English

Instruction and operation manual

S 452

Thermal mass flow sensor

Dear Customer,

Thank you for choosing our product.

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

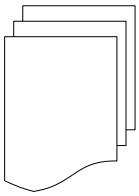
Should the device be tampered with in any manner other than a procedure which is described and specified in the manual, the warranty is cancelled and the manufacturer is exempt from liability.

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 to 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 must 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 a 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 allowed to use the product in explosive areas. Please contact the manufacturer.
- 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 must be <90%, no condensation.

2. Application

The S 452 is a flow sensor which is designed to measure the consumption of compressed air and gases within the permissible operating parameters. These parameters can be found in the technical data section.

The S 452 can measure the following values:

- Velocity of the compressed air or gas.
- Volume flow of the compressed air or gas.
- Total consumption of the compressed air or gas.

The default factory settings are: Velocity in m/s, Volume flow in m^3/h and Total Consumption in m^3. Other units can be programmed by the optional display or the service kit.

The S 452 flow sensor is developed to be used in explosive areas.

The S 452 flow sensor is mainly used in compressed air systems and process gases measurement in industrial environment.

3. Features

- Direct measurement of mass flow and standard flow without the need of pressure and temperature compensation.
- Inline types for smaller pipes.
- No moving parts, no clogging.
- All sensor parts which come into contact with the measurement medium are made of stainless steel 316L.
- Robust metal enclosure is suitable for outdoor applications in harsh environments.
- Wireless bluetooth interface for connecting on site.
- Optional display directly on the sensor, showing flow rate, consumption, medium temperature and diagnostic result.

4. Technical data

4.1 General

Parameters	Standard unit flow: m^3/h other units: m^3/min, l/min, l/s, cfm, kg/h, kg/min, kg/s Standard unit velocity: m/s
Reference conditions	ISO1217 20 °C 1000 mbar (Standard-Unit) DIN1343 0 °C 1013.25 mbar (Norm-Unit)
Principle of measurement	Thermal mass flow
Sensor	Resistive sensor
Measuring medium	Air, gas (non corrosive gas)
Operating temperature	-40 °C ... 100 °C (medium temperature) -40 °C ... 65 °C (ambient temperature)
Humidity of the measured medium	< 90%, no condensation
Operating pressure	Max. 4.0 MPa
Housing material	Al alloy
Material of the probe tube, sensor head and the screwing	Stainless steel 316L
Protection class	IP67
Dimensions	See Chapter 5. Dimensional drawing.
Display (optional)	Graphic display, 128 x 64
Tube diameter	DN15 … DN80
Screwing thread	M32 x 1.5
Weight	1.25 kg (instrument only, doesn't include the measuring section)

