip
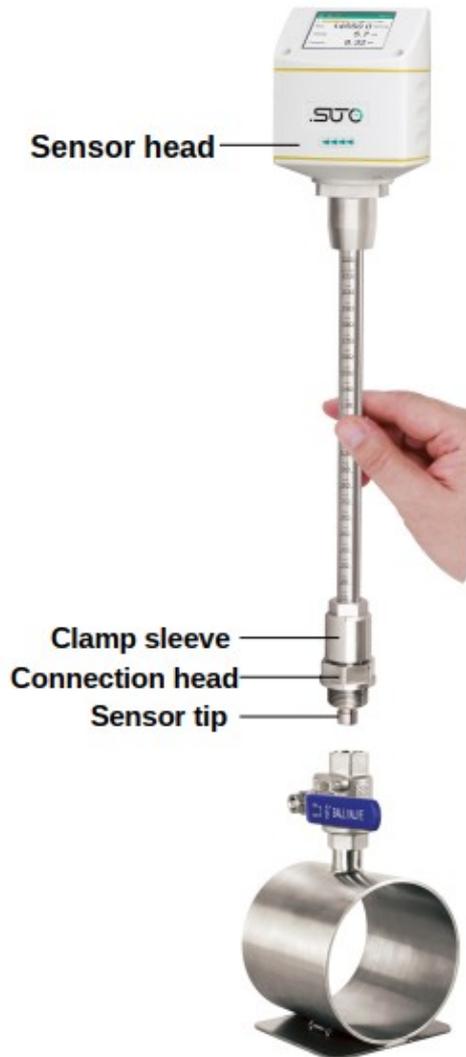
1. Close the ball valve.

2. Move the connection head to keep the sensor tip completely covered by the connection thread (see photo on the left).

3. Embed the O-shaped sealing ring to the groove in the connection head.

4. Screw the connection head tightly to the ball valve using a spanner. And then move the flow sensor to keep the flow direction sign (on the sensor head) and the flow direction pointing to the same direction.

5. Open the ball valve and tighten the clamp sleeve manually.

6. Perform **zero flow calibration**. For detailed steps, see instructions described on page 23.

7. Move the flow sensor slightly to the determined insertion depth by means of the scale on the sensor shaft.

8. Tighten the clamp sleeve so that the flow sensor cannot be moved by the pressure in the pipe while can be moved by hand.
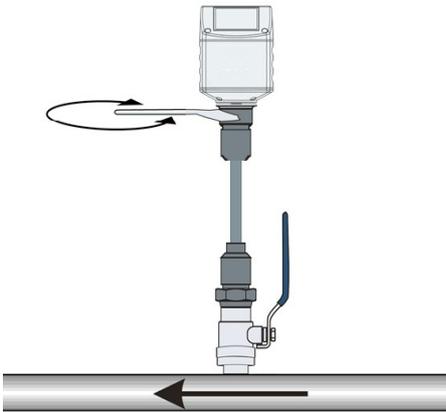
9. Use the alignment key to keep the sensor align to the pipe and point to the flow direction. See the figure on the left.
Note: The angle deviation must be not greater than ± 2° to the perfect position, as shown in Figure 1.

10. Tighten the clamp sleeve using a spanner with clamping torque of 20...30 Nm.

11. Double check the installation depth because the shaft might be moved from its original position by the compressed gas.

Maximum angle deviation of a proper installation:
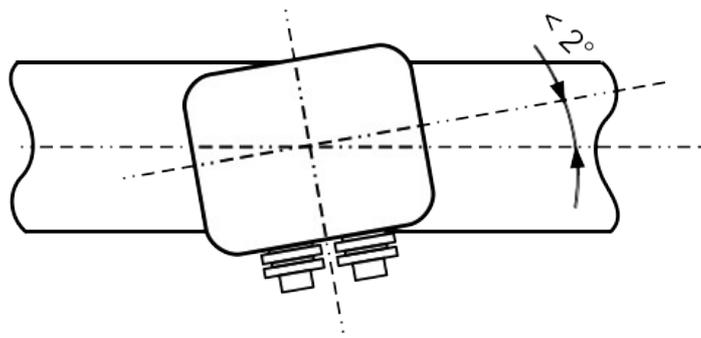
Figure 1: Top view

6.5 Performing the zero flow calibration

The zero flow calibration is a compulsory operation during the installation of the sensor. Use one of the following methods to perform the calibration:

- The service App S4C-FS, available on the Google Play store or our Website for free download
- The optional local display

6.5.1 Prerequisites

Before you start the calibration, make sure the following conditions are met:

- The sensor must have been mounted on top of the G 3/4" ball valve.

- The ball valve must be opened with the sensor tip outside of the pipe. That is, the sensor tip still remain inside the ball valve.

These ensure that the sensor is exposed to the system pressure during calibration.

6.5.2 Using the service App S4C-FS

This is the most convenient way especially when the sensor is not equipped with the optional local display.

1. On your mobile device, download the S4C-FS App from the **SUPPORT** > **Downloads** menu on https://suto-itec.com or from Google Play store as needed.

2. Turn on Bluetooth on your mobile device.

3. Launch the **S4C-FS** App.

   Sensors that are within the reach of your Bluetooth signal while not connected with other S4C-FS Apps are displayed on the home screen.
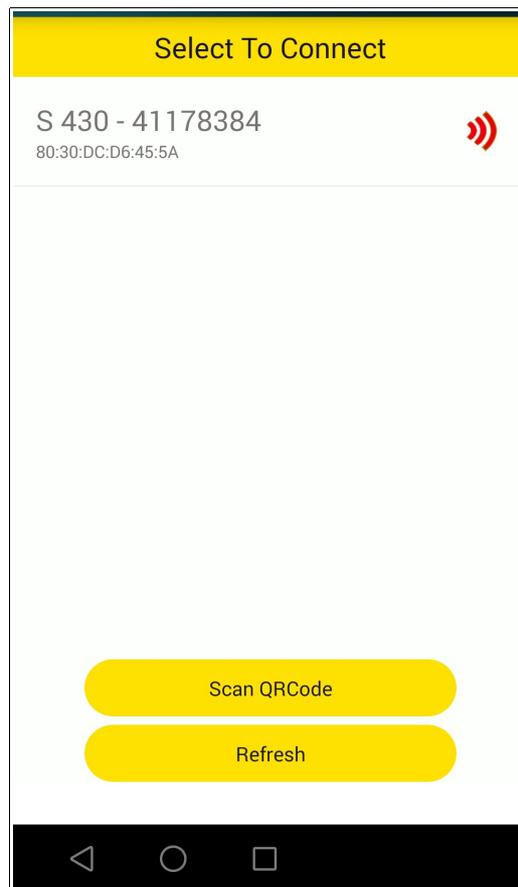
Note: A red Wireless Connection icon is displayed behind a connected sensor, which indicates that the sensor is successfully

connected but accessible in the read-only mode. In this mode, you can only view the online parameter values and existing settings.

4. Click the **Scan QR Code** button, and then scan the QR code provided on the calibration certification.

A green Wireless Connection icon is displayed indicating that the sensor is accessible in the editable mode.

Note: Only through scanning the QR code can you edit system settings and perform calibrations.

5. Click the **System** icon.

6. On the **System** screen that appears, click **Calibration** and follow the onscreen instructions to perform the zero flow calibration.

6.5.3 Using the local display

See steps 4 and 5 described in the following Figure 3.

Figure 2: Steps to expose the sensor to the system pressure
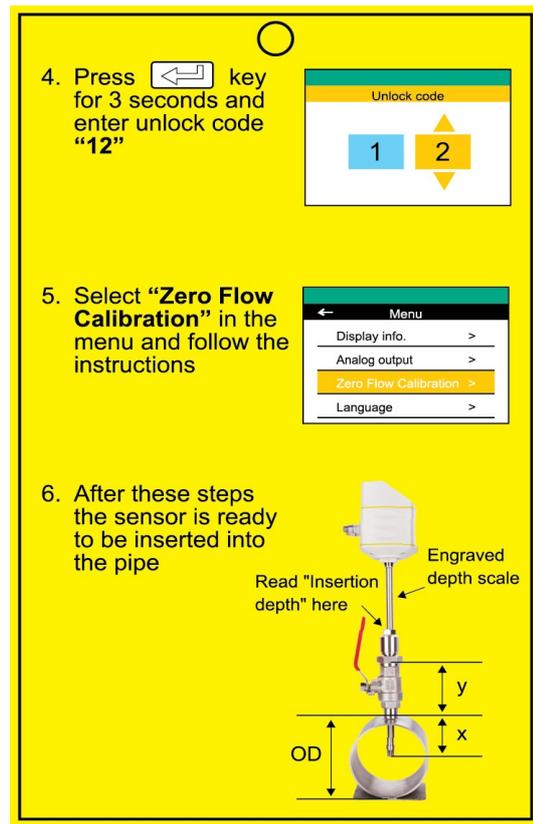
Figure 3: Steps to perform the zero flow calibration

6.6 Removing the sensor

⚠ **WARNING!**

The removal of sensors under pressure can be dangerous! Be aware that the sensor can be shot out of the ball valve if you do not carefully follow the steps described below!

For your information: The sensor is exposed to a force of 18 kg at the 8-barg system pressure; a force of 32 kg at 16-barg system pressure!! Hold the sensor very tight when releasing the clamp sleeve.

1. Hold the flow sensor firmly.

2. Release the clamp sleeve from the connection head very slowly while keeping your hand on the top of the sensor head.

3. Pull out the shaft slowly until the sensor is fully returned into the value.

4. Close the ball valve.

5. Unscrew the connection head and pull the flow sensor out of the ball valve.

6.7 Making electrical connection

The flow sensor is equipped with two M12 connector plugs - "A" and "B". Cables are connected to the sensor through the M12 connector plugs.

Connector plug A
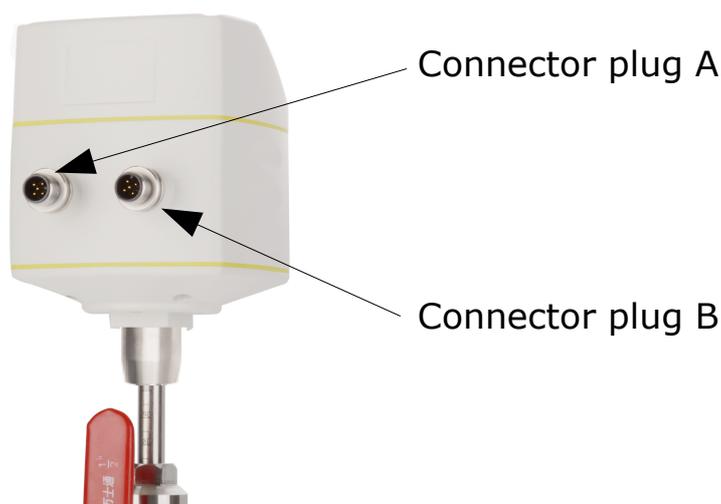
Connector plug B

Connection pins – M12 connector plug
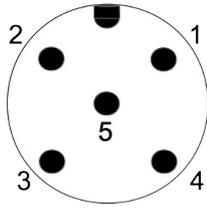
Connection pins
(view from the clamping side)

Pin assignment – M12 connector plug

Output Version	Connector	Pin 1	Pin 2	Pin 3	Pin 4	Pin 5
Modbus	A	SDI	-VB	+VB	N/A	N/A
	B	GND	-VB	+VB	+D	-D
Pulse and analog	A	SDI	-VB	+VB	N/A	N/A
	B	N/A	SW	SW	+I	-I
M-Bus	A	SDI	-VB	+VB	N/A	N/A
	B	N/A	-VB	+VB	M	M
Wire colour		brown	white	blue	black	grey

Legend for pin assignment

GND: Ground for Modbus

SDI: Digital signal (internal use)

-VB: Negative supply voltage

+VB: Positive supply voltage

+I: Positive 4 … 20 mA signal

-I: Negative 4 … 20 mA signal

SW: Isolated pulse switch input/output

D+:   Modbus data +

D-:   Modbus data -

M: M-Bus data

N/A: Not applicable

ATTENTION!

Do not screw the M12 connector using force. Otherwise, it may damage the connection pins.

7 Configuration

After the installation is completed, change the sensor settings of your choice using the service App S4C-FS, local display (optional), or service kit (optional).

Note: You can also use these tools to view parameter values and error messages.

7.1 Description of sensor settings

Settings provided on S 430 come into the following categories.

7.1.1 Flow settings

Parameter	Description
Pipe diameter	Enter the pipe diameter in the unit of mm.
Gas type	Select the gas type. To measure steam, select "steam" as the gas type.
Flow type	Make a selection from: • Flow: Total measured volumetric flow (air + moisture) at standard conditions as configured (for example, 20 °C, 1000 hPa) • Dry Air Flow: Measured volumetric flow of air only at standard conditions as configured (for example, 20 °C, 1000 hPa) • FAD: Free Air Delivery calculated based on the total measured volumetric flow at programmed intake conditions (for example, 25 °C, 980 hPa, 30 %rH) • Working Condition Flow: Working volumetric Flow at fluid pressure and temperature.
Installation	Select an installation method • Center Installation • 100mm insertion depth

7.1.2 Unit settings

Configure units for flow, pressure, temperature, and consumption.

7.1.3 Reference conditions

View reference settings at standard condition and norm condition.

Configure reference settings at the customer condition as needed.