4.2 Electrical data

Power supply	16 ... 30 VDC, 5 W

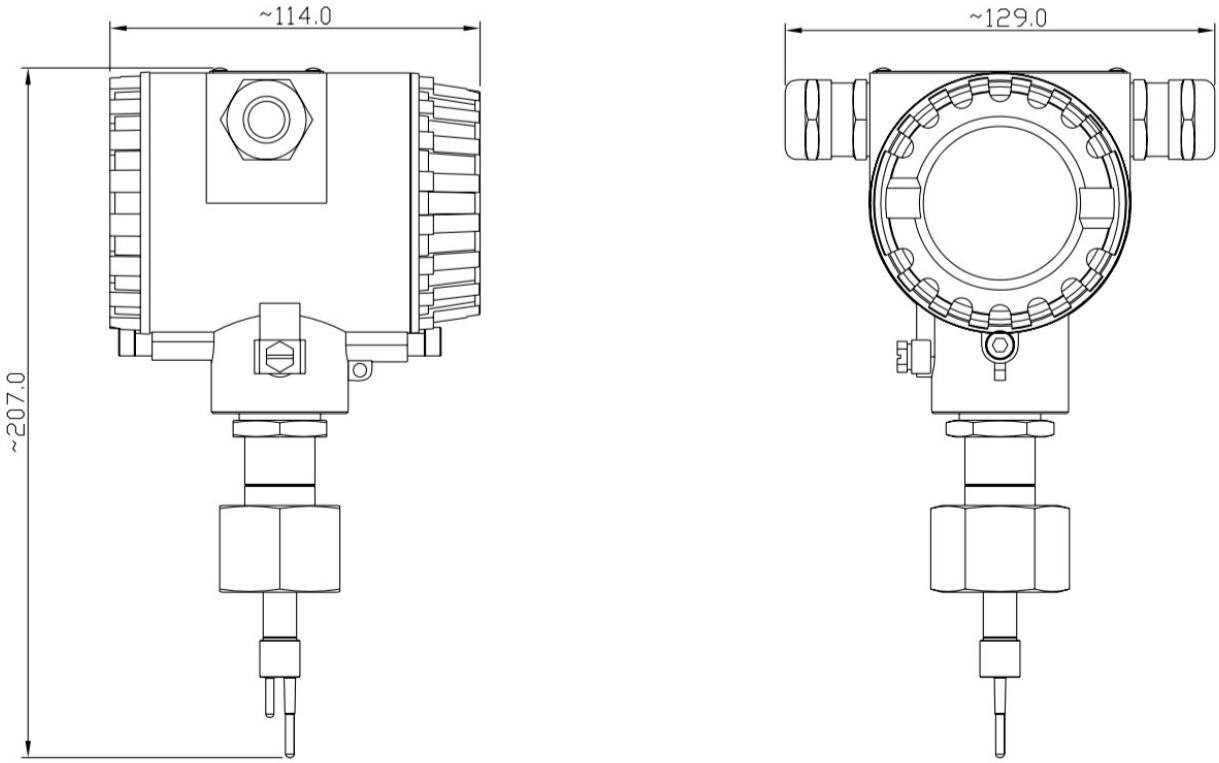
4.3 Output-signals

Analog output	See chapter 9.1
Pulse output	See chapter 9.2
HART output	See chapter 9.3
Modbus output	See chapter 9.4
M-Bus output	See chapter 9.5

4.4 Accuracy

Accuracy	Inaccuracy: ±1.5% of reading + 0.3% of full scale Repeatability: 0.25% of reading
Stated accuracy at	Ambient/process temperature 23°C ±3°C Ambient/process humidity <90% Process pressure at 0.6 MPa

5. Dimensional drawing



6. Determination of the installation point

In order to maintain the accuracy stated in the technical data, the sensor must be insert in the centre of a straight pipe section with unhindered flow characteristics.
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 etc..
Please consider that enough space exists at your site for a adequate installation as described in this manual.

ATTENTION!

Wrong measurement is possible if the sensor is not installed correctly.

- Careful attention must be paid to the design of the inlet and outlet section. Obstructions can cause counter-flow turbulence as well as turbulence in the direction of the flow.
- It is strongly recommend not to install S 452 permanently in wet environment as it exists usually right after a compressor outlet.

7. Inlet and outlet section

The S 452 with tube diameters from DN15 to DN25 already has the required inlet and outlet sections. No additional straight sections are needed.

For the S 452 with diameters from DN32 to DN80, the S 452 has a shortened inlet section and requires additional straight sections at the inlet and outlet. The additional length for the particular diameters are listed in the table below.

Flow obstructions before the measurement section	Additional length for DN32 [mm]		Additional length for DN40 [mm]		Additional length for DN50 [mm]		Additional length for DN65 [mm]		Additional length for DN80 [mm]	
	inlet	outlet	inlet	outlet	inlet	outlet	inlet	outlet	inlet	outlet
Slight curve (bend <90°C)	175	-	227.8	9.5	362.2	65.5	551.8	144.5	760.8	204.5
Reduction (Tube narrows towards measurement section)	265	-	353.5	9.5	521,5	65.5	758.5	144.5	938.5	204.5
Expansion (Tube expands towards measurement section)	265	-	353.5	9.5	521.5	65.5	758.5	144.5	938.5	204.5
90°C bend or T piece	265	-	353.5	9.5	521.5	65.5	758.5	144.5	938.5	204.5
2 x 90°C bends on one level	445	-	563	9.5	787	65.5	1103	144.5	1343	204.5
2 x 90°C bends 3 dimensional change of direction	985	-	1191.5	9.5	1583.5	65.5	2136.5	144.5	2556.5	204.5
Shut-off valve	1345	-	1610.5	9.5	2114.5	65.5	2825.5	144.5	3365.5	204,5