7.1.4 Factory settings

Configure filter grade at the scale of 0 to 127.

7.1.5 Output settings

Configure output settings for Modbus such as the device address, Baud rate, Parity, and Stop bit

7.1.6 Language setting

Select the UI language.

7.2 Configuration using the service App S4C-FS

This is the most convenient way especially when the sensor is not equipped with the optional local display.
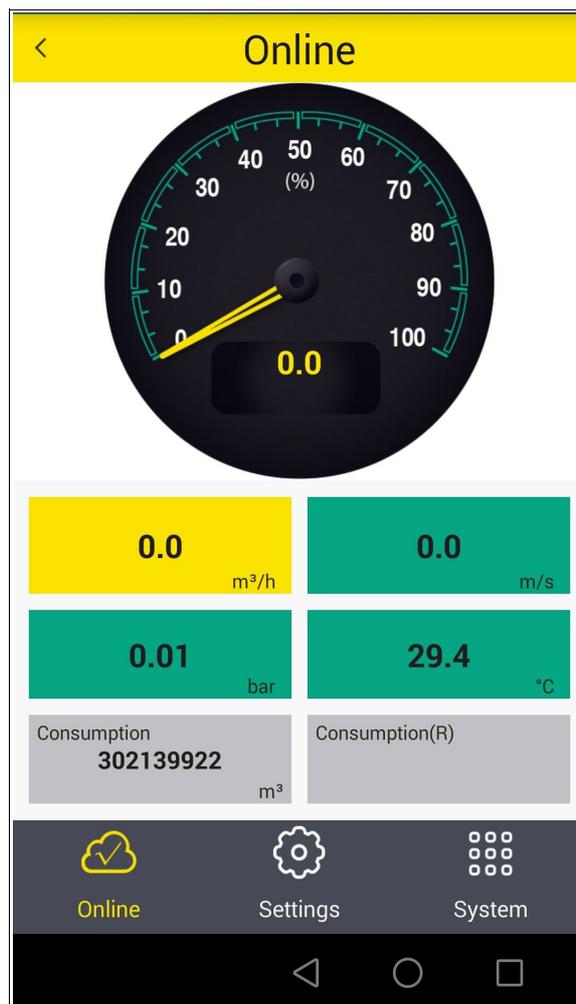
The App is available for Android systems. You can download the service App from the Google Play store or our Website.

To change settings using the App, you must scan the QR code on the calibration certificate. This ensures that only valid users can change the sensor settings.

For more detailed instructions, refer to steps described on page 24.

7.3 Configuration using the optional sensor display

For sensors equipped with a local display, you can make configurations using the display.

Enter key

Up key

Down key

7.3.1 Starting process

After powered on, the display automatically starts an initialization procedure. In the next eight seconds the display will show the current software version and build up the connection with the sensor. Now the display goes to the standard mode, showing the online values such as flow, velocity and pressure, alternately.

7.3.2 About the home page
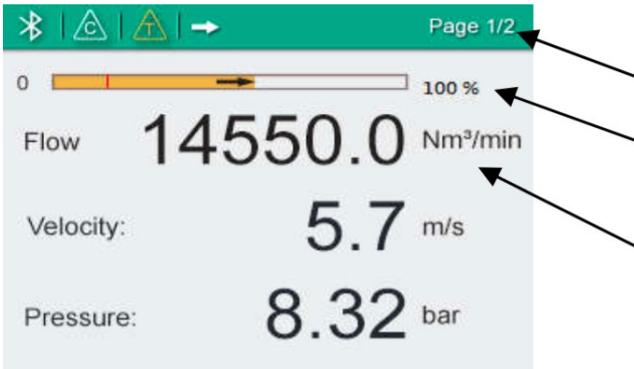
Home page:

- Status bar
- Moving bar to indicate flow and cut-off value
- Measuring values

Icons are shown in the status bar indicating status or warnings for the sensor in service. The following table provides descriptions for these icons.

Icon	Description
	Calibration expired
	Temperature over operating range
	Flows over measuring range
	Pressure over operating range
	Pressure sensor damaged
	Temperature sensor damaged
	Flow direction

7.3.3 Configuration instructions
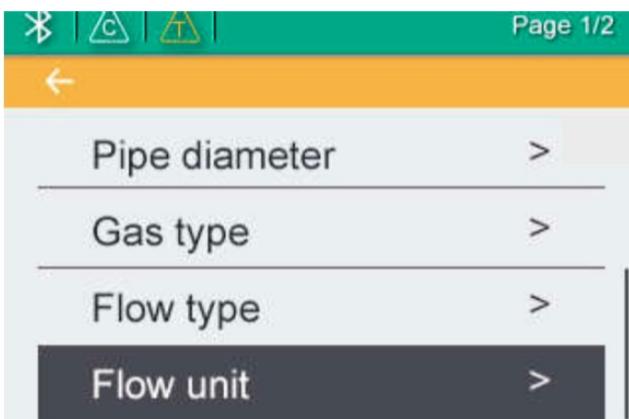
1. Press the **Enter** key (>3s).

2. Enter the unlock code:12 using the **Up** and **Down** keys, and then enter **Enter** key.

3. Use the **Up** and **Down** keys to choose the parameter that you want to change.
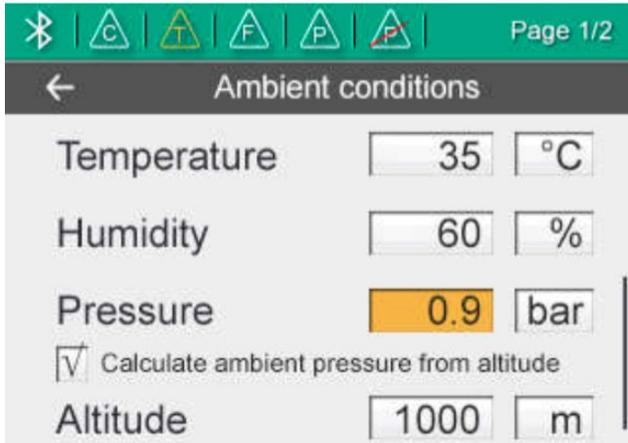
4. Use the **Up** and **Down** keys to select desired entry box or adjust the values.

5. Press the **Enter** key to confirm the changes.
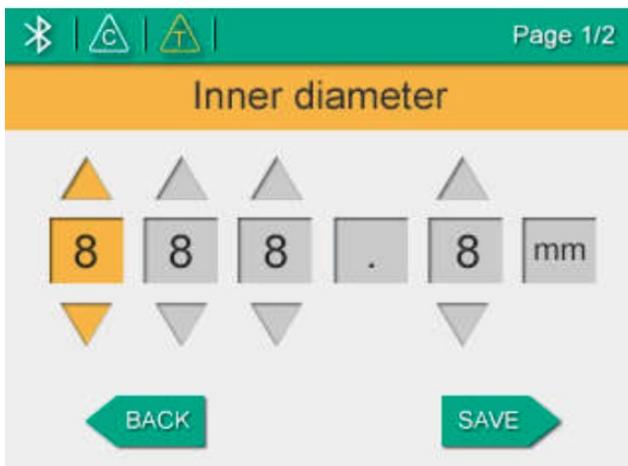
8   Sensor signal outputs

8.1   Analog output

The sensor has an analogue output range of 4...20 mA. This output can be scaled to match a desired measuring range. Standard is the range from 0 to max. flow depending on the pipe diameter. The corresponding flow in different pipe sizes can be found in the Appendix section. For other ranges, please contact the manufacturer.

8.2   Pulse output

The sensor will send out one pulse per consumption unit. This pulse output can be connected to an external pulse counter to count the total consumption. The number of m^3 per second are summed up and indicated after one second. Pulse length depends on consumption rate.
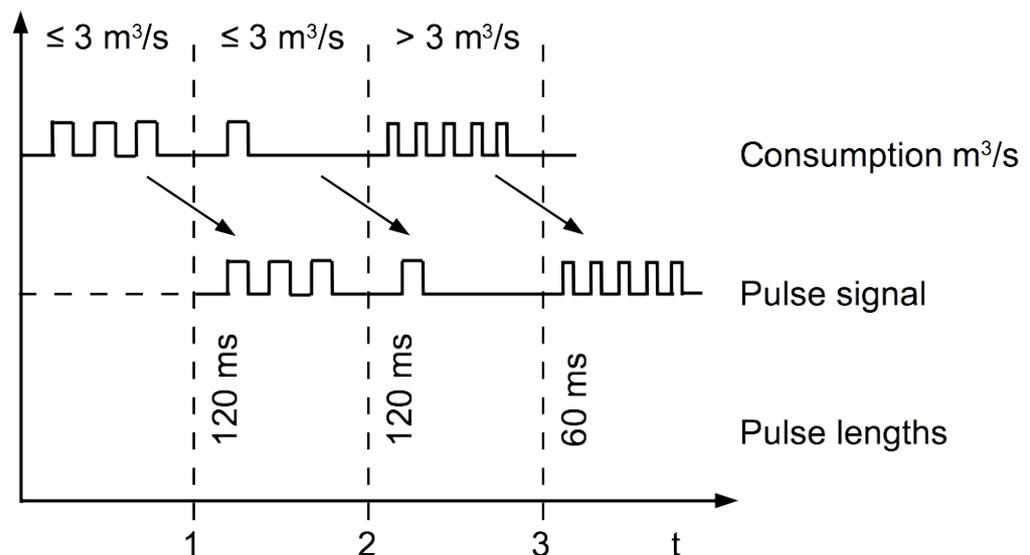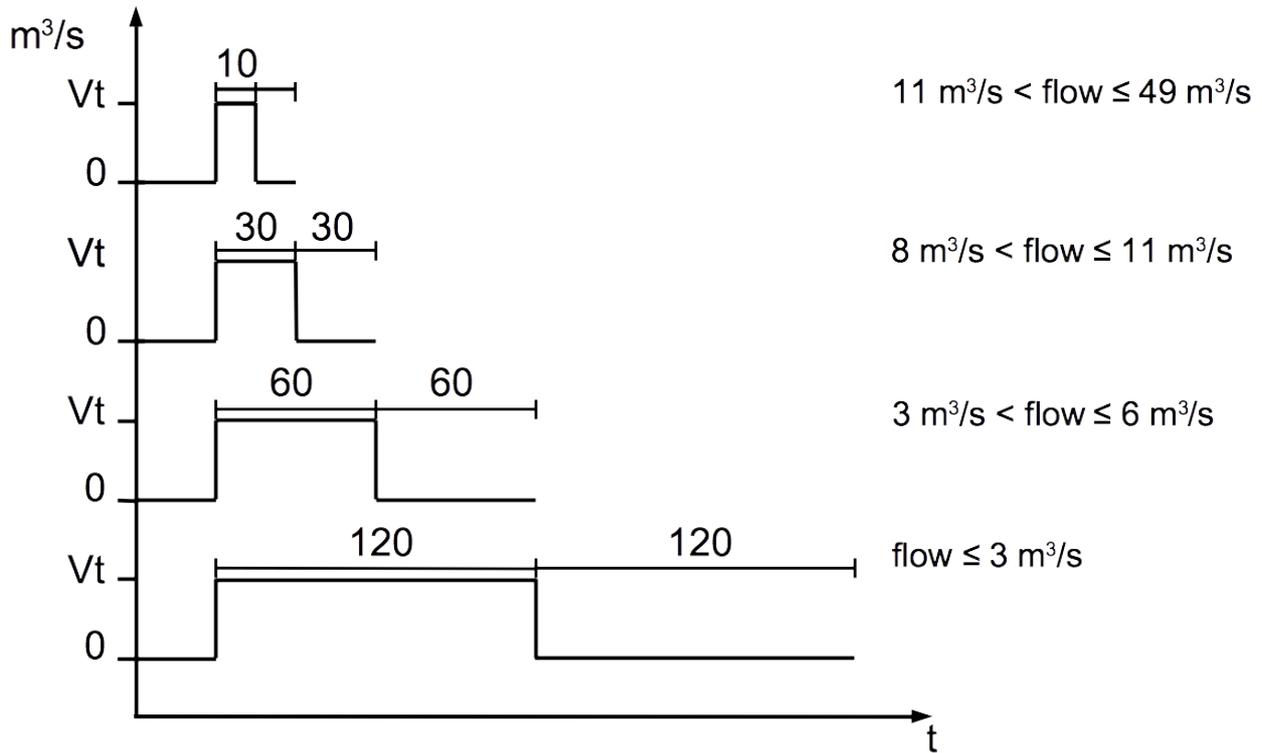
In case the flow rate is higher than 50 m^3/s, l/s of ft^3/s, the S 430 can not output the pulses with default settings (one pulse per consumption unit). For this the pulse can be set by our service software or a connected display to 1 pulse per 10 consumption units or 1 pulse per 100 consumption units. For example, if set to 1 pulse per 10 m^3, the sensor will send one pulse each 10 m^3.