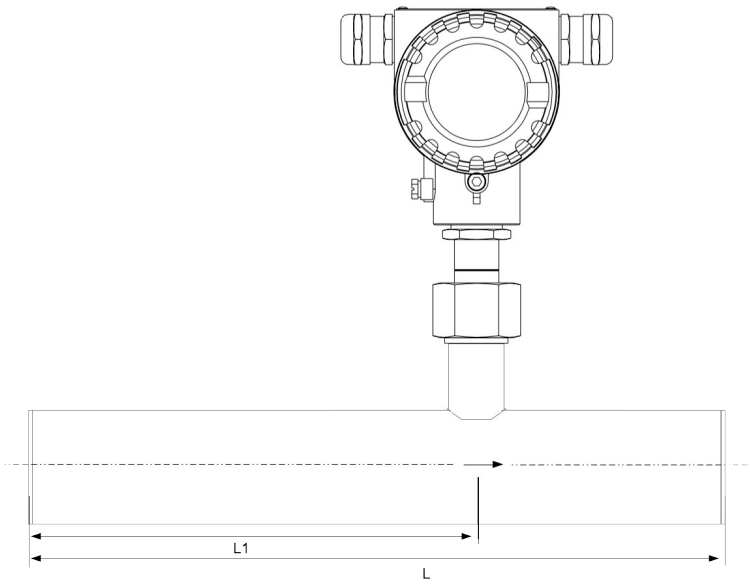
8. Sensor installation

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

Qty	Description	Part no.
1	Sensor	S695 0452
1	Sealing ring	No P/N
1	Bluetooth dongle	No P/N
1	Measuring section	A1301 ... A1306 (R thread) A1321 … A1328 (Flange, EN-1092-1) A1341 … A1348 (Flange, ANSI 16.5)
1	USB disk (with Service Software stored)	No P/N
1	Instruction manual	No P/N
1	Calibration certificate	No P/N

The S 452 is shipped with mounted measurement section.

Please make sure that the sensor is installed correctly to the flow direction in the tube. Make sure that the flow direction indicated on the housing matches the flow direction of the compressed air or gas. The gas flows from the inlet (long pipe section) to the outlet (short pipe section) like illustrated in the picture below.



8.1 Removal of the flow sensor

The following steps explain the procedure of an appropriate removal of the sensor.

ATTENTION!

Only remove the sensor if the system is in a pressure-less condition.

1. Hold the sensor.
2. Release the terminal nut at the connection thread.
3. Pull out the shaft slowly.
4. The measuring section can be closed with the optional closing cap, so the system can be operated normal during maintenance.

Re-installation after maintenance:

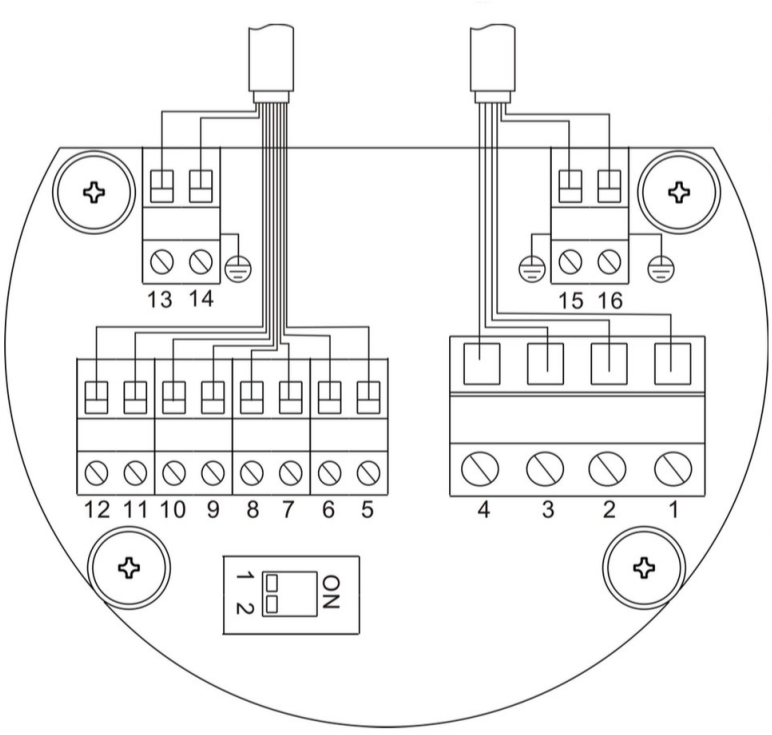
- The re-installation of the measurement device is simple as the sensor unit fits into the pipe section only in one position.
- Please make sure that the o-ring is inserted.
- Close the terminal nut tightly to mount the sensor correctly.

8.2 Electrical connection

When installing the cables please consider following points:

- Keep the stripped and twisted length of cable shield as short as possible.
- Screen and ground the signal lines.
- Unused cable entries must be closed with closers.
- Cable outer diameter should be between 6 and 8 mm.
- Single wire cross section area should be between 0.25 ... 0.75 mm^2.
- The thread size for the cable glands is M20 / 1.5.

Connection diagram



Pin	Pulse and analog	Modbus	M-Bus	HART
1	GND_{SDI}	GND_{SDI}	GND_{SDI}	GND_{SDI}
2	$+V_B$	$+V_B$	$+V_B$	$+V_B$
3	$-V_B$	$-V_B$	$-V_B$	$-V_B$
4	SDI	SDI	SDI	SDI
5	D1	D1	D1	D1
6	D2	D2	D2	D2
7	P1	P1	P1	
8	P2	P2	P2	
9	$-I_1$	$-I_1$	$-I_1$	$-I_1$ / -HART
10	$+I_1$	$+I_1$	$+I_1$	$+I_1$ / +HART
11	$-I_2$	+D	M1	
12	$+I_2$	-D	M2	
13		GND_M		
14	Earth	Earth	Earth	Earth
15	Earth	Earth	Earth	Earth
16	Earth	Earth	Earth	Earth

Legend to pin assignment

SDI	= Digital signal (internal use)	P1	= Pulse output 1
GND_{SDI}	= Ground for SDI	P2	= Pulse output 2
$+V_B$	= Positive supply voltage	D1	= Direction input D1 (flow switch)
$-V_B$	= Negative supply voltage	D2	= Direction input D2 (flow switch)
$+I_1$	= Positive signal output (analog 1)	+D	= Modbus data+
$-I_1$	= Negative signal output (analog 1)	-D	= Modbus data -
$+I_2$	= Positive signal output (analog 2)	M1	= M-Bus 1
$-I_2$	= Negative signal output (analog 2)	M2	= M-Bus 2

9. Signal outputs

9.1 Analog output

The S 452 in the standard configuration comes with 2 analog outputs and 1 pulse output. All signals are electrically isolated. The analog output can be used as an active output (current is sourced through the positive connection pin) or passive output. In the passive configuration a current signal is modulated into the external signal voltage.

Active	:	4 to 20mA, RL < 400 Ω
Passive	:	4 to 20mA, supply voltage 18... 30 VDC, RL < 500 Ω
For HART	:	RL ≥ 250 Ω
Uncertainly	:	< 0.3 % of reading
Resolution	:	0.005 mA

9.2 Pulse output

No switch, no polarity required, galv. Isolate

Max. rating	:	30 VDC, 200 mA
Pulse width	:	10 ... 100 msec (depending on flow rate)

The maximum number of pulse per second is limited to 45 pulse per second. As a result depending on the flow rate and the selected consumption unit the maximum flow rate is limited to the values in the table below.

Unit	**Max flow**		
Pulse / consumption unit	1/1	1/10	1/100
m^3/h	162,000	1620000	16,200,000
m^3/min	2,700	27,000	270,000
l/min	2,700	27,000	270,000
cfm	2,700	27,000	270,000
Kg/h	162,000	1,620,000	16,200,000
Kg/min	2,700	27,000	270,000
Kg/s	45	450	4,500
	Default	To be configured by service software	

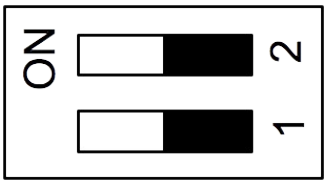
9.3 HART output

The HART signal is modulated on analog output 1. In case S 452 is used in a multi-drop configuration (more than 1 slave on the 4-20 mA line) the analog output cannot be used.

Device type	: Slave
Polling address	: 1 to 15 Bus address can be set through software
Physical interface	: BELL 202
Protocol version	: V 5.2
Tag	: S 452
Tag description	: Flow meter
Frame/parity/Stop	: 8, O, 1

9.4 Modbus output

The version with Modbus comes with one analog output and one pulse output. The Modbus communication requires to activate terminal resistors at the last device on the bus system. If the S 452 is the last device on the bus system, the DIP switches on the connector board should be set to “ON” position.



Termination resistor network switch

Device type	: Slave
Address rage	: 1 to 251 Bus address can be set through software
Physical interface	: RS485 in accordance with EIA/TIA-485 standard
Baudrates	: 1200, 2400, 4800, 9600, 19200, 38400, 57600, 115200 Baud
Transm. mode	: ASCII, RTU
Response time	: Direct data access = 0 to 255 ms (can be configured)

Remarks

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

Index	Channel description	Unit	Resolution	Format	Length	Modbus address
0	Velocity	m/s	0.1	FLOAT	4-Byte	0
1	Flow	m^3/h	0.1	FLOAT	4-Byte	6
2	Consumption	m^3	1	UNIT32	4-Byte	12
3	Reverse consumption	m^3	1	UNIT32	4-Byte	18
4	Medium temperature	°C	0.1	FLOAT	4-Byte	24
5	Ambient temperature	°C	0.1	FLOAT	4-Byte	36

Remarks

- All numbers are in the little-endian format.
- Function code: 03.
- Different units have different precisions.

9.5 M-Bus output

The version with M-Bus comes with one analog output and one pulse output.

Device type	:	Slave
Address rage	:	1 to 251 Bus address can be set through software
Physical interface	:	Meter-Bus, EN1434-3
Baudrates	:	300, 2400, 9600 Baud
Frame/parity/Stop	:	8, E, 1

10. Configuration

To fully utilize the functionality of S 452, you must make configurations in the flow meter accordingly.

The following table gives an overview about the available settings.

Area	Available settings	Default
Measurement	Tube diameter Flow unit Consumption unit Reference conditions Gas type selection Consumption counter Operation pressure Flow direction	According the ordered section m^3/h m^3 P_s= 1000 hPa; T_s= 20°C Air 0 m^3 0.6 MPa Standard
Analogue output 1	Measurement channel Scaling Active / passive	Flow 4 mA: 0 m^3/h 20 mA: max flow Active
Analogue output 2	Measurement channel Scaling Active / passive	Medium Temperature 4 mA: -50 °C 20 mA: 200 °C Active
Pulse output	Pulse / Alarm Pulses per consumption unit	Pulse 1
HART	Fieldbus address Manufacturer ID Device type code	0 255 0
Modbus	Device address Baudrate Framing/parity/Stop bit Transmission mode	1 19200 8, N, 1 RTU
M-Bus	Address Manufacturer code Baudrate	0 END 300