Example:

Volume flow [m^3/h]	Pulse length [ms]	Max. consumption [m^3]
$\leqq$ 10800	120	10800
> 10800	60	28800
> 28800	30	57600

8.3 Pulse connection diagram

Using the isolated pulse switch (Connector B Pin 2 and 3)

Variant 1:
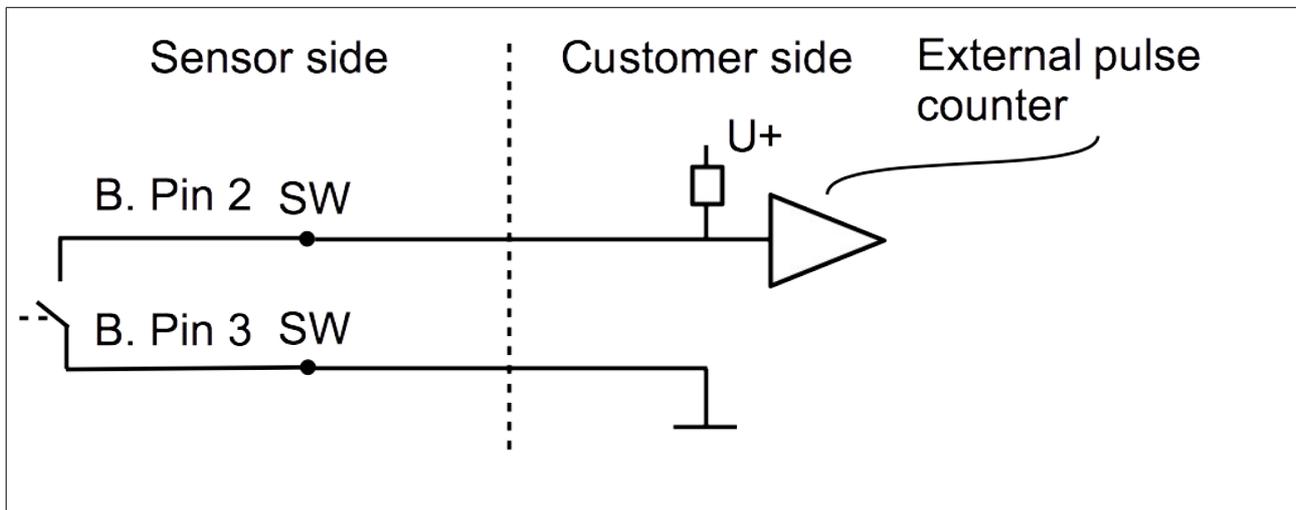
Variant 2:
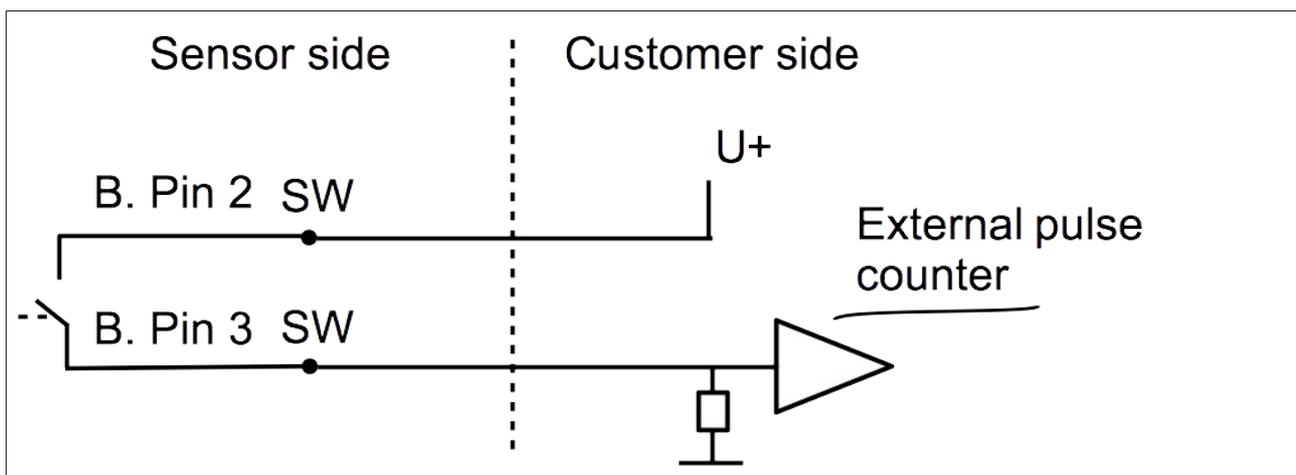
8.4 Modbus output

Mode   : RTU

Baud rate   : 19200

Device address   : 1

Framing / parity / stop bit   : 8, E, 1

Response time   : 1 second

Response delay   : 0 ms

Inter-frame spacing   : 7 char

Remarks

Modbus communication settings can be changed by the service software S4C-FS.

ID	Channel description	Resolution	Format	Length	Modbus address
0	Gas temperature	0.1	FLOAT	4 Byte	0
1	Pressure	0.001	FLOAT	4 Byte	2
2	Velocity	0.1	FLOAT	4 Byte	4
3	Flow	0.1	FLOAT	4 Byte	6
4	Consumption	1.0	UNIT32	4 Byte	8
5	Reverse velocity	0.1	FLOAT	4 Byte	10
6	Reverse flow	0.1	FLOAT	4 Byte	12
7	Reverse consumption	1.0	UNIT32	4 Byte	14
8	System status	1.0	UNIT32	4 Byte	24

Remarks

- All numbers are in little-endian format.

- All values are scaled in the physical unit as selected by users.

Interpretation of system status

Bit	Description
2	Measurement overrange
3	Temperature overrange
4	Pressure overrange
5	Pulse overrange
6	Calibration overdue
8	Differential pressure sensor broken
9	Pressure sensor broken
10	Temperature sensor broken
11	NTC broken
15	Flow direction: 0: standard 1: reverse
16	BT module connected

8.5 M-Bus output

Manufacturer code / Fabrication No.   : 0x15C4 / serial number

Baud rate / parity   : 2400 bps / even

Device address   : primary address: 1; secondary address: serial number

Response delay / timeout   : 7ms / 500ms

Channel	Data information field (DIF)	Unit	Factor*
Counter	04	m^3	1
Flow	04	m^3/h	0.1
Temperature	04	°C	0.1
Pressure	05	bar	1
* **Note**: The displayed value equals to the channel reading multiplied by the factor.			

9 Calibration

The sensor is calibrated before delivery. The calibration date is printed on the certificate which is shipped with the sensor. The accuracy of the sensor is regulated by the on-site conditions. Parameters such as oil, high humidity or other impurities can affect the calibration and furthermore the accuracy. We recommend you calibrate the sensor at least once a year. The calibration is excluded from the product warranty. For more information, please contact the manufacturer.

10 Maintenance

To clean the sensor it is recommended to use distilled water or isopropyl alcohol only. If the contamination can not be removed the sensor has to be inspected and maintained by the manufacturer.

11 Disposal or waste

Electronic devices are recyclable material and do not belong in the household waste.
The device, the accessories and its packings must be disposed according to your local statutory requirements. The dispose can also be carried by the manufacturer of the product. Please contact the manufacturer for details.