Area	Available settings	Default
	Access number	0

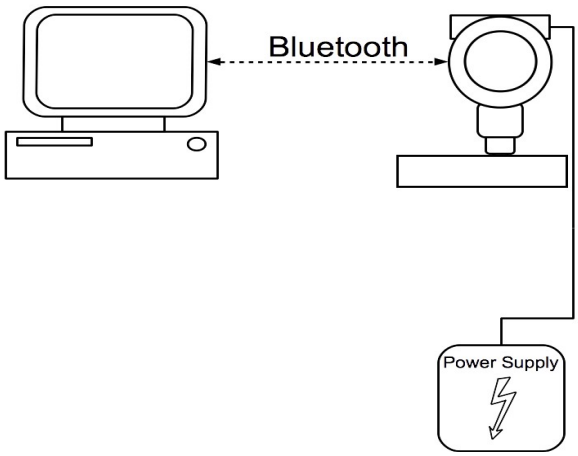
To configure S 452 settings, use the service software stored in the USB disk that comes with the delivery package.

1. Install the service software on a Windows® PC.
2. Make sure that the PC can communicate with the sensor through one of the following ways:
   - Bluetooth way—Make sure the PC has a Bluetooth interface. If the PC does not have, insert the USB dongle that comes with the sensor.
   - Cable way—Use an optional service kit to connect the PC with the sensor.
3. Power up the S 452.
4. Follow the onscreen instructions in the service software to make configurations. You can also refer to the online help file for more information.

Notes:

For the Bluetooth connection:

- Ensure that the distance between S 452 and PC is not more than 5 meters.
- Ensure that the PC Bluetooth antenna points roughly towards the direction of the display (front part).



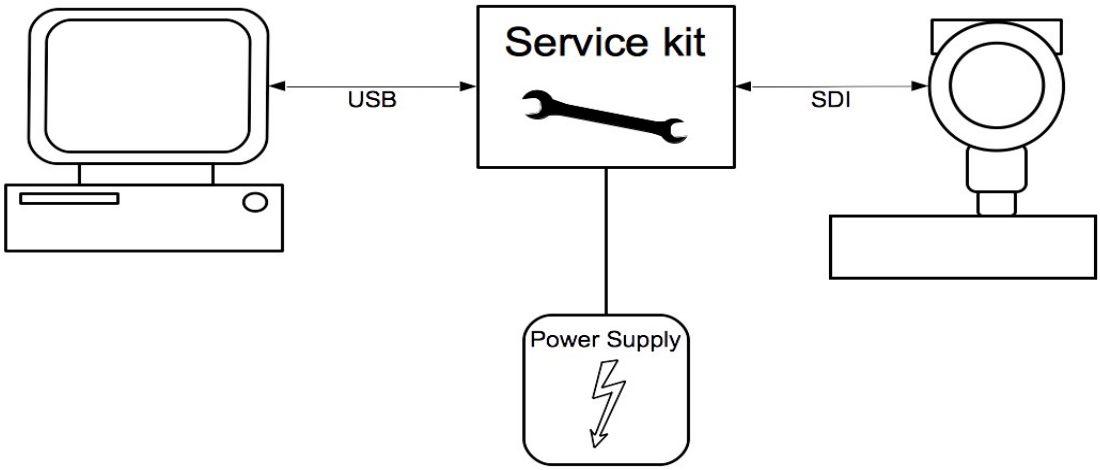
11. Optional extra accessories

11.1 Sensor display

The sensor display shows values of the velocity, the flow and the consumption as well as error messages.

11.2 Service kit

The following diagram shows the connection when using the optional service kit. Please ensure that the power supply of S 452 or the service kit is connected because the USB port cannot supply enough power.



12. Calibration

The sensor is calibrated ex work. The exact calibration date is printed on the certificate which is supplied together with the sensor. The accuracy of the sensor is regulated by the on-site conditions, and parameters like oil, high humidity or other impurities can affect the calibration and furthermore the accuracy. However, we recommend you calibrate the instrument at least once per year. The calibration is excluded from the instruments warranty. For the calibration service, please contact the manufacturer.