12 Warranty

SUTO provides a warranty for this product of 24 months covering the material and workmanship under the stated operating conditions from the date of delivery. Please report any findings immediately and within the warranty time. If faults occur during the warranty time SUTO will repair or replace the defective unit, without charge for labour and material costs but there is a charge for other service such as transport and packing costs.
Excluded from this warranty is:

- Damage caused by:

  ○ Improper use and non-adherence to the instruction manual.

  ○ Use of unsuitable accessories.

  ○ External influences (e.g. damage caused by vibration, damage during transportation, excess heat or moisture).

The warranty is cancelled when one of the following situations occurs:

- The user opens the measurement instrument without a direct request written in this instruction manual.

- Repairs or modifications are undertaken by third parties or unauthorised persons.

- The serial number has been changed, damaged or removed.

Other claims, especially those for damage occurring outside the instrument are not included unless responsibility is legally binding.

Warranty repairs do not extend the period of warranty.

ATTENTION!

Batteries have a reduced warranty time of 12 months.

13 Appendix A - Analogue output

Scaling table analogue output (standard range):

Medium: Air at ISO 1217; 20 °C; 1000 mbar

Tube			Flow							
inch	PLF	mm	m³/h	m³/min	l/min	l/s	cfm	kg/h	kg/min	kg/s
1 1/4"	0.776	32.80	472.10	7.87	7868.3	131.14	277.9	560.7	9.35	0.16
	0.784	36.00	574.57	9.58	9576.2	159.60	338.2	682.5	11.37	0.19
	0.785	36.30	584.93	9.75	9748.9	162.48	344.3	694.8	11.58	0.19
1 1/2"	0.792	39.30	691.72	11.53	11528.7	192.15	407.1	821.6	13.69	0.23
	0.793	40.00	717.49	11.96	11958.2	199.30	422.3	852.2	14.20	0.24
	0.797	41.80	787.47	13.12	13124.5	218.74	463.5	935.3	15.59	0.26
	0.800	43.10	840.36	14.01	14006.0	233.43	494.6	998.2	16.64	0.28
	0.804	45.80	953.69	15.89	15894.9	264.92	561.3	1132.8	18.88	0.31
2"	0.810	50.00	1145.11	19.09	19085.2	318.09	674.0	1360.1	22.67	0.38
	0.811	51.20	1202.22	20.04	20037.0	333.95	707.6	1428.0	23.80	0.40
	0.812	53.10	1294.69	21.58	21578.2	359.64	762.0	1537.8	25.63	0.43
	0.813	54.50	1365.54	22.76	22759.1	379.32	803.7	1622.0	27.03	0.45
	0.818	57.50	1529.37	25.49	25489.4	424.82	900.2	1816.5	30.28	0.50
	0.820	60.00	1669.32	27.82	27821.9	463.70	982.5	1982.8	33.05	0.55
	0.823	64.20	1918.19	31.97	31969.9	532.83	1129.0	2278.4	37.97	0.63
2 1/2"	0.824	65.00	1968.69	32.81	32811.4	546.86	1158.7	2338.3	38.97	0.65
	0.825	68.90	2214.70	36.91	36911.7	615.19	1303.5	2630.6	43.84	0.73
	0.827	70.30	2311.21	38.52	38520.1	642.00	1360.3	2745.2	45.75	0.76
	0.827	71.10	2364.11	39.40	39401.8	656.70	1391.5	2808.0	46.80	0.78
	0.829	76.10	2714.85	45.25	45247.5	754.13	1597.9	3224.6	53.74	0.90
3"	0.830	80.00	3003.87	50.06	50064.4	834.41	1768.0	3567.9	59.46	0.99
	0.831	82.50	3198.39	53.31	53306.5	888.44	1882.5	3798.9	63.32	1.06
	0.831	84.90	3387.18	56.45	56453.1	940.88	1993.6	4023.2	67.05	1.12
	0.832	90.00	3810.93	63.52	63515.5	1058.59	2243.0	4526.5	75.44	1.26
4"	0.833	100.00	4710.50	78.51	78508.4	1308.47	2772.5	5595.0	93.25	1.55
	0.834	107.10	5409.63	90.16	90160.5	1502.67	3184.0	6425.4	107.09	1.78
	0.834	110.00	5706.55	95.11	95109.2	1585.15	3358.8	6778.1	112.97	1.88
5"	0.835	125.00	7377.83	122.96	122963.9	2049.40	4342.4	8763.2	146.05	2.43
	0.835	133.70	8440.57	140.68	140676.1	2344.60	4967.9	10025.4	167.09	2.78
6"	0.836	150.00	10636.80	177.28	177280.1	2954.67	6260.6	12634.1	210.57	3.51
	0.836	159.30	11996.66	199.94	199944.3	3332.40	7061.0	14249.3	237.49	3.96
	0.837	182.50	15764.26	262.74	262737.7	4378.96	9278.5	18724.3	312.07	5.20
	0.837	190.00	17086.58	284.78	284776.3	4746.27	10056.8	20294.9	338.25	5.64
8"	0.838	200.00	18955.11	315.92	315918.6	5265.31	11156.6	22514.3	375.24	6.25
	0.838	206.50	20207.22	336.79	336787.0	5613.12	11893.5	24001.5	400.03	6.67
10"	0.839	250.00	29652.71	494.21	494211.8	8236.86	17452.9	35220.6	587.01	9.78
	0.840	260.40	32209.47	536.82	536824.6	8947.08	18957.8	38257.4	637.62	10.63
12"	0.840	300.00	42750.79	712.51	712513.2	11875.22	25162.2	50778.1	846.30	14.11
	0.840	309.70	45560.04	759.33	759334.0	12655.57	26815.6	54114.8	901.91	15.03
	0.840	339.60	54781.89	913.03	913031.5	15217.19	32243.4	65068.2	1084.47	18.07
	0.840	400.00	76001.41	1266.69	1266690.2	21111.50	44732.8	90272.1	1504.54	25.08
	0.840	500.00	118752.20	1979.20	1979203.4	32986.72	69894.9	141050.2	2350.84	39.18
	0.840	600.00	171003.17	2850.05	2850052.9	47500.88	100648.7	203112.3	3385.20	56.42
	0.840	700.00	232754.32	3879.24	3879238.6	64653.98	136994.1	276458.4	4607.64	76.79
	0.840	800.00	304005.64	5066.76	5066760.6	84446.01	178931.0	361088.5	6018.14	100.30
	0.840	900.00	384757.14	6412.62	6412618.9	106876.98	226459.6	457002.6	7616.71	126.95
	0.840	1000.00	475008.81	7916.81	7916813.5	131946.89	279579.7	564200.8	9403.35	156.72

14 Appendix B – Modbus communication example

03 (0x03) Read holding register

Request   Response

Slave address	1 byte	Slave address	1 byte
Function code	1 byte	Function code	1 byte
Starting address Hi	1 byte	Byte count	1 byte
Starting address Lo	1 byte	Register Hi	1 byte
No. of points Hi	1 byte	Register Lo	1 byte
No. of points Lo	1 byte	:	:
CRC	2 bytes	Register Hi	1 byte
		Register Lo	1 byte
		CRC	2 bytes

05 (0x05) Write single coil

Request   Response

Slave address	1 byte	Slave address	1 byte
Function code	1 byte	Function code	1 byte
Coil address Hi	1 byte	Coil address Hi	1 byte
Coil address Lo	1 byte	Coil address Lo	1 byte
Data Hi	1 byte	Data Hi	1 byte
Data Lo	1 byte	Data L	1 byte
CRC	2 bytes	CRC	2 bytes

16 (0x10) Write multiple registers

Request		Response	
Slave address	1 byte	Slave address	1 byte
Function code	1 byte	Function code	1 byte
Starting address Hi	1 byte	Starting address Hi	1 byte
Starting address Lo	1 byte	Starting address Lo	1 byte
No. of registers Hi	1 byte	No. of registers Hi	1 byte
No. of registers Lo	1 byte	No. of registers Lo	1 byte
Byte count	1 byte	CRC	2 bytes
Data Hi	1 byte		
Data Lo	1 byte		
:	:		
Data Hi	1 byte		
Data Lo	1 byte		
CRC	2 bytes		

17 (0x11) Report slave ID

Request		Response	
Slave address	1 byte	Slave address	1 byte
Function code	1 byte	Function code	1 byte
CRC	2 bytes	Byte count	1 byte
		Slave ID	2 bytes
		Device run indicator	2 bytes
		Product code	2 bytes
		Product name	20 bytes
		CRC	2 bytes

15 Appendix C - LRC and CRC calculation

LRC generation

The Longitudinal Redundancy Checking (LRC) field is one byte, containing an 8–bit binary value. The LRC value is calculated by the transmitting device, which appends the LRC to the message. The device that receives recalculates an LRC during receipt of the message, and compares the calculated value to the actual value it received in the LRC field. If the two values are not equal, an error results.

The LRC is calculated by adding together successive 8–bit bytes in the message, discarding any carries, and then two's complementing the result. The LRC is an 8–bit field, therefore each new addition of a character that would result in a value higher than 255 decimal simply 'rolls over' the field's value through zero. Because there is no ninth bit, the carry is discarded automatically.

A procedure for generating an LRC is:

1. Add all bytes in the message, excluding the starting 'colon' and ending CRLF. Add them into an 8–bit field, so that carries will be discarded.
2. Subtract the final field value from FF hex (all 1's) to produce the ones–complement.
3. Add 1 to produce the twos–complement.

Placing the LRC into the Message

When the 8–bit LRC (2 ASCII characters) is transmitted in the message, the high–order character will be transmitted first, followed by the low–order character. For example, if the LRC value is 61 hex (0110 0001):

Colon	Addr	Func	Data Count	Data	Data	Data	Data	LRC Hi	LRC Lo	CR	LF
								"6" 0x36	"1" 0x31		

Example: an example of a C language function performing LRC generation is shown below.

The function takes two arguments:

unsigned char *auchMsg; /* A pointer to the message buffer containing binary data */

                      /* to be used for generating the LRC,   */

unsigned short usDataLen; /* The quantity of bytes in the message buffer.   */

LRC generation function

static unsigned char LRC(unsigned char *auchMsg, unsigned short usDataLen)
 {

    unsigned char uchLRC = 0 ;   /* LRC char initialized */

    while (usDataLen––)   /* pass through message buffer */

        uchLRC += *auchMsg++ ;   /* add buffer byte without carry */

    return ((unsigned char)(–((char)uchLRC))) ;   /* return twos complement */

}

CRC generation

The **C**yclical **R**edundancy **C**hecking (CRC) field is two bytes, containing a 16-bit binary value. The CRC value is first generated by the transmitting device, which appends the CRC to the message. The device that receives recalculates a CRC during receipt of the message, and compares the calculated value to the actual value it received in the CRC field. If the two values are not equal, an error results.

There are many ways of calculating a CRC checksum. To ensure correct calculation, please refer to [Reference 1] Modbus over serial line, where detailed descriptions and programming examples are available. Even more information and programming examples in different programming languages can be found on: www.modbus.org searching for CRC.

Below is a short text description of how the CRC is calculated. This description is then followed by a C programming example.

1. Load a 16-bit register with FFFF hex (all 1's). Call this the CRC register.

2. Exclusive OR the first 8-bit byte of the message with the low-order byte of the 16-bit CRC register, putting the result in the CRC register.

3. Shift the CRC register one bit to the right (toward the LSB), zero-filling the MSB. Extract and examine the LSB.

4. (If the LSB was 0): Repeat step 3 (another shift). (If the LSB was 1): Exclusive OR the CRC register with the polynomial value 0xA001 (1010 0000 0000 0001).

5. Repeat steps 3 and 4 until 8 shifts have been performed. When this is done, a complete 8-bit byte will have been processed.

6. Repeat steps 2 through 5 for the next 8-bit byte of the message. Continue doing this until all bytes have been processed.

7. The final content of the CRC register is the CRC value.

8. When the CRC is placed into the message, its upper and lower bytes must be swapped as described below.

Placing the CRC into the message

When the 16-bit CRC (two 8-bit bytes) is transmitted in the message, the low-order byte will be transmitted first, followed by the high-order byte.

For example, if the CRC value is 1241 hex (0001 0010 0100 0001):