13. Maintenance

To clean the sensor, it is recommended to use distilled water or isopropyl alcohol only.

ATTENTION!

Do not touch the surface of the sensor plate.

Avoid mechanical impact on the sensor (e.g with a sponge or a brush).

If the contamination can not be removed, you must have the sensor inspected and maintained by the manufacturer.

14. 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.

15. 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:

- If users open the measurement instrument without a direct request written in this instruction manual.

- If repairs or modifications are undertaken by third parties or unauthorised persons.
- If 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 month.

Appendix A - Analogue output

Scaling table analogue output:

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

Tube			Flow							
inch	nominal Diameter	mm	m³/h	m³/min	l/min	l/s	cfm	kg/h	kg/min	kg/s
1/2”	DN 15	16.10	29.33	0.49	488.9	8.15	17.3	34.8	0.58	0.01
3/4”	DN 20	21.70	57.34	0.96	955.7	15.93	33.7	68.1	1.14	0.02
1”	DN 25	27.30	95.03	1.58	1583.8	26.40	55.9	112.9	1.88	0.03
1 1/4”	DN 32	36.00	171.37	2.86	2856.1	47.60	100.9	203.5	3.39	0.06
1 1/2”	DN 40	41.90	235.99	3.93	3933.1	65.55	138.9	280.3	4.67	0.08
2”	DN 50	53.10	386.14	6.44	6435.7	107.26	227.3	458.6	7.64	0.13
2 1/2”	DN 65	68.90	660.53	11.01	11008.9	183.48	388.8	784.6	13.08	0.22
3”	DN 80	80.90	916.17	15.27	15269.6	254.49	539.2	1088.2	18.14	0.30

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

Tube			Flow							
inch	nominal Diameter	mm	m³/h	m³/min	l/min	l/s	cfm	kg/h	kg/min	kg/s
1/2”	DN 15	16.10	58.55	0.98	975.8	16.26	34.5	69.5	1.16	0.02
3/4”	DN 20	21.70	114.44	1.91	1907.3	31.79	67.4	135.9	2.27	0.04
1”	DN 25	27.30	189.66	3.16	3160.9	52.68	111.6	225.3	3.75	0.06
1 1/4”	DN 32	36.00	342.01	5.70	5700.2	95.00	201.3	406.2	6.77	0.11
1 1/2”	DN 40	41.90	470.99	7.85	7849.8	130.83	277.2	559.4	9.32	0.16
2”	DN 50	53.10	770.67	12.84	12844.5	214.07	453.6	915.4	15.26	0.25
2 1/2”	DN 65	68.90	1318.30	21.97	21971.7	366.19	775.9	1565.8	26.10	0.43
3”	DN 80	80.90	1828.51	30.48	30475.1	507.92	1076.2	2171.8	36.20	0.60

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

Tube			Flow							
inch	nominal Diameter	mm	m³/h	m³/min	l/min	l/s	cfm	kg/h	kg/min	kg/s
1/2”	DN 15	16.10	110.16	1.84	1836.0	30.60	64.8	130.8	2.18	0.04
3/4”	DN 20	21.70	215.33	3.59	3588.8	59.81	126.7	255.8	4.26	0.07
1”	DN 25	27.30	356.85	5.95	5947.5	99.13	210.0	423.9	7.06	0.12
1 1/4”	DN 32	36.00	643.52	10.73	10725.3	178.76	378.8	764.4	12.74	0.21
1 1/2”	DN 40	41.90	886.19	14.77	14769.8	246.16	521.6	1052.6	17.54	0.29
2”	DN 50	53.10	1450.06	24.17	24167.6	402.79	853.5	1722.3	28.71	0.48
2 1/2”	DN 65	68.90	2480.46	41.34	41341.1	689.02	1459.9	2946.2	49.10	0.82
3”	DN 80	80.90	3440.45	57.34	57340.9	955.68	2025.0	4086.5	68.11	1.14

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

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
};
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);
```