Addr	Func	Data count	Data	Data	Data	Data	CRC Lo	CRC Hi
							0x41	0x12

High-order byte table
/* Table of CRC values for high–order byte */
static unsigned char auchCRCHi[] = {
0x00, 0xC1, 0x81, 0x40, 0x01, 0xC0, 0x80, 0x41, 0x01, 0xC0, 0x80, 0x41, 0x00,
0xC1, 0x81, 0x40, 0x01, 0xC0, 0x80, 0x41, 0x00, 0xC1, 0x81, 0x40, 0x00, 0xC1,
0x81, 0x40, 0x01, 0xC0, 0x80, 0x41, 0x01, 0xC0, 0x80, 0x41, 0x00, 0xC1, 0x81,
0x40, 0x00, 0xC1, 0x81, 0x40, 0x01, 0xC0, 0x80, 0x41, 0x00, 0xC1, 0x81, 0x40,
0x01, 0xC0, 0x80, 0x41, 0x01, 0xC0, 0x80, 0x41, 0x00, 0xC1, 0x81, 0x40, 0x01,
0xC0, 0x80, 0x41, 0x00, 0xC1, 0x81, 0x40, 0x00, 0xC1, 0x81, 0x40, 0x01, 0xC0,
0x80, 0x41, 0x00, 0xC1, 0x81, 0x40, 0x01, 0xC0, 0x80, 0x41, 0x01, 0xC0, 0x80,
0x41, 0x00, 0xC1, 0x81, 0x40, 0x00, 0xC1, 0x81, 0x40, 0x01, 0xC0, 0x80, 0x41,
0x01, 0xC0, 0x80, 0x41, 0x00, 0xC1, 0x81, 0x40, 0x01, 0xC0, 0x80, 0x41, 0x00,
0xC1, 0x81, 0x40, 0x00, 0xC1, 0x81, 0x40, 0x01, 0xC0, 0x80, 0x41, 0x01, 0xC0,
0x80, 0x41, 0x00, 0xC1, 0x81, 0x40, 0x00, 0xC1, 0x81, 0x40, 0x01, 0xC0, 0x80,
0x41, 0x00, 0xC1, 0x81, 0x40, 0x01, 0xC0, 0x80, 0x41, 0x01, 0xC0, 0x80, 0x41,
0x00, 0xC1, 0x81, 0x40, 0x00, 0xC1, 0x81, 0x40, 0x01, 0xC0, 0x80, 0x41, 0x01,
0xC0, 0x80, 0x41, 0x00, 0xC1, 0x81, 0x40, 0x01, 0xC0, 0x80, 0x41, 0x00, 0xC1,
0x81, 0x40, 0x00, 0xC1, 0x81, 0x40, 0x01, 0xC0, 0x80, 0x41, 0x00, 0xC1, 0x81,
0x40, 0x01, 0xC0, 0x80, 0x41, 0x01, 0xC0, 0x80, 0x41, 0x00, 0xC1, 0x81, 0x40,
0x01, 0xC0, 0x80, 0x41, 0x00, 0xC1, 0x81, 0x40, 0x00, 0xC1, 0x81, 0x40, 0x01,
0xC0, 0x80, 0x41, 0x01, 0xC0, 0x80, 0x41, 0x00, 0xC1, 0x81, 0x40, 0x00, 0xC1,
0x81, 0x40, 0x01, 0xC0, 0x80, 0x41, 0x00, 0xC1, 0x81, 0x40, 0x01, 0xC0, 0x80,
0x41, 0x01, 0xC0, 0x80, 0x41, 0x00, 0xC1, 0x81,0x40
} ;

Low-order byte table
/* Table of CRC values for low–order byte */
static char auchCRCLo[] = {
0x00, 0xC0, 0xC1, 0x01, 0xC3, 0x03, 0x02, 0xC2, 0xC6, 0x06, 0x07, 0xC7, 0x05,
0xC5, 0xC4, 0x04, 0xCC, 0x0C, 0x0D, 0xCD, 0x0F, 0xCF, 0xCE, 0x0E, 0x0A, 0xCA,
0xCB, 0x0B, 0xC9, 0x09, 0x08, 0xC8, 0xD8, 0x18, 0x19, 0xD9, 0x1B, 0xDB, 0xDA,
0x1A, 0x1E, 0xDE, 0xDF, 0x1F, 0xDD, 0x1D, 0x1C, 0xDC, 0x14, 0xD4, 0xD5, 0x15,
0xD7, 0x17, 0x16, 0xD6, 0xD2, 0x12, 0x13, 0xD3, 0x11, 0xD1, 0xD0, 0x10, 0xF0,
0x30, 0x31, 0xF1, 0x33, 0xF3, 0xF2, 0x32, 0x36, 0xF6, 0xF7, 0x37, 0xF5, 0x35,
0x34, 0xF4, 0x3C, 0xFC, 0xFD, 0x3D, 0xFF, 0x3F, 0x3E, 0xFE, 0xFA, 0x3A, 0x3B,

0xFB, 0x39, 0xF9, 0xF8, 0x38, 0x28, 0xE8, 0xE9, 0x29, 0xEB, 0x2B, 0x2A, 0xEA,
0xEE, 0x2E, 0x2F, 0xEF, 0x2D, 0xED, 0xEC, 0x2C, 0xE4, 0x24, 0x25, 0xE5, 0x27,
0xE7, 0xE6, 0x26, 0x22, 0xE2, 0xE3, 0x23, 0xE1, 0x21, 0x20, 0xE0, 0xA0, 0x60,
0x61, 0xA1, 0x63, 0xA3, 0xA2, 0x62, 0x66, 0xA6, 0xA7, 0x67, 0xA5, 0x65, 0x64,
0xA4, 0x6C, 0xAC, 0xAD, 0x6D, 0xAF, 0x6F, 0x6E, 0xAE, 0xAA, 0x6A, 0x6B, 0xAB,
0x69, 0xA9, 0xA8, 0x68, 0x78, 0xB8, 0xB9, 0x79, 0xBB, 0x7B, 0x7A, 0xBA, 0xBE,
0x7E, 0x7F, 0xBF, 0x7D, 0xBD, 0xBC, 0x7C, 0xB4, 0x74, 0x75, 0xB5, 0x77, 0xB7,
0xB6, 0x76, 0x72, 0xB2, 0xB3, 0x73, 0xB1, 0x71, 0x70, 0xB0, 0x50, 0x90, 0x91,
0x51, 0x93, 0x53, 0x52, 0x92, 0x96, 0x56, 0x57, 0x97, 0x55, 0x95, 0x94, 0x54,
0x9C, 0x5C, 0x5D, 0x9D, 0x5F, 0x9F, 0x9E, 0x5E, 0x5A, 0x9A, 0x9B, 0x5B, 0x99,
0x59, 0x58, 0x98, 0x88, 0x48, 0x49, 0x89, 0x4B, 0x8B, 0x8A, 0x4A, 0x4E, 0x8E,
0x8F, 0x4F, 0x8D, 0x4D, 0x4C, 0x8C, 0x44, 0x84, 0x85, 0x45, 0x87, 0x47, 0x46,
0x86, 0x82, 0x42, 0x43, 0x83, 0x41, 0x81, 0x80, 0x40
};

```c
unsigned short CRC16(unsigned char *puchMsg, unsigned short usDataLen){
  unsigned char uchCRCHi = 0xFF;          /* high byte of CRC initialized */
  unsigned char uchCRCLo = 0xFF;          /* low byte of CRC initialized */
  unsigned uIndex ;                       /* will index into CRC lookup table */
  while(usDataLen—)                       /* pass through message buffer */
  {
        uIndex = uchCRCHi ^ *puchMsg++ ;  /* calculate the CRC */
        uchCRCHi = uchCRCLo ^ auchCRCHi[uIndex] ;
        uchCRCLo = auchCRCLo[uIndex] ;
  }
    return (unsigned short int)((uchCRCHi << 8) | uchCRCLo);
